Comisión
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Productivity in the Chilean Copper Mining Industry

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Productivity in the Large Scale Copper Mining Industry

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Acronyms

All the acronyms are in their spanish versions.

AIA	Association of Industrialists of Antofagasta
APRIMIN	Association of Industrial Mining Suppliers
CCM	Council of Mining Competencies of the Mining Council
CIS	Centers of International Excellence
ChP	Primary Crushing
CNE	National Energy Commission
CNID	National Council of Innovation for Development
COCHILCO	Chilean Copper Commission
CODELCO	National Copper Corporation
COMPIN	Commission of Preventive Medicine and Disability
CONAF	National Forestry Corporation
CONICYT	National Commission for Scientific and Technological Research
CORFO	Corporation for the Promotion of Production
DGA	National Water Bureau
EE	Energy Efficiency
EMTP	Technical Education in High School
ENAMI	National Mining Company
ERNC	Non-Conventional Renewable Energy
EVAST	Assessment and Surveillance of Environment and Occupational Health
IEAM	Specific Tax on Mining Activity
IIMCh	Institute of Mining Engineers of Chile
INE	National Statistics Institute
INGEMMET	Geological, Mining and Metallurgical Institute
FESUC	Federation of Supervisors of Codelco
FESUMIN	Federation of Mining Supervisors
FIE	Strategic Investment Fund

FIC	Innovation Fund for Competitiveness
FIRR	Regional Investment and Reconversion Fund
FMC	Mining Federation of Chile
FTC	Federation of Copper Workers
LOC	Constitutional Organic Law on Mining Concessions
LSO	Social License to Operate
MINNOVEX	Innovative and Export Mining
ML	Grinding
OGP	Office of Large Project Management
ILO	International Labor Organization
ONEMI	National Emergency Office
ONG	Non-Governmental Organization
OTEC	Technical Training Organizations
PC	Concentrator
PHm	Hydrometallurgical Plant
PPCM	World Class Supplier Program
TFP	Total Factor Productivity
SEA	Environmental Assessment Service
SEIA	Environmental Impact Assessment System
SENCE	National Service of Training and Employment
SERNAGEOMIN	National Service of Geology and Mining
SIC-SING	Central Interconnected System - Northern Interconnected System
SONAMI	National Mining Society
SUSESO	Social Security Superintendence
SQM	Chemical and Mining Society
SVS	Superintendence of Securities and Insurance
UAI-CORFO	Adolfo Ibañez University - Corfo

The Chilean Productivity Commission

The Chilean Productivity Commission is an institution created through Presidential Decree No. 270, of February 9, 2015. It is an independent, autonomous and consultative institution, whose mission is to advise the Government of Chile on issues aimed at increasing productivity, focusing on the improvement of the citizens' well-being, proposing evidence-based public policies, which consider the views of civil society in general.

It has a technical and transversal council of eight members appointed by the President of the Republic for a three year period.

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It's permanent challenge is to increase productivity in order to improve the lives and well-being of people.

Foreword

The mining sector, specifically, the copper mining industry, is essential to Chile's economic and social development. Mining contributes significantly to national income, tax revenue, jobs and business opportunities, and, ultimately, the country's growth.

Given its importance, the Government has requested us to review the evolution of productivity in the Chilean Copper Mining Industry, and propose measures to improve it. This study, the Chilean Productivity Commission's first, suggests that there is wide scope for improvement, both in public entities and the mining sector, and particularly in mining companies.

As an extractive sector, the mining industry may generate adverse effects and negatively affect the surrounding communities. Therefore, it must be subject to a series of governmental protocols and regulations, and also to society's permanent scrutiny. Our study angles its recommendations towards international best practices, with the aim of increasing productivity and thus generating economic gains for the country, without sacrificing social, environmental, occupational safety and community relations standards.

The study was developed by the team of the Technical Secretariat of the National Productivity Commission, under the supervision and unanimous approval of the Presidential Advisory Council. It benefited from the support of both Chilean and international mining companies that provided vital information on their performance. The Ministry of Mining, Ministry of Economy, Sernageomin, Ministry of Labor, the Consejo Minero, Valor Minero, Aprimin, Chilean Chamber of Construction, among many others, collaborated in the development of this report. The contributions of MatrixConsulting, Cochilco and Fundación Chile were especially important to this analysis. The Commission is grateful to a large number of people, workers, business people, experts, officials, academics, and others related to industry, for their significant support to our inquiry, both in work meetings and in the hearings that took place for this study. Without them, this study would not have been possible.

Joseph Ramos	**Alfie A. Ulloa**
President	Executive Secretary

May 2017

Terms of reference

Request from the President of the Republic to the National Productivity Commission: Terms of Reference.

Objective

The purpose of the consultation is to identify the main barriers to the country's mining productivity growth, and propose possible actions of improvement.

Expected Product

The quantification of mining productivity, both at the aggregate and disaggregate level and analysis of its determinant factors.

The analysis should evaluate the determinants of productivity, defining the incidence of factors, both at the sectoral level and the firm level. Based on this, propose recommendations that will allow for an increase in productivity, reduce gaps regarding international benchmarks, and thus bring the national industry to those standards.

For the construction of indicators and the analysis requested, it is necessary to raise primary data. A productivity database for the sector will be produced based on the information generated, which can be updated over time. This will allow for a constant evaluation both of the relevant variables' performance and measures implemented.

In particular, the following should be considered:

- An analysis of different methodologies and measurements of the sector's productivity.
- The generation of productivity indicators at various levels of aggregation [1] to identify the productivity gaps of different activities of the mining process in Chile with respect to international benchmarks.
- A determination of the most relevant gaps that limit productivity, considering -when possible- international benchmarks, and identifying the incidence of the factors that explain it.
- A proposal of measures aimed at reducing these differences, taking into account best international practices and the opinion of industry experts.
- Proposed actions and other recommendations should consider both those within reach of the government and those that require coordinated actions from the industry and other participants in society.
- A development of a roadmap that considers feasibility and priorities necessary to implement the measures identified and their expected impact (critical actions in the short and medium term, and other strategic ones with greater horizon).

[1] Levels of aggregation in the economy refers to different ways of grouping economic factors: production, emplyment, investment, etc.

Preface

Chile has trebled its average standard of living in the last 30 years. However, it still faces the challenge of catching-up with developed countries' welfare standards: higher per capita income and better income distribution, quality coverage in social areas such as education and health, environmental protection, and institutional robustness, among others. Improving productivity is one of the main drivers to achieve these goals.

Among the factors that improved Chileans' quality of life is productivity, which until 1999 contributed around 2.3% per year to growth. However, the indicator has exhibited a severe deceleration since 2000 and has barely contributed to growth by 0.1% a year over the last fifteen years[2]. If the productivity growth rate of the 1990s had maintained, the country would have a per capita income level one-third higher than the current one.

The primary -but not sole- cause of this troublesome deceleration in the economy's aggregate productivity was the reduction in mining productivity, of approximately 75% since the 2000s according to standard indicators. Although this report questions the magnitude of this deterioration, for we propose a methodology that estimates it at around 14%, the critical productive decline of the sector since 2000 is undeniable, with an annual fall of 1% in its total productivity.

Due to copper's gravitating impact on our economy and its importance in future development thanks to our high mining reserves, the National Productivity Commission's first government-mandated study was to examine the evolution of the sector, and present proposals to reverse the deterioration in mining productivity.

Copper mining constitutes more than 10% of GDP and more than 50% of exports. It also represents one in three dollars of foreign direct investment received in the country and about 15% of last decade's tax revenue. Indirectly, mining impacts through different multiplier effects through the purchase of goods and services. For every direct mining employment, there are at least two jobs in other sectors. According to SERNAGEOMIN, the immediate employment of the industry is of around 70.000 jobs, reaching 150.000 workers

[2] Comisión Nacional de Productividad (2017). La Productividad en Chile: Una Mirada de Largo Plazo. Informe Anual 2016, Comisión Nacional de Productividad. Santiago, Chile. [Productivity in Chile: A long term view. Annual Report 2016]

including contractors. The regional impact is even greater. For example, in the region of Antofagasta, employment associated with mining activities accounts for approximately 20% of total local employment.

Chile is a small country, except for its copper production. Our nation produces about one-third of the world's copper and has a third of the estimated global reserves. Currently, there are portfolio investments for about US$50 billion[3] for the 2016-2025 period. However, the last twenty-five years have been exceptional for the copper mining industry in Chile. The country increased by three times the amount of copper produced between the years 1990 and 2003, and during the super-price cycle (from 2004 to 2012), the copper pound's price multiplied by three. Events such as these will hardly occur again in the future. These less favorable conditions in the short and medium term imply considerable challenges for the sector to maintain its leadership worldwide.

Chile cannot overlook the potential that nature has granted it by having a third of the world's copper reserves; to do so would be to stall the country's economic development. Chile does not control the price nor the ore´s grade, but it can influence its productivity and its costs. Reversing the decline in mining productivity is fundamental so that it can continue contributing to the growth of the country.

Figures from the Fraser Institute's latest annual survey on mining and exploration confirm the urgency to meet the industry's challenges.[4] Chile ranked 39th out of 104 destinations in the Investment Attraction index in 2016 as a copper producer. Not only is it an unfavorable position for our primary industry, but it also accounts for a systematic decline in recent years. This deterioration is absolute - granted that Chile worsened in several dimensions - but also relative since several competing countries registered significant improvements. Both are important and should be taken seriously. Chile has vast copper reserves, but this does not guarantee that the investment will flow towards the country, especially when other mining destinations permanently improve their institutional and economic systems concerning resources.

We focused our international benchmarking study (see Chapter 3) so as to identify good practices applicable to Chile, in the best provinces of Australia, Canada, and the United States, which hold the highest places in this index. The Fraser Institute index includes two sub-indices: (i) the physical/geological potential (60%) and (ii) policies perception in 15 dimensions (40%). The decline of Chile from general place 11 (2015) to 39 (2016) is due especially to the decrease in physical/geological attractiveness, with a fall from 8th place (2012), to the 11th (2015), and then to 49th (2016).

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3 One billion equals a thousand million.

4 See: https://www.fraserinstitute.org/studies/annual-survey-of-mining-companies-2016

There is not much we can do concerning our mining potential, except for allocating more funds and resources, and, generating greater availability of land for exploration. In contrast, public policies are within the country's scope of action. Chile's fall from place 18 (2012) to 26 (2015), and to 35 (2016) should be seriously analyzed. While such a marked deterioration in Chilean policies and regulations is unlikely, perception towards them has nonetheless seriously worsened.

The sub-index on public policy perception is composed of 15 dimensions, and the worst evaluated in Chile are: (i) insufficient geological information available, (ii) labor relations, (iii) infrastructure, (iv) disputes over land and concessions, (v) environmental regulation and (vi) community relations. Despite the ambition of this report, it is not possible to cover everything. However, except for the tax issue and environmental regulation, we have analyzed several issues, and presented several proposals for improving current policies, aimed at increasing the sector's productivity without reducing social and environmental protection standards.

In this context, the President of the Republic entrusted the National Productivity Commission with the task of recommending a set of measures, both public and sectoral, to complement the efforts already initiated by the different public, trade union, and private entities. The objective is to reverse the negative trend that productivity has shown for the past 15 years in the sector, and this requires everybody's contribution.

It is important to mention the efforts made by the Ministry of Mining, COCHILCO and SERNAGEOMIN, CORFO, and the Ministry of Economy through the Alta Ley National Mining Program and the Strategic Investment Fund. The Alianza Valor Minero, the Mining Council (Consejo Minero), the National Mining Society (SONAMI), supplier associations, and the various federations of mining workers, among others have all contributed to the undeniable success of Chilean mining; and they all share the responsibility of extending this success in the long term.

The National Council for Innovation for Development published "Mining and Sustainable Development of Chile: Towards a Shared Vision" in 2014, proposing a "Virtuous, Inclusive and Sustainable" future mining industry. In response to their proposals, public-private organizations such as Alta Ley and Valor Minero were created, focused on innovation and communities respectively. During 2015, the Alta Ley Mining Program, in coordination with Fundación Chile published the Technological Roadmap 2015-2035 for the Copper Mining Industry. The agreed public-private sector targets for 2035 are: (i) to reach a production of 7.5 million tons per year, (ii) to move from 40 percent in output in the first quartiles of global costs to 80 percent, and (iii) quadruple the number of world-class exporting suppliers so as to reach exports of US$4,000 per year. The challenge is substantial: without new investments, Chile will be producing 4 million metric tons (from the current 5.5 million tons) in the same period. Since its foundation, Valor Minero has focused on the search for effective relationship mechanisms between mining companies and communities. It is essential to emphasize that solutions to the challenges facing the mining industry require the joint determination of different actors, rather than separate entities. This National Productivity Commission's work aims to complement the efforts above mentioned.

This report has two parts. Part 1 presents an overview of the industry, a detailed analysis of the evolution of its productivity, and a comparative study of labor and capital benchmarking. Twelve national large-scale mining operations and other selected ones in Australia, Canada, the United States, Sweden, and Peru were chosen for their excellent performance and for being considered as best practices in the industry worldwide. Confidentiality of the data provided by the companies and anonymity is carefully safeguarded. A characterization of the supplier sector is also provided.

Part 2 examines various topics relevant to the sector: water and energy resources, relationships with communities, labor and security aspects, mining exploration, medium extraction, and suppliers. Recommendations for public, sectoral or private application are given for each topic.

The country, the government, and the industry face a major challenge. We hope that this report, our first contribution, furthers the discussion.

Executive Summary

Importance of Mining in Chile

Mining, specifically copper mining is the most significant economic activity in Chile. Copper mining represents over 10% of GDP, more than 50% of exports, and is the leading recipient of foreign direct investment: accounting for one in every three dollars entering the country. The sector has grown steadily in the past 60 years: it tripled between 1960 and 1990; and trebled again during 1990-2016, reaching 5.5 million tons in 2016 causing Chile to be the world's leading producer, accounting for 30% of total production. The country also boasts a third of the known world reserves, the largest at a global level. Copper opens a window of opportunity to expand our development, and thus achieve economic and social progress.

Given the sharp price increase during 2004-2014, Chile raised not only its copper production but also its value. Exports grew from an average of US$1.4 billion[5] between 1960 and 1990 to US$5.5 billion between 1990 and 2003 and then US$34 billion during the so-called "super-cycle" (2004-2014). The value exported in 2016 was of US$28 billion.

Between 1994 and 2003, mining accounted for approximately 6% of fiscal revenues, a contribution that tripled between 2004 and 2014, reaching an annual average of 20%. Including state enterprises (Codelco and Enami), copper contributed US$96 billion to the treasury in 2004-2014, ten times more than the previous decade (US$9 billion). This allowed the accumulation of more than US$20 billion in Sovereign Wealth Funds[6]. From 2015, the contribution returned to the levels previous the super-cycle.

Given its size and development, the ecosystem around mining involves many organizations and functions and is highly complex in its interactions. Nationally, there is no other sector like it: it includes (i) large, medium and small enterprises; (ii) state owned; transnational and local capital; (iii) a significant supplier sector (both domestic and foreign); workers' organizations, (v) companies and suppliers associations, and (vi) specialized State agencies.

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5 One billion equals one thousand million,

6 Pension Reserve Fund and Economic and Social Stabilisation Fund (FRP and FEES in spanish, respectively).

Chile has a clear comparative advantage in the mining sector, particularly in copper mining, and must take advantage of the potential that nature has provided: a third of the world's copper reserves are in Chile. In fact, no country rich in natural resources has achieved development by overlooking its comparative advantage, and Chile is no exception. It is not a matter of focusing our development exclusively on mining, but instead, taking advantage of opportunities to develop and diversify our economy.

The benefit to Chile and the attractiveness of mining investment depends on the difference between the price of copper and its production costs. Chile does not control the price of copper or the mineral's grade, but it can manage its productivity and thus its costs. Reversing the deterioration in the copper mining industry's productivity is fundamental for it to continue making its valuable contribution to the national development. Hence, the Government has mandated the National Productivity Commission this report, with the aim of proposing a strategy that will allow the country to regain its international leadership, not only regarding reserves and production but also in productivity. As it will be seen, the implementation of this strategy will require the joint effort of both public and private sectors: that is, the State, mining companies and their workers, contractors, suppliers and civil society.

This Commission considers that the set of recommendations proposed for both the public and private sectors are the basis of a mining strategy that ensures the industry's continuity, its expansion and its adaptation to new technological challenges and social demands. Applied separately, the 53 recommendations of this study would have limited impact. As in any complex system, the most restrictive component will determine the set's potential. However, applied as a whole, and centered on twelve proposed strategic areas, the impact is maximized. Due to its complexity and magnitude, the sector is in a privileged position to reach agreements and implement long-term policies around this strategy, which will be decisive in the country's future development.

Main Findings

In recent years, commodity-producing countries have seen their productivity growth rate decline. Chile is no exception. The 2016 Annual Report of the National Productivity Commission found that the total factor productivity (TFP) of the Chilean economy as a whole decelerated from 2.3% annually in the 1990s to 0.1% per year in 2000. The primary, though not the only reason, was the reduction in mining productivity. This fall was mainly due to the companies' reaction to the super cycle of copper prices, which led them to prioritize the level of production over other criteria such as efficiency.

In fact, copper production rose 19% between 2000 and 2014. However, this required 79% more energy, 157% more labor, and 178% more capital. This explosive growth in the use of inputs to achieve a modest increase in production entailed a heavy fall in productivity, which, according to some studies, was around 70% during the super cycle. However, this measure does not take into account that during the period, the ore's grade deteriorated significantly, which meant mining, loading and processing an additional 40% of mineral to achieve the same amount of fine copper. Nor does it take into account the long gestation period of capital investment, which makes the investment yield its fruits up to 5-7 years later. Adjusting for the factors mentioned above, which are external to management, our best estimate displays a mining TFP deterioration of around -1% per year, much less than the general estimate. Nonetheless, this is an unsatisfactory result, since productivity is expected to improve over time.

The fall in productivity since 2000 occurred both in mines with higher and lower productivity. In fact, the price surge induced all companies to favor production and thus take advantage of the high margins, even at the expense of productivity.

Given the significant gaps in productivity encountered, it is evident that there is room for improvement within companies. There are differences in productivity amongst mine sites, even after correcting for geological and geographic factors. For example, according to observations from the sample of large-scale mining companies in Chapter 3 of this report, in the year 2000, the least productive operations required 82 working hours to move a kiloton of material, but 162 working hours in 2014. The median-productivity mining companies went from 26 (2000) to 63 (2014) working hours per kiloton moved; while the high-productivity group went from 19 (2000) to 22 (2014) working hours per kiloton moved. This labor productivity indicator and the total productivity measures not only confirm the gaps at different levels between these three groups, but also their tendency to worsen productive performance. According to our estimates, total factor productivity at mine site level fell between 0.7% and 1.6% per year between 2000 and 2014.

A particularly important aspect of this study was the detailed comparative analysis (presented in Chapter 3) of the productive performance of 12 Chilean mining operations (75%

of the national production) and seven international mines, specially selected for being of international best practice (benchmarking). The capital's productivity was measured with information obtained from each operation for all 12 months of 2015, considering the intensity of equipment use (time of use), and labor productivity (person-hours per kiloton moved). The sample accounts for 35% of the world's copper production and 50% of the production of deposits that yield over 100,000 tons per year. This sample generates confidence regarding the representativeness and value of the analysis.

More than 500 people in the mining industry were interviewed for this study. They included operators, supervisors, executives, analysts, civil servants, members of civil society and industry experts. A series of open public hearings were held in the cities of Antofagasta, Iquique, Calama, La Serena, Copiapó, Sierra Gorda, Coquimbo, and Santiago. Over 700 people attended: from civil society, business, regional authorities, and workers. Likewise, mines considered as "best practice" were visited in Australia, Canada, the United States, Sweden and Peru, and in each case the opinion of executives, workers and experts were taken into account. Correspondingly, meetings were also held with government and industry bodies. To our knowledge, no other study of this magnitude exists worldwide.

The "benchmarking" analysis for the 2015 productivity indicators confirms the marked heterogeneity between local mines: the most efficient operation of the national sample required an average of 43 working-hours to move a thousand tons of material, while the less effective one required 115 working-hours for the same job. The average national sample was 67 working hours to move a kiloton of material[7]. That is to say, there are differences of more than 100% in labor productivity within different mines in the Chilean large-scale mining industry (over 100,000 tons of annual copper). External factors, common to all companies, such as regulations, do not explain these differences. Likewise, this analysis takes into account factors such as distance, the slope of the open pit, load capacity in trucks and the ore's grade. Therefore, the bulk of the differences in productivity is attributable to reasons pertaining the mine itself, and especially, to the management of personnel and assets, and the design and adherence to the mining plan.

When comparing the Chilean sample with the international sample, the results are even more troublesome. The average working hours required by the world's best practice sites to move a kiloton of material (30 working-hours) is less than half the national average (67 working-hours). On average, the mines of the national sample required more than double the working-hours to perform the same task as the international sample during the year 2015. Moreover, the best performance local operation requires 44% more working-hours

7 It is important to note that the least productive mines present a significant deviation from the sample median (53), and therefore distort the national average (67).

than the average of the best international mines. In Chile, 1.8 people work at the plant and support areas for each person that works within the pit itself, while in the international mines that ratio is 1.3. These differences may be capturing institutional, regulatory, or generalized gaps common to the Chilean industry, such as human capital, and suggest that there is room for productivity improvement through public interventions.

Concerning capital use, Chilean mines exhibit substantial differences amongst those of best international practice. For example, regarding transport, the international mines use the equipment an additional 10% of hours a day, and there are differences of 80% between the best and the worst in Chile. At the plant level, the international sample uses the milling asset 13% more, and there are differences of 25% between the best and the worst in Chile.

In short, there is room for improvement. First, to raise the productivity of the worst Chilean mines to the level of the best in the country, which concerns the companies themselves. Second, to bring the national average closer to the international one which requires both public and regulatory policy improvements.

Accounting for 65% of mining employment, suppliers and contractors have an impact on the productivity of the industry. Their importance is fundamental since mining companies focus their attention on the business core: ownership, operation, and management of the deposits, and have outsourced several functions to their suppliers. Therefore, a significant part of the industry's success depends on the suppliers' productivity and competitiveness.

In short, the bulk of short-term productivity gains will depend on factors manageable by the mining companies themselves (a "private good"). However, an important part will be based on better public and regulatory policies (a "public good") as well as factors determined by the companies' relations with each other and with their suppliers and contractors (a "club or sectorial good"). Approaching the global frontier of efficiency will require everybody's effort, and benefit all.

The future of the Chilean copper mining industry, and in particular, the materialization of the 7.5 million metric tons of annual production projected for 2035 according to the Alta Ley National Mining Program, depend on the convergence of several factors: (i) a better internal management; (ii) the availability of land for exploration and exploitation, (iii) the increase in exploration expenditure, (iv) the emergence of new projects and the expansion of existing mines, (v) water and energy availability, (vi) a strategic relationship with suppliers , (vii) and the industry's ability to operate with a "social license", among others. Issues regarding taxation and environmental permits go beyond the scope of this study, but it would be desirable in both cases to carry out a similar benchmark analysis with the best practice jurisdictions.

In organizational terms, many aspects differ from the countries that exhibit best practices. The rotation of senior executives has entailed little adherence to a consistent strategic plan in the medium term. At the domestic level, there are significant differences in labor practices. However, compared to the international referents, we observe that there are higher hierarchical layers, little mobility between levels, less span of control, remuneration with an emphasis on production over productivity, among other aspects.

Concerning exploration, Chile has lost its appeal with respect to other mining destinations. In areas such as public and relevant geological information, Chile has lagged behind regarding the perception of policies towards the sector or the availability of land to explore. Chile's participation in the exploration market (18% in the case of copper) is less than its involvement in production and reserves (30%), which threatens the sustainability of our future leadership. Notwithstanding technological advances that maximize the worth of this potential and the expansion of current projects, in the long term the ability to generate wealth will be based on the discovery and development of new deposits and, therefore, is directly linked to the exploration efforts.

The current system of mining concessions should be improved in line with international best practices. Non-mining agents use the concessions for speculative purposes, which, on the one hand, directly affects the sector by reducing the availability of land, and on the other, indirectly affects strategic resources such as water and energy. In several regions of mining interest, the concession area for exploration or exploitation exceeds the total area of the respective territory, due to the overlap of concessions. This means that a company cannot request new concessions unless they overlap them and wait for the predecessors to abandon them. On a larger scale, there are no available spaces to explore in the country's main metallogenic zones, which constitute an important entry barrier for the discovery of new deposits. The low cost of the protection obligations of the Chilean system, consisting of low-cost patents that do not require or encourage the execution of exploration or exploitation activities or investments aggravates the situation. Reference countries impose a mixed protection system, which includes a patent and the demonstrable execution of mining labors.

As for water and energy, the sector has adjusted itself regarding the cost and availability of these strategic resources. Both resources are efficiently used, in conjunction with the increase in seawater use, which is expected to equal the use of continental water by 2026. There is room for improvement on the use of seawater, linked to regulatory policies and better industry coordination to share infrastructure and take advantage of economies of scale.

Suppliers will be decisive in the competitiveness of the industry and, if successful, the public-private programs that support them will contribute to greater knowledge and innovation. They can also constitute a new and important source of export within the global value chain in mining.

It is important to develop interoperability standards that allow the exchange of data and test spaces to facilitate innovation and scaling up. On the other hand, there is room for improvement regarding homologation of requirements to suppliers and contractors, reducing accreditation times and costs.

The feasibility of increasing production through new projects or expansion of existing ones relies heavily on the acceptance of companies and their activities within the surrounding communities: namely, the so-called "social license to operate." A better relationship with communities implies greater legitimacy, less conflict, and lower costs. This is all the more relevant as the mining activity approaches the country's central regions, where half the known reserves are found. However, these areas have higher population density, more competition with other activities and the complexity of potential conflicts.

The sector has evolved favorably concerning job security, where accident and fatality rates register declining trends. This trend has enabled the mining industry to have the lowest accident rates in the country's economy. When comparing the sample of twelve Chilean mines with the benchmarked countries, we find similar accident rates occurring per million hours worked. At the firm level, the best Chilean operation has a better indicator than the international operations considered, and only three national mines present rates higher than the international sample, confirming that the Chilean large-scale mining industry has converged in recent years towards the best global practices in this area. There was also a substantial fall in fatalities: in 2000, just one fatal accident was recorded for every 2,289 employee, in 2014, one for every 6,960 employee. In other words, one fatal accident is recorded for every 132 million tons of material moved in 2000, versus one for every 342 million tons in 2014. The challenge to reduce the fatality rate persists, which, despite all the progress, is still the highest among sectors of the economy.

According to the Labor Directorate, 85% of the workers of the large-scale mining industry work 12-hour days, with shifts of 7x7 or 4x4. 80% evaluate them positively and prefer the 7x7 shift. However, mining companies, subcontractors, and suppliers must request the Labor Directorate’s authorization, despite all previous agreements between companies and workers, for authorities to consider these workdays exceptional. This process may take up to 40 days and is required for all new employees or contractors. Approximately 6,000 requests for exceptional workdays are processed a year (half of the country's yearly requests) in Antofagasta and Calama, which constitutes a significant burden for the Directorate.

Concerning human capital, the sector's requirements are unsatisfactorily met both qualitatively and quantitatively. There is an excess of supply of professionals, who in turn receive training of small relevance to the sector. On the other hand, there is an excessive demand for technicians and operators, who in turn find it difficult to train or certify their competencies adequately. Industry efforts are moving in the right direction, but they require greater speed and commitment. Public-private coordination is crucial in this area.

Chile's future mining industry will tend to develop on a medium scale. The deposits discovered during the last decade correspond to smaller deposits, and half of the country's reserves are located in the central zone, where implementing large mining projects is more difficult due to higher population density, and increased competition for the land. Hence, the sector's objective and the country's priority must be the convergence of a medium-scale mining industry towards world frontier standards regarding operational practices, sustainability, and relationships with the communities. The current medium-scale mining sector presents critical gaps at the national level, and its productivity has deteriorated in recent years at rates that double the annual fall in productivity in the large-scale mining industry, and at the same time trebles the accumulated fall.

Main Recommendations

The study results are a set of 53 specific recommendations in the areas of public and regulatory policies (a "public good") and sectoral policies, which require everybody's joint action, including mining companies, contractors, suppliers and communities (a "club or sectorial good"). Also, a series of suggestions based on good practices for business management (a "private good") arose during the development of this report. We must point out that all recommendations were unanimously approved by the commisson's counselors.

(i) Good practices for company management (a "private good")

Although it exceeds this Commission's mandate, this study identified good practices regarding problems that are manageable by each company or mine. Converging towards these "good practices" are the best short-term opportunities for the sector, and do not require government intervention.

Productivity is recurrently perceived as a central, crosscutting issue and a continuous and long-term process that arose in the interviews. It is viewed as a pillar of the operational philosophy of best practices. This vision is characterized by the search of a "global optimum" in the maximization of the mine's efficiency as a whole and not by the vision of "silos" or isolated improvements around the productive processes, characteristic of several operations in Chile, aiming at a "local optimum." With the aim of maintaining this effort in time, the selected best practice mines try to minimize the rotation of senior executives, a common practice in Chile: in recent years the industry suffered successive changes in short periods. With long-term vision and a stable executive level to maintain company strategies, international enterprises focus on their overall productivity and not only on the productivity of productive processes. Again, this has been identified as common practice in Chilean mines, where bonuses depend on isolated processes and have little or no part attached to the entire operation. This generates substantial efficiency losses in the passage from one process to another. Companies must reduce the rotation of top executives, seek global optimization, and use bonuses and compensation mechanisms linked to profits and global indicators, to converge towards these management practices.

Two aspects are evident when visiting international best practice mines and interviewing their teams: 1) the use of technology and 2) the autonomy and initiative with which operators work. Regarding the first point, the operating stations or the level of both technology and equipment at the control centers do not differ with those existing in Chile. However, the best practice mines use them intensely, while in Chile they seem to be underutilized. In local mines, a common anecdote is that processes that may be automatically operated are used in manual mode, thus maximizing labor without increasing the production, and therefore reducing the productivity. Therefore, the difference between Chile and international operations would not be the availability of technology, but its usage. It is worth mentioning the use of operational data to generate information, which minimizes failures thanks to their predictive capacity, and the associated intervention mechanisms, are key in preventive maintenance processes. The combination of a real-time monitoring system, systematic analysis of hydraulic parts, and single fleet management seem to maximize the efficiency of mobile equipment in the mining area. A global vision, as opposed to an isolated one, allows a maintenance operator to remove a truck for preventive inspection (based on analysis information and sensors), without a mine supervisor having to worry about a production bonus.

A second relevant point concerns the staff's autonomy and initiative. Chile has between six to eight hierarchical layers, versus four or five in the best international mines. The span of control in Chile is small, due to a larger amount of top layers, with fewer workers per supervisor, contrary to the international trend. This is evidence of a control-based management culture, which reduces initiative, restricts autonomy, dilutes responsibilities between layers, and raises costs. Greater emphasis on autonomy and empowerment of operators would reduce the hierarchical layers and increase the breadth of control. This obviously requires more significant instruction, especially to multi-functional workers, and requires training supervisors in areas such as leadership and team management. In Chile, time is not only lost in meetings oriented to "control," but also, the supervisors' time is spent on administrative tasks (paperwork) at the expense of spending time in better planning and organization. This should be a primary focus for the mining companies, even though it is partly associated with the internal reaction to the authority's regulation demands.

In addition to greater autonomy, the best international companies seek to identify and empower their workers, who may be promoted to supervision posts and even to management after duly training. However, this does not happen in Chile: and the absence of a meritocratic culture is not exclusive to the mining sector. In addition to more autonomy and career potential, the selected international mine workers are multifunctional in areas for which they have been certified (and where they do not assume risks that they cannot control). For multifunctionality to work, continuous training programs are required in technical and soft skills and remunerated accordingly. The Mining Competencies Council of the Mining Council (Consejo de Competencias Mineras of the Consejo Minero) has identified these aspects: profiles are recommended, competencies are defined, and certification is proposed. Nevertheless, the application is still incipient.

(ii) Good practices in public policy (a "public good")

This set of recommendations refers to six major action areas where government intervention is required, in either public management improvements or regulatory changes.

First, improve the unnecessarily long and cumbersome process of approving or rejecting large projects. The process should be shortened to a proposed goal of three years. A step forward would be to implement the measures of the Presidential Advisory Commission for the Environmental Impact Assessment System, SEIA, which mostly requires changes in particular and specific regulations rather than changes in generally applicable legislation. At the sectoral level, it is urgent to establish a clear road map of the permits and times needed for the approval of desalination plant projects. The coordination of these processes is a highly complex task for all those involved; however, it must be a priority in the State given the enormous economic impact of the delays. The formal implementation of a Large Projects Office, similar to the Canadian model, where a public executive accompanies the project and its processes and works through with parallel and non-sequential procedures, with prompt responses, should be a priority in government. This office seeks to facilitate regulation compliance, not its evasion. If it is possible to respond in three years or less in Australia and Canada - wich are countries that have stricter environmental, safety and community consultation requirements than Chile - any greater delay than this in Chile is pure public sector inefficiency.

Secondly, enhance our future development and sustainability in Chile's share in the copper market. The country must attract investment by making mining exploration in general more attractive. In fact, Chile's share in exploration spending is about half of our share of production or reserves. Attracting more investment in exploration requires reforming the mining concessions system to increase the availability of land, and eliminate speculative practices currently allowed. The relevant geological information available to public should also be increased. We propose a mixed protection system, with ascending value of the patent and concessionaire requirements that directly encourage the activity. Patents should be of higuer value and the same for all kinds of minerals, so as to meet international levels. The concessionaire may discount from the patent the amount spent in obtaining geological information and mining investment, but they will be ascendant progressively in case he does not exploit the mining property. We also propose to modify the term of concession for exploration to three years renewable twice, with the resignation of part of the area granted at each renewal. For the exploration concession's renewal, relevant geological information must be submitted to the State, as well as minimum work plans. The consecutive requests for mining concessions (a common practice in Chile) from related persons or in successive periods of time must be eliminated. Application for an exploitation concession should require mineralization evidence and minimum work plans. Under a new regime, a temporary limit on the 30-year exploitation concession should be established, which can be renewed with priority for the same period repeatedly and indefinitely. Sernageomin must be reinforced, and endowed with the capacity required to inspect the proposed modifications.

Third, to facilitate operational continuity through agreements between companies and workers. We suggest re-establishing the option of "adaptability pacts," on which there was a majority agreement in Congress in the context of the 2016 Labor Reform, extending the possibility of exceptional work-days without the need for approval by the Labor Directorate: in 4x3 shifts, 4x4 and 7x7 shifts.

Fourth, generate a more flexible and robust labor market, for the benefit of both workers and companies. The sector would benefit from establishing a "mining passport" that provides mobility to workers between jobs and companies and covers aspects of safety, health, and labor competencies. Along with security certifications, for pre-occupational and professional health certification, any currently valid health exams should be accepted, to reduce duplication of examinations and its costs. Likewise, it would be useful if the Labor Directorate facilitated the extension of exceptional workdays of the constituent companies to the contractors and the incorporation of information technologies to the authorization process.

Fifth, enhance human resource. This resource is as valuable as the natural resource, but unlike the geological data, human resource can be better utilized, trained and strengthened. In this, the companies, the industry as a whole, and the Government share responsibilities. The mining labor market has qualitative and quantitative shortcomings. The Mining Council's Mining Competencies Council defined a set of competencies and skills required for functions and trades in the sector. This framework should be institutionalized in the definition of content and expertise of the industry's careers, both in instruction and training. This is particularly important for medium-sized mining, which focuses its search for human capital in high schools and technical training centers. The skills acquired by workers, including through training carried out by the companies, should be certified by Chile Valora, or by private entities, in particular for the workers who have multifunctional positions.

Sixth, improve the sector's safety, with the aim of reducing fatalities. As evidenced by the information analyzed, the greatest gaps concerning the best global practices were recorded in labor productivity measures. The challenge of the industry is to improve its safety indicators while raising production and productivity, an achievable challenge in the light of global best practices. Sernageomin should facilitate both the incorporation and exit to the Registry of the Basic Induction Homologated Course in Mining, which would broaden the program and allow extending the accreditation of necessary safety requirements common to all mines. Due to the characteristics of the country, the impact on health in the long term due to working at high altitudes should be monitored.

iiii) Recommendations for joint action in the sector (a "club or sectorial good")

In addition to the areas of intervention for companies and government, an ecosystem that facilitates the relationship between businesses, suppliers, contractors, workers, communities, universities, research centers, etc. would strengthen the entire sector. This is the sector's responsibility, but the articulating role of the State is essential in catalyzing events, improving coordination, and correcting asymmetries. Recommendations destined to enhance collaboration arose in six areas of action, which have the characteristics of a sectoral public good or, in other words, a "club good." As they are actions that benefit the industry as a whole, no single company can provide them.

First, innovation can be enhanced through several identified actions. The sector would benefit from shared testing, piloting and training facilities. Abandoned sites or periods with idle capacity in medium-sized mining could fill this need. Interoperability between communications and information systems should be maximized in all mining processes with instruments linking supplying companies and mining companies through standard protocols.

Second, explore the possibility of sharing private infrastructure and generating economies of scale, particularly in new seawater desalination projects, or in transport infrastructure and their intermodal integration. Incorporating medium-sized mining into these private agglomeration processes would generate additional gains.

Third, work on improving the inefficiencies in the relationship between companies and their contractors. The primary deficit is the absence of approved and homologous requirements for admission to the mines. The establishment of common standards between mines, companies, and contractors would reduce time, capital and operational costs, and increase the productive capacity of the mines, benefitting companies, and their suppliers.

Fourth, expand private sector-level interventions that benefit from public support. The National Mining Program Alta Ley is a good example, specifically the development of world-class suppliers and the Open Innovation Platform between Alta Ley and Fundación Chile. These efforts should continue and public-private partnership actions should extend to other areas of mutual interest.

Fifth, develop and strengthen the medium-sized mining industry. Significant progress is expected in the future medium-sized mining industry, and a development and deepening of a capital market should be a priority. It would be important to expand financial instruments to ensure mine closures. Joint Guarantee Funds, similar to those established in Western Australia, are a good model to consider. In addition to being less expensive than warranty bills, they would take care of recovering abandoned tailings and dumps.

Sixth, promote a better relationship between mining companies and communities, with a continuous consultation system from the on-start. A set of participation guides for large projects produced by the authority (similar to those implemented in the Ministry of Energy) would favor a model of permanent dialogue. Likewise, progress in the implementation of the measures of the Presidential Advisory Commission for the Environmental Impact Assessment System (SEIA) would accelerate the proposals of establishing early relationships, indigenous consultation and strengthening of citizen participation. In the case of disputes, establish a system of conflict resolution, such as that promoted by Valor Minero, where those involved can request mediation, arbitration or conciliation, as well as create a certification entity that enables and enhances the organizations participating in the dialogue processes. Given the direct relationship between local authorities and companies, implementation of the Presidential Advisory Council against Conflicts of Interest, Influence Peddling and Corruption Processes, regarding funds received by local governments, is recommended to establish a better institutional framework, with greater transparency and efficiency.

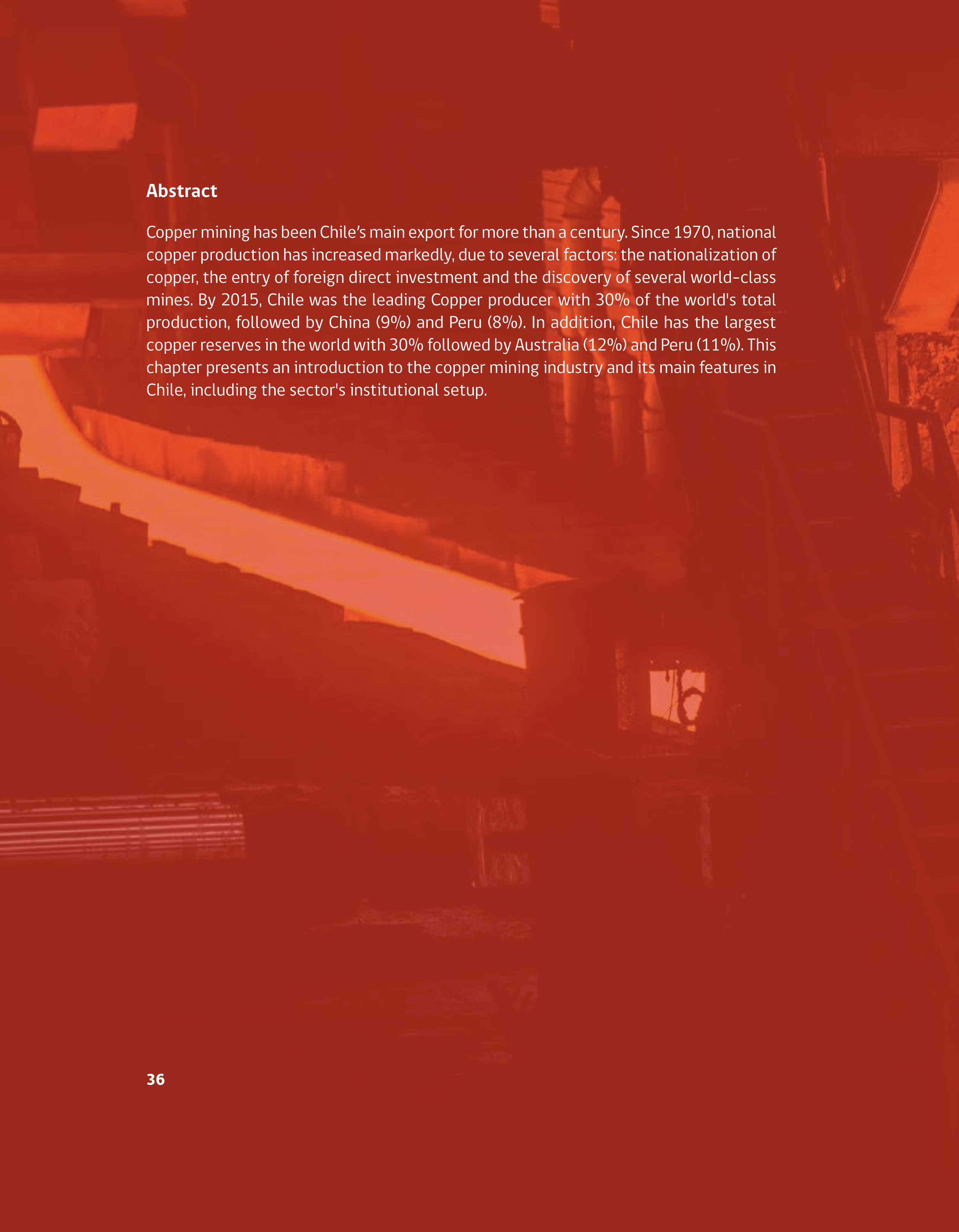
This report is the first of its kind carried out in the country, and it should not be the last. Its value lies not only on the provision of information but also in generating a constructive and objective dialogue on which companies, workers, and authorities can advance. For this reason, the Chilean Copper Commission (Cochilco), or any other agency that the Government may consider, produce frequent productivity indicators, and comparative studies similar to ours. Advancement to this study would be complementing it with a study pertaining medium-sized mining companies, comparing their performance with international operations, and laying a baseline analysis of their evolution. Similar comparisons with countries of best practice regarding the tax system, SEIA, and the set of licenses and permits required to undertake a mining project would allow Chile's attractiveness to be monitored in comparison to its competitors.

Part 1

Characterization of the Copper Mining Industry in Chile

Chapter 1

Chilean Copper Mining Industry



Abstract

Copper mining has been Chile's main export for more than a century. Since 1970, national copper production has increased markedly, due to several factors: the nationalization of copper, the entry of foreign direct investment and the discovery of several world-class mines. By 2015, Chile was the leading Copper producer with 30% of the world's total production, followed by China (9%) and Peru (8%). In addition, Chile has the largest copper reserves in the world with 30% followed by Australia (12%) and Peru (11%). This chapter presents an introduction to the copper mining industry and its main features in Chile, including the sector's institutional setup.

Key points

- Mining and its suppliers are a key sector for the economic and social development of the country.
- The country needs the joint effort of both the public and private sector to expand the mining activity, and thus achieve the desired levels of economic and social development.
- The mining industry is in a privileged position to reach agreements and implement long-term policies in a mining strategy that would be decisive in the development of the country.

1.1. Introduction

This chapter outlines the main characteristics of the Chilean Copper Mining Industry and its relevance for the country. Its objective is to give the reader an introductory perspective on the copper mining industry's productive process.

1.2. Copper's productive processes

Man has mined copper for thousands of years, as the mineral was readily available in metallic form. However, at present, it is scattered over large areas, and mixed both with other minerals and with sterile material. Therefore, the productive process faces complex and rising challenges, increasingly requiring more technological sophistication. In fact, during the past two decades, the mineral ore has depreciated strongly due to resource depletion, and reduction in the mineral-sterile ratio, converging towards lower grade ore.

The first stage associated with the productive process in the Copper Mining industry begins with the formulation of a Mining Project. This phase starts several years before the mine becomes operative and may take as long as 8 to 15 years (see Figure 1.1). The project begins with the Exploration, which leads to the discovery of a potential ore deposit. The deposit is drilled to develop a profile study, and evaluate the possible production levels. This particular stage takes approximately one year and is followed by several pre-feasibility engineering studies, which may take up to three more years. Feasibility studies, which last another full year at least, conclude this process. Given the results of these studies, the decision as to whether invest to exploit the reservoir or not, is the following step. The average time between a pre-feasibility study and the start of the mine operation is around eight years. Environmental impact assessments and permit processes are carried out in parallel to the pre-feasibility studies and should be, for the most part, ready for the following stage of Engineering, Procurement, and Construction.

Figure 1.1 - Stages of a Mining Project prior to Operation

Source: National Productivity Commission

Upon approval of the feasibility studies, and once the plant is designed and the financial structuring is set, begins the construction, which will result in an operational mine. Overcoming these stages allows the "Mining Project" to become a "Mining Operation", which consists of the ore extraction from the mine and its subsequent transport to the plant for processing.

The extraction process varies according to the type of mine, which may be either an open pit or an underground mine.[1]

Nonetheless, in both cases, the main sub-processes are drilling and blasting to separate the ore from the rock, followed by its loading and transport to the plant. In the plant, the rock is crushed and ground to reduce its size, freeing valuable minerals from the gangue material. There are primary, secondary and tertiary crushers depending on the size of crushed rock.

The extraction process is similar to all copper deposits. However, as in all mining operations, the ore must be concentrated, and these processing techniques vary depending on the nature of the copper ore extracted: whether they be oxides or sulfides. Oxides are closer to the surface, and therefore are extracted first, whereas the sulfides are found at a greater depth.

The ground material is transported to the plant where it is then leached, which consists of the copper extraction through electro-winning, whereby copper is freed into a solution of sulfuric acid. The copper sulfate that results is then stripped off copper by electrolysis, synthesizing copper cathodes. A third of the Chilean copper production (31% in 2015) correspond to oxides, and 50% of total exports correspond to cathodes.

For sulfur deposits, after crushing, the material is reduced to smaller diameters in milling. Then a pulp is formed with water and chemical reagents, in a process called Froth Flotation.   A copper concentrate (with approximately 30% copper content) is obtained by skimming of, collecting and drying the material. In Chile, sulfides account for two-thirds of copper production (69% in 2015), and half of the exports.

Approximately 50% of the country's copper exports are copper concentrate. However, the other 50% is further smelted or refined, obtaining finally copper cathodes.

The prices of minerals are determined by stock markets, such as the London Metal Exchange. The price (in dollar cents per pound of copper) reflects the value of a "Grade A" cathode of 99.99% purity. In the case of copper concentrates, the price will depend on its

[1] In Chile, the main underground copper mines are the Andina (mixed) and El Teniente (underground) divisions of Codelco. The first represents 4% of the country's production, the second 8% (2015).

purity degree. The price of copper concentrate depends on the quality of the concentrate, considering its copper concentration levels, and the presence of residual contaminants .[2]

1.3. Copper Mining in Chile

Since the beginning of the Republic, Chile has had a significant role in the world copper market. Mining, which can be either metallic or non-metallic, is one of the most important sectors of the Chilean economy. Among the first, copper, gold, silver, zinc and lead are the most important. In the copper mining industry, deposits may be polymetallic, yielding not only copper but also other minerals as by-products. Chile has a predominance of copper deposits with molybdenum, but gold, silver, and other minerals are also found.

1.3.1. Brief History of the Mining Activity in Chile (1800-2000)

In 1803, by the time the colonial era was coming to an end, entrepreneur Juan Egaña presented a report to the Real Tribunal de Minería giving an account of the state of the Chilean mining industry, noting the existence of around 200 mines, mostly copper.

Although not as striking as the extraction of silver or saltpeter, copper mining played a major role in the nineteenth century. The industrial revolution generated a substantial demand for this mineral, met by Chilean producers since the second decade of the XIX century. Since 1825, shipments destined for the foundries of Swansea in England remarkably increased.

In 1831, the introduction of the reverberatory furnace by Charles Lambert revolutionized the techniques of copper smelting by using copper sulfides, which were originally discarded. In the 1840s, stone charcoal fuel for furnaces and smelters were installed in Coquimbo, Tongoy, and Guayacan to melt the ore extracted from the recently discovered Tamaya deposit[3]. Thanks to Tamaya, copper production increased significantly in 1852, reaching its highest level in the 1870s, and placing Chile as the world's leading copper exporter with 52,000 metric tons in 1876, accounting for almost 40% of the world´s production.

However, the boom was not sustainable. Chile reduced its production by half in 1899 mainly due to: (i) the fall in international prices from 1875; (ii) the progressive depletion

2 Which raise the processing cost diminishing the value of the concentrate.

3 José Tomás Urmeneta, un empresario del Siglo XIX. Ricardo Nazer, Colección Sociedad y Cultura Centro de investigaciones Diego Barros Arana, DIBAM 1993.

of high-grade deposits; and (iii) the technological backwardness of extraction techniques that did not permit the exploitation of massive deposits of lower grade copper. In addition, Chilean businessmen could not afford to modernize operations, motivating the sale of mines to foreign companies. All these aspects meant that by 1905 Chile's share in the world market fell to 4%.

The global approach to the issue of lower grade mines was to exploit copper porphyry in a profitable way, whereby for every ton of material extracted, only one or two percent was copper, requiring a considerable technological change in both extraction and processing procedures. It also involved investing large amounts to operate a mine profitably. The United States developed new technologies, such as the flotation processes previously described, allowing the northern country to become the world leader in copper production.

Granted that Chile had the largest world reserves of copper porphyry distributed along the Andes Mountains, North American companies developed increasing interest in the Chuquicamata and Potrerillos deposits in the north, and at El Teniente in the central zone. These companies made substantial investments to start up the operation of the new copper deposits. By the end of the 1920s, the production of these deposits accounted for 93% of national copper production and 17% of world production, reaching a maximum of 21% of global copper in 1945. Chile thus recovered the place that it had already occupied in the mid-nineteenth century as the world's largest copper producer.

During the first decades of the twentieth century, copper replaced nitrate as the country's main export and began to make significant tributary contributions. Chile was increasing taxes on mining and accumulating technological capabilities in a process that culminated in the nationalization of the Copper Mining Industry in 1971. Chuquicamata, El Salvador, and El Teniente became thus property of Codelco. At that time, Codelco's production was close to 600 thousand tons per year, and increased at an annual average rate of 4.2% between 1971 and 1991, increasing its share of the world market from 9% to 12% in those same years.

Although the 1974 DL600[4] provided guarantees for foreign direct investment, significant investments came along with the return to democracy in 1990. During that decade, many copper mines and deposits were discovered, and the country received an unprecedented flow of foreign investment close to US$20 billion.[5] This allowed for an expansion of the total copper produced of 11% per year during that decade, and Chile increased its production from 1.6 million tons in 1990 to 4.6 million tons in 2000. Thus, Chile once again became the main copper producer generating a third of the world's copper.

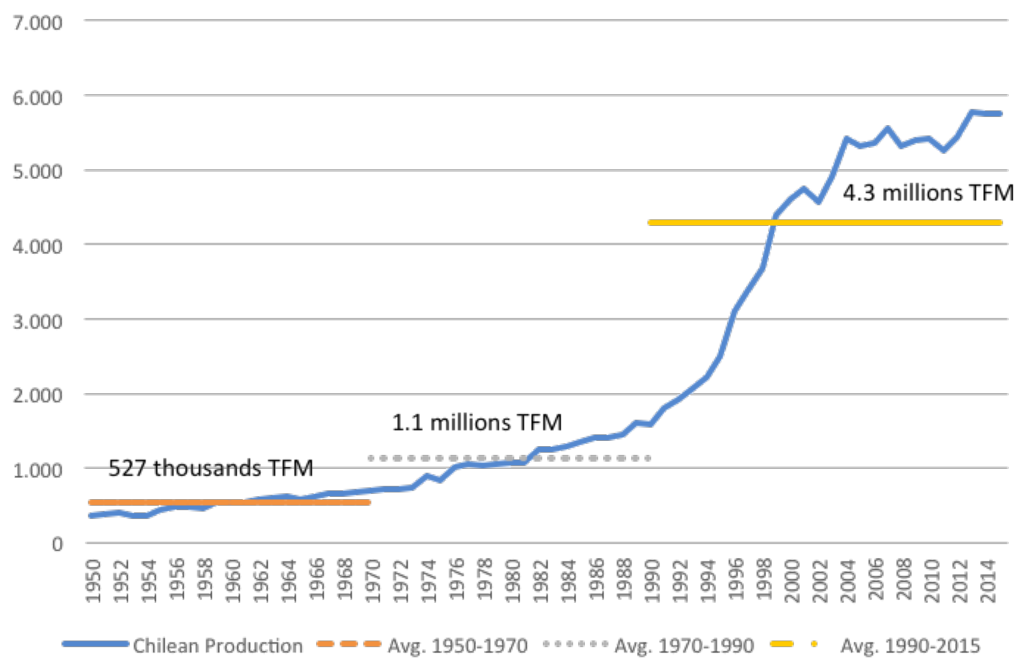
4 Law Decree #600 (D.L 600)

5 Foreign Investment Committee and Basic Statistics, Study and Strategic Management, Codelco.

1.3.2. The Copper Mining Industry today

The Copper Mining Industry in Chile has substantially changed its production scale during the past six decades (see Figure 1.2). In the period before 1990, production increased slowly: the 1950-1970 averages correspond to the production of roughly half a million tons, while in the period 1970-1990, the amount of production doubled to 1,1 million tons. Between 1990 and 2010 production trebled, with an average of 4 million tons. [6] The bulk of the rise was between 1990 and 2004.[7]

Figure 1.2 - Copper Production in Chile 1950-2015 (thousands of metric tons)



Source: National Productivity Commission based on Cochilco

6 During this period, Escondida, the biggest copper mine in the world started production.

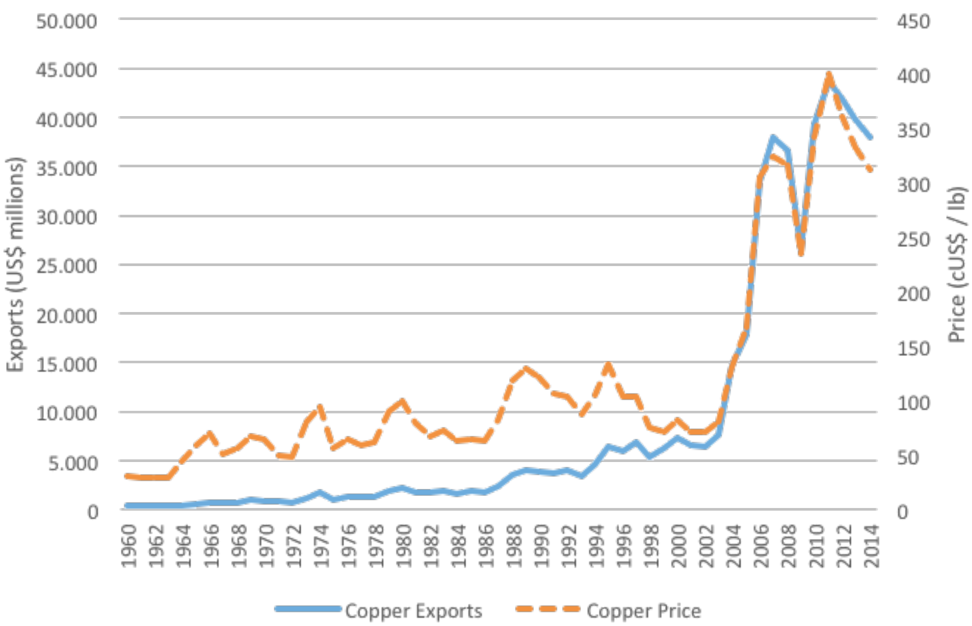
7 During this period, 14 operations started producing. In 2015, they accounted for 58% of copper production, including 3 operations from Codelco, that represent 39% of Codelco total production (2015).

How much copper do we export?

Copper exports averaged US$1,400 million during the period 1960-1990 (see Figure 1.3). During the period of greatest productive expansion (1990-2003), copper exports averaged US$5,500 million annually. During the super-cycle period, 2004-2014, exports averaged US$34,000 million per year. By 2015, exports reached US$30,000 million, representing an approximate reduction of 30% from the peak value in 2011, which was US$44.000 million.

Between 1960 and 1990 the price doubled, while between 1990 and 2011 it quadrupled (all in current dollars).

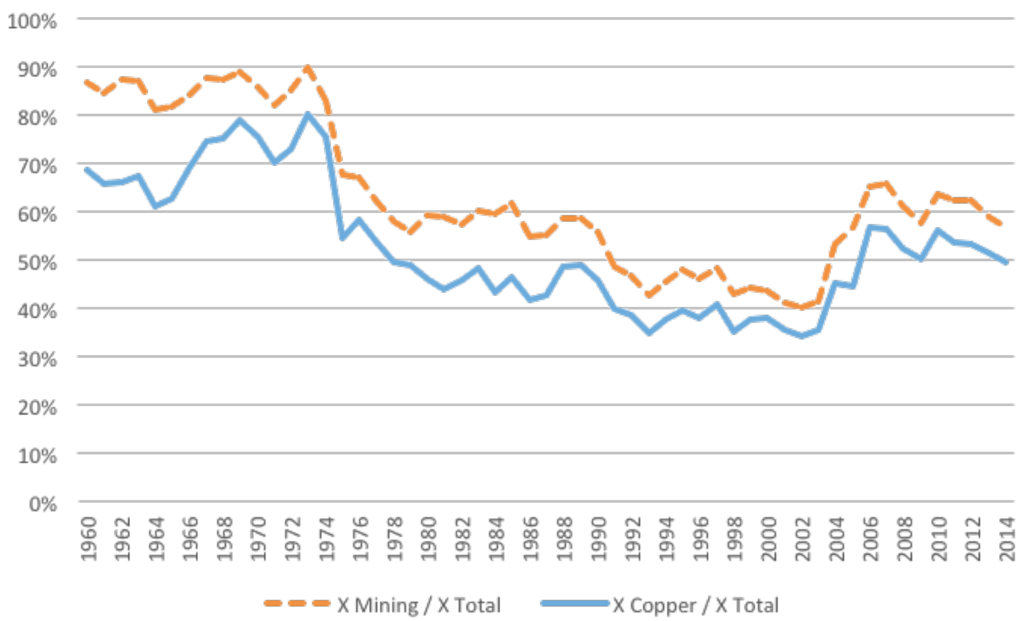
Figure 1.3 - Exports and Copper Price 1960-2015 (US$ MM; c US$ / lib)



Source: National Productivity Commission based on Cochilco

Copper has been Chile's main export for over a century, accounting for at least a third of its value. In fact, during the period 1960-2015, copper mining averaged 52% of the total exports (see Figure 1.4). In 2015, copper mining exports accounted for 48% of the value of total exports, and 12% of GDP for that year.

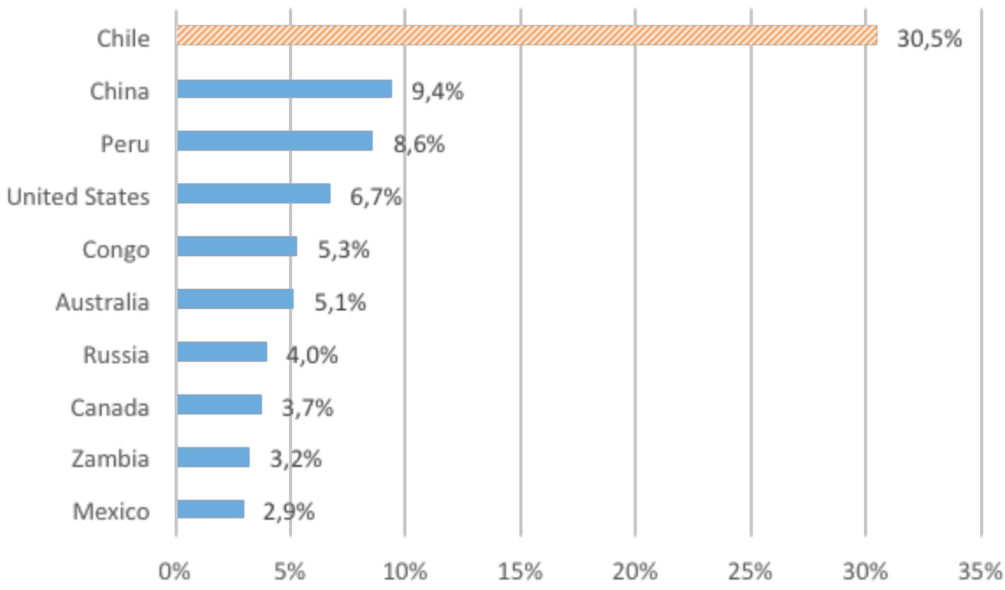
Figure 1.4 - Copper and Mining Share of Total Exports 1960-2015 (%).



Source: National Productivity Commission based on Cochilco

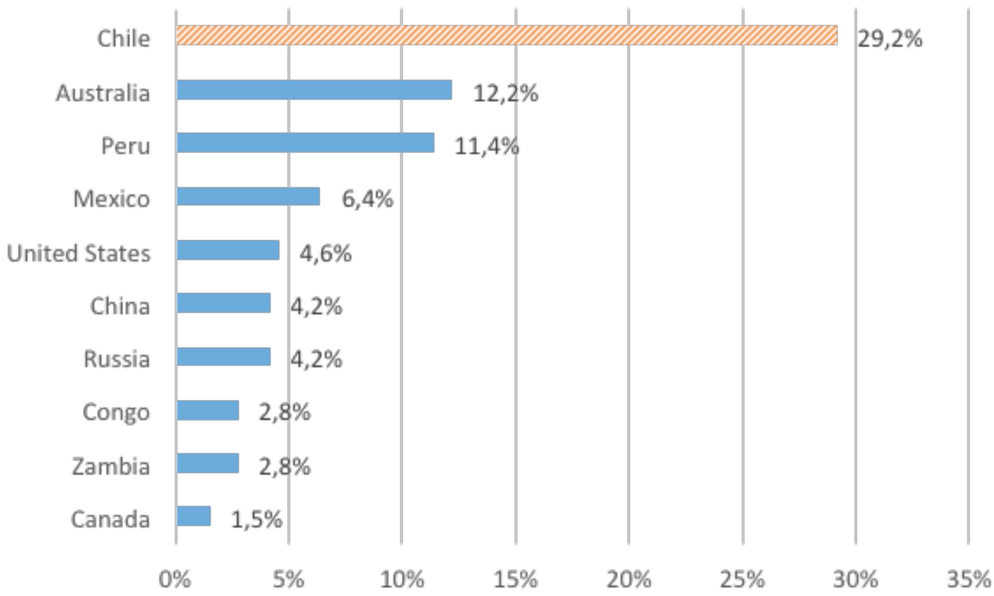
During 2015, Chile was the main copper producer accounting for 30.5% of the world's total. China follows with 9.4% and Peru with 8.6% (see Figure 1.5). Additionally, Chile has the largest copper reserves in the world (29.2%) followed by Australia (12.2%) and Peru (11.4%) (Figure 1.6).

Figure 1.5 – Copper Production by Country 2015 (% World Production)



Source: National Productivity Commission based on US Geological Survey

Figure 1.6 – Copper Reserves by Country 2015 (% World Production)



Source: National Productivity Commission based on US Geological Survey

What and where do we export?

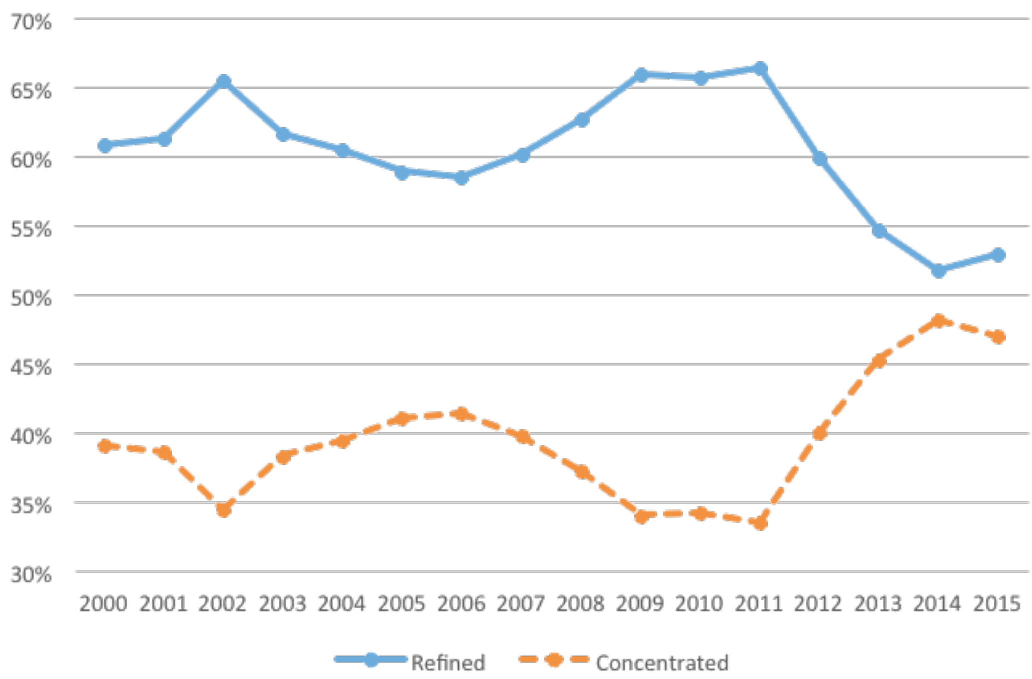
Copper production can either be refined (copper cathodes and blister) or bulk (copper concentrates) (see Figure 1.7). The latter has gained share in exports over the last decade and are sent to smelters and refineries abroad, mainly in China.

From 1990 to 2015, Chilean copper exports to Asia grew from 38% to 74% (see Figure 1.8), to the detriment of exports to Europe, whose share of copper shipments fell from 48% in 1990 to 12% in 2015. Exports to the Americas, mainly the United States, were around 14% during the 90s, reaching a maximum of 28% in 2001, before falling again to 13% (2015).

China received barely 0.2% of copper exports during the 1990s. A decade later, in 2000, China received 12.2%. By 2015, China represented the main destination of Chilean copper exports, receiving 43% of this mineral, followed by Japan and South Korea, 11% and 8% respectively.

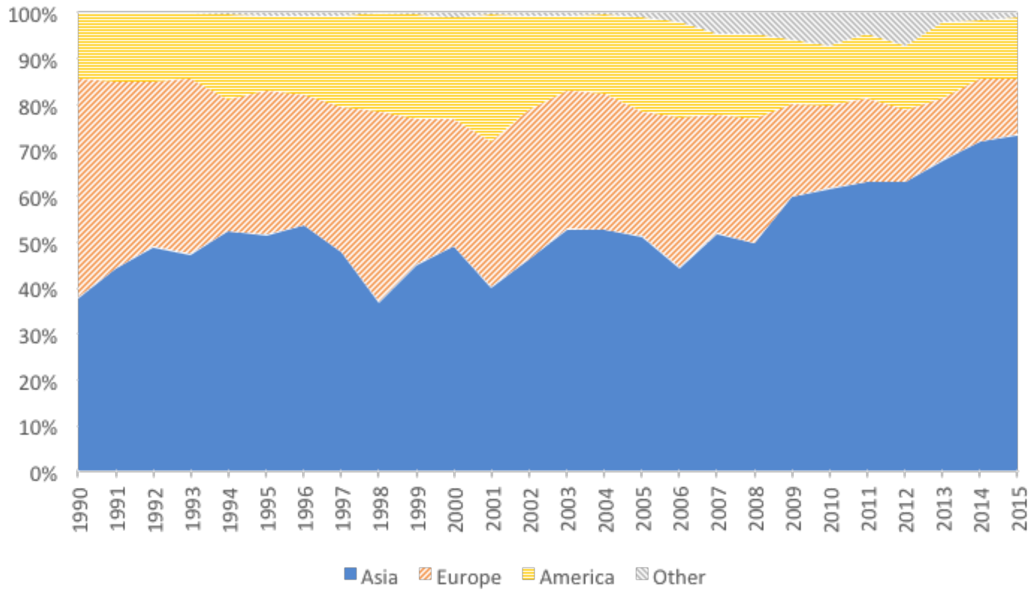
Figure 1.7 - Copper Exports per Category 2000-2015

(%; thousands of metric tons)



Source: National Productivity Commission based on Cochilco

Figure 1.8 - Destination of Copper Exports 1990-2015 (%; US$ current)



Source: National Productivity Commission based on Cochilco

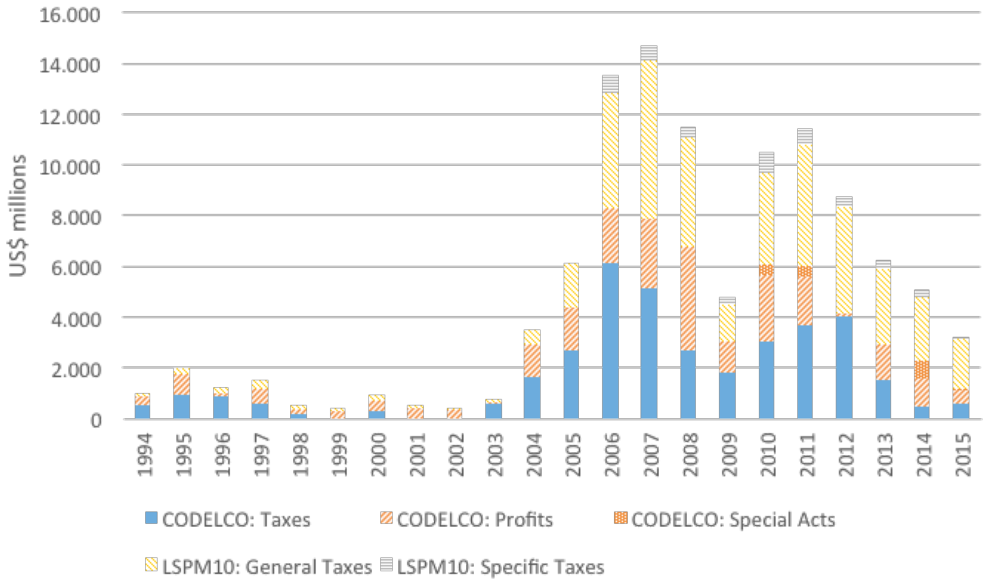
What is the copper mining industry's contribution to the State?

Between 1994 and 2003, the average contribution of the mining industry to fiscal revenues was 5.9%, whereas, during the period 2004-2014, the contribution practically tripled - as did the copper price - reaching an annual average of 19.6% (see Figure 1.9). This was fundamental in the accumulation of over US$20 billion in Sovereign Wealth Funds.[8] By 2015, these contributions returned to levels similar to 2003, reaching 6.1% of tax revenues.

Including the state companies CODELCO and ENAMI, the mining industry contributed to the treasury with US$96,000 million during 2004-2014, ten times higher than the previous decade. It is worth mentioning that the price of copper, and therefore its relevance in fiscal revenues, presents high volatility in real terms (see Figure 1.11).

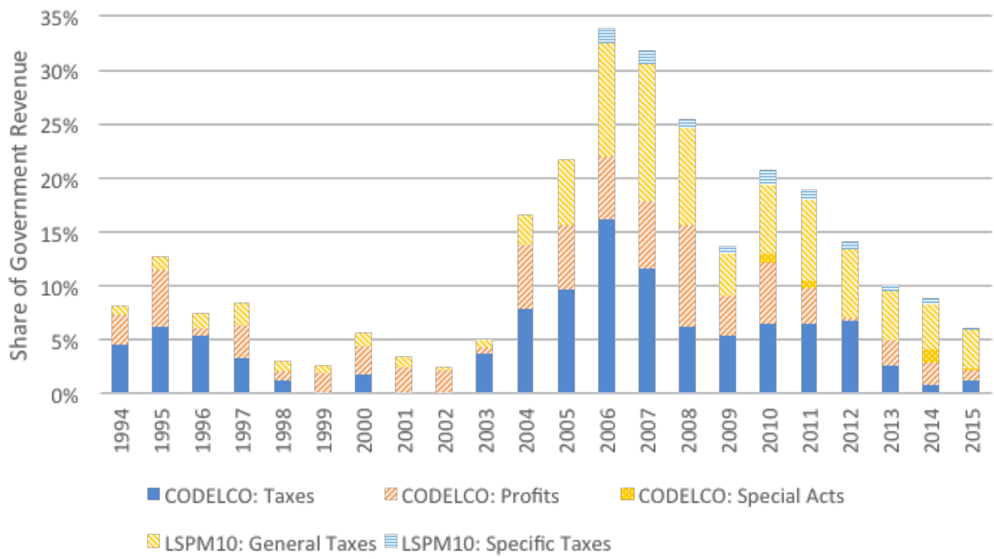
[8] Pension Reserve Fund (FRP in Spanish) an Economic and Social Stabilization Fund (FEES in Spanish).

Figure 1.9 - Copper contribution to Tax Revenues 1994-2015
(US$ current millions)



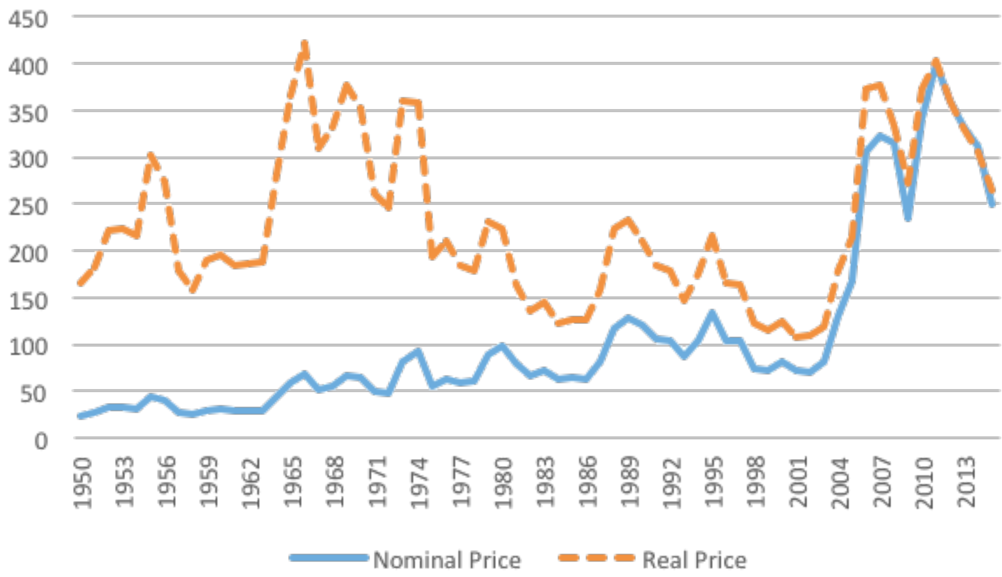
Source: National Productivity Commission based on DIPRES

Figure 1.10 - Copper Share in Tax Revenues 1994-2015 (%)



Source: National Productivity Commission based on DIPRES

Figure 1.11 - Copper Price Evolution 1950-2015 (cUS$/lb)



Source: National Productivity Commission based on Cochilco
Note: Real Price Base 2012=100

How is the Specific Tax on Mining Activities used?

The Specific Tax on Mining Activities (IEAM in Spanish) corresponds to a compensation payment for the mineral resource exploitation carried out by mining companies. Created in 2005[9], this tax revenue allows the creation of two funds (the Innovation Fund for Competitiveness (FIC) and the Regional Investment and Reconversion Fund (FIRR)). They seek to promote economic sustainability in the long term through investment in innovation and to benefit the regions of the country, especially mining ones.

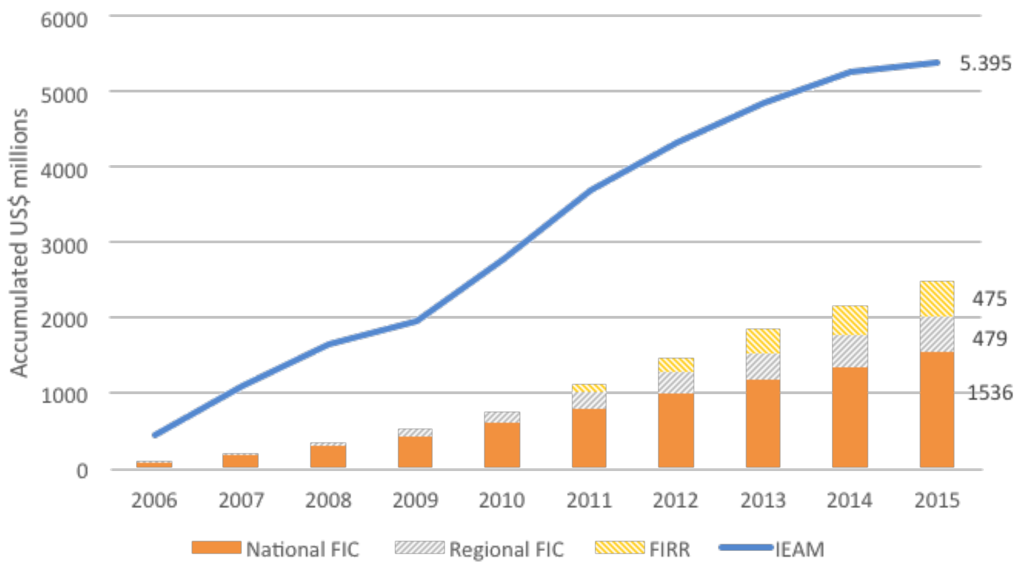
The FIC allocates resources to science projects, research, business innovation, technology transfer, and entrepreneurship, through public agencies (mainly CORFO and CONICYT).

9 Current IEAM, modified in 2010, taxes progressively the operational rent of a mining company depending on its annual sales. Marginal tax rate varies from 5% to 34,5% depending on operational rent, effective tax rate varies from 5% to 14% . The IEAM is deductible from the tax base for the income tax that is payed by all the private firms in Chile. Mining companies with annual sales from 12.000 to 50.000 copper metric tons or equivalent are taxed at a lower rate and mining companies with annual sales lower than 12.000 tons aren't affected by the IEAM.

74% of it was allocated in the period 2006-2016, and 24% for local projects during the same period. The FIRR, created in 2010, funds regional and municipal development efforts.

Figure 1.12 shows the difference in gross income accumulated by the IEAM, which amounts to almost US$5.4 billion. Budgeted expenditures for the related funds (FIC and FIRR) were almost US$2.5 billion over the period 2005-2015. The difference between the income from the IEAM and the expenditures budgeted in the FIC and FIRR have been saved in the Social Pension Reserve and Economic Stabilization Funds.

Figure 1.12 - Fiscal Revenues through IEAM, and FIC/FIRR Budget



Source: Cochilco based on DIPRES

How much does Chile spend on mining R&D?

It is a well-known fact that Chile, at the aggregate level, spends less on R&D than the average OECD countries (and leading mining countries). Table 1.1 evidences the huge gaps with Australia, the most similar to Chile in demographic terms and composition of exports.

Although Australia doubles the per capita income of Chile, differences in innovation significantly exceed this difference: spending in R&D is at least five times greater than the percentage of GDP and almost 18 times higher than the amount of researchers/ scientists. Additionally, Chile has a different spending mix since private sector participation is half that of Australia and there are far fewer scientists in the industry. In fact, private expenditure on R&D per Australian worker is approximately 26 times that of the Chilean worker.

Table 1.1 Main Science and Technology Indexes in Australia and Chile (2010*)

Indexes	Australia	Chile
Expenditure in R+D (% GDP)	2,2%	0,3%
Private expenditure in R+D (% total R+D)	61,1%	29,6%
University expenditure in R+D (% total R+D)	24,2%	38,5%
Public expenditure in R+D (% total R+D)	12,1%	3,7%
Non-profit private expenditure on R +D	2,6%	28,2%
Private expenditure on R & D per worker (US$ PPP)	1.039	39
Number of Researchers (total)	92.649	5.440
Researchers in Private Sector (n °)	36.309	1.298
Researchers in the Public Sector (n °)	8.283	292
Researchers in Higher Education (n °)	53.588	3.274

Source: National Productivity Commission based on OECD

Note: Number of researchers refers to the equivalent in full workdays.

Years are 2010 or latest available.

Despite the differences mentioned above (in absolute and relative terms), mining plays a relevant role in domestic R&D expenditure in the country. As an example, Codelco spent about US$60 million during 2015, and in some years of the super-cycle, this figure exceeded US $ 100 million. On the other hand, the presence of transnational mining companies implies that the country should also benefit from the R&D that these companies carry out in their native countries.

Additionally, there are important public-private initiatives such as the Centers of International Excellence (CEI in Spanish) financed by CORFO, which represent an investment of approximately US$4 million per year, of which a maximum of US$2 million is public funding. Of the 13 existing CEI, there are three that are particularly focused on the mining industry (CSIRO-Chile, Emerson, Sustainable Mining Institute) and at least two others have participated in projects with this industry (Fraunhofer and Telefónica). However, public and private mining R&D does not reach 0,5% of the sector's sales.

In sum, Chile has a lower level of R & D expenditure than other reference mining countries, but has advanced in the generation of a consensus diagnosis on the current technological challenges (see Section 1.4) -materialized in the Technological Road Map of Alta Ley Mining National Program-.

1.3.3. Institutionality in Copper Mining in Chile

The adequate institutional framework for a natural resources sector requires a number of agencies and regulations: (i) a legal framework that grants governance (with landholder rights) to the exploration and mining of mineral resources; (ii) an administrative framework for the extraction of mineral resources; (iii) productive policies regulating industrial and artisanal mining activities; (iv) a system for managing general and particular taxes; (v) policies related to the health and safety of workers and environmental issues; and (vi) a relevant geological information base, among others.

The current mining landholder system is based on the granting of exploration and mining concessions by the courts of law. In legal matters, the Mining Code has remained stable since its creation in 1981, and the Constitutional Organic Law on Mining Concessions (LOC in Spanish) is the only one of its kind to remain unchanged with the subsequent return to democracy.

The Mining Ministry was created in 1953, and its mission is to lead the development of public policies around mining, with the ultimate aim of increasing the contribution of such activity to national development.

The Chilean Copper Commission (Cochilco), created in 1976 is a decentralized organization with legal status, a board of directors (among which is the Minister of Mining) and own assets. Its mission is to advise the Government on the elaboration, implementation, and control of policies, strategies, and actions that contribute to the sustainable development of the national mining sector. Also, it must safeguard the State's interests in its mining companies, overseeing and evaluating its management and investments.

Cochilco supports the Ministry of Mining in the formulation of public policies, and the minister is part of its directory.

The National Service of Mining and Geology (Sernageomin) is a decentralized organization that has its own legal status and individual assets; it contributes to government programs in the development of mining and geological policies as well as advising the Ministry of Mining. Sernageomin is in charge of issues such as mining security, the gathering of geological information, the closures of mines, amongst other functions.

The Chilean Copper Corporation (Codelco), created after the nationalization of copper in 1971, is an independent company fully owned by the Chilean State, whose primary business is the exploration, development, and mining of copper resources and by-products; copper refining, and its subsequent commercialization. It produces 10% of the global copper production and has the largest amount of copper reserves in the world (8% of the total). Codelco's production surpasses countries like China and Peru (second and third world producer), and its reserves exceed those of countries like Mexico and the United States.

The National Mining Company (Enami), created in 1960 focuses on meeting the needs of small and medium-sized mining. Enami aims to promote the development of these sectors in Chile, concerning the purchase, processing, and commercialization of minerals, as well as technical and financial assistance to easily access the international metal market.

The National Mining Society (SONAMI) and the Mining Council (Consejo Minero in spanish) are the two most relevant trade associations. SONAMI brings together all the mining companies, while the Mining Council gathers the 16 largest mining companies. On the supplier's side, there are the Association of Industrial Mining Suppliers (APRIMIN), the Association of Industrialists of Antofagasta (AIA) and Innovative Mining and Export (MINNOVEX). On the workers' side, there are the Copper Workers' Federation (FTC), Codelco's Supervisors Federation (FESUC), the Chilean Mining Federation (FMC), and the Federation of Mining Supervisors (FESUMIN), among others.

This Institutionality is quite complete regarding organizations and functions, and complex in its interaction. Codelco explores and produces, Cochilco and Sernageomin provide information of the mining activity, and help define policies. Enami enhances the activity in small and medium-sized mining. There are also all the relevant trade associations, capable of articulating the visions and interests of both mining companies and suppliers, and groups that safeguard the interests of the mining workers.

Finding 1.1. Mining and its suppliers constitute the most important sector of the Chilean economy in a series of indicators relevant to economic and social development. Chile has a clear comparative advantage in the mining industry, particularly in copper mining. The country will not achieve the desired levels of economic and social development if it does not expand the activity of the sector, and this will not happen without the efforts of both the public and private sector.

Finding 1.2. The ecosystem around mining is complete regarding organisms and functions, and very complex in its interaction. No other sector can compare at the national level: (i) large, medium and small enterprises; (ii) state-owned, transnational corporations and local capitals; (iii) a significant domestic and foreign suppliers sector; (iv) an organized workers' groups, (v) associations representing companies, providers and workers, and (vi) specialized State and Government agencies. Due to its complexity, the sector is in a privileged position to reach agreements and implement long-term policies in a national mining development strategy.

Institutionality and new projects

Chile is a mining power. As we have pointed out in this chapter, the sector is fundamental for the economic and social development of the country, as to GDP contributions, exports, tax revenues, the destination of foreign investments, and others. Mining will continue to be a highly relevant sector in the economy in the future, considering the level of accumulated investment in both physical and human capital and the natural conditions of the country. With approximately a third of the world's copper reserves, Chile possesses privileged geological conditions to attract investment, but it must have the institutional mechanisms to evaluate them properly.

The sector depends on the development of large investment projects, be they expansions of existing operations or new operations, which in turn are developed within an institutional framework. With high environmental, social and economic standards in conjunction with efficient and coordinated processes, clear rules and low uncertainty, the mining industry can be a major participant in the country's development. This requires greater efficiency in the public management of several state agencies, and greater coordination between the state agencies, to increase efficiency and decrease the time of approval or rejection of large projects. The "list of permits and normative obligations for a mining project" contains some 2,067 normative articles for mining projects, which in turn give rise to 220 sector permits necessary for a project. [10]

The evaluation processes of large investment projects, including mining projects, takes four and more years in Chile. These processes do not necessarily have specific deadlines for each of their stages, and they suffer from superposition or overlapping of faculties, redundancy, and repetition in the requests, and require the participation of several public services. Last but not least, there is uncertainty about its results.

Other countries whose mining sector has a significant participation in their economies, such as Canada or Australia, have established mechanisms that safeguard both society and companies, maximize the number of projects, and accelerate their implementation, ensuring strict compliance with environmental standards, security, and respect for indigenous and local communities. These objectives are fulfilled by: (i) precise definition of the responsible people, the liabilities, and criteria to be considered, (ii) definition of clear, transparent, and public standards, and clarity on deadlines for receiving, processing, evaluating company information, and publicly communicating the results (detailing the reasons for approval or rejection), (iii) the existence of mechanisms for the solution of conflicting objectives, (iv) the minimization of duplicate information, agencies with overlapping mandates, and discretionary processes, and (v) legal certainty regarding the decision, including appeals mechanisms.

The creation of a Large Projects Office (LPO) that follows the international best practices principles would be a contribution to the existing Chilean Institutionality. The LPO would be in charge of supporting and coordinating the different public services involved in the evaluation of projects, and in obtaining permits for large investment projects. This would benefit not only Mining but also Energy, Infrastructure and other sectors with large projects that need to be supported. The LPO would have three main objectives: (i) to support the project executor in its relationship with the competent authorities, and it's compliance to meet the required obligations for making the project feasible, (ii) to support state agencies in their coordination with each other, and their relationship with the executor and (iii) to deliver the outcome (project rejection or approval) as soon as possible. Examples of these offices exist in several countries, considered best practices, both at federal and regional levels, such as Australia and Canada.

An LPO would seek to rationalize processes by ensuring compliance with the regulator's mandate and carry them out in the most efficient and effective manner. It would safe-

[10] http://sisnor.minmineria.cl

guard that all necessary monitoring and control processes take place promptly and by the best available practices. It is important to emphasize that the purpose of the LPO is to reduce project approval times through greater efficiency by coordinating and monitoring responsible institutions and the rationalizing of procedures and permits. The objective is not, nor should it be, to facilitate the approval of projects by lowering environmental requirements, safety standards or of respectful treatment to local communities. On the other hand, the LPO is not in charge of evaluating or making technical decisions, for each evaluating action corresponds to the competent agencies, while the LPO has a coordinating role. It is not an office intended to facilitate the project executor's evasion of regulation but designed to promote compliance with the rules within a reasonable time.

The Major Projects Management Office (MPMO), created in Canada in 2007 is the first of its type. [11] The MPMO improved project evaluation process through a more predictable regulatory mechanism, with high-quality impact assessments, and a more consistent, coordinated and meaningful citizen consultation (and in some territories with a consultation to native or indigenous communities). Through this, they managed to reduce the processing times of large projects from four to two years. British Columbia in Canada and South Australia in Australia federally apply a similar model.

According to best practices, an LPO must have at least the following components:

- To be a one-stop shop (in the initiation and coordination of the procedure).
- Have a defined map of proceedings, permits, and licenses to obtain, as well as the respective responsible public entities.
- Support and coordinate the public services and companies involved in the process.
- Define, along with the responsible entities, the reasonable deadlines, according to the magnitude of the project and the procedures required.
- Monitor and facilitate (online) procedures and timelines committed by each of the public organizations involved.

[11] The MPMO was created with the follow mission: (i) to ensure the effective and prompt evaluation of major projects through a global management -environmental evaluation, regulatory permits, indigenous consultations-, (ii) to provide a one-window stop for project evaluation at federal level, (iii) assign responsibility and accountability along the process, (iv) to implement horizontal practices to improve the system. See https://mpmo.gc.ca/home

- Be a centralized mechanism of transparency in the process and the final decision.

The Australian Productivity Commission defined a five-criterion action plan to improve its system using the Canadian model as best practice. The proposal considers: (i) a precise definition of regulatory criteria (and priorities for conflicting objectives), (ii) reducing duplication of permits, (iii) improving certainty, transparency, and accountability in the system, (iv) improve deadlines and overall coordination, and (v) provide a precise definition of mitigation mechanisms and approval conditions. [12]

An important aspect of the LPO is its management transparency. In some cases, society may question the existence of such a support entity, and object to its role as facilitator, seeing it as a mechanism to avoid compliance with the regulation. Therefore, to further credibility and restrict objections, it is essential that the LPO be a Government created entity, with a clear mandate and responsibilities, which conducts its actions in a public and transparent manner.

In Chile, an attempt has been made to fulfill the role of an LPO in a variety of ways, and both the current and the previous Government have assigned teams to coordinate and support the evaluation management of large projects. Currently, the entity that seeks to fulfill the coordination function is the Pro-Investment Committee, part of the Ministry of Economy, although it still stands far from the level of resources and institutionalization that would make it more useful.

Finding 1.3. The Chilean institutional process of approving or rejecting large projects is unnecessarily long and cumbersome, far from international best practices.

Recommendation 1.1: Establish a Large Projects Office, whose function would be reducing project approval or rejection deadlines, through greater efficiency and coordination among the various public agencies involved in the process at national and regional level. The LPO should be institutionalized and endowed with action mechanisms to those of best international practices, including transparency criteria.

http://www.pc.gov.au/inquiries/completed/major-projects

1.4. Conclusions

1.4.1 Summary of Findings

Finding 1.1. Mining and its suppliers constitute the most important sector of the Chilean economy in a series of indicators relevant to economic and social development. Chile has a clear comparative advantage in the mining industry, particularly in copper mining. The country will not achieve the desired levels of economic and social development if it does not expand the activity of the sector, and this will not happen without the efforts of both the public and private sector.

Finding 1.2. The ecosystem around mining is complete regarding organisms and functions, and very complex in its interaction. No other area can compare at the national level: (i) large, medium and small enterprises; (ii) state-owned, transnational corporations and local capitals; (iii) a significant domestic and foreign suppliers sector; (iv) an organized workers' groups, (v) associations representing companies, providers and workers, and (vi) specialized State and Government agencies. Due to its complexity, the sector is in a privileged position to reach agreements and implement long-term policies in a national mining development strategy.

Finding 1.3. The Chilean institutional process of approving or rejecting large projects is unnecessarily long and cumbersome, far from international best practices.

1.4.2 Summary of Recommendations

Recommendation 1.1: Establish a Large Projects Office, whose function would be reducing project approval or rejection deadlines, through greater efficiency and coordination among the various public agencies involved in the process at national and regional level. The LPO should be institutionalized and endowed with action mechanisms similar to those of best international practices, including transparency criteria.

Chapter 2

Productivity in Chilean Copper Mining

Abstract

Our best estimate indicates that mining productivity fell at a rate of 1% per year since the year 2000. This holds using both types of productivity measurements commonly in use - output per worker (or the partial productivity of labor) and total factor productivity (TFP). We consider that the best measure of output per worker is tons of material moved per worker and not value added or tons of copper per worker, for tons of material moved (correctly) excludes from the measurements of productivity factors, which are exogenous to the mining operation, such as the grade of the ore or the mineral-waste rock ratio. Using this measure, we found that the partial productivity of labor fell 15% in the period 2000-2014. We also estimated the total factor productivity at a firm level, a measure that includes not just labor but capital, where capital was adjusted to take into account the long gestation period of mining investment, and where, once again, we corrected for the decline[1] in the grade of the ore. The results were similar. TFP falls 14% between 2000 and 2014. These results corroborate the drop in productivity found in the empirical literature in Chile, but indicate a substantially lower deterioration than the majority of such studies, for these do not adjust for the aforementioned factors.

Key points

1 Ore, ore grade, and stripping ratio.

- During the period 2000-2014, the country increased its copper production, but labor productivity shows a contraction of 15%.
- During the period 2000-2014, both energy consumption, labor contracting and capital investment grew. As of 2007, labor contracting and capital investment grow twice as much as energy.
- The total factor productivity of the copper mining sector, adjusted by endogenous and exogenous factors to the operation, shows a drop of 1% per year between 2000 and 2014, accumulating a reduction of 14% in the period.
- The factors that contributed positively to copper production were increases in processed ore, energy, and labor. While ore grade and total factor productivity contributed negatively to growth.
- There are significant productivity gaps in Chilean mines, and there is a general worsening of productivity throughout the period of analysis (2000-2014).

2.1. Introduction

Over the past 15 years, commodity-producing countries have recorded a decline in aggregate productivity, particularly in natural resource-based sectors, consequently generating a negative impact on the aggregate productivity of the economy[2]. In Chile, most productive areas exhibit a decrease in aggregate productivity indicators, and this is even more notorious in the mining sector.[3] In fact, our 2016 National Productivity Commission Annual Report found that the Total Factor Productivity (TFP) of the economy as a whole decelerated from 2.3% per year in the 1990s to just 0.1% per year in 2000. It was mainly caused by the fall in mining productivity, which decreased by -9% per year since 2000, compared to an increase of over 2% per year in the 1990s.

However, these measures are based on traditional estimates of productivity. This entails that in the case of natural resource sectors; the information used in the estimation cannot be corrected by factors intrinsic to the natural resource. This chapter aims to improve measurement by incorporating mining-specific factors, usually ignored, and taking advantage of information available at operation level.

In literature, different productivity indicators are used to analyze its evolution. In this particular case, the partial productivity of labor[4] is used as an indicator, measured as tons of copper produced divided by the number of workers. Although this metric is simple to calculate, it has significant biases. Among the most important are: (i) it does not consider exogenous factors that determine the productive capacity of the mining sector (e.g. ore grade and stripping ratio[5]); and (ii) does not correct for other productive factors involved in the process, for example, amount and type of equipment (capital) or the period in which the capital comes into operation. Ignoring these factors implies that impacts in these areas end up mistakenly imputed to productivity.

2 For instance, according to the OECD, value added per worked hour in the Norwegian mining and basic services fell 4% per year on average during 2000-2015. In Australia, the same indicator fell 5% per year on average (2000-2011), and in Canada it showed a yearly average fall of 1% (2007-2013).

3 National Productivity Commission, Annual Report 2016.

4 Following the OECD manual (OECD 2001, Annex I), the relationship between the product and one of the productive factors in particular (for example, labor), can be defined as factor productivity or partial factor productivity.

5 From 100% of moved material in the mine sub process, a proportion is waste rock wich ends in dumps, The rest is ore that continues to the plant for producing copper. Ore grade refers to the copper proportion in the ore. An operation with a higher stripping ratio (waste/ore) loses competitiveness as it has to focus its efforts in moving more waste rock.

Since standard productivity measures do not take into account changes in the ore grade, its deterioration, as occurred in the past years, is perceived as lower productivity.[6] In fact, more material must be extracted, loaded, hauled and processed to obtain the same amount of copper.[7] Studies that use the volume of copper produced (or added value per worker), exhibit falls in productivity of 50% (or more) during the 2000-2015 period, strongly overestimating the decline in productivity by not taking into account ore grade deterioration. If instead, we use quantity of tons of material moved[8] per unit of labor, we take care of the geological factors pointed out above (i) as the moved material[9] incorporates both the ore grade and the stripping ratio.

If the impact of other productive factors that affect productivity is not corrected, then this measure may still be biased (point (ii)). For example, equipment with greater loading capacity increases the amount of moved material per worker. Nevertheless, this improvement is not due to higher labor productivity, but rather to a better use of equipment. Hence, a better estimate of productivity is the so-called total factor productivity (TFP), which considers the set of factors or inputs in use. While the TFP jointly corrects the effects of labor and capital, in its traditional form it does not take into account the exogenous factors mentioned above. Therefore, mines with better ore grade will seem more productive or efficient. Conversely, if the grade deteriorates, it will appear as a fall in productivity when it is rather due to factors exogenous to the management of the operation. Therefore, a better estimate of TFP should consider incorporating these aspects associated with the natural resource, in addition to capital and labor. In the particular case of the model used in this chapter, three factors are incorporated: (i) ore, (ii) ore grade, and (iii) stripping ratio.[10]

Mining investments do not yield results during the year they are accounted for, but rather in subsequent periods, therefore, not to consider the maturity of investments would also lead to a bias in the measure of TFP. In fact, this leads to perceiving a sharp TFP fall when the investment increases significantly, as occurred during the second half of 2000.

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6 In the TFP case, a decrease in the index is observed, while for partial productivity a smaller amount of fine copper is produced doing a similar task.

7 Which affects in productivity indexes, be it TFP, partial, marginal, and others.

8 Material moved includes: i) waste, rocks without economic value that goes to waste rock dumps; y ii) a smaller proportion of ore that can be processed for obtaining copper.

9 Considers both ore and waste. The number is obtained based on data from Cochilco from the average ore grade per mine plus the recovery rate that gives an estimate of the ore extracted, while using the stripping ratio, the material moved by mine is obtained.

10 From material moved, given a certain stripping ratio, an amount of ore is obtained that ends up being processed in the plants, and conditional to the ore grades, copper is obtained. That is, the stripping ratio, the ore and its grade help explain the impact of the natural resource on copper production.

In fact, the estimates that use this value-added methodology, without considering the maturity of the projects, show declines of around 60-75% for the same analysis period.

The correct estimation of the productivity of a natural resource sector should consider all the above factors. With this in mind, this study estimated productivity at the level of Chilean labor, examining: (i) use of capital,[11] (ii) labor -employment-, (iii) ore grade, (iv) stripping ratio, and (v) ore. Our estimation confirms that Total Factor Productivity has fallen during the last 15 years, although at a lower degree than what has been usually reported in the empirical literature for Chile.

The chapter is structured as follows. Section 2.2 examines productivity at Copper Mining. Section 2.3 performs an analysis of Total Factor Productivity in this industry. Section 2.4 discusses the evolution of partial labor productivity, and section 2.5 presents the results and conclusions of the chapter.

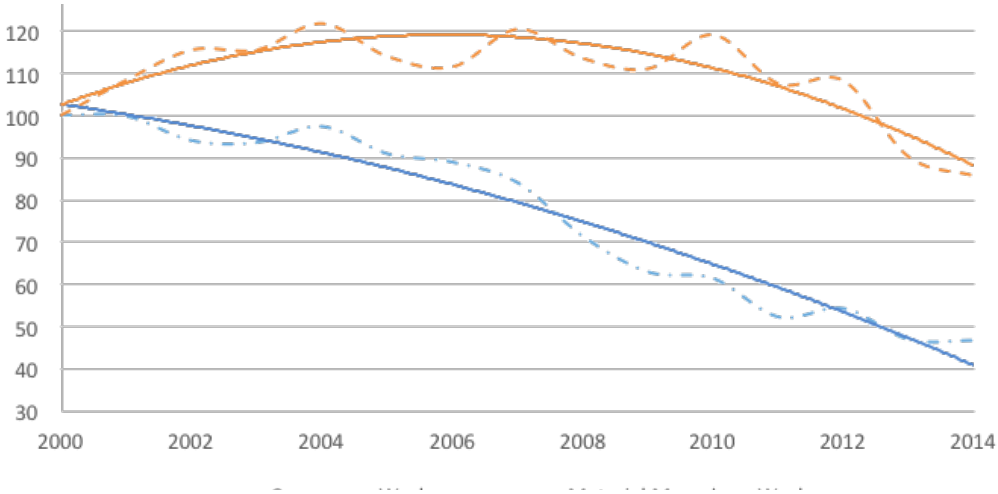
2.2. Productivity in the Copper Mining Industry in Chile

Figure 2.1 shows the evolution of labor productivity considering both copper and moved material per worker. The dashed lines in the figure show the evolution of the partial labor productivity series, while the continuous (non-linear) lines show the trend of these series. The measure that shows the copper produced per worker presents a productivity drop of 54% for the period. Therefore, we can mistakenly conclude that in the year 2014 half the amount of copper was produced (by an equivalent worker) than in the year 2000 when the effect of the factors associated with the natural resource is not considered.

As explained, the indicator erroneously attributes geological deterioration to the productive capacity of the worker. Even if the operator maintains his productivity capacity (and moves the same amount of material), an increase in the stripping ratio or a deterioration in the ore grade will necessarily imply a fall in the production of copper. The red line in Figure 2.1 measures material moved per worker and corrects for such effects: granting a much lower drop in productivity, of around 15%.

[11] Including energy as a proxy, or adjusting the intensity of use of capital by this variable. For cases where the capital or capital adjusted for intensity was used, the capital variable is lagged one period to consider the effect of the maturation of the project. In the case of the variable energy, it captures the intensity of capital use at each moment of time.

Figure 2.1 – Copper Mining Productivity in Chile (Baseline 2000=100).



Source: National Productivity Commission based on Cochilco.

In fact, the index increases (2000-2004), stabilizes (2004-2006), and then falls steadily (2007-2014). This evolution is compatible with a commonly accepted hypothesis, whereby the Chilean mining industry improved its productivity after the massive inflow of foreign capital, technology and organizational practices that entered Chile in the 1990s, stabilized when it reached a certain maturity previous the price super cycle, and declined during the second half of 2000. In short, the fall in Chilean mining productivity (measured as material moved per worker) is a phenomenon that has intensified in recent years, with an average growth of 5% between 2000 and 2004, 0% between 2004-2007, and -5% between 2007 and 2014.

This evolution of mining productivity is not unique to Chile. In fact, similar impairments are observed in mining countries such as Australia, the United States, and Peru (only Canada shows smalls improvements).[12] As we shall see, it is likely that this general deterioration is associated with the reaction of mining companies to the price super cycle.

12 See Cochilco reports with analyses based on material moved based on Wood MacKenzie.

2.2.1. Literature Review

As will be shown later in this chapter, Total Factor Productivity (TFP), reveals a similar dynamic to partial labor productivity. Several studies have concluded consistently that the TFP of the mining sector has decreased over the last decade,[13] regardless of the methodology used. Applying the traditional growth accounting methodology -without correcting for geological factors or investment gestation periods- the CNP Annual Productivity Report (2016) estimated an average annual growth rate of 2.1% for the period 1990-2000, but an annual average fall of 8.9% for the period 2000-2015. On the other hand, using the same methodology, the UAI-CORFO report (2014) estimates that the mean annual growth rate of TFP in the mining sector ranges from 3.3% for the period 1993-1998 to -8.3% between 2000-2014. Corbo and González (2014) estimate (using the same methodology) that the contribution of the mining TFP to the growth of the sector for the period 1998-2003 was -1.5% per year, whereas for the periods 2004-2008 and 2009-2011 its contribution was of -8.3% and -15.9%, respectively. None of these measures considers the deterioration in neither ore grade nor other geological factors that negatively affect productivity, which results in an exaggeration in the deterioration of the sector's productive capacity.[14]

Cochilco´s analysis shows results that are more consistent with those presented in this chapter.[15] A 2013 study incorporates the geological factor in its TFP estimates by using ore grade and energy consumption (as an approximation of the ore downgrade), and estimated that the TFP fell at an average annual rate of 6.2% (versus -9.3% uncorrected by ore grade). However, when energy consumption is considered, the average annual fall is 4.8%. Cochilco (2014) incorporates other factors and estimates the annual average decline in TFP between 2000 and 2013 at -1.6%. These studies maintain the negative trend in TFP, but the rate of the reduction is much lower and the estimate is more accurate.

The commonly accepted hypothesis for the decline -in both global as well as Chilean-mining productivity since 2000 is attributed to the companies' reaction to the super-cycle commodity price (see Figure 2.2). The increase in prices and operating margins during the super-cycle made it profitable to prioritize production over other criteria, including process efficiency and costs. In fact, it turned out to be profitable to operate less rich

13 See, for example, Jara et al. (2010), Cochilco (2014), Corbo & González (2014), De Solminihac et al. (2014), and UAI-CORFO (2014)

14 Moreover, Corbo and González (2014) estimate using value added (not fine copper), and refer (among others) to the increase in the cost of inputs as one of the factors that reduced the value added of the sector to the economy. This indicator is also sensitive to variations in input costs, which increased considerably during the period.

15 See Cochilco (2013, 2014).

mines, to lower the cut-off grade[16] (which translates into a change in the stripping ratio), hire less skilled labor, buy less efficient trucks, keep capital and redundant labor,[17] or accelerate projects, so as to take advantage of the extraordinary but transitory prices. Therefore, the hypothesis regards that in the period of analysis, profits increased but productivity decreased.

Figure 2.2 - Evolution of Price and Operational Costs[18] for Copper Mining in Chile (US$ cents)

Source: Cochilco (2015).

2.2.2. Geological factors

During the years 2000-2014 copper production increased by 19% (see Figure 2.3).[19] This growth was most significant during the first part of the cycle, 17% in the 2000-2004 period (when the partial productivity of labor grew), and subsequently of 2% during 2004-2014. However, it is worth mentioning that this 19% increase in copper production

16 Refers to the minimum ore grade to be the processed by the plant.

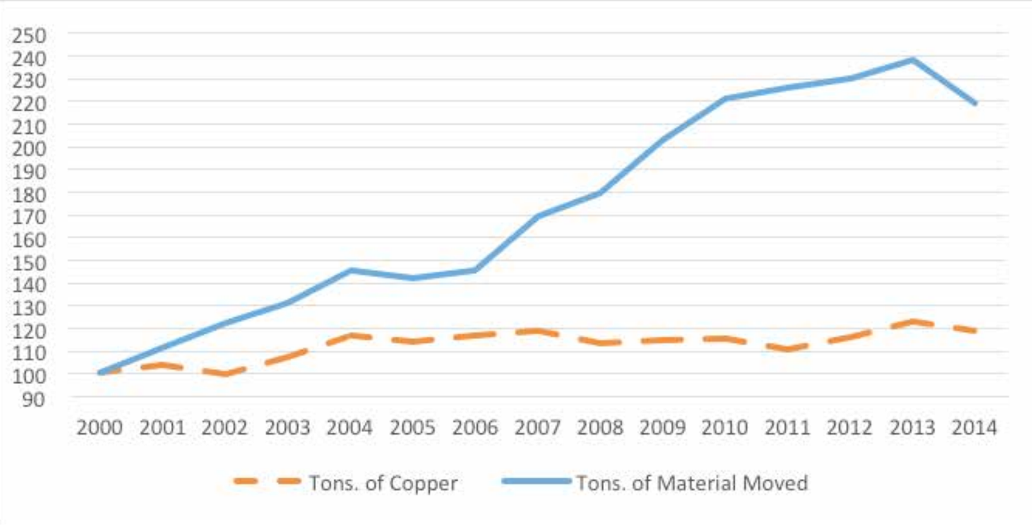
17 During the period, additional workers (subcontracted) were hired as replacements for absences. These contracts were informally called "meat contracts".

18 Operational costs include extraction costs, mineral processing, refining, freight and expenses.

19 A sample of 26 copper mining operations is used, accounting for nearly 90% of Chilean copper production. This sample includes: Andacollo, Andina, Candelaria, Cerro Colorado, Chuquicamata, Collahuasi, El Abra, El Soldado, El Teniente, El Tesoro, Escondida, Esperanza, Gabriela Mistral, Lomas Bayas, Los Bronces, Los Pelambres, Manto Verde, Mantos Blancos, Michilla, Ministro Hales, Pucobre, Quebrada Blanca, Radomiro Tomic, Salvador, Spence, and Zaldivar.

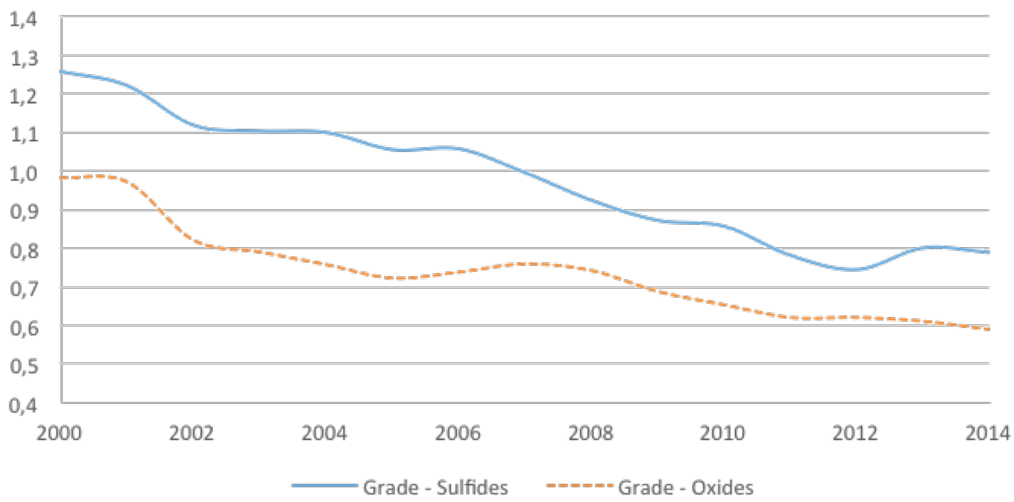
demanded a 119% increase in the extracted material (see Figure 2.3). The mining factors mentioned above explain this enormous and increasing gap: (i) the ore grade (a criterion that is endogenous according to the cut-off grade, which in turn, defines the ore from waste rock); (ii) the stripping ratio and (iii) the recovery rate (ability to extract copper from ore). As the first two factors are determined by geological factors, they are considered exogenous to the mines; while the third is associated with internal (endogenous) factors.

Figure 2.3 – Production Index of Refined Copper and Material Moved in Copper Mining (Baseline 2000=100)



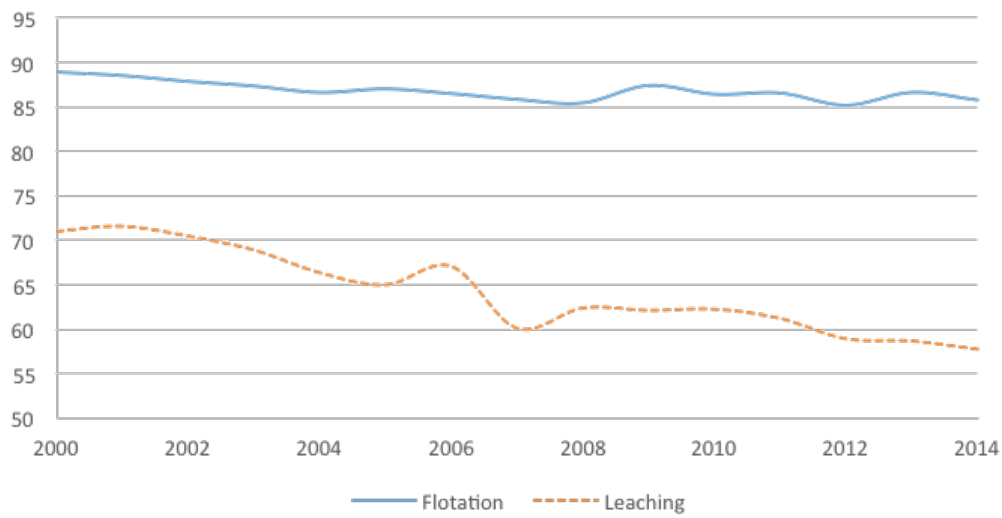
Source: National Productivity Commission based on Cochilco.

Figure 2.4 Average Copper Grade per operation (Large scale Copper Mining, %)



Source: National Productivity Commission based on Cochilco.

Figure 2.5 Average recovery rate per operation (Large scale Copper Mining, %).



Source: National Productivity Commission based on Cochilco.

The gap between copper produced (which grows 1.4% annually) and moved material (which increases 5.1% annually) is a reflection of the depreciation of the mines' natural capital, measured as the fall in the ore grade. Based on the Cochilco data, the ore grade shows a permanent decline from 2000. The average grade on sulfide deposits fell from 1.3% to 0.8%, while that of oxide deposits fell from 1% to 0.6% (Figure 2.4). In 2000, the grade associated with sulfide deposits was almost 28% higher than the oxides' grade, whereas by 2014 this gap increased to 33%, after a heavy drop in both. These data are highly relevant considering that in Chile the oxide-based production was 16% of the total in 1990-1999, but one-third in 2000-2014.

The recovery rate associated with the flotation process[20] (sulfide deposits) shows a drop of around 3% for the whole period; while the reduction related to the leaching process (oxide deposits) is 18% (see Figure 2.5). Since the leached oxides have a lower grade, their recovery rates have fallen proportionally more. Part of the deterioration in aggregate mining productivity is due to the substantial proportion of material processed by leaching, which exhibits worse recovery rates and a higher ore grade decline.

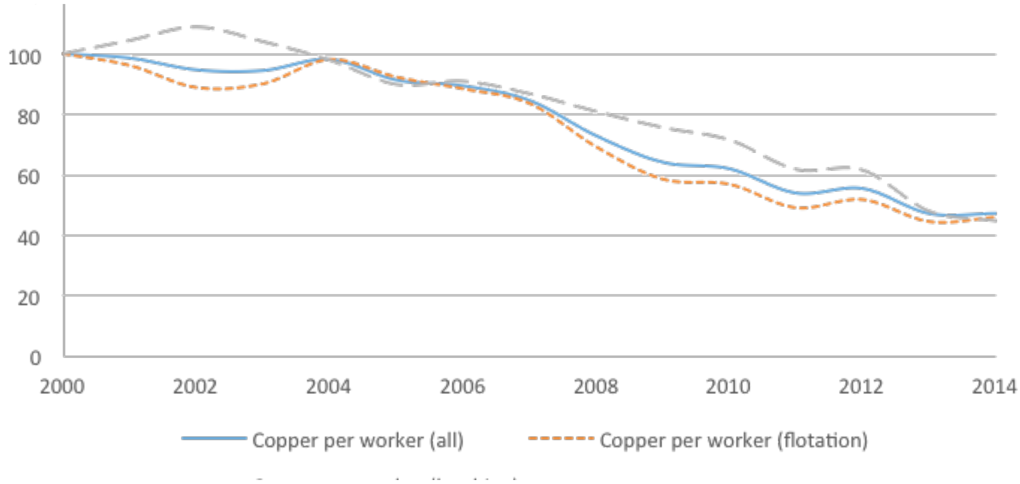
In summary, copper produced per worker in both sulfur (concentrate production) and oxide (leach production) deposits, viewed separately or on average, shows productivity losses of more than 50% (see Figure 2.6).

As we have explained, any metric that uses "copper production" biases the measure of factor productivity, since it imputes to the measured factor the geological deterioration in the deposits, which have fallen around 40% in the last 15 years. In our measurement of partial labor productivity, we use material moved per worker, which, as shown in Figure 2.7, presents a different evolution.[21] The indicator shows that productivity per worker increased by 22% during 2000-2004, remained stable until 2006, and fell in the following decade, accumulating a total drop of 15% (see Figure 2.7). When separated by processes, the index of leached (oxide deposits) ore per worker shows a fall of 5% in the whole period; while in flotation processes (sulfur deposits), it drops 29%. Notice the break for both measures around the year 2007, during the boom of the super price cycle.

20 The recovery rate is the effective percentage of copper that is obtained once the ore in the plant has been processed. If the plant works efficiently, the recovery rate may reach 100% and therefore the copper equivalent to the grade is obtained.

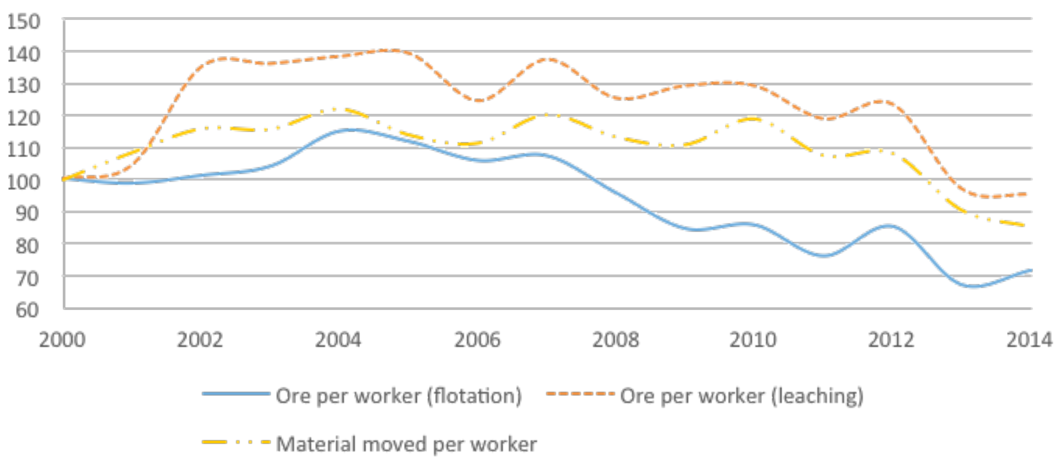
21 Material moved considers ore, this is, material that goes from mine either to the plant to be processed or waste rock, that goes to waste dumps.

Figure 2.6 – Index of labor productivity per operation (Baseline 2000=100).



Source: National Productivity Commission based on Cochilco.

Figure 2.7 – Index of material moved per worker at operation level (Baseline 2000=100).



Source: National Productivity Commission based on Cochilco.

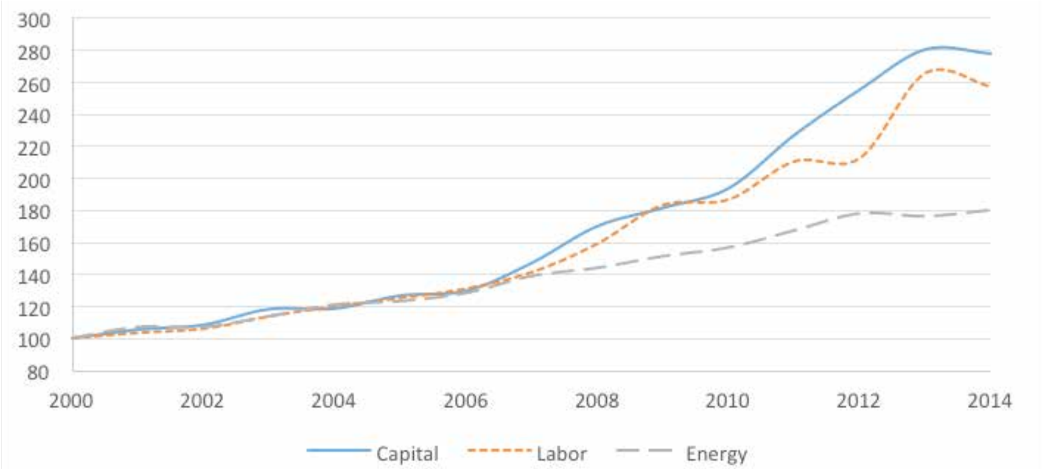
2.2.3. Productive factors: capital, labor and energy

With great success, and following the evolution of prices, copper production between 2000 and 2014 rose 19% (increased 17% between 2000 and 2004, and 2% between 2004 and 2014). This increase required significant capital investments, rise in employment, and higher energy consumption (see Figure 2.8). However, since 2007, there were sharp increases in capital investment and contracting, which partly explains the structural break in 2007 and the accentuation of negative trends in productivity indicators (see Figures 2.1 and 2.7).

The full evolution of these numbers is impressive. In the period 2000-2007, employment (either direct employees or through contractors) in copper mining increased by 41%. This increase was doubled to 82% in the period 2007-2014. That is, in the analysis term, copper mining operations more than doubled (157%) their staff. The expansion in capital investment was even greater, as the capital's stock increased by 47% between 2000 and 2007 and almost doubled (90%) between 2007 and 2014. That is, during the analysis period, the operations of the Copper Mining Industry almost tripled its capital level (178%) (See Figure 2.8). Energy consumption (electric and fuel) shows a more stable pattern, with a 79% increase over the period. In summary, between 2000 and 2007 the factors grew in a parsimonious way, but after 2007, energy consumption grew at an average annual rate of 4%, while capital and employment increased at around 7-8% a year.

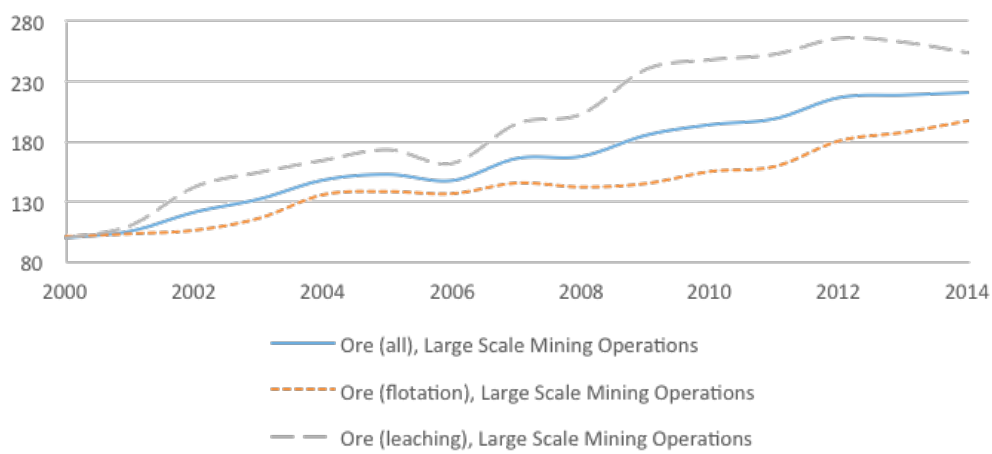
In short, between 2000 and 2014 the sector increased the production of copper by 19%. To achieve this, it had to move more than double the amount of material in mines (119%), use 79% more energy, duplicate the number of jobs (157%), and use even more capital (178%). Also, the processed ore was higher in oxide deposits (leaching processes) of lower grades and lower recovery rates (see Figure 2.9).

Figure 2.8 – Index of Productive Factors (Baseline 2000=100).



Source: National Productivity Commission based on Cochilco.

Figure 2.9 – Index of Processed Ore (Baseline 2000=100)



Source: National Productivity Commission based on Cochilco.

In summary, the productive dynamics of copper mining in the last 15 years account for the following:

> **Finding 2.1:** During the period 2000-2014, the country increased its copper production by 19%; 17% occurred between 2000 and 2004, the remaining 2% between 2007 and 2014. During this period, the partial labor productivity shows a fall of 54% copper produced per worker, but 15% if material moved per worker is considered. Other countries show similar dynamics.
>
> **Finding 2.2:** During the period 2000-2014, energy consumption grew by 79%, labor by 157%, and capital investment by 178%. Between 2000 and 2007, demand growth for capital, labor, and energy was balanced around 5-6% per year. Between 2007 and 2014, energy use grew by 4% per year, while capital investment and labor contracting rose by 7-8% per year

2.3. Total Factor Productivity

The partial productivity measures of the previous subsection are easy to interpret, but they only establish a relationship between two indexes (production and employment). Therefore, they display biases when comparing more complex systems that occupy not only labor but also other productive factors. Hence, the importance of a productivity estimate that considers the incidence of all productive factors, such as Total Factor Productivity (TFP), and adjusting for the factors specific to mining, as shown above. [22]

2.3.1. Methodology

With the theory of the firm as the basis for the theoretical framework, a Cobb-Douglas type function was used to describe the productive process. Each mine is considered as the unit of analysis, and the mine's capital and employment are incorporated in a traditional manner. In addition, as copper production depends on the natural resource, it is influenced by geological factors, so the following variables are included in the production function:

22 This section is partially based in CNP and Cochilco (2016).

(i) the quality of the natural resource (ore grade); (ii) the stripping ratio; and finally (iii) the amount of ore available for processing.

The first and second criteria (already described), seek to subtract the impact of the loss of ore quality (a factor not managed by the company) from the productivity measure. The third criterion considers ore as a necessary input for the production of copper.

Therefore, the function to be estimated considers the factors: (i) Capital ($K_{i,t}$); (ii) Level of employment ($H_{i,t}$); (iii) ore grade ($L_{i,t}$); (iv) ore ($M_{i,t}$); and (v) stripping ratio ($R_{i,t}$). The function is described by the following expression:

$$Y_{i,t} = A_{i,t}(K_{i,t})^{\alpha}(H_{i,t})^{\beta}(L_{i,t})^{\gamma}(M_{i,t})^{\delta}(R_{i,t})^{\eta}\exp(\xi_{i,t})$$

$A_{i,t}$ captures the productivity level of the mine *i* in period *t*, while the parameters [23] α, β, γ, δ, and η summarize the input-output elasticity associated with physical capital, labor, ore grade, available amount of ore and the stripping ratio, respectively.[24] Finally, the term ε (a residue) captures the rest of the possible effects capable of influencing production, such as productive shocks, price shocks, inefficiencies, measurement errors, etc.

As mentioned, it is necessary, for this analysis, to consider the existence of lags between the investment in capital and its impact on production. The period in which the investment in physical capital is accounted for does not necessarily correspond to the period in which that investment is also being used. This means that in the production function described above, rather than using the capital level of the period in question ($K_{i,t}$), estimates the capital lagged for a year used (i.e: $K_{i,t}$–1).

Unlike previous work, our estimates simultaneously use ore grade and energy consumption at the firm level (mine operation). In addition, we work with real production measures, not value added.[25] Energy consumption (electricity and fuel) is used to correct the intensity of use of capital and as a proxy for the adequate level of capital utilized in the production process. In the first case, and considering a period lag in capital, we have that the capital stock employed in the production function turns out to be:

23 No constraints were imposed on the sum of the parameters. When performing the F-test on the null hypothesis that the sum of the parameters associated with variables controlled by the operation (capital / energy, labor and ore) was 1 (p-value = 0.19).

24 The concept of elasticity is associated with the degree of sensitivity that an input has over the level of production. For example, an increase of 1% in the level of employment should increase in β% the level of production, assuming that the rest of the inputs remains equal.

25 Our variable is real copper production in comparison to the value added index (which discounts the costs of intermediate inputs). Thus, it is possible to have falls in value added with increases in production, resulting from the increase in an input cost.

$$\widetilde{K}_{i,t} = exp\,(\ln E_{i,t} - \ln E^{T}_{i,t}) \times K_{i,t-1}$$

Where the first expression on the right-hand side of the equation is the deviation of the logarithm of energy consumption ($E_{i,t}$) concerning the logarithm of its trend ($E^{T}{}_{i,t}$).[26] This expression seeks to capture the cyclical factors, and therefore, correct the measure of productivity faced with changes in demand and supply. An alternative estimation, following Costello (1993), simply replaces the capital's level ($K_{i,t}$) by the level of energy consumption ($E_{i,t}$) in the production function.

Therefore, the total factor productivity of the mines was estimated using the Maximum Likelihood method.[27] Specifically, in each of the estimates, a fixed effect was used for the mines, as well as a tendency (linear or non-linear) for each of the mines (and in some cases unique to the sample). Once the TFP estimation has been obtained at the mine level, and following the index number theory, the indicators are added at the mine level using the Törnqvist-Theil index, allowing the aggregate TFP to be decomposed into one (long-term) trend component and the other associated with productive (short-term) shocks.

Other extensions were also incorporated, such as (i) an additional model (coming from the stochastic frontier literature) that includes a new error term that captures inefficiencies, such as distance from the frontier of production possibilities, and (ii) a model with persistent shocks, consistent with a sector with intensive use of fixed capital and dependent on an exogenous factor such as the quality of the natural resource. The latter allows a shock (a situation not previously considered in the extraction strategy) to affect the productive capacity in a contemporary way and persist in future periods. As was also pointed out, specifications were estimated, which considered trends unique to each mine, to capture their aspects (such as technology or characteristics of the deposit).

26 A Hodrick-Prescott filter is used to obtain the trend component. The parameter used for this case was 100.

27 Maximum Likelihood is used since estimated values under this methodology are consistent. This means that estimated parameter values converge (equal) to the real value, as the number of observations used for the estimation grows.

2.3.2. Results

The information used for the estimates between 2000 and 2014,[28] were provided by Cochilco, with data that includes median and large-scale copper mining.. The variables used in the analysis are: (i) metric tons of copper ($Y_{i,t}$),); (ii) physical capital in millions of dollars in 2013 ($K_{i,t}$) (iii) employment, including subcontracted employees ($H_{i,t}$); (iv) energy consumption in GWh, including electric and fuel consumption ($\xi_{i,t}$); (v) annual average ore grade ($L_{i,t}$); (vi) tons of ore to be processed ($M_{i,t}$); and (vii) the stripping ratio ($R_{i,t}$).

Since some of the mines in the sample started operations after 2000, and that several observations lack information for the complete period, estimations were made with an unbalanced panel. A dummy variable per mine is included in all regressions.

Among the considered models, those that incorporated tendency variables in the production function[29] showed a better statistical performance,[30] and a significant and negative result is observed for the tendency coefficient on each estimate that included the variable. That is, our estimation confirms that the multifactorial productivity (TFP) of a representative mine, tended to deteriorate over time. This overall deterioration in the productive capacity of the factors persists despite the adjustment by endogenous factors (capital, labor, and ore), and exogenous factors (ore grade and stripping ratio), confirming that there are other factors that explain the productive deterioration.[31]

Different information criteria[32] (statistical tests) were used in order to select the estimate with the best adjustment. The AIC, AICc and HQC tests suggest that the model we will call Model A, and which considers linear trends (to the log of TFP) for each mine, presents the best adjustment. Specifically:

$$y_{i,t} = \mathrm{a}_i + \mathrm{b}_i\, t + \alpha\, e_{i,t} + \beta\, h_{i,t} + \gamma\, l_{i,t} + \delta\, m_{i,t} + \eta\, r_{i,t} + \xi_{\,i,t}$$

Where lowercase variables refer to the logarithm of the variable in levels.[33] The production function that best specifies the process[34] is the one that considers as exogenous factors

28 Andacollo, Andina, Candelaria, Cerro Colorado, Chuquicamata, Collahuasi, El Abra, El Soldado, El Teniente, El Tesoro, Escondida, Esperanza, Gabriela Mistral, Lomas Bayas, Los Bronces, Los Pelambres, Manto Verde, Mantos Blancos, Michilla, Ministro Hales, Pucobre, Quebrada Blanca, Radomiro Tomic, Salvador, Spence, Zaldivar.

29 And thus, they are considered part of the TFP components.

30 Akaike (AIC), Bayesian (BIC), Akaike with finite sample correction (AICc), and Hannan-Quinn (HQC).

31 Ore grade and the stripping ratio are determined by nature, and, in that sense, are exogenous.

32 Akaike (AIC), Bayesiano (BIC), Akaike with finite sample correction (AICc), y Hannan-Quinn (HQC)

33 Here the TFP long run component is given by exp(a_i+b_i -t) , and the short run component is given by exp(ξ_t).

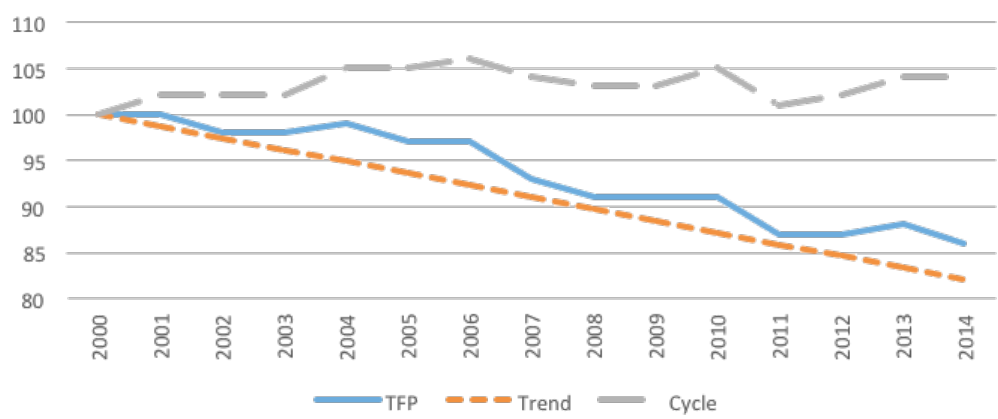
34 According to the previous information criteria.

ore grade and stripping ratio, and views as input: labor, ore to be processed, and energy (as a proxy for the capital used). The latter coincides with the arguments put forward by Topp et al. (2008) on the efficient use of physical capital, and Costello's (1993) proposal regarding the use of energy consumption as an approximation of the level of capital utilization. Out of simplicity, we shall call this specification Model A.

As a first conclusion, the aggregated TFP decreases steadily throughout the analysis period, since the trend estimated by the model can cancel the effect of productive shocks at all times. Estimates show that (on average) the tendency decreased at 1.0% per year, for a cumulative contraction of 14 percentage points between 2000 and 2014 (see Figure 2.10). This means that if the same combination of productive inputs had persisted, along with similar geological factors, the production in 2014 would have been 14 percentage points lower than in 2000, due to the fall in joint factor productivity.

Figure 2.11 shows the contribution of each factor to the growth of copper production between 2000 and 2014. Ore, energy (proxy for capital services), and labor contributed positively. Ore grade and the TFP[35] contributed negatively. We can conclude from the figures that: (i) the average annual growth in copper production was 2.1% between 2000 and 2007 and 0.3% between 2008 and 2014, (ii) ore is the resource that contributes mostly to growth, and (iii) TFP shows a negative contribution around 1% consistently in both periods.

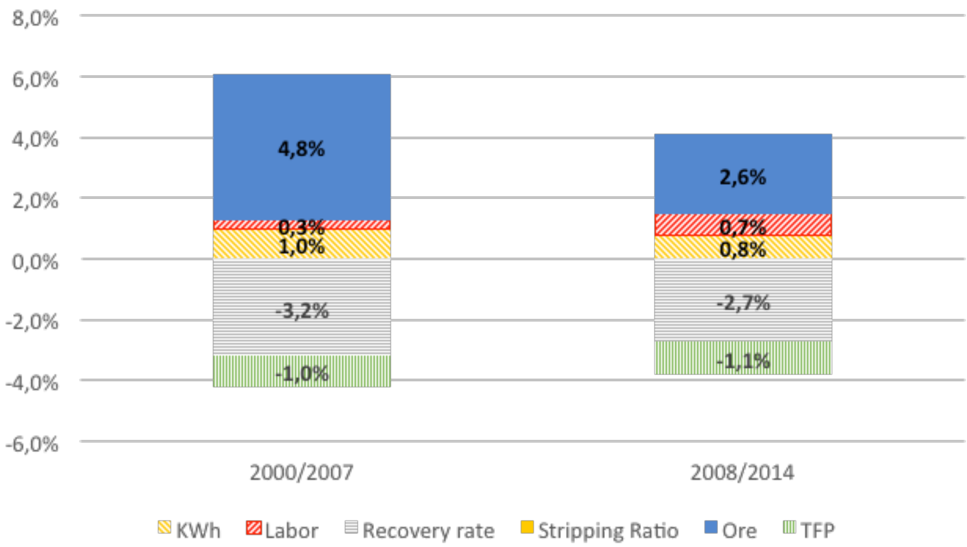
Figure 2.10 – TFP Decomposition Model A, Index (Baseline 2000=100).



Source: National Productivity Commission based on Cochilco.

35 In the case of stripping ratio, the impact was null.

Figure 2.11 – Factor contribution to copper production, Index (Baseline 2000=100).



Source: National Productivity Commission based on Cochilco.

Finding 2.3: The total factor productivity of the copper mining sector, corrected by endogenous and exogenous factors to the operation, shows a drop of 1% per year between 2000 and 2014, accumulating a reduction of 14% in the period.

Finding 2.4: The factors that contributed to production were processed ore (3.6% per year), energy (0.9% per year) and labor (0.5% per year). Instead, ore grade (-3%) and factor productivity (-1%) contributed negatively.

2.3.3. The Super Cycle Copper Price Hypothesis

As previously mentioned, a commonly accepted hypothesis suggests that the fall in the TFP in the copper mining was caused mainly by the reaction of the mining companies to the price cycle. Specifically, the leap in the price of copper between 2003 and 2011 made it profitable to prioritize production over other objectives, such as cost control and efficiency improvements.[36] In addition, the intensiveness of capital, and the extent to which the start-up period turns out to be, led to focus on short to medium-term operational strategies adjustments that are not necessarily optimum over a longer horizon.[37]

Analyzing the recovery rate and its relation to productivity would be a first approximation to validate this hypothesis. The recovery rate measures for a given level of ore grade, the actual amount of copper extracted from the ore, and it is a factor controlled by the operation. For example, longer processing time, a higher grinding rate of ore, more energy in blasting or grinding, greater use of reactants, etc., will increase the recovery rate, but usually with decreasing marginal yields. Hence, it may be profitable to reduce the recovery rate in higher price periods (and thus higher costs of opportunity times for processing), since the benefit of faster processing may compensate (decreasing) advantages of a higher recovery rate. Therefore, if higher prices cause such a reduction in the recovery rate and a lower recovery rate induces a lower TFP, one would expect to find a positive relationship between TFP growth and the return rate, as shown in Figure 2.12.

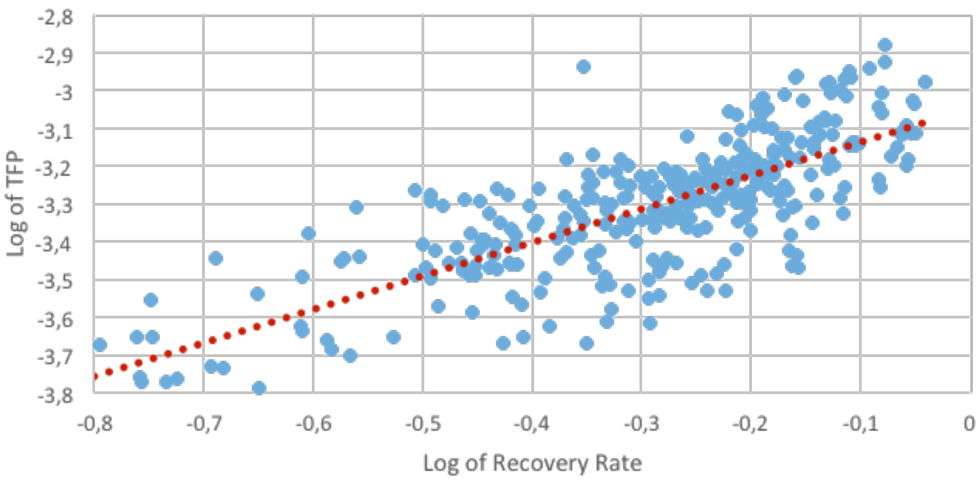
36 The implementation of improvements brings benefits but also comes with risks of reducing production. In other words, the opportunity cost of efficiency improvements was very high during that period.

37 Be $\Pi_t = p_t A_t F(X_t) - w_t X_t$ the utility of t of a firm and be $g_y^t = (\partial y_t / \partial t) \cdot (1/y_t)$, the growth rate in t of variable y. Then, considering utility increases (cycle), with fully differentiating utility in terms of time and re-ordering terms, we get to the following expression:

$$g_{\Pi}^t = (g_p^t + g_A^t + g_x^t \cdot \xi_x^t) + (g_p^t + g_A^t + g_x^t \cdot \xi_x^t - g_w^t - g_x^t) S_x^t > 0$$

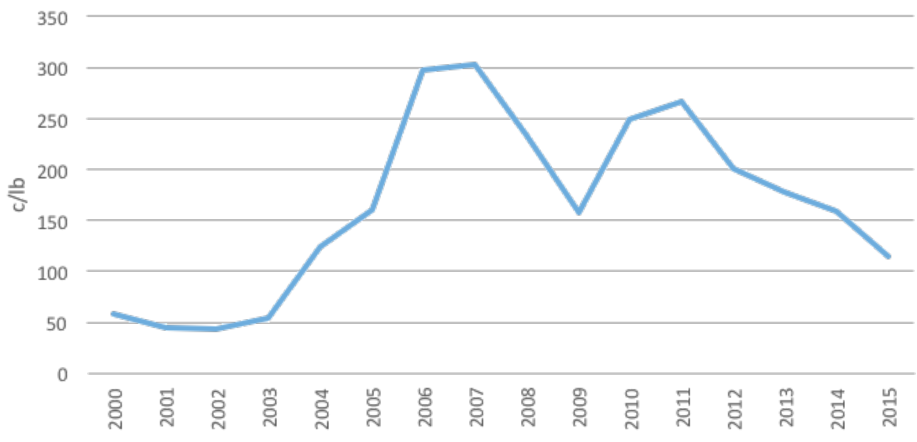
where $\xi_x^t > 0$ y $S_x^t > 0$ are product-elasticity of factor and X_t is its costs in terms of utility in t, respectively. Then, by saying that to a large extent the economic costs $(g_w^t + g_x^t) \cdot S_x^t > 0$ and efficiency $(g_A^t < 0)$ were absorbed by the huge margins asociated to the price cycle, we are saying that, as a sufficient condition can be given by $g_p^t > -g_A^t + g_w^t + g_x^t > 0$. Although other less restrictive conditions, still allow for utility growth $(g_{\Pi}^t > 0)$ with TFP falls $(g_A^t < 0)$.

Figure 2.12 – Relationship between productivity and recovery rate (values in log).



Source: National Productivity Commission based on Cochilco.

Figure 2.13 – Operational Margin (Copper Price – C1).



Source: National Productivity Commission based on Cochilco.

Figure 2.13 presents further evidence that may support the hypothesis of the negative impact of the super-cycle price on productivity. The figure shows the operating margin's evolution, estimated for the period, according to Cochilco's data. Quadrupling the operating margins during this period countered the adverse effect of the ore grade and the aging of the mine allowing greater investment in capital and workforce. In short, given these prices, the mining operations prioritized maximizing the extraction of ore over the productivity of the process, and given high prices, this decision was profitable.

As prices have normalized, companies (as of 2015) no longer put their focus on production at any cost, but rather in both increasing productivity and reducing costs. Part of the added effect of this improvement will be given by the increase in the cut-off grade (for as prices fall, not all mines remain profitable).

2.4. Evolution of Labor's Partial Productivity

The available information allows us to analyze the evolution not only of aggregate productivity measures (meso) but also at the operation level (micro). Following analysis concludes that, regardless of the measure used, different Chilean mining operations exhibit high heterogeneity in productivity levels, and that it has deteriorated in the sector in the last 15 years.

2.4.1. Partial labor productivity of Chilean copper mines

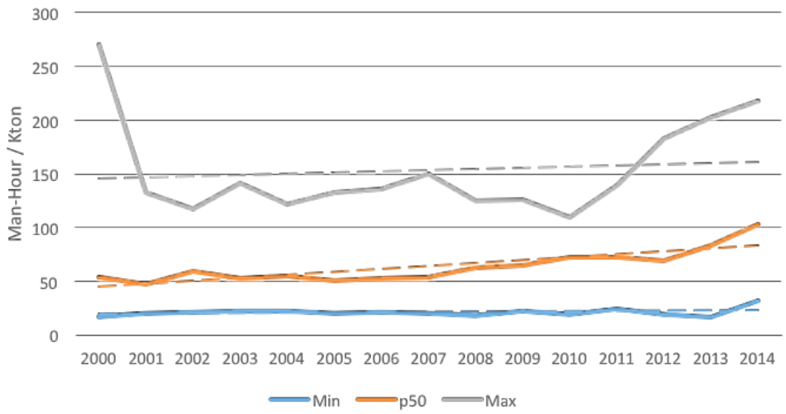
Labor partial productivity measures the relationship between the working hours used at the mine and the moved material (either waste rock or ore). For example, if two identical operations move the same amount of material per year and have different endowments, say one uses twice as many person-hours, then the productivity gap between them is double.[38] Although this is a partial measure, and therefore there are still factors that explain part of the difference (for example, different intensities of capital use), at least we know that this measure takes care of the mines' exogenous factors (ore grade and stripping ratio).

Figure 2.14 shows the level of partial productivity and its evolution for all mines that annually produce over 50,000 tons of copper. They were grouped into three categories: average productivity (50th percentile of the sample), high productivity (requiring fewer person-hours per kiloton of moved material-i.e. the most productive mines for each period), and low productivity (the least productive mines in each period). The solid lines show the effective dynamics of the mentioned categories, while the dotted ones demonstrate their tendency. Conclusions are: (i) productivity fell for all groups, since more

[38] Due to data availability, it is not possible to estimate the hours actually worked, and therefore an annualized measure of 2,190 man-hours per job per year is used, the equivalent of considering 12 daily work hours in 7x7 shifts.

person-hours were required for each amount of moved material in 2014, the median of the sample required 83 person-hours to move the same amount of material as in 2000, which, at that time, only required 47 working hours; (ii) there is a 7-fold gap in the level of productivity between the most and least productive company in 2000: the lowest productivity group required 137 person-hours per kiloton of moved material, while in 2014 it required 157 person-hours. The best performers used 19 person-hours in 2000 and 22 person-hours in 2014; and (iii) the gap marginally increased over time[39] as a result of the deterioration in the worst mines' performance.[40]

Figure 2.14 - Evolution of partial productivity of labor (Min, p50, Max), large scale mining sample[41] (man hours per kiloton moved).



Source: National Productivity Commission based on Cochilco.

Figure 2.15 presents similar measures but refers to the large-scale mining operations (that produce over 100,000 tons of copper a year). This sample is used in Chapter 3 of this report (Benchmark Analysis). In this case, the information reveals that all groups worsen their performance and that there is a substantial heterogeneity between mines when comparing the ratio of the partial labor productivity metrics.[42]

39 The gap was 7.1 times in 2000 and increased to 7.3 in 2014.

40 Inefficiency in the one with worst performance grew 0.96% per year as for the best performance it increased at 0.82% yearly.

41 Mining operations with annual copper production over 50 thousand tons (fine copper equivalent).

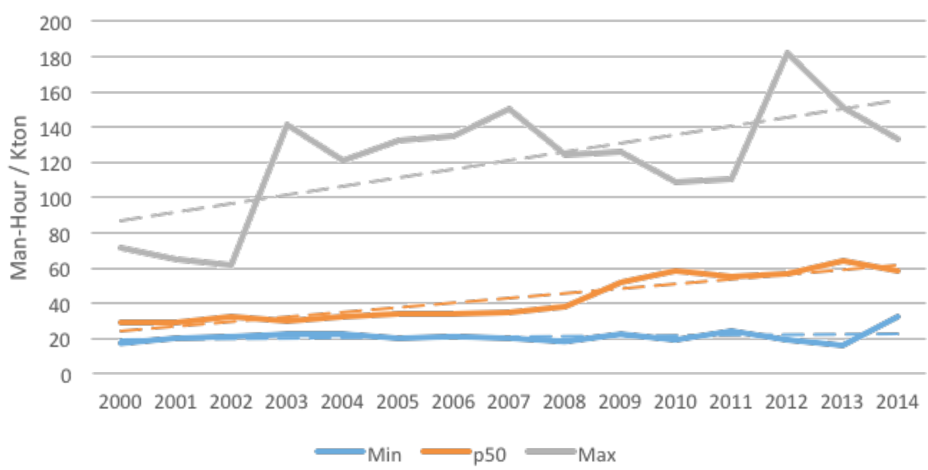
42 The ratio between the partial productivity of labor from the most efficient to the least efficient mines ranges from 4.2 times (in 2000) to 7.4 times (in 2014). This is interpreted as: in 2000, less efficient mines performed a task similar to the most efficient mines, but with 4.2 times more person hours, while for the year 2014 the least efficient did the same work with 7.4 times more

The worst performing category is very far from the rest. By 2000, the worst performing mine required about 82 person-hours per kiloton moved, but by 2014, this number increased to 162. The 50th percentile group worsened from 26 (2000) to 63 (2014) person-hours per kiloton moved. The best performing mine got worse from 19 in 2000 to 22 in 2014.

Moreover, gaps have been narrowing between the middle and lower efficiency groups because the productivity of the average group deteriorated at a faster rate (-6.6% average per year) than the least efficient did (-4.9% average per year). The best performing group also lowered its productivity, but at an average pace of -0.8% per year, so it distanced itself from the rest.

It is not easy to explain the registered gaps, even in the sample of companies that produce over 100,000 tons per year (world-class mines operated by transnational companies). The following chapters will examine the factors accounting for these gaps, as well as for those between national and best international practices.

Figure 2.15 - Evolution of the partial productivity of labor (Min, p50, Max), benchmark sample (person hours per kiloton moved).



Source: National Productivity Commission based on Cochilco.

person hours than the most efficient mines. Performing a similar analysis, but between the median of the sample and the most efficient, the ratio shows that most of the mines (median) required at least 1.3 times more person hours than the most efficient in 2000, and for 2014 they required 2.9 times more person hours than the most efficient ones.

Finding 2.5. Using a labor productivity indicator that considers the person-hours required to move a thousand tons of material, there are significant gaps in Chilean mines, and a general worsening of productivity is observed throughout the analyzed period (2000-2014). When gaps increase, it is because the less efficient group (in relative terms) increases its inefficiency at a higher rate than the other group. Conversely, when gaps decrease, it is because the more efficient group (in relative terms) worsens its productivity more rapidly.

Finding 2.6. The evolution of the gaps, as well as the tendency for productivity to fall in the analyzed period, is a robust result, independent of the sample associated with large scale mining, confirmed even in mines that produce over 100,000 tons per year, mostly exploited by large world-class companies.

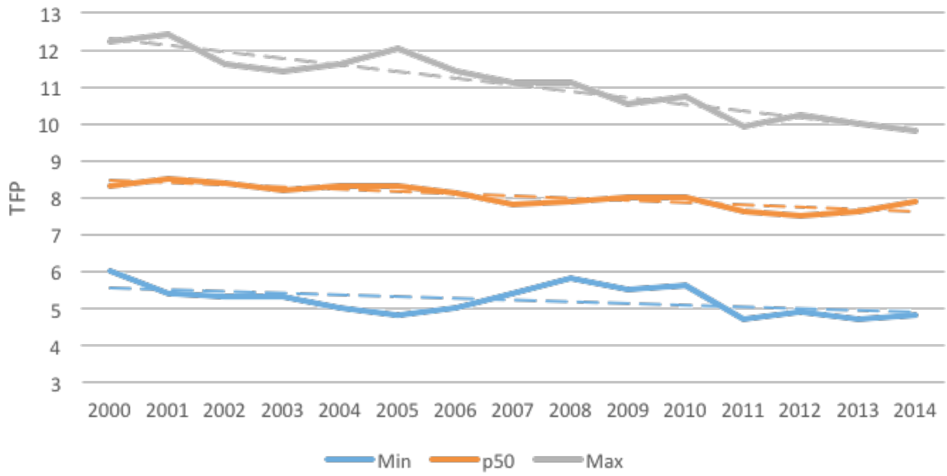
2.4.2. Total Factor Productivity in Chilean Copper Mines

The previous analysis based on partial labor productivity takes care of exogenous factors (ore grade and stripping ratio) but leaves out other factors relevant to productivity at the operation level, such as capital use. With this in mind, total factor productivity (TFP) analysis was made using the estimations of the previous subsection.[43] Figure 2.16 presents the TFP estimates for the best performance categories, median, and worst performance. In this analysis, the higher the index, the more productive the mine.

There are three highlighted results: (i) heterogeneity -and the gaps in performance between mines- are maintained (levels are not comparable to those of partial productivity); (ii) gaps are persistent during the period; and (iii) independent of the initial productive level, there is a permanent drop in productivity.

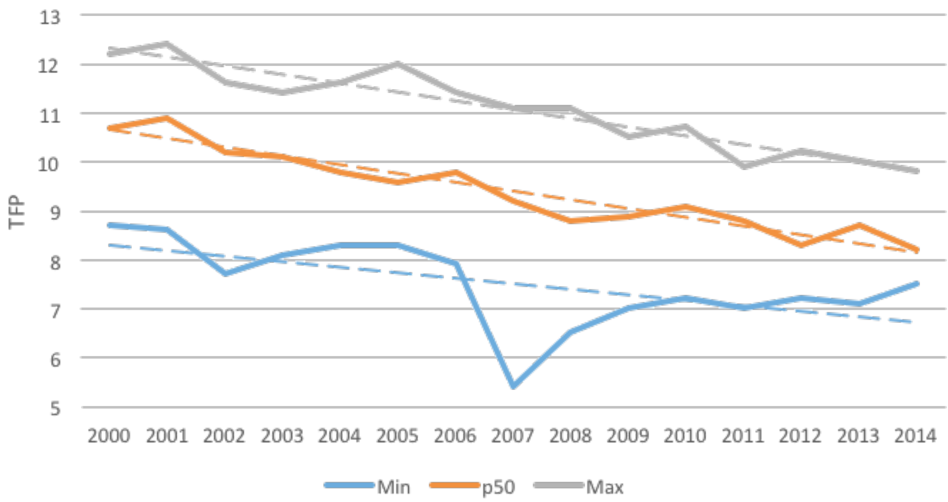
[43] Although it is difficult to interpret economically the level obtained from PTF, one way to do it is as the amount of production obtained if there were one unit of each input that affects production. In any case, in this part of the study we focus on the trend and the relative distance between the categories, therefore, interpretation of the TFP value does not restrict or distort the analysis.

Figure 2.16 – TFP Evolution (Min, p50, Max), Large scale mining sample.



Source: National Productivity Commission based on Cochilco.

Figure 2.17 – TFP Evolution (Min, p50, Max), national benchmark sample.



Source: National Productivity Commission based on Cochilco.

As with the case of partial labor productivity, we analyzed the evolution of TFP for the sub-sample of 12 mines that produce over 100,000 tons included in Chapter 3 (Benchmark analysis). Figure 2.17 presents estimates for this sample, with similar results: (i) significant gaps persist (although smaller in magnitude), (ii) the deterioration of productivity is general and (iii) the decline of productivity is persistent over time. The gap between the most and least productive groups range from 57% (2000) to 42% (2014). The fall in productivity in the best performing group is -1.7% per year, while in the worst performing group -1% annually, accounting for a reduction in the observed gaps. The median group shows the greatest deterioration, with an average annual fall in their TFP of 1.9%.

Findings 2.7: Estimates of total factor productivity (TFP) consistently show significant gaps between Chilean mines, and a permanent drop during the analysis period similar to that given by partial labor productivity, confirming the results found in the previous review.

Finding 2.8: The fall in TFP fluctuates at an average annual rate of 1% and 1.9% according to the initial level of productivity of the mines.

2.5 Conclusions

In summary, when analyzing the evolution in productivity of copper mining in Chile (2000-2014), a negative trend appears for the last 15 years, a period that coincides with the super-cycle of prices. Countries intensive in natural resources such as Chile, exhibit similar results. However, our estimate (-14%) is lower than usually reported (-54%), since this study made an estimation of productivity at the mine level, considering: (i) the use of capital (including energy as a proxy, or adjusting the intensity of capital use, and a lag period between capital accounting and commissioning); (ii) work level; (iii) ore grade and stripping ratio; and (iv) ore. The main reasons explaining these estimation differences are: (i) the use of energy as a proxy for the service of capital (not used by other studies as an explanatory variable); (ii) inclusion of the ore grade (only Cochilco's study does so by giving similar figures); the inclusion of the ore and stripping ratio (both with significant effects in the production)[44]; the use of information at the mine level (the Cochilco studies are the

[44] We are not aware of any study that considers both factors at the same time.

only ones that resemble in this sense, the rest occupy sectoral data of the Central Bank of Chile); the use of effective production and not added value.[45]

2.5.1 Summary of Findings

Finding 2.1: During the period 2000-2014, the country increased its copper production by 19%; 17% occurred between 2000 and 2004, the remaining 2% between 2007 and 2014. During this period, the partial labor productivity shows a fall of 54% copper produced per worker, but 15% if material moved per worker is considered. Other countries show similar dynamics.

Finding 2.2: During the period 2000-2014, energy consumption grew by 79%, labor by 157%, and capital investment by 178%. Between 2000 and 2007, demand growth for capital, labor, and energy was balanced around 5-6% per year. Between 2007 and 2014, energy use grew by 4% per year, while capital investment and labor contracting rose by 7-8% per year.

Finding 2.3: The total factor productivity of the copper mining sector, corrected by endogenous and exogenous factors to the operation, shows a drop of 1% per year between 2000 and 2014, accumulating a reduction of 14% in the period.

Finding 2.4: The factors that contributed to production were processed ore (3.6% per year), energy (0.9% per year) and labor (0.5% per year). Instead, ore grade (-3%) and factor productivity (-1%) contributed negatively.

Finding 2.5: Using a labor productivity indicator that considers the person-hours required to move a thousand tons of material, there are significant gaps in Chilean mines, and a general worsening of productivity is observed throughout the analyzed period (2000-2014). When gaps increase, it is because the less efficient group (in relative terms) increases its inefficiency at a higher rate than the other group.

45 In OECD terms, it can be said that "Gross Output" was used instead of "Value Added". Using value added, as Corbo and Gonzalez (2014) highlight, is deeply affected by significant increases in input costs, but this does not necessarily relate to effective productive capacity. It does relate to the capacity to generate value added.

Conversely, when gaps decrease, it is because the more efficient group (in relative terms) worsens its productivity more rapidly.

Finding 2.6: The evolution of the gaps, as well as the tendency for productivity to fall in the analyzed period, is a robust result, independent of the sample associated with large scale mining, confirmed even in mines that produce over 100,000 tons per year, mostly exploited by large world-class companies.

Findings 2.7: Estimates of total factor productivity (TFP) consistently show significant gaps between Chilean mines, and a permanent drop during the analysis period similar to that given by partial labor productivity, confirming the results found in the previous review.

Finding 2.8: The fall in TFP fluctuates at an average annual rate of 1% and 1.9% according to the initial level of productivity of the mines.

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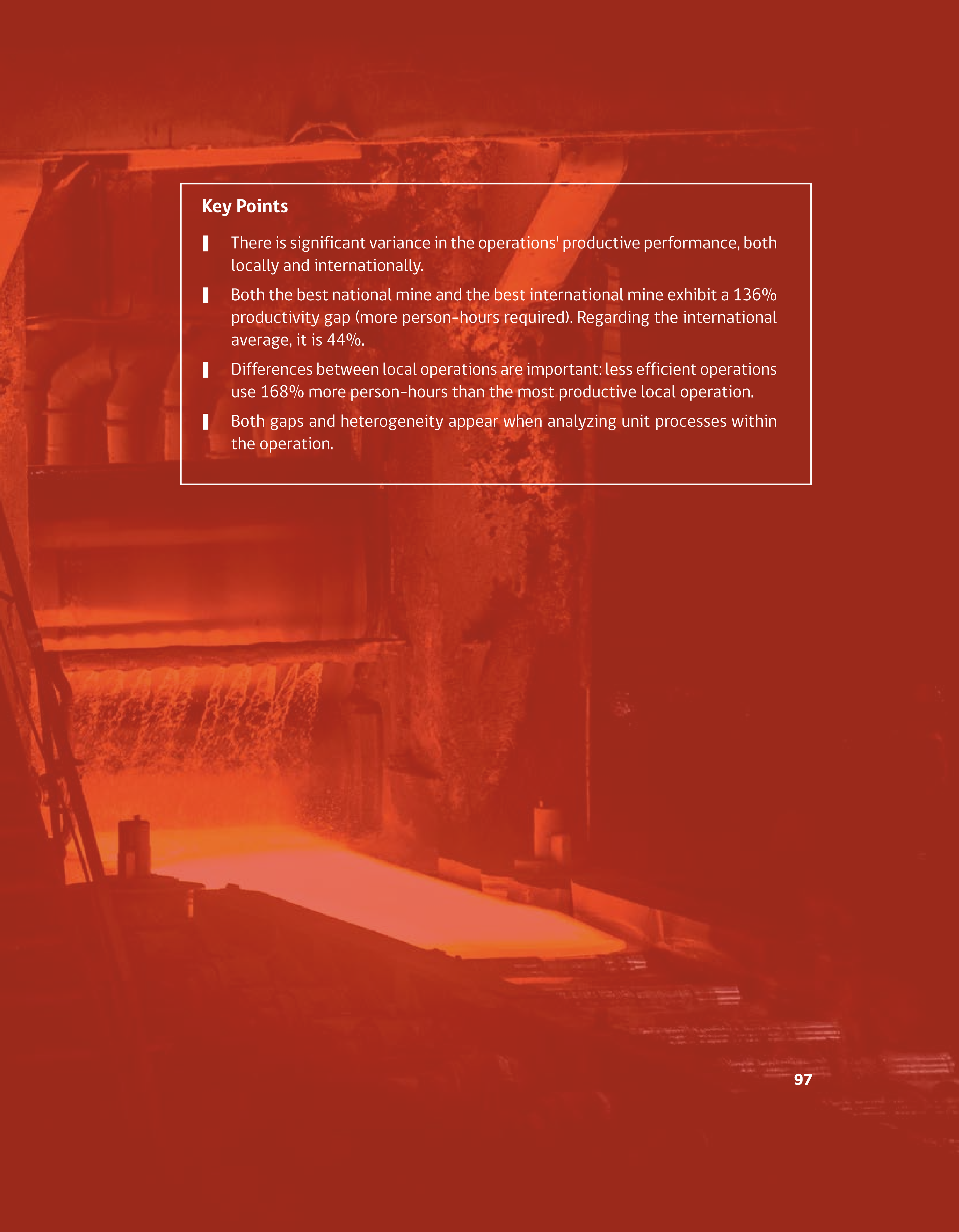
Chapter 3

Benchmark Analysis

Abstract

This chapter presents a productive characterization of twelve Chilean mining operations with annual production over 100,000 tons each. This sample accounts for approximately 75% of Chile's copper production. These were analyzed using labor's partial productivity and effective capital use-time. We compare the sample's performance at the national level, and against a group of international operations considered best practice: Australia, Canada, the United States, and Peru. Overall, the sample accounts for 35% of the world's total copper production and 50% of global copper production of mines that produce over 100,000 tons. The findings display a considerable heterogeneity in the productive performance of the evaluated Chilean operations, and substantial productivity gaps with respect to the international sample.



Key Points

- There is significant variance in the operations' productive performance, both locally and internationally.
- Both the best national mine and the best international mine exhibit a 136% productivity gap (more person-hours required). Regarding the international average, it is 44%.
- Differences between local operations are important: less efficient operations use 168% more person-hours than the most productive local operation.
- Both gaps and heterogeneity appear when analyzing unit processes within the operation.

3.1. Introduction[1]

This chapter provides a characterization of the productive capacity of 12 large scale Chilean copper mines (annual output over 100,000 tons), which together produce around 75% of Chile's copper production. In addition, information was obtained through interviews in 10 international operations in Australia, Canada, the United States, Sweden, and Peru (see Table 3.1).[2] Overall, the sample represents 35% of the world's copper production and 50% of the world's copper production of over one hundred thousand tons. With this sample, we are sure of the representativeness and value of the analysis. To our knowledge, there is no other exercise of this magnitude worldwide.

Except for Chile and Peru, the sample of international operations is located in developed countries, with high standards in social and environmental matters, labor security, and relations with communities, which also have greater per capita incomes than Chile. This bias is deliberate. The objective of our analysis is not to compare the performance of Chilean mines with the rest of the world, but with those of best international practices, with good social, labor and environmental indicators.[3] In that sense, the study allows us to see the improvement potential of the country implicitly subject to the conditions above mentioned. That is to say, the comparison exercise not only considers productive capacities between Chile and other nations but also studies them in an adequate institutional framework, where the quest to improve the productive capacity of the sector is not at the cost of reductions in safety norms or environmental conditions. So, in addition to being the country with the highest production levels and copper reserves, Chile could also be the world mining frontier in terms of productivity, safety, and sustainability, although in order to do so, the country must overcome several barriers.

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1 The bulk of the information and analysis presented in this chapter was raised within the framework of the Mining Productivity Program of the National Productivity Commission and Fundacion Chile, with the fundamental support of Matrix Consulting. The capital productivity indicators were calculated by the company CGS using the RMES platform. The Commission thanks the companies and operations mentioned here for their support and willingness to provide information. The Mining Council of Chile, as well as several private institutions in Australia, Canada, Sweden, Peru and United States were a valuable support in the development of this chapter. In the public sphere, several authorities from these countries were interviewed to enrich our analysis. The Australian Government Trade Commission for Australian (AusTrade) in the Embassy of Australia in Chile, and Business Sweden in the Swedish Embassy in Chile were decisive in the support given to the CNP team that visited those countries.

2 Only seven of them agreed to provide operational data.

3 In the case of Peru, it is interesting to consider it within the sample as it is the closest competitor (in production and foreign investment in mining) that has characteristics similar to Chile.

The chapter is structured as follows. Section 3.2 presents the methodology used for the benchmark analysis. Section 3.3 and 3.4 examine the productive capacity of the mines, specifically the Labor Partial Productivity and the Capital Partial Productivity, respectively. Section 3.5 presents the results and conclusions of the chapter.

3.2. Methodology

For the analysis described in this chapter, each of the selected national operations was visited to gather the necessary information. Each operation yielded primary (raw) information for 2015, with maximum openness at the level of seven unit processes. Accessing the raw information allowed us to standardize the aggregate metrics and compare them between mines, considering that not all have the same unit processes and that the information is coded differently at each operation. In addition to quantitative production information, information was gathered on the staff, machinery, and physical and geographic characteristics of each mine. During the visits, interviews with management, supervision and operational teams were also held. The visits lasted between three and five days at the national mines.

At international mines, data was collected similarly, although for reasons of confidentiality the level of access to information was lower.[4] Of the international sample, two mines were visited in each country, although we acquired data from only seven of the ten international mines.[5] In each country, not only did we interview people at the mines, but also with representatives of government agencies, universities, associations, and mining companies. At the international operations, the visits lasted one day.

Three aggregate levels of analysis were considered: open pit mines, concentrator plant and hydrometallurgical plant, and seven unit processes examined: loading and hauling (at the open pit); crushing and grinding (at the concentrator plant); and crushing, dry area and wet area (at the hydrometallurgical plant). For the analysis, we measured material moved in the open pit, processed material[6] at the concentration plant, and stacked material in the hydrometallurgical plant.[7] As explained in the previous chapter, copper is

4 Unlike national operations, information from international operations was provided directly by each, but productivity indexes were built on the same methodology in order to ensure comparability.

5 Although two sites were visited in Sweden, they were not included in the metrics due to their production level.

6 Ore.

7 In open pit mining, the operation of El Teniente is excluded from the national sample because it is an underground mine, and therefore not comparable with the rest of the observations. However, for some of the other processes (when applicable) such observation is available.

not used as an input in the productivity measure since this metric biases the analysis in favor of mines with better ore grades and a lower stripping ratio, distorting the analysis and prompting a loss in comparability.

Table 3.1. National and international study sample (2015)

National Mines (2015 production)	International Mines (2015 production)
Escondida (1.153 Kton.)	Highland Valley (CAN, 133 Kton.)
El Teniente (471 Kton.)	Gibraltar (CAN, 73 Kton.)*
Collahuasi (455 Kton.)	Morenci (USA, 203 Kton.)
Los Bronces (438 Kton.)	Bagdad (USA, 80 Kton.)
Los Pelambres (376 Kton.)	Safford (USA, 91 Kton.)
Chuquicamata (309 Kton.)	Antamina (PER, 345 Kton.)
Radomiro Tomic (316 Kton.)	Cerro Verde (PER, 277 Kton.)
Andina (224 Kton.)	Olympic Dam HQ (AUS, 114 Kton.)*
Centinela (221 Kton.)	Prominent Hill (AUS, 126 Kton.)
Spence (176 Kton.)	Iron Ore (AUS, 233 Kton.)*
Candelaria (150 Kton.)	
Gabriela Mistral (125 Kton.)	

* Mines that did not provide data for the study.

Source: Cochilco and Matrix Consulting.

The diversity of the mines compared was a major challenge in this study. The sample includes, on the one hand, mines designed and constructed at different times, with various levels of production, different ore grade and geometry; and on the other, operations with particular capital levels, employment, and organizational culture. In order to make them comparable, we used standardized criteria. For example, in mine processes (loading and hauling) the standardization considered three corrective factors. The first one is applied according to the hopper capacity of the trucks (and assuming that the choice of the loader matches the vehicle used) since larger capacity hoppers carry more material yielding an apparent higher productivity when in fact it accounts for a different capital availability. To correct this, each operation's hopper capacity is weighted against the average of the rest of the sample operations' hopper capacity. The second corrective factor is applied according to the operation's geometry, since smaller pits or pits with shallower inclinations allow more material to be moved in less time. An estimated factor that characterizes the operation regarding the mining cycle (average time a truck takes from loading to discharge at the crushing, waste rock dumps or stacking site), the pit's inclination, and the distance between the mine and the plant or the waste rock dumps, corrects this effect.[8] Operational stops due to climatic factors were also considered as a third factor, acknowledging that mines in the national sample have winter operations.[9]

Another major challenge was to standardize the criteria for categorizing information. The stages of each process were homogeneously defined, and the stop types (whether planned or not), or of maintenance (corrective or not), etc. were determined. Information was requested from the national mines directly from the dispatch center and was organized and classified with a single criterion. Information was received from the international mines with aggregates and predefined classifiers, to make them comparable. This criterion of information delivery and processing applies to all indicators, including the adequate provision of the employees according to the areas of analysis.

For confidentiality reasons, no specific information is released on mines or companies. However, part of the study resulted in a confidential report for each mine that provided data, and it received in return information on its relative position in relation to other mines, the latter unidentified.

3.3. Partial Labor Productivity

This section describes the mine's productive capacity according to a partial labor productivity indicator. This indicator measures person-hours required to move a thousand tons of material (in the case of the operation as a whole and the particular case of the pit processes). Also, it measures person-hours per material processed at the concentration plant, or the person-hours per stacked material concerning hydrometallurgical plants.

3.3.1. Indicator

According to the selected metric, an operation is considered more productive when there is fewer person-hours dedicated to moving (mine), processing (plant) or stacking (hydrometallurgy) thousand tons of material during 2015. This indicator is constructed

8 Methodology developed by Matrix Consulting within the framework of the benchmark study.

9 Specifically, a geometric mean is obtained with these three factors. The value obtained from this average is multiplied with labor productivity.

using the volumes of each process, the mine employees (including subcontractors[10]), and the average annual hours per worker.[11]

This partial labor productivity indicator serves to focus attention on the measure of the force of the operation (person-hours). A mine with high "partial labor productivity" requires less person-hours per unit of material moved, processed or stacked. However, as explained in the previous chapter, this does not imply that performance is the worker's sole responsibility since other factors affect the outcome. For example, the quantity and quality of available capital, organizational management, the human capital and labor skills, etc., also affect metrics. In short, the measure used here reflects not only the worker's productive capacity but also the mutual influence of the different productive factors.[12]

3.3.2. Results on partial labor productivity

With the information from operations in the national and international sample, and after applying the standardization and correction mentioned above, we estimated the productivity indicator for the national mines and a national average and compared them with the best international mines and with the sample's global average.[13] Figure 3.1 show the results, where the bars indicate the number of workers-hours associated with one thousand tons of material moved for each of the 11 national operations. [14]

10 Available data does not allow for distinguishing between own employees and contractors.

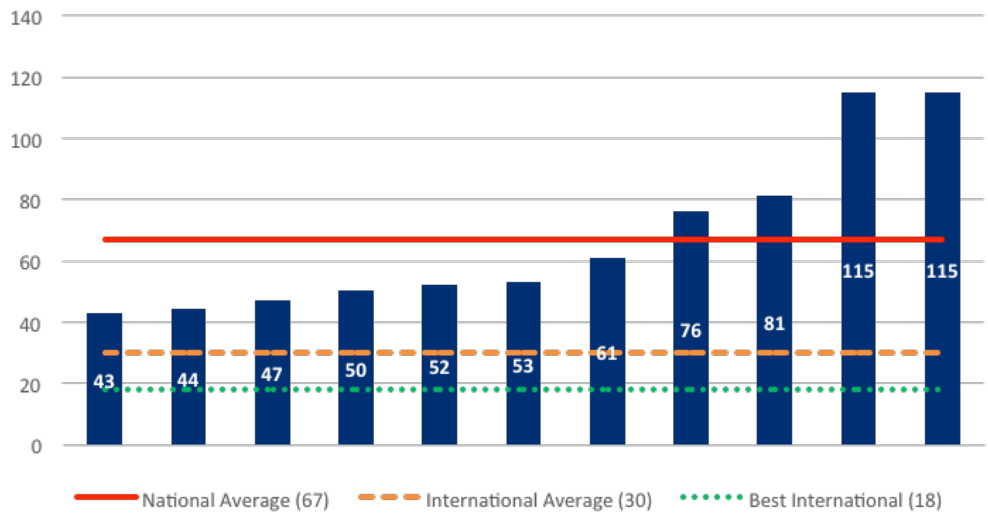
11 The Full Time Equivalent (FTE) or Jornada Equivalente used in this study is 2,190 annual hours per worker for the case of the national sample. For the international sample, 2,000 annual hours per worker is used. The latter number is obtained from the average of the past 15 years based in Cochilco and Wood Mackenzie.

12 See OCDE (2001).

13 In this case, the FTE considers 2,190 annual hours per worker for Chile and 2,000 annual hours per worker for the international sample. Only open pit and mixed mines are considered.

14 El Teniente is excluded as it is an underground mine.

Figure 3.1 Partial Labor Productivity, 2015
(Person-hours per kilo ton of material moved).



Source: National Productivity Commission based on MatrixConsulting.

The figure shows a marked heterogeneity among local mines, as already observed in Chapter 2. According to the indicator, during 2015 the most efficient operation in the national sample required an average of 43 person-hours to move a thousand tons of material, while the less effective required 115 person-hours for the same job. The national average was 67 person-hours per thousand tons of material.[15]

Beyond statistical analysis, these gaps -greater than 100%- between the least and most productive mines are difficult to explain due to external factors, such as the regulations or norms applied. In addition, corrections for geographic factors, the trucks capacity, and exogenous factors such as the ore grade were used for the sample. With this in mind, the bulk of these differences must be attributable to the mines' particular factors, especially personnel and asset management, as well as the mining plan.

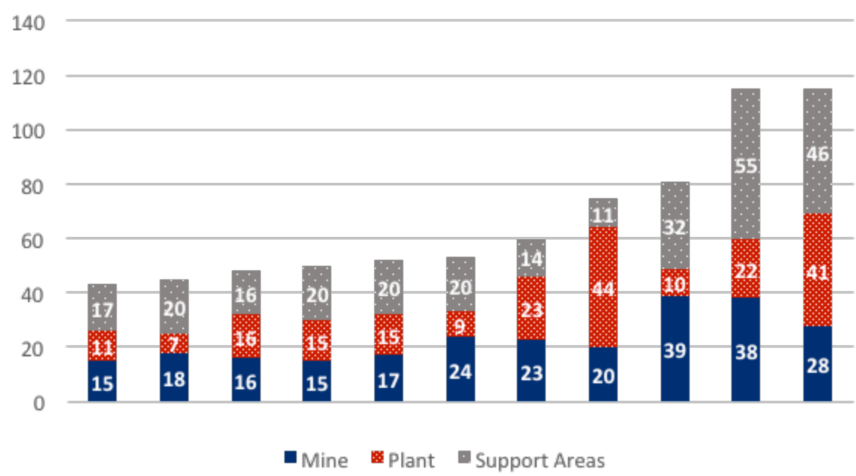
The analysis also shows a significant gap between the national and international indicators and suggests that there is ample scope for improvement in productivity, taking

15 It is important to notice that less productive mines show an important deviation from the sample median (53), and thus, distort the national average (67).

into account the observed performance of the most efficient (and best practices) mines worldwide. The average of the international sample (30) is slightly less than half the national average (67). That is to say, in 2015 the domestic mines required more than twice the amount of person-hours per thousand tons of material moved than the international average. Also, it is worth mentioning that the local best-performing operation shows 44% more person-hours than the average world sample and 139% more than the best international mine. This productivity gap may be capturing differences associated with institutional, normative, or gaps in labor skills.

Figure 3.2 is equivalent to the previous graph but shows the person-hours composition in national mines, under the areas of mine, plant and support.[16] Although there is no clear pattern to link the structure of the hours with the performance of the operation, the figure suggests that at a higher proportion of person-hours in the areas of plant or support on person-hours in the mine, it is more likely to exhibit a worse performance. For example, the least efficient operation has the highest proportion of person-hours in support areas (1 to 1.6 in the mine). The second less efficient operation is very close (1 to 1.5), while the fourth (least efficient) shows the highest ratio between plant and mine hours of (1 to 2.2).

Figure 3.2 Composition of partial labor productivity, 2015
(Person-hours per kilo ton of material moved)



Source: National Productivity Commission based on MatrixConsulting.

16 Support area includes support services to the operation, personnel services, electric services, management (administration and finances), human resources, security, occupation health, environment and communities, OPEX projects, between others.

Based on information from the mine area (see Figure 3.3), estimations show that the average productive capacity of the international operations exceeds the national average.[17] Specifically, the international sample shows an average productivity of 13 person-hours per kiloton of material moved, while the national average is 24 person-hours per kiloton of material.[18] Also, the international operation with the best performance shows a productivity of 9-person-hours per kiloton of material moved. In this sense, the gap observed in Figure 3.2 between the national average and the international values turns out to be slightly higher than the difference found in the mine area, suggesting that the other areas (plant and support) have an incidence on the national indicator. Thus, being the international average of 30 person-hours, and of these, 13 person-hours come exclusively from the mine area, then the other 17 person-hours must come from the plant area and support. The implications are that, for each person that works in the mine area per hour (at the international mines) 1.3 person-hours are used in the other areas. Furthermore, in the national sample, the average is 67 person-hours, of which 24 hours correspond to the mine area and 43 hours from other sectors. In other words, for each person working in the mine per hour, 1.8 person-hours are employed in other areas.

As mentioned, this distribution (and proportion) of person-hours in the different areas may be one of the possible causes of observed gaps. Another reason for this difference may not be due to the number of person-hours, but to failures that affect operational continuity, reducing the flow of material moved in the domestic operations, therefore, for the same number of available person-hours less material is moved or processed.

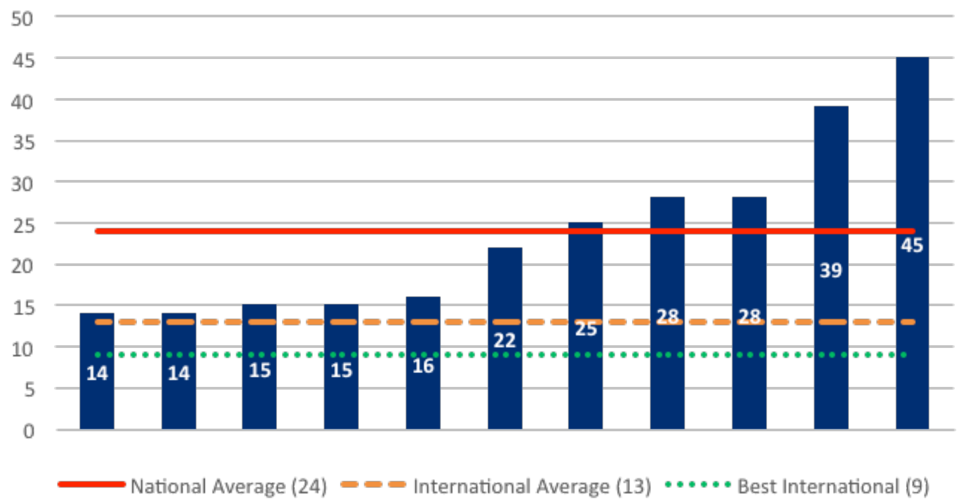
Figure 3.4 presents the productivity results of the process associated with the Concentrator Plant (CP) at the national level, which considers thousands of tons of processed ore and the plant's person-hours.[19] Like the previous cases, there is a considerable heterogeneity between the local mines. Figure 3.4 shows that the most effective CP uses 29 person-hours to process a thousand tons of mineral material, while the least productive one uses 91 hours. The less efficient plant has an unusual value, however, the company validated this information.

17 In order to not be redundant, the figure is not shown considering that Figures 3.2 and 3.3 are linked to the whole mine productivity.

18 At the national level, the gap between the least efficient and the most efficient is 212%. This is equivalent to say that the least efficient national mine uses 30 more person-hours than the most efficient national mine.

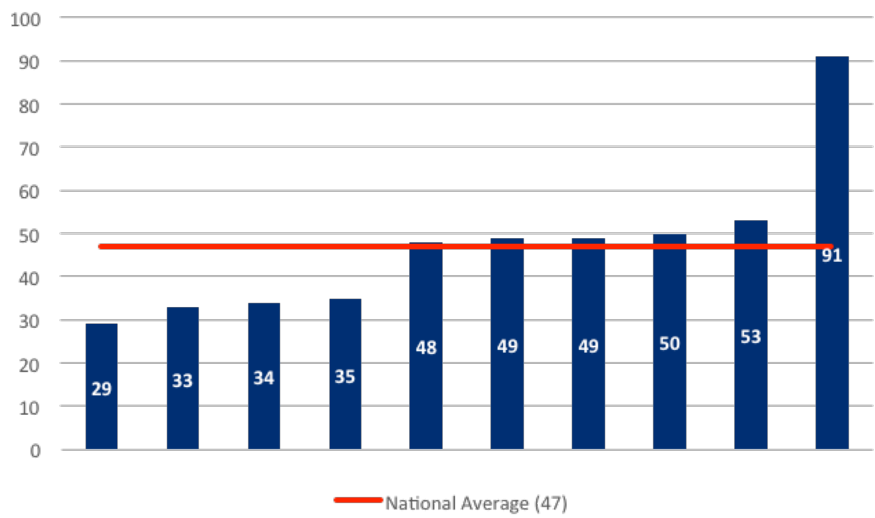
19 Although international data is available, employees allocation classified as "plant area" are specific to each operation, thus providing non-representative results. In the case of hydrometallurgy plants, there are no international data available to do the benchmark analysis.

Figure 3.3 Partial Labor Productivity in Open Pit Mining, 2015
(Person-hours in mine per kilo ton of material moved)



Source: National Productivity Commission based on MatrixConsulting.

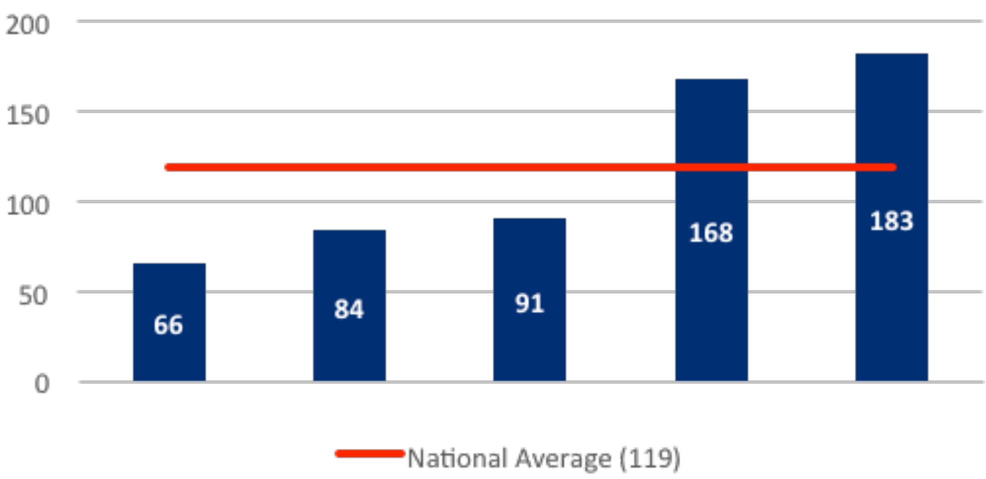
Figure 3.4 Partial Labor Productivity in Concentrator Plants, 2015
(Person-hours in plant per kilo ton of processed ore)



Source: National Productivity Commission based on MatrixConsulting.

Figure 3.5 presents the productivity results for the Hydrometallurgical Plant (HmP) in the national sample. Similar to the previous cases, the local operations show significant gaps: between the most efficient operation and the least efficient one, there are 177% more person-hours per stacked kiloton of material. This result could be due to a greater amount of person-hours used, or to failures in the productive process that imply less stacked material during the same period.

Figure 3.5 Partial Labor Productivity in Hydrometallurgical Plants[20], 2015
(Person-hours in hydrometallurgical plants per kilo ton of stacked material)



Source: National Productivity Commission based on MatrixConsulting.

Finding 3.1: There is a high dispersion in the productive performance of the Chilean operations evaluated. The most efficient operation uses 43 person-hours per thousand tons of material moved, while the least efficient operation uses 115 hours. On average, it took 67 person-hours to move a thousand tons of material during 2015, although most (median) used 53 person-hours.

Finding 3.2: When compared with international operations, there are significant gaps at productivity levels. On average, the international sample operations accomplish the same task occupying 37

[20] Only some operations process oxides, so there are fewer observations of these plants.

person-hours less than the national average (67), and 23 hours less than most domestic operations.

Finding 3.3: The results suggest that less productive operations have a more heterogeneous composition of person-hours in different areas. Less productive operations tend to have, either a greater proportion of person-hours at the plant compared to the mine or a higher percentage of support services. On average, a national mine has 1.8 person-hours in the plant and support per person-hour in the mine, while for the international case this indicator is 1.3.

Finding 3.4: The productivity gap between the best national (43) and the best international mine (18) is 25 person-hours per kiloton of material moved. That is, the best domestic mine is 139% more inefficient than the best in the international sample. When the best performing national mine is compared to the international average, this difference is reduced to 13 person-hours. That is, the most efficient national mine is 44% more inefficient than the mean of the international sample.

Finding 3.5: Productivity at the Mine area shows that, on average, domestic operations use 24 person-hours per thousand tons of material moved. Gaps between local operations are important (221% more inefficient regarding the best performing mines). Concerning the international sample, on average, they carry out the same task using 11 person-hours less, again a gap of over 100%.

Finding 3.6: Concentrator Plant productivity shows that, on average, domestic operations use 47 person-hours to process a thousand tons of material. The difference between the most and least productive mine is 62 person hours, i.e., the least productive is 214% more inefficient than the best.

Finding 3.7: Hydrometallurgical Plant productivity shows that, on average, domestic operations use 119 person-hours to stack a thousand tons of material. The difference between the most and least productive mine is 116 person-hours, i.e., the least productive is 177% more inefficient than the best.

3.4. Partial Capital Productivity

The efficiency in the use of capital (equipment and machinery) is also used to describe the productive capacity of the operations. Specifically, capital utilization was considered for the seven unit-processes already described, in the mine, the Concentrator Plant, and the Hydrometallurgical Plant.

3.4.1.Indicators

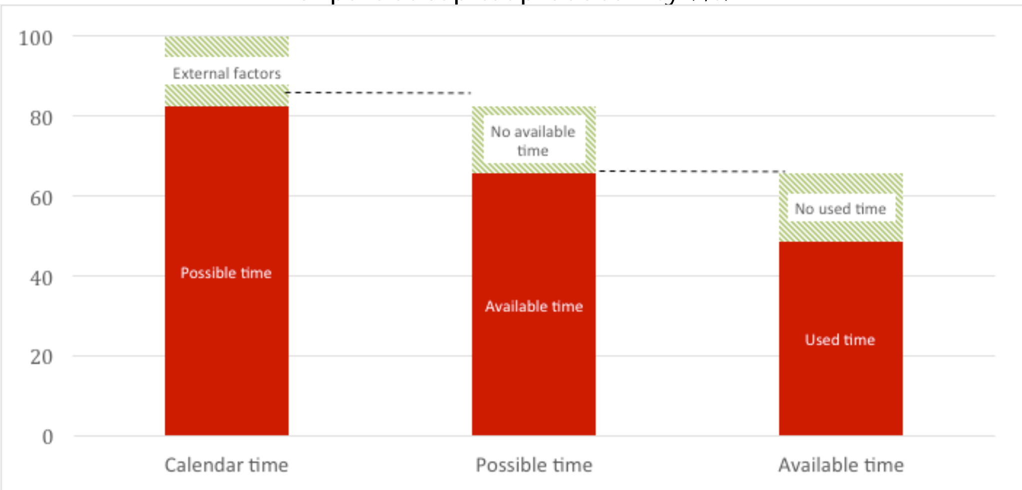
The proportion of time that the asset is effectively operating, called asset efficiency, defines the productive performance of capital. Specifically, this index estimates the proportion of the time the asset is used for over a base time, for each of the seven unit processes under analysis. This metric is constructed on the basis of one year of operation (2015), deducting from it the exogenous factors common to each of the unit processes.[21] In other words, of 365 days, non-operative days resulting from events that reduce the possible use time of capital due to non-manageable situations are subtracted. For example, blasting time at an open pit is an exogenous factor that forces to halt loading and hauling processes, therefore, generating non-use hours of the assets. Or, as is the case of several Chilean operations that must temporarily halt their operation in the mine during the winter season, which generates hours of non-use of the assets.

Once we deduct the exogenous factors to the calendar time (365 days) we obtain the possible time, which is the time that the asset can effectively be used. The time associated with the asset maintenance (either planned or corrective), when the asset is not available must also be subtracted. By deducting from the possible time the maintenance time, we obtain the available time. The time spent in stops (whether scheduled or not), must also be subtracted, because, although the equipment is available it is not always in use. Examples of programmed stops would be security talks, transfers, lunch, shifts delays, etc. Examples of unscheduled stops would be those that derive from the lack of coordination within processes. Once these factors are deducted from the available time, we obtain the used time. Therefore, the efficiency of the asset refers to the proportion of time equivalent to the used time.[22] Figure 3.6 summarizes the analysis.

[21] For example, weather and energy shortcuts could affect the complete productive process. Nevertheless, upstream or downstream stops are exogenous stops that affect specifically the unitary process.

[22] There is no information available to do a comparison of effective performance. This requires assuming that, in general, the productive capacity of the asset is similar between plants and the difference derives from hours in use.

Figure 3.6. Distribution of time losses for calculation of partial capital productivity (%)

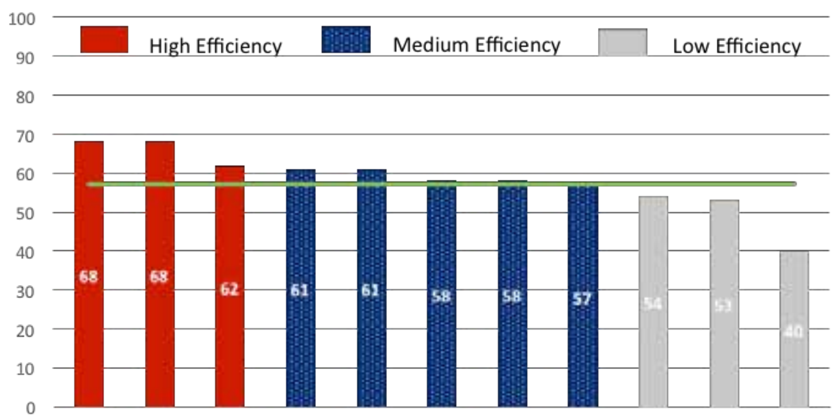


Source: MatrixConsulting.

3.4.2. Loading

The loading process occurs within the pit area and corresponds to the management of both electric and hydraulic shovels that load the trucks either with ore for the plant or waste rock for the dumps.

Figure 3.7. Asset Efficiency Loading, 2015 (% of possible time)

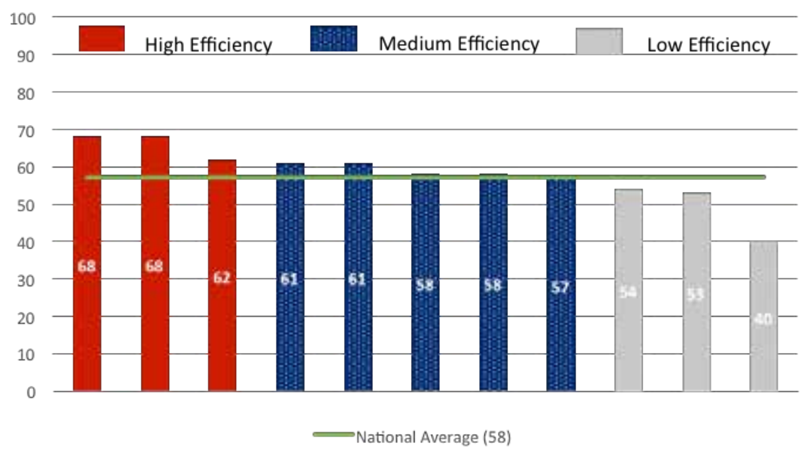


Source: National Productivity Commission based on MatrixConsulting.

As shown in Figure 3.7, the average efficiency in the use of the assets for the Chilean loading process reaches 58% of the possible time, while the best national operation equals 68% of that time, and the worst one reaches 40% (28 % gap). The collected data also show that, on average, the proportion of possible time associated with non-utilization of the asset (see Figure 3.7 and 3.8) is distributed into 21% for corrective or preventive maintenance and 21% for scheduled or unscheduled stops.[23]

Figure 3.9 shows the average and maximum values of availability and efficiency in the use of the shovels for both the domestic and the international samples. In this case, the analysis is presented as a percentage of the actual calendar time, not of the possible time.[24] Under this criterion, the gap between the national average (77%) and the international average (90%) is 13 percentage points. Instead, the best national operation (85%) is five percentage points below the international average (90%), and eight points under the best international (93%). The national mine with less availability of the asset reached 72%.

Figure 3.8. Asset Availability Loading, 2015 (% of possible time)

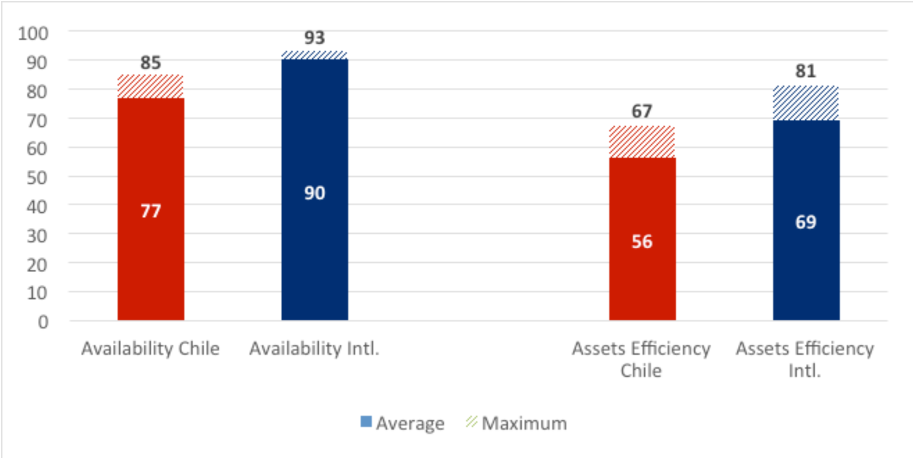


Source: National Productivity Commission based on MatrixConsulting.

23 The average proportion of availability is 79% of possible time, and thus, 21% relates to maintenances. Then, the difference between 79% and 58% is the average time regarding stops.

24 There was not direct access to the information of international mines and thus, stops could not be allocated to exogenous factors.

Figure 3.9. Asset Availability and Efficiency Gaps in Loading, 2015 (% of calendar time).



Source: National Productivity Commission based on MatrixConsulting.

Analyzing the level of asset efficiency regarding the gap with the international sample, the average of domestic operations is 13 percentage points lower than the mean of the international sample. The best national mine is 14 percentage points below the best international operation. If we consider this analysis and equate the calendar time to 24 hours we would have, on average, that loading time in Chile is available 18.5 hours versus 21.6 hours of the international sample. In the case of Chile, of these 18.5 hours, the equipment is used 13.4 hours. For the international sample, of the 21.6 hours available, the equipment is used 16.6 hours, or 24% more than in Chile. If operational continuity implies using the asset 24 hours a day, 365 days a year, this would mean that loading of the international sample (on average) uses the asset 49 days more days than the national average. Finally, in the national sample, the mine that has the lowest proportion of asset efficiency is 38%.

Finding 3.8: Productivity associated with loading shows significant gaps at the national level: as for the asset efficiency, the gap is 28 percentage points. The biggest differences in this gap are due to stops, followed by maintenance.

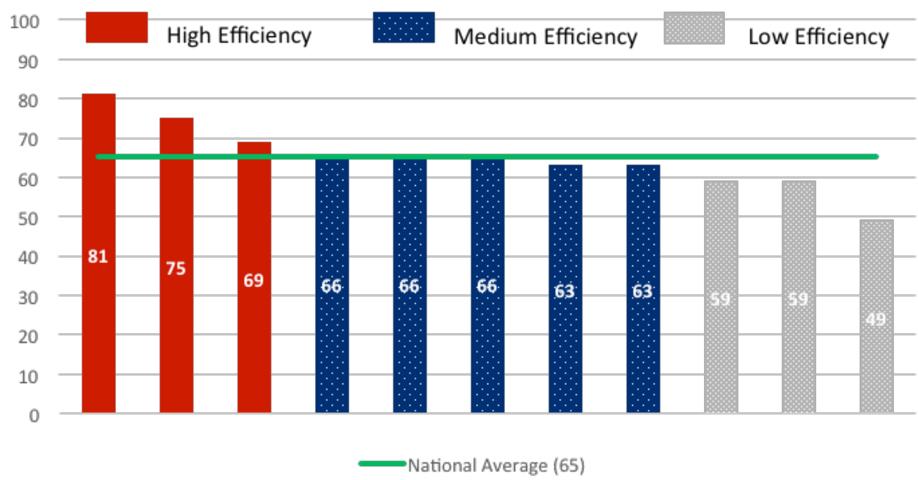
Finding 3.9: On average, the international sample uses the shovels 24% more time than the national average. This would be equivalent to using the asset an additional 49 days a year if the asset was used 24 hours, 365 days a year.

3.4.3 Hauling

The Hauling process occurs within the open pit area, which corresponds to the transportation of the waste rock to the dump, and the ore to the plant. From the data collected, there is a 32% gap between the most efficient operation and the least efficient operation. (See Figure 3.10) The average truck efficiency in the sample is 65% of the possible time, which implies that 35% of the possible time is correlated with maintenance and stops.

By analyzing Figures 3.10 and 3.11, we can conclude that, as in the case of loading, the heterogeneity in the efficient use of the asset is accounted for by the time related to the stops, rather than the time associated with maintenance.[25] Corroborating the above, Figure 3.11 shows that there are operations with high availability of the asset, but little efficiency in asset use. There are also operations that are part of the high-efficiency group that manage to correct the low (relative) availability with fewer stops.

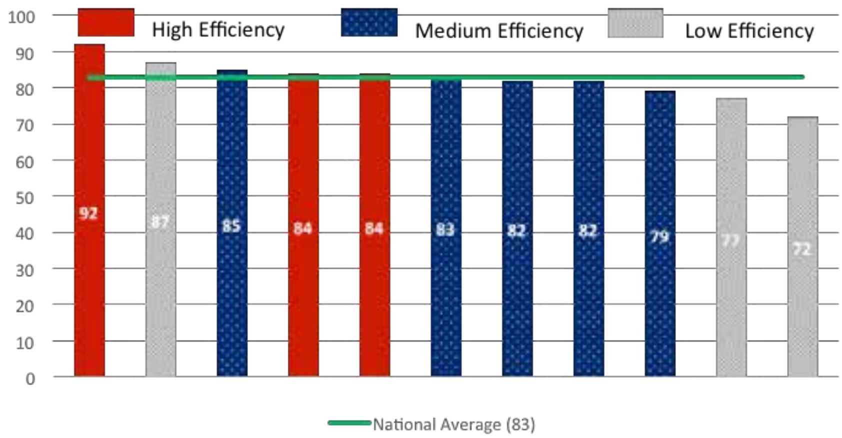
Figure 3.10. Asset Efficiency Hauling, 2015 (% of possible time)



Source: National Productivity Commission based on MatrixConsulting.

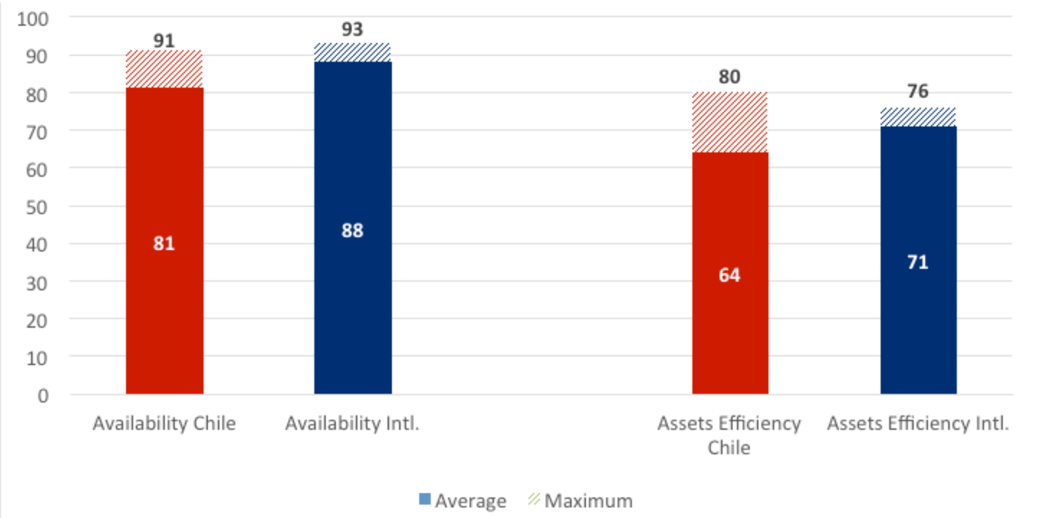
[25] Availability gap is 20 percentage points, with an average of 17% of possible time associated to maintenances, while the efficiency gap is 32 points with an average of 18% of possible time associated to stops.

Figure 3.11. Asset Availability Hauling, 2015 (% of possible time)



Source: National Productivity Commission based on MatrixConsulting.

Figure 3.12. Asset Availability and Efficiency Gaps in Hauling, 2015 (% of calendar time)



Source: National Productivity Commission based on MatrixConsulting.

Figure 3.12 shows the gap in hauling availability and efficiency between national and international sample operations (based on calendar time). The difference between the average national sample (81%) and international (88%) is seven percentage points. Note that the national operation with better availability (91%) exceeds the average of the international sample. Moreover, at the level of asset efficiency, the best national operation outperforms the best international operation. The national sample's average efficiency is below the international sample by seven percentage points. The national mines with less availability and efficiency in the use of the asset are 72% and 47% of the calendar time, respectively.

If we equate the calendar time of this analysis to a 24-hour span, we would have that, on average, in Chile, the trucks are available 19.4 hours versus 21.1 hours of the international sample. In Chile, of these 19.4 hours, the asset ends up being effectively used 15.4 hours, while the international sample, on average, uses 16.9 hours (out of the 21.1 hours available). That is, the international sample uses an additional 10% of the truck per day that the national mines. If operational continuity implies using the asset 24 hours a day, 365 days a year, this would mean that the international sample's transport (on average) uses the asset 23 more days than the national average.

Finding 3.10: Productivity associated with hauling has significant gaps at the national level: as for asset use, the gap is 32 percentage points. Stops account for the biggest difference of this gap, followed by maintenance.

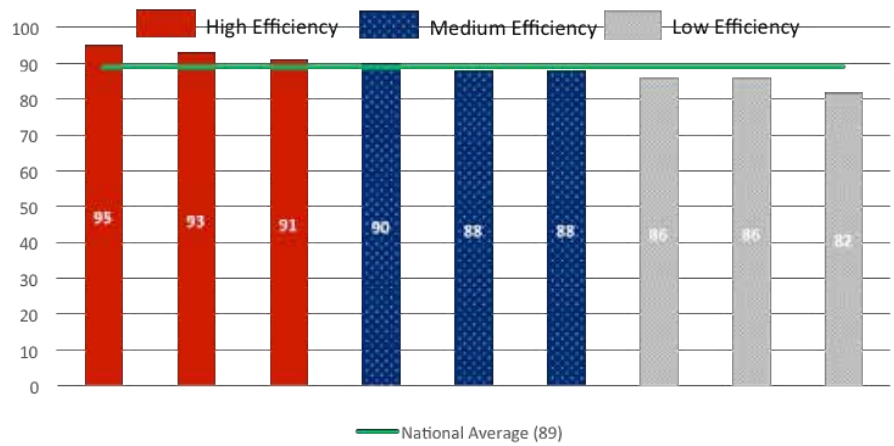
Finding 3.11: On average, the international sample has 10% more hauling efficiency than the national average. This means that the asset is used 23 more days a year by the international sample if we consider a use of 24 hours a day, 365 days a year.

3.4.4. Concentrator Plant

This section analyzes the use of the Concentrator Plant (CP), which processes the mineral material to obtain copper concentrate. For this analysis, we consider the Primary Crushing and Grinding processes, which (roughly) consist of reducing the mineral rock to optimum levels of granularity for obtaining copper concentrate through the flotation process.

Figure 3.13 shows the gap regarding the efficient use of the concentrator plant for the national sample.[26] We can observe the high degree of efficiency under the same process parameters previously used. The gap between the most and least efficient use is 13 percentage points, and the average of the sample is 89%.

Figure 3.13. Asset Efficiency Concentrator Plant, 2015 (% of possible time).

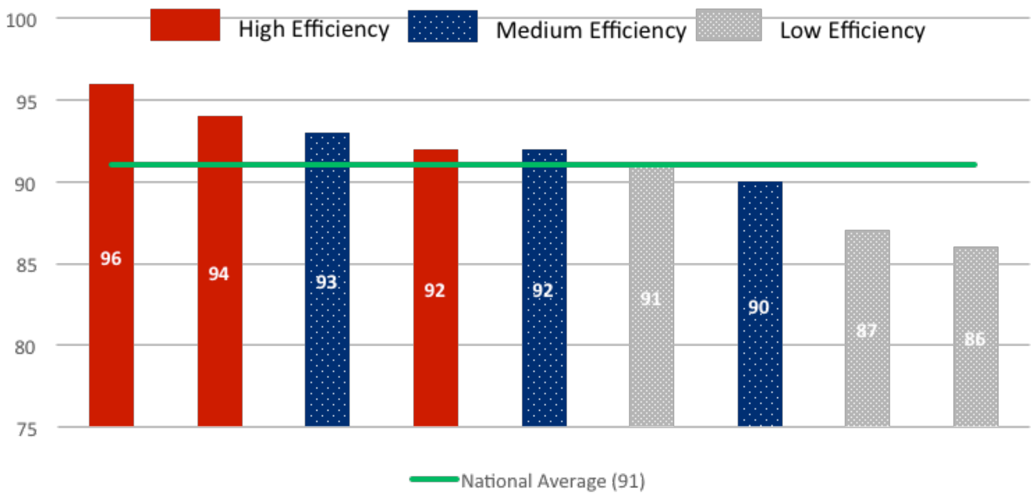


Source: National Productivity Commission based on MatrixConsulting.

According to Figure 3.14, on average, 9% of the possible time is used in maintenance (either corrective or planned), while 2% of the possible time corresponds to stops (either programmed or not). That is, unlike the previous cases, the maintenance (on average) explains largely the national gaps. However, there is (marginally) a greater gap in the case of efficiency (13 percentage points) than in availability (10 percentage points).

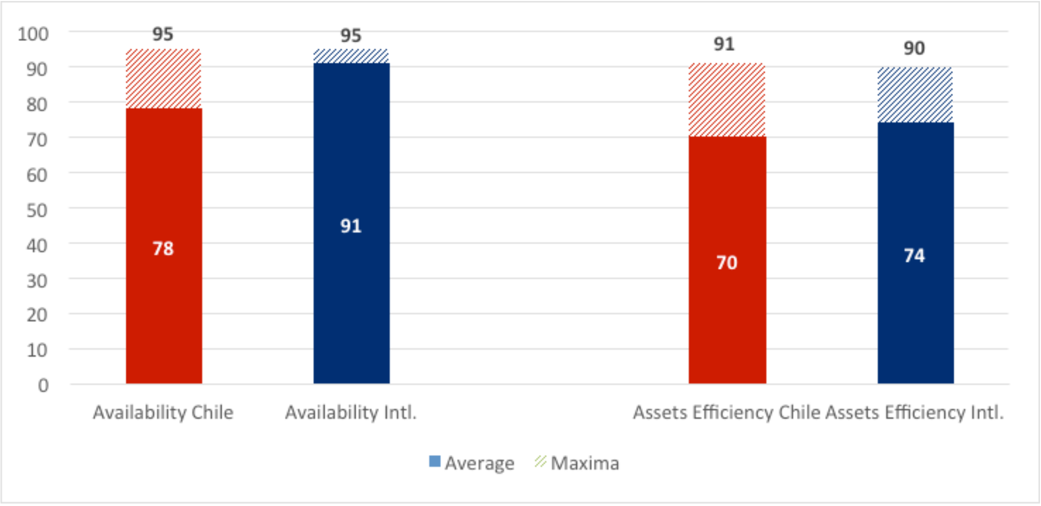
26 In this case, the metric is aggregated from time of Primary Crusher and Grinding.

Figure 3.14. Asset Availability Concentrator Plant, 2015
(% of possible time)



Source: National Productivity Commission based on MatrixConsulting.

Figure 3.15. Asset Availability and Efficiency Gaps in Primary Crusher, 2015
(% of calendar time)

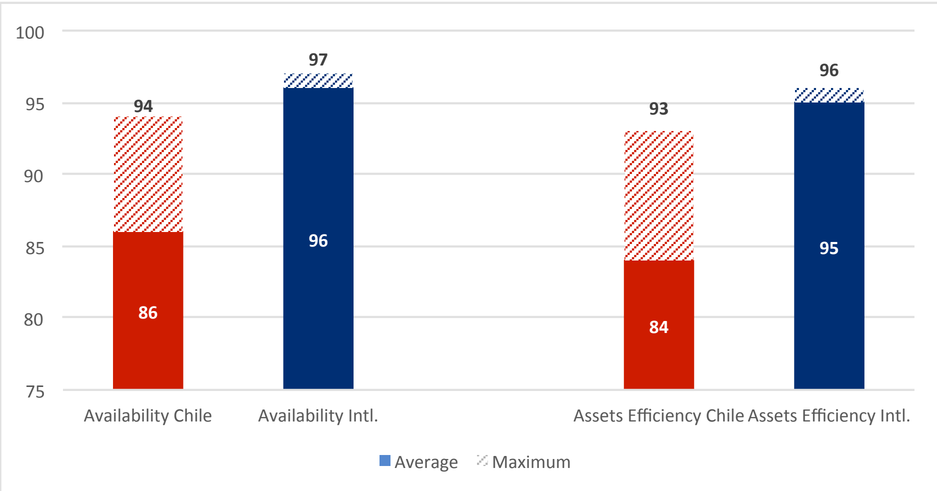


Source: National Productivity Commission based on MatrixConsulting.

Figure 3.15 presents the average and maximum value of the availability and efficiency associated with the Primary Crushing of the national and international sample.[27] The difference (average) between the national and international sample is 13 percentage points in availability (78% vs. 91%), and four percentage points in efficient use (70% vs. 74%). National mines with greater availability and higher asset efficiency do as well or better than international operations. Similar to the assets previously analyzed, the national sample presents mines with low availability (57% of the calendar time) and efficiency (42%).

In the case of Grinding, the gaps are relatively larger compared to Primary Crushing (see Figure 3.16). The national average is ten percentage points from the international average, while asset efficiency is 11 percentage points below the international average. Like the previous case, there are observations with low availability (75%) and asset efficiency (73%) in the national sample associated to Grinding.

Figure 3.16. Asset Availability and Efficiency Gaps in Grinding, 2015
(% of calendar time)



Source: National Productivity Commission based on MatrixConsulting.

27 For comparability reasons, availability and efficiency have calendar time as base time.

Finding 3.12: The national gap in the efficient use of the Concentrator Plant is 13 percentage points, with an average of 89% of possible time.

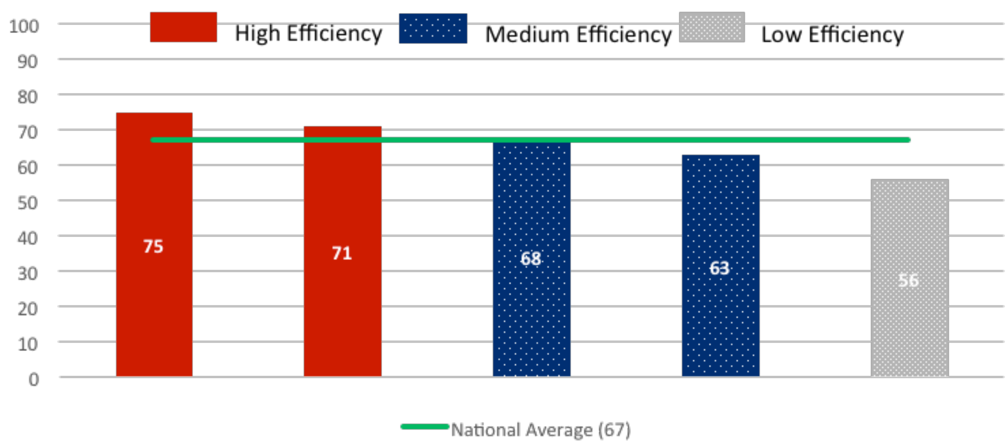
Finding 3.13: Maintenance is the greatest source of heterogeneity in the efficient use of the Concentrator Plant of the national sample.

Finding 3.14: Compared to the national average, the international sample is 13% more efficient in Grinding and 6% more in the Primary Crusher.

3.4.5. Hydrometallurgical Plant

The Hydrometallurgical Plant (HmP) processes the ore by reducing it (crushing) and applying a solvent (dry area) concluding with the electrowinning process (wet area). No information is available on the international sample for this process. The information collected (see Figure 3.17 and 3.18) shows gaps of 17 percentage points in the availability of the plant, while the asset efficiency turns out to be 19 percentage points (both based on possible time).

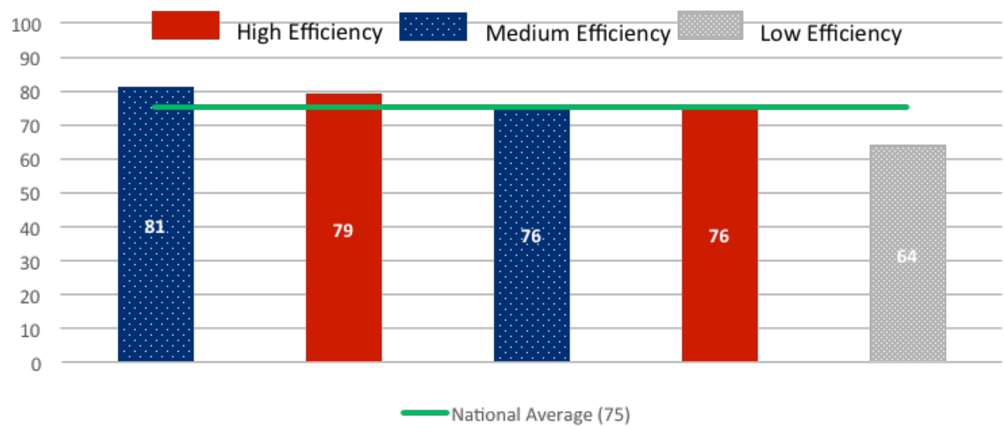
Figure 3.17. Asset Efficiency Hydrometallurgic Plant, 2015
(% of possible time)



Source: National Productivity Commission based on MatrixConsulting.

In the HmP, on average, 25% of the possible time is associated with maintenance and 9% with stops (both scheduled and not). Therefore, the primary source of heterogeneity related to asset efficiency comes from maintenance.

Figure 3.18. Asset Availability Hydrometallurgic Plant, 2015
(% of possible time)



Source: National Productivity Commission based on MatrixConsulting.

Finding 3.15: The national gap in the efficient use of the Hydro-metallurgical Plant is 19 percentage points. The greatest source of heterogeneity in the efficient use of the Hydrometallurgical Plant comes from maintenance.

3.5. Conclusions

We presented productive results and a benchmark analysis using data from 12 national mines and seven international mines considered as best practices. With this information, (comparable) partial labor and capital productivity indexes were constructed. In the first case, the index measures the operation's effort (measured as person-hours) for moving, processing or stacking material from the mine. In the second case, the index measures the proportion of time that the capital is being used.

The results associated with partial labor productivity show important gaps between national and international mines. The best national mine requires 43 working hours for every thousand tons of material moved, while the most efficient international mine requires 18 working hours. If we consider the average of both samples, per thousand tons, in the case of Chile, it takes 67 person-hours, while in the international sample, only 30.

The results associated with partial capital productivity also show gaps between national and international operations. These gaps (in favor of the international benchmark) do not exceed 14 percentage points of calendar time, with gaps around seven percentage points being the most common. If the calendar time is taken to a 24-hour equivalent, on average, the capital of international operations is used 1.7 hours more than in Chile per day, which may seem marginal, but considering that such difference occurs daily per mine, it implies an additional 26 days a year of operating time.

The results show that the gap at the national level is critical. In the case of the partial labor productivity, the most productive operation has a ratio of 43 working hours per thousand tons of material moved, versus the least efficient with 115. For the mine, concentrator plant and hydrometallurgical plant, the gaps show similar proportions.

In the case of capital productivity (measured as efficient use), when measured by the possible time, the difference between national mines tends to be around 23 percentage points. However, this time base considers endogenous factors, such as upstream or downstream stops in the process production line. It is worth mentioning that these stops represent about 60% of these exogenous factors, with significant dispersion.[28] Here lies the greatest cause of time losses, which may be managed by the operation. If we consider the latter, the gaps in the different unit processes increase significantly.

Table 3.2 summarizes the gaps in availability and capital efficiency described above. The main figures are the averages, and the figures in brackets, show the range of the national sample. As can be seen, the existing variance is important.

28 With the exception of hauling, which tends to vary around 20%.

Table 3.2. Asset Availability and Efficiency 2015

	Availability (hours per day)		Asset Efficiency (hours per day)	
	Chile	International	Chile	International
Loading	18.5 (20.4 - 17.3)	21.6	13.4 (16.1 - 9.2)	16.6
Hauling	19.4 (21.7 - 17.2)	21.1	15.4 (19.2 - 11.3)	16.9
Primary Crusher	18.7 (22.9 - 13.8)	21.8	16.7 (21.9 - 10.0)	17.7
Grinding	20.5 (22.4 - 18.0)	23.0	20.2 (22.3 - 17.4)	22.8

Source: National Productivity Commission based on MatrixConsulting.

Given these results, as well as those presented in Chapter 2, it is imperative to highlight the importance of continuing the efforts of gathering information at the mine level, which would allow both the public sector and the operations themselves to understand some of the factors that are affecting their productive capacity. One of the advantages that this industry has over others is that it does not compete with the final product. This implies that the competitive advantages are on the side of efficiency and costs. Being able to share certain information and good practices allows the industry - as a whole - to be much more competitive in today's scenarios.

Recommendation 3.1 Through the Chilean Copper Commission, or another agency that the government deems appropriate, produce indicators and periodic studies of productivity in the mining sector similar to those in this chapter, such as to complement the regular studies of competitiveness that the Chilean Copper Commission is already doing.

3.5.1. Summary of Findings

Finding 3.1: There is a high dispersion in the productive performance of the evaluated Chilean operations. The most efficient operation uses 43 person-hours per thousand tons of material moved, while the least efficient operation uses 115 hours. On average, it took 67 person-hours to move a thousand tons of material during 2015, although most (median) used 53 person-hours.

Finding 3.2: When compared with international operations, there are significant gaps at productivity levels. On average, the international sample operations accomplish the same task occupying 37 person-hours less than the national average (67), and 23 hours less than most domestic operations.

Finding 3.3: The results suggest that less productive operations have a more heterogeneous composition of person-hours in different areas. Less productive operations tend to have, either a greater proportion of person-hours at the plant compared to the mine or a higher percentage of support services. On average, a national mine has 1.8 person-hours in the plant and support per person-hour in the mine, while for the international case this indicator is 1.3.

Finding 3.4: The productivity gap between the best national (43) and the best international mine (18) is 25 person-hours per kiloton of material moved. That is, the best domestic mine is 139% more inefficient than the best in the international sample. When the best performing national mine is compared to the international average, this difference is reduced to 13 person-hours. That is, the most efficient national mine is 44% more inefficient than the mean of the international sample.

Finding 3.5: Productivity at the Mine area shows that, on average, domestic operations use 24 person-hours per thousand tons of material moved. Gaps between local operations are important (221% more inefficient regarding the best performing mines). Concerning the international sample, on average, they carry out the same task using 11 person-hours less, again a gap of over 100%.

Finding 3.6: Concentrator Plant productivity shows that, on average, domestic operations use 47 person-hours to process a thousand tons of material. The difference between the most and least productive mine is 62 person hours, i.e., the least productive is 214% more inefficient than the best.

Finding 3.7: Hydrometallurgical Plant productivity shows that, on average, domestic operations use 119 person-hours to stack a thousand tons of material. The difference between the most and least productive mine is 116 person-hours, i.e., the least productive is 177% more inefficient than the best.

Finding 3.8: Productivity associated with loading shows significant gaps at the national level: as for the asset efficiency, the gap is 28 percentage points. The biggest differences in this gap are due to stops, followed by maintenance.

Finding 3.9: On average, the international sample uses the shovels 24% more time than the national average. This would be equivalent to using the asset an additional 49 days a year if the asset was used 24 hours, 365 days a year.

Finding 3.10: Productivity associated with hauling has significant gaps at the national level: as for asset use, the gap is 32 percentage points. Stops account for the biggest difference of this gap, followed by maintenance.

Finding 3.11: On average, the international sample has 10% more hauling efficiency than the national average. This means that the asset is used 23 more days a year by the international sample if we consider a use of 24 hours a day, 365 days a year.

Finding 3.12: The national gap in the efficient use of the Concentrator Plant is 13 percentage points, with an average of 89% of possible time.

Finding 3.13: Maintenance is the greatest source of heterogeneity in the efficient use of the Concentrator Plant of the national sample.

Finding 3.14: Compared to the national average, the international sample is 13% more efficient in Grinding and 6% more in the Primary Crusher.

Finding 3.15: The national gap in the efficient use of the Hydro-metallurgical Plant is 19 percentage points. The greatest source of heterogeneity in the efficient use of the Hydrometallurgical Plant comes from maintenance.

3.5.2. Summary of Recommendations

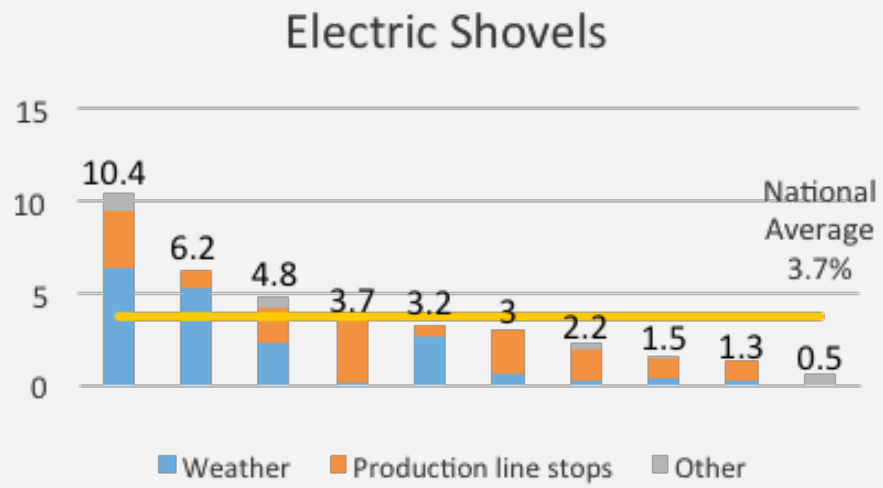
Recommendation 3.1: Through the Chilean Copper Commission, or another agency that the government deems appropriate, produce indicators and periodic studies of productivity in the mining sector similar to those in this chapter, such as to complement the regular studies of competitiveness that the Chilean Copper Commission is already doing.

3.5.3. Annex - Other Figures

This Annex figures were made by the National Productivity Commission based on Matrix Consulting.

1. Loading

Figure A.1 Time loss due to external factors in Loading, 2015 (% of calendar time)



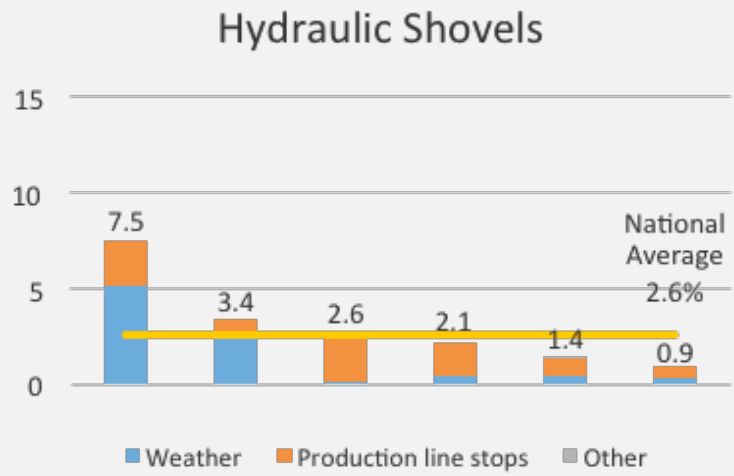
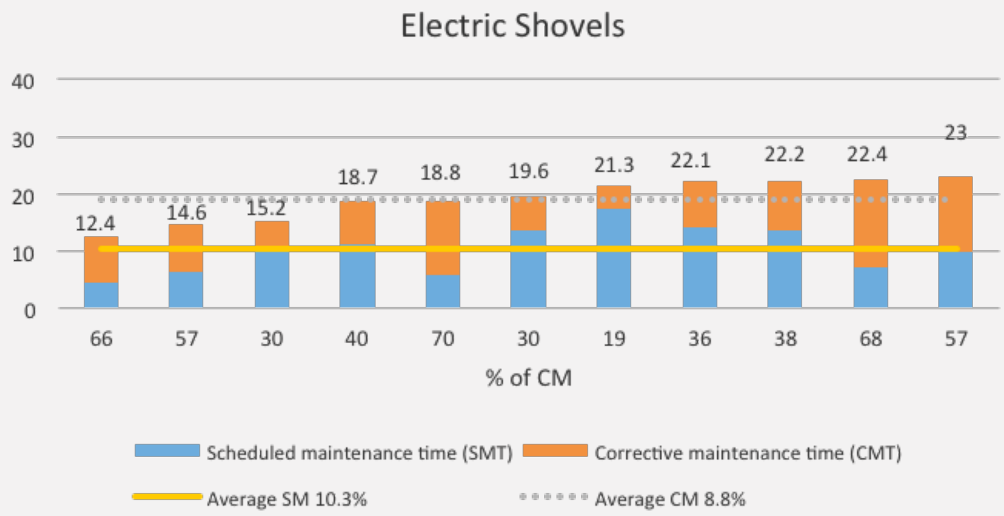
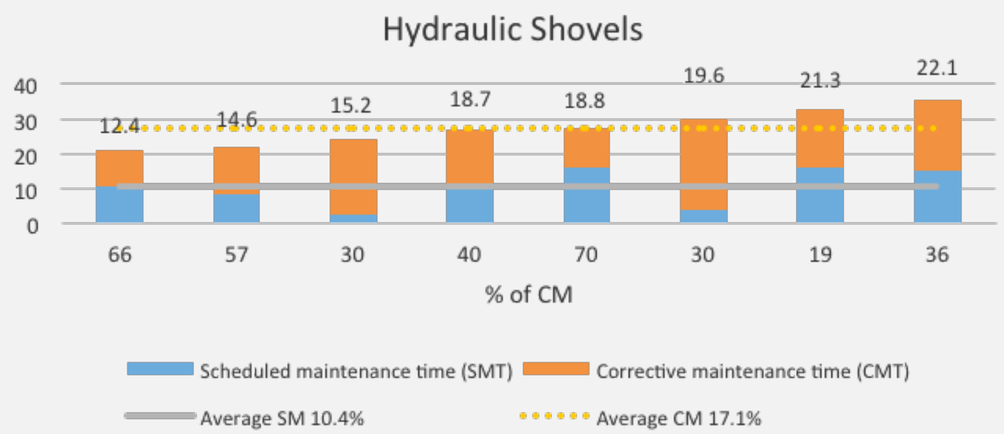


Figure A.2 Maintenance Loading Assets, 2015 (% of possible time).





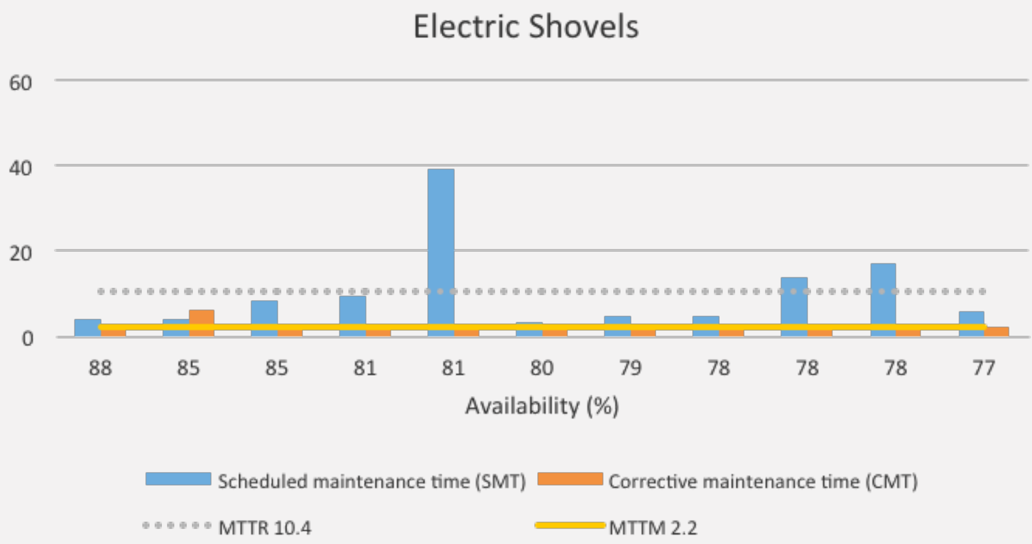
Source: MatrixConsulting

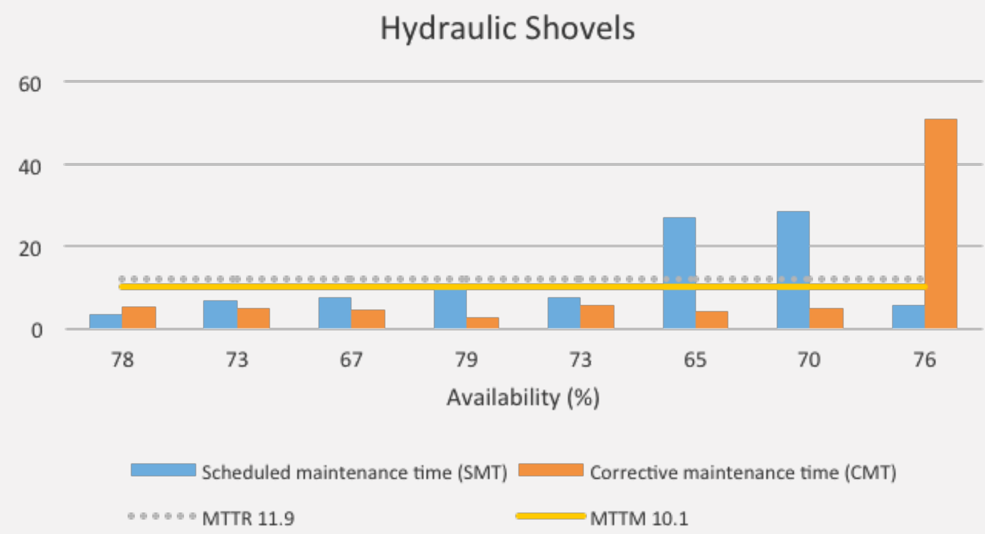
Figure A.1 reveals that the two main reasons for stops in the Loading process are both climate and stops in the production line. The latter, is exogenous to the loading process itself but not to the operation as a whole. Therefore, managing this would improve the operation's mining plan.

Figure A.2 shows that there is no clear pattern between scheduled maintenance and corrective maintenance that explains the greater asset use. However, Figure A.3 shows that operations that spend more time on scheduled maintenance tend to have greater asset use.

Figure A.4 shows that the greater efficiency in asset use is in the stops, although the ratio between scheduled or unscheduled stops does not seem to provide much information. Excluding the two outliers' observations in each shovel types, the proportion of unscheduled stops tends to be somewhat higher than the scheduled ones.

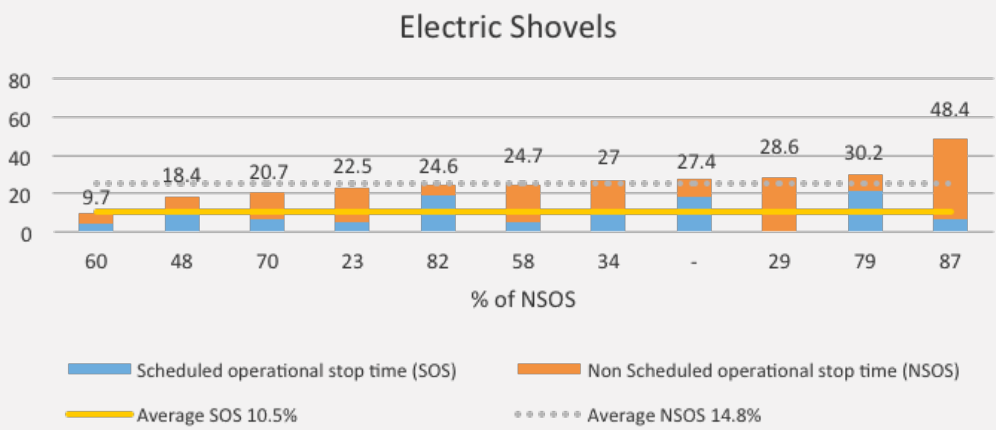
Figure A.3 Average time in Loading Maintenance, 2015 (hours)

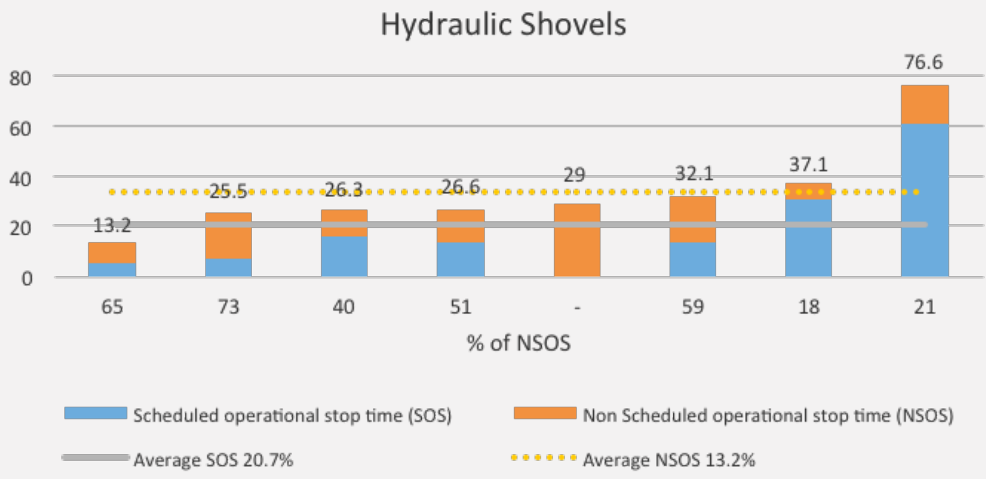




Source: MatrixConsulting

Figure A.4 Loading stops, 2015 (% of possible time)

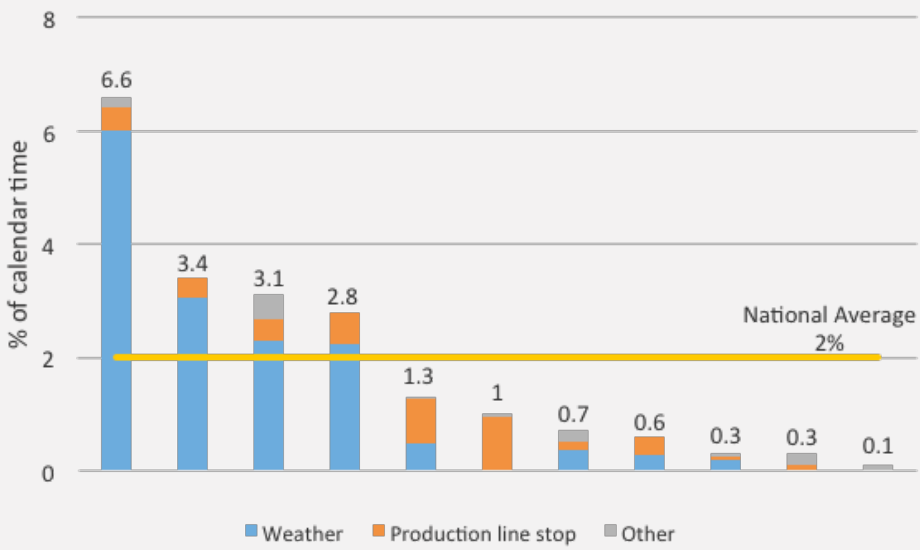




Source: MatrixConsulting

2. Hauling

Figure A.5 Time loss due to external factors in Hauling, 2015 (% of calendar time)

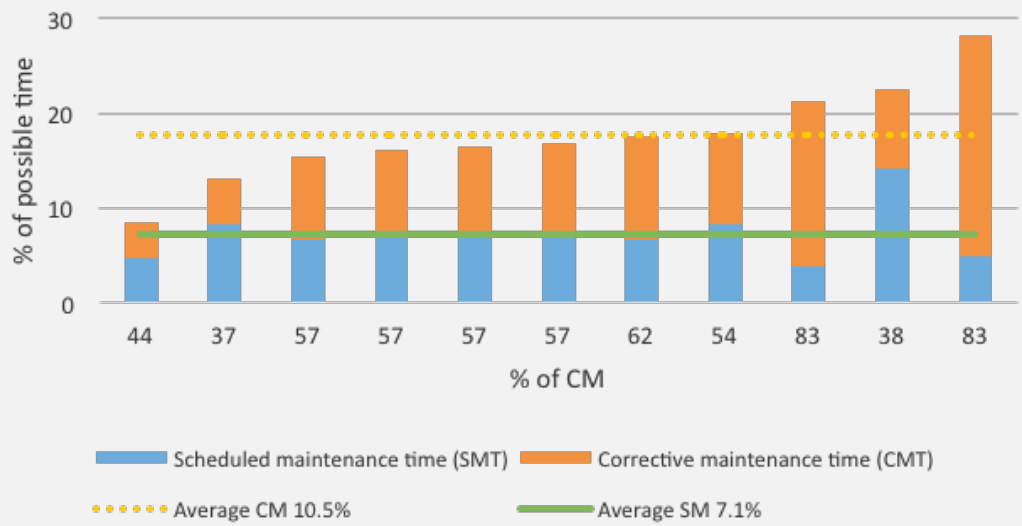


Source: MatrixConsulting

In hauling, unlike loading, exogenous stops are mainly due to climatic factors (see Figure A.5). However, as in the previous case, efficient asset use tends to be less explained by maintenance times than stop times (see Figure A.6 and Figure A.7).

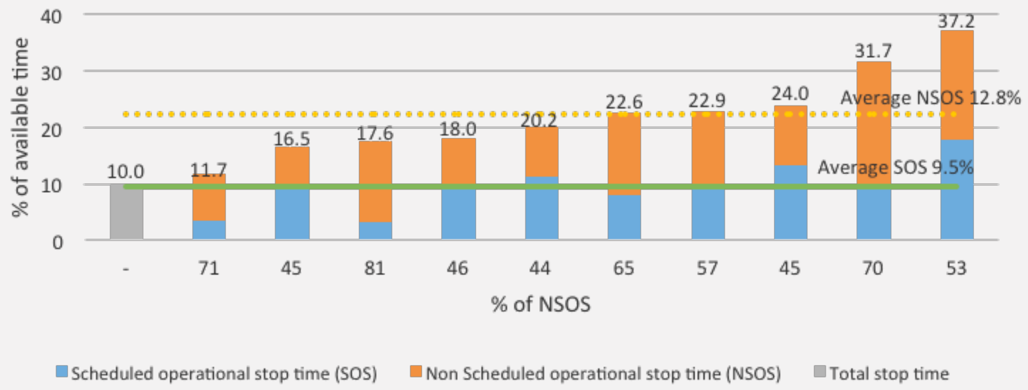
As in the case of loading, in hauling, the proportion of unscheduled stops tends to be somewhat higher than scheduled stops (safety talks, lunches, transfers). Therefore reducing stop times -due to lack of coordination in the process itself (unscheduled stops) - would be an improvement.

Figure A.6 Maintenance Hauling Assets, 2015 (% of possible time)



Source: MatrixConsulting

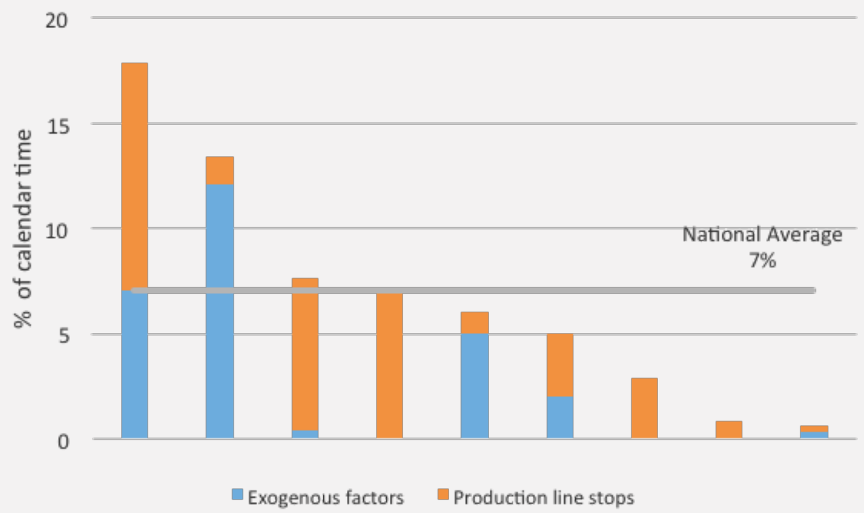
Figure A.7 Time loss due to external factors on Hauling, 2015
(% of calendar time)



Source: MatrixConsulting

3. Concentrator Plant (Crushing and Grinding)

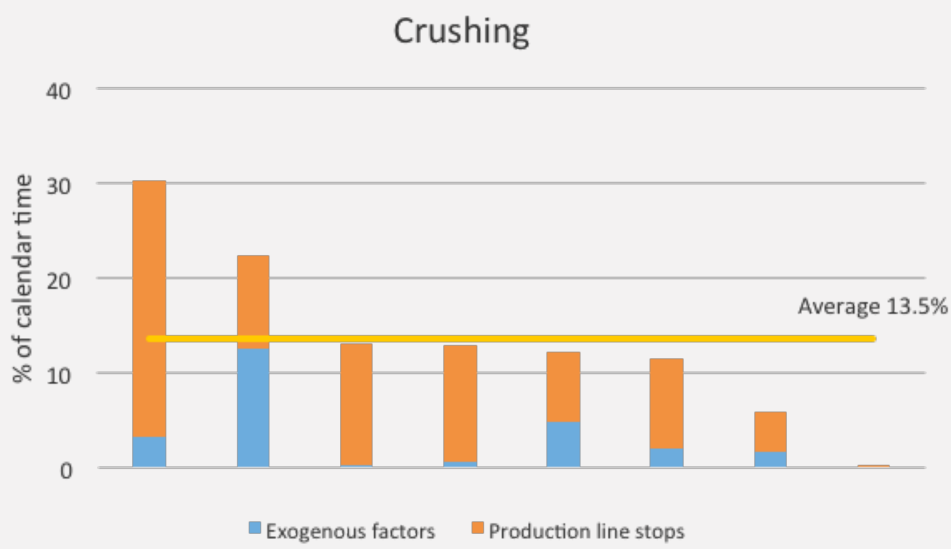
Figure A.8 Time loss due to external factors on Concentrator Plant, 2015 (% of calendar time)

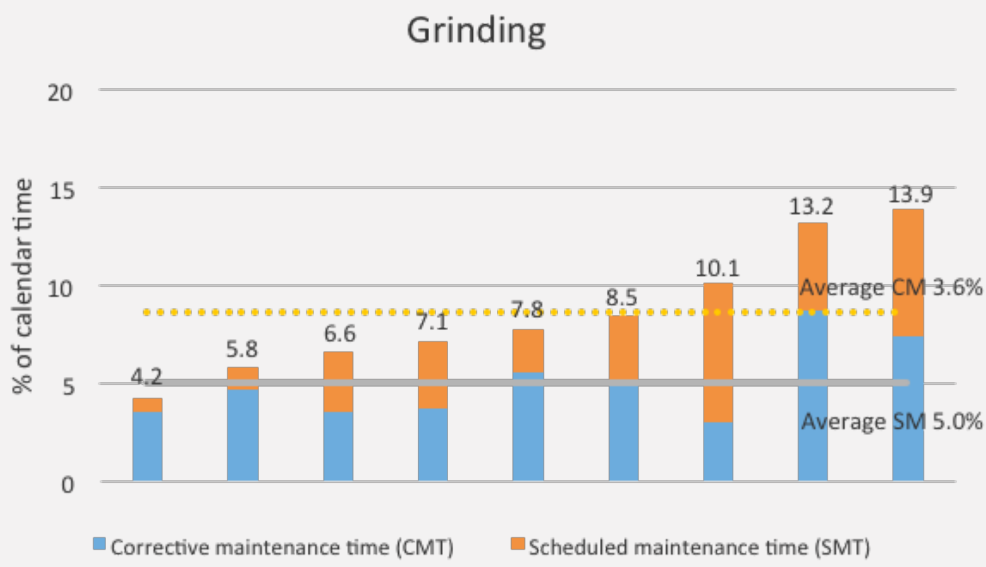


Source: MatrixConsulting

Figure A.8 shows the proportion and reasons that cause exogenous stops in concentrator plants. Unlike the two previous cases, stops are mainly due to stops in production lines, i.e. operational factors (possibly manageable) that are off the unitary process' scope. Reductions in these production line stops would allow a higher asset use. When crushing and grinding are observed (as part of the concentrator plant's processes), a greater heterogeneity is observed. In extreme cases 27% of the calendar time corresponded to line stops close to 100 days (see Figure A.9). Thus, primarily, production line stops generated in the plant are absorbed by the crushing process and to a lesser degree by the grinding process. An improvement in this area could have a significant (and positive) impact in the operations' mining plans.

Figure A.9 Time loss due to external factors on Crushing and Grinding, 2015 (% of calendar time)





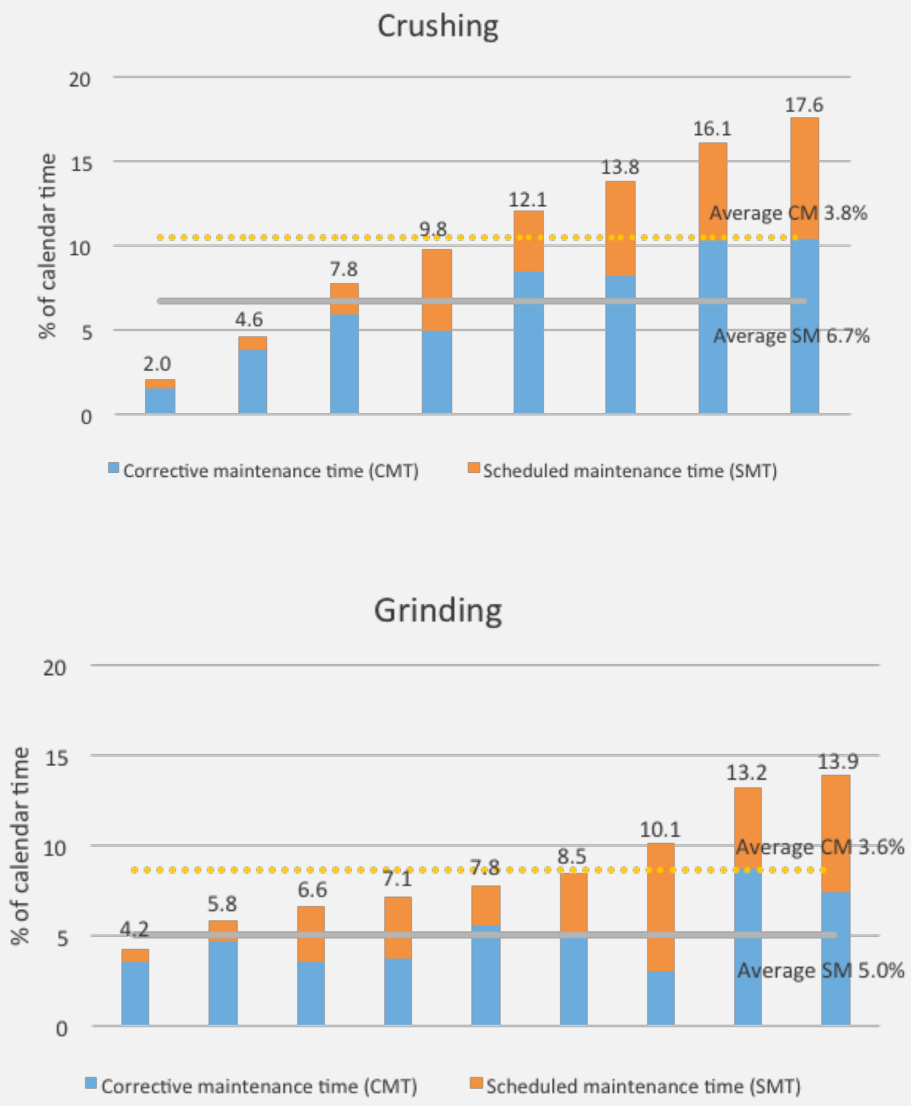
Source: MatrixConsulting

Maintenance reduces the possible time of asset use; however, it is not the main driver in the effective time of use, as Figure A.10: shows. In fact, in some cases, those who have less efficient asset use occupy less possible time than other mines with a better asset use.

When comparing crushing and grinding processes stops (see Figure A.11) there are substantial differences in magnitude. Stops in crushing are several times higher than in grinding. There are two outliers' observations regarding the planned stops in the crushing process. In the case of these observations, unless there is a particular reason, there is an opportunity to improve the processes associated with stop time.

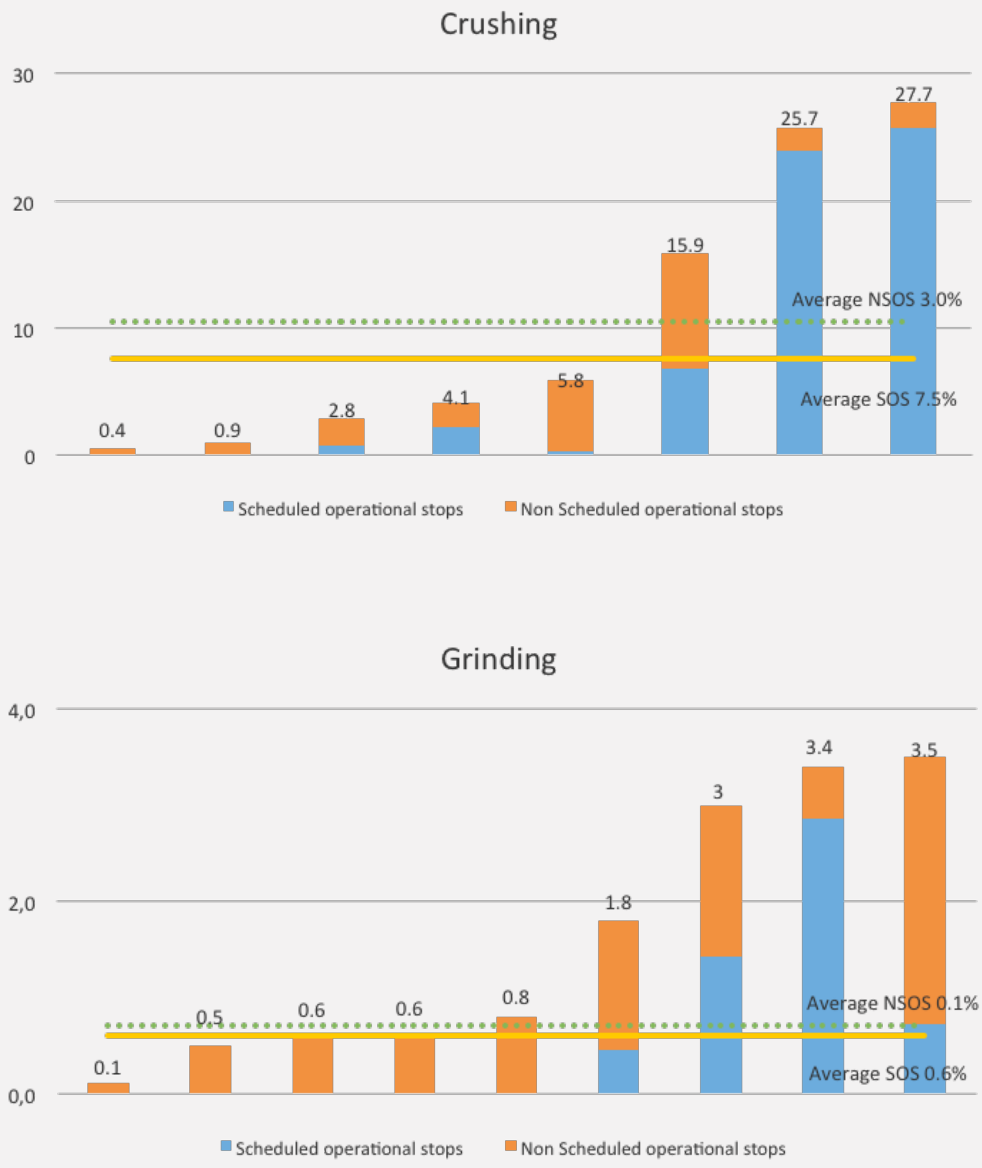
However, as mentioned, considering possible time as the base, unlike loading and hauling, maintenance tends to consume more time, time that potentially could be used by the asset. Nonetheless, it seems that the fundamental issue lies in line stops.

Figure A.10 Maintenance Crushing and Grinding Assets, 2015 (% of possible time)



Source: MatrixConsulting

Figure A.11 Crushing and Grinding stops, 2015 (% of available time)

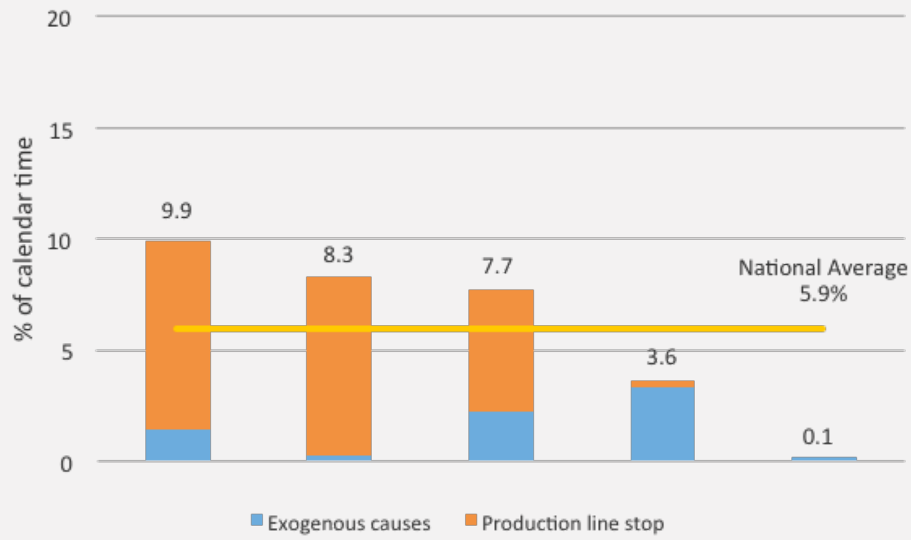


Source: MatrixConsulting

4. Hydrometallurgical Plant (Primary Crushing, Dry area and Wet area)

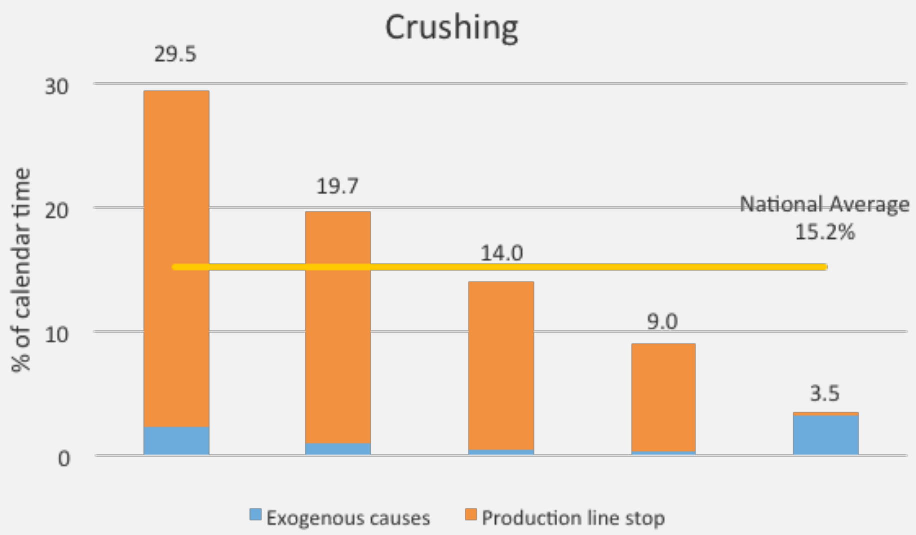
As in the case of the concentrator plant, Figure A.12 shows that the main source of line stops, which affects the possible time of asset use, is due to the operation's internal management that actually causes these line stops. When analyzing the stops according to the unitary processes, crushing, dry area and wet area, a significant heterogeneity in the stops levels is observed. Primary crushing is the most affected process by time loss due to exogenous factors (see Figure A.13).

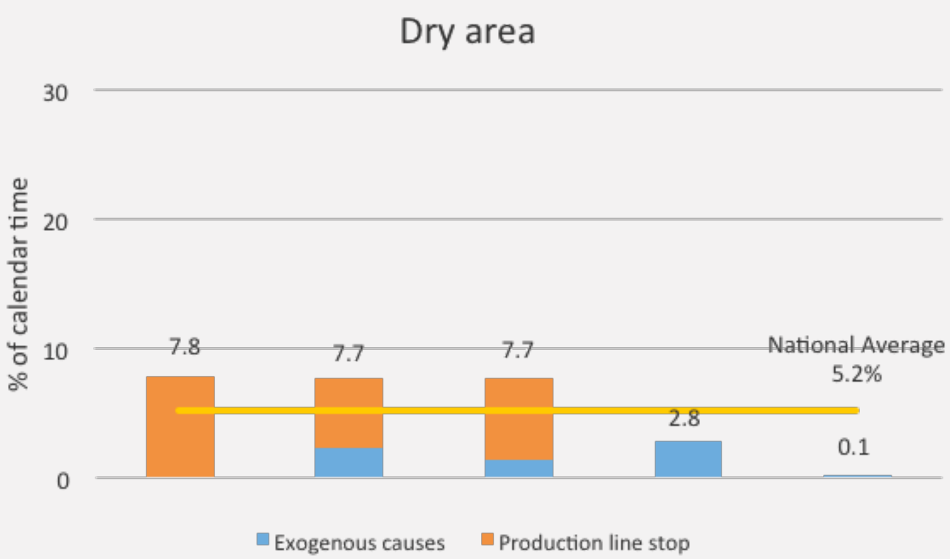
Figure A.12 Time loss due to external factors on Hydrometallurgical Plants, 2015 (% of calendar time)

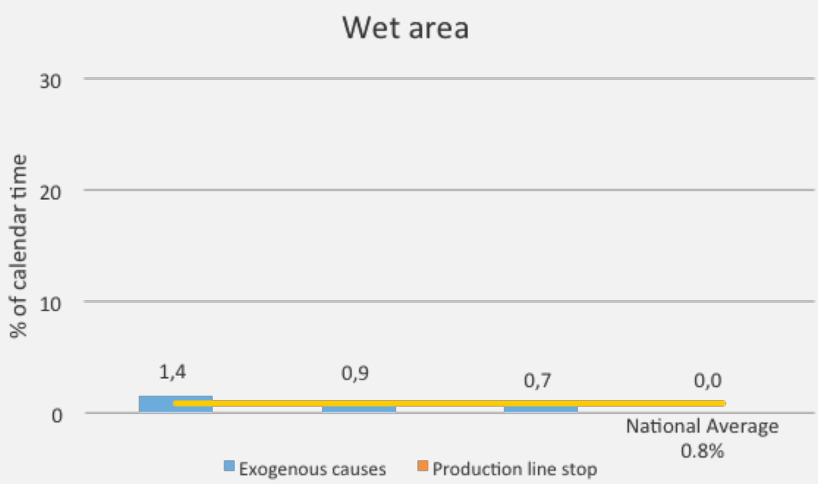


The main reason for exogenous stops in unit processes, particularly crushing and dry area, are due to line stops (Figure A.13). Operations can improve their organization so that part of the lost time is used in activities that contribute to productivity, influencing positively on mining operations plans.

Figure A.13 Time loss due to external factors per unit process, 2015 (% of calendar time)



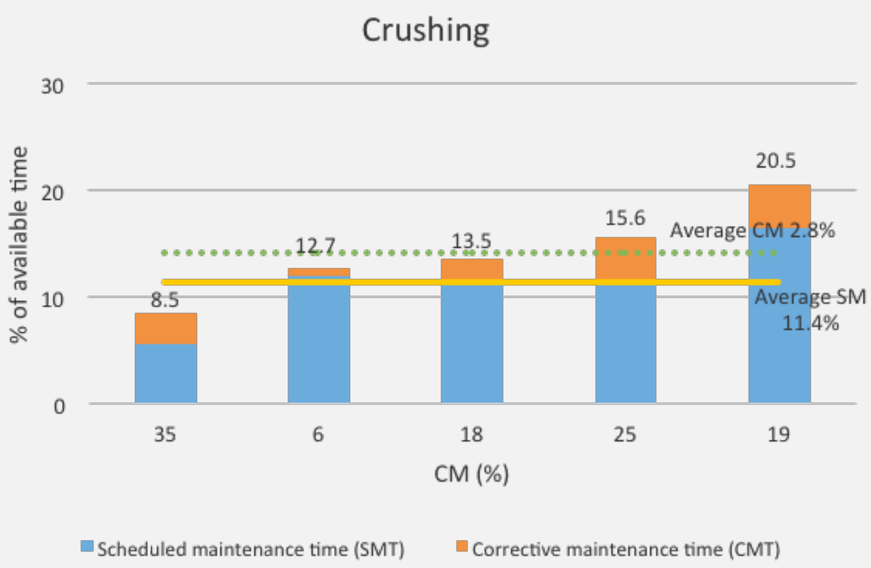


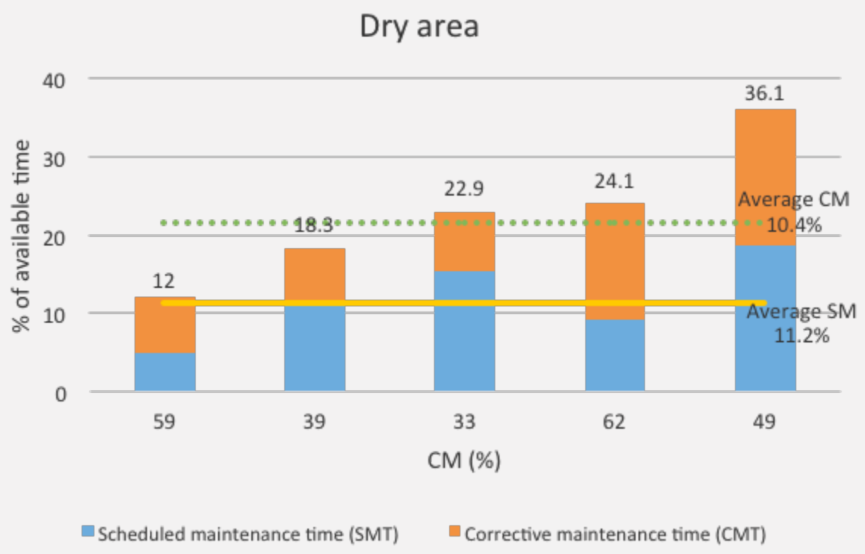


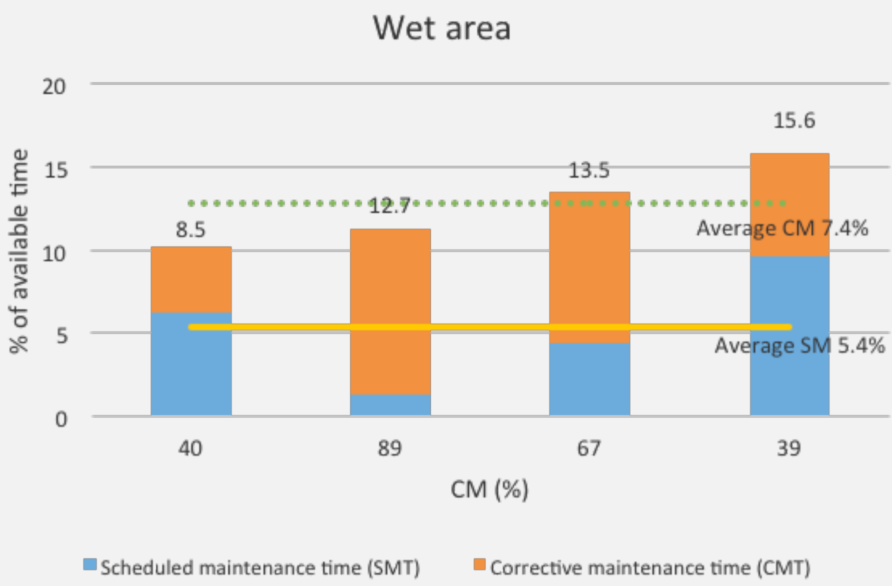
Source: MatrixConsulting

Regarding the maintenance process, Figure A.14 shows the proportion as well as the decomposition of the time used in maintenance per unit process. There is no direct relationship between maintenance time and efficient asset use associated with the hydrometallurgical plant.

Figure A.14 Maintenance Hydrometallurgical Plants per unit process, 2015 (% of available time)

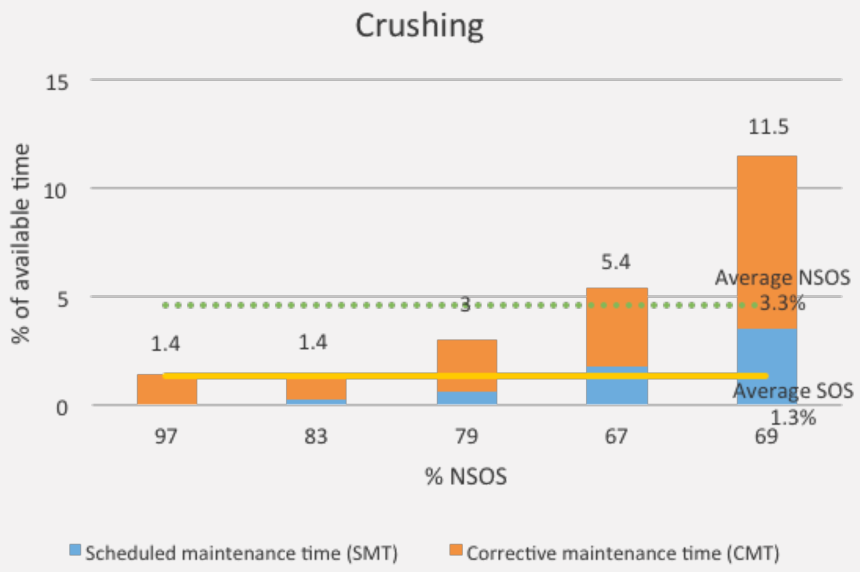


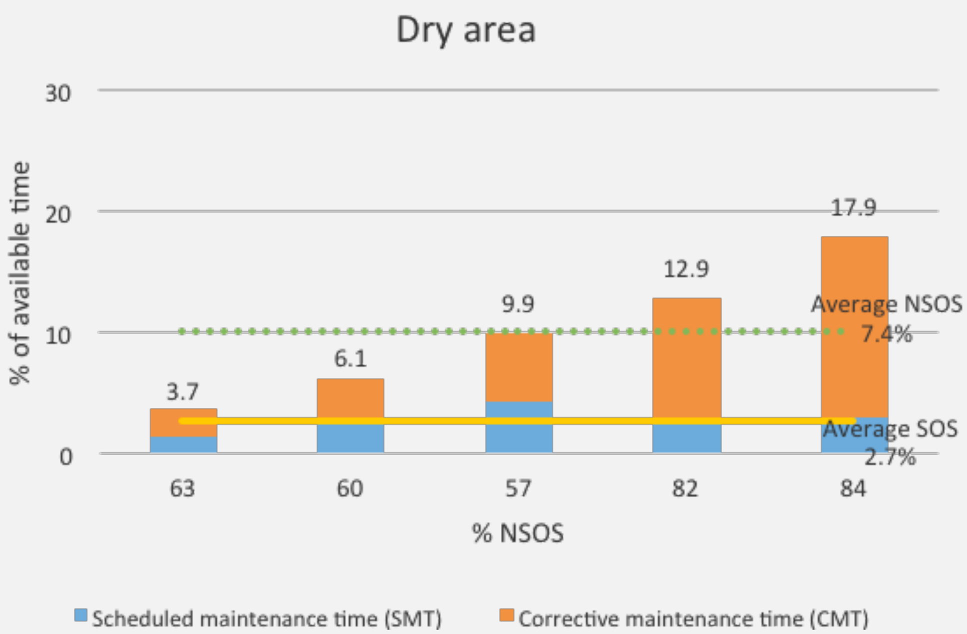


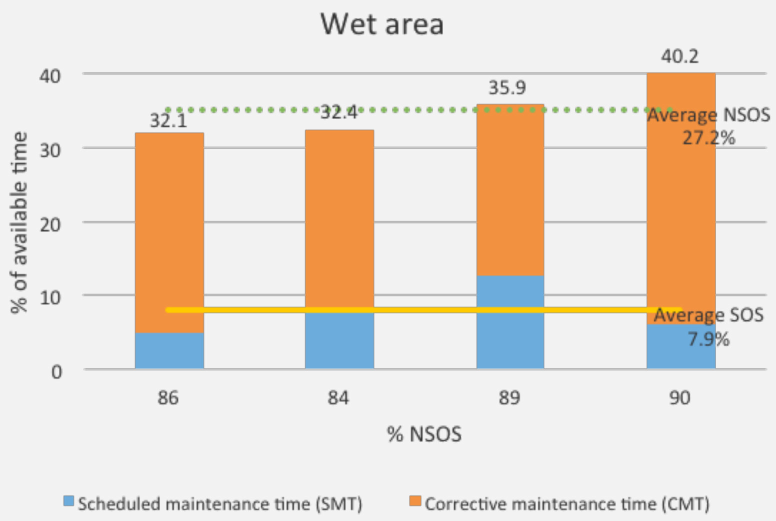


Source: MatrixConsulting.

Figure A.15 Maintenance Hydrometallurgical Plants per unit process, 2015 (% of available time)







Source: MatrixConsulting

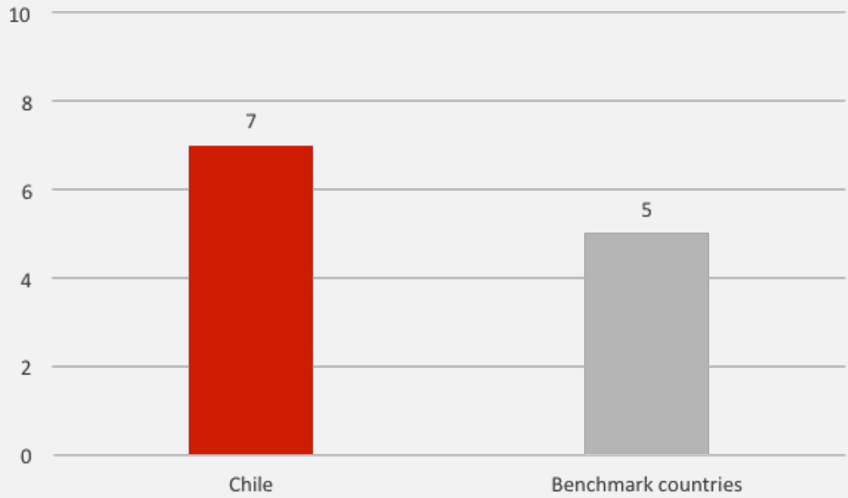
Differences in stops explain the efficient asset use. Operations with the lowest proportions of stops are those that present a greater asset use (as a share of the base time) (Figure A.15.). It seems that both, the dry and especially the wet area, are the bottlenecks in this part of the process. There is a non-negligible proportion of unscheduled stops in the case of the wet area.

5. Reducing hierarchical layers

Chile has two additional hierarchical levels on average compared to benchmark countries (United States, Australia, Sweden and Canada) (see Figure A.16).

Additionally, the sample used for this study shows that there are more management levels (2.8 for Chile versus 2 for international mines) and supervision (3 for Chile versus 2.4 for international mines). As for the differences, there are similar distributions in supervision (between 2 and 4 for Chile, versus between 1 and 3 for international mines). However, the management levels for Chile vary between 2 and 4, while for international operations the average is 2 with no variance (see Figure A.17).

Figure A.16 Average number of hierarchical levels in the operation, 2015.



Source: MatrixConsulting

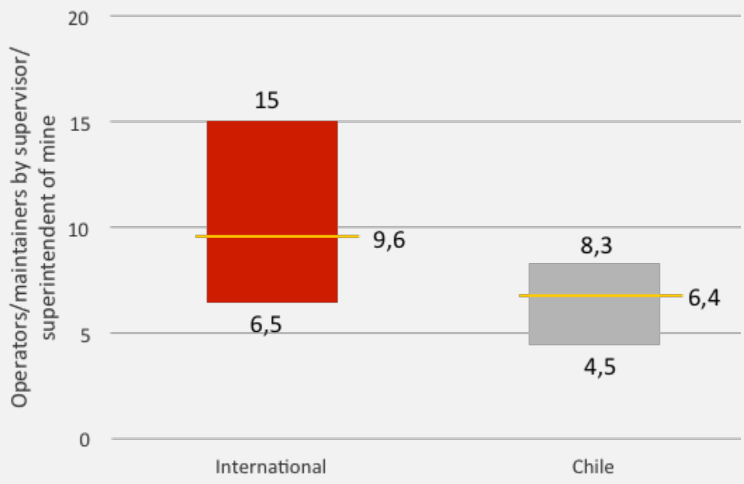
Figure A.17 Number of hierarchical levels in Chilean and International Operations, 2015 (Max, min, average)

Source: MatrixConsulting

6. Management control

According to different interviews and other information gathered, there is a control "culture" that has led to the reduction of new initiatives, as well as to the dilution of responsibilities (supported by bureaucracy and paperwork), which results in higher costs. In summary, the "control" culture in Chile translates into an excessive amount of supervision, so that the number of operators and maintainers per supervisor or mine superintendent is significantly lower than international operations (see Figure A.18). A smaller "control span" establishes inflexibility, and for most actions requires a validation process, thus reducing the worker's ability to react or make decisions when facing a particular situation, delaying the processes.

Figure A.18 Span of Control in Mine, 2015 (average)

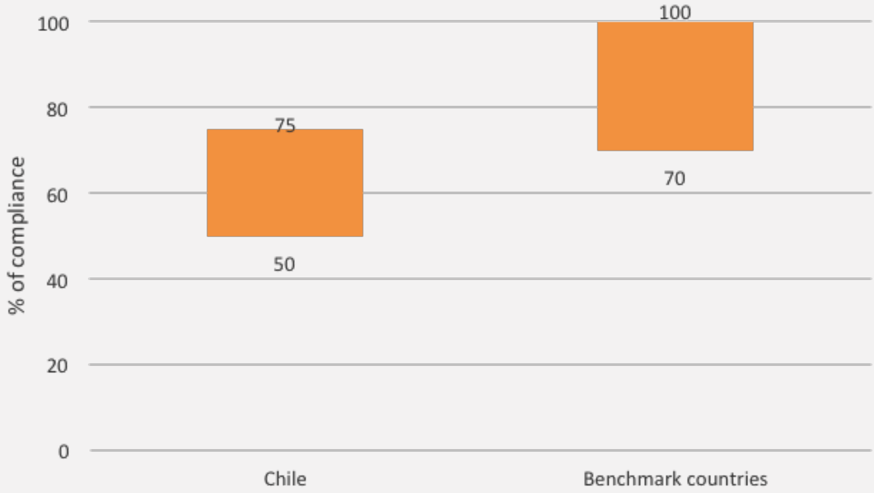


Source: MatrixConsulting

7. Improve adherence and compliance with plans.

The range of adherence to Chile's maintenance plans is well below that of the benchmarked countries (see Figure A.19). The most compliant Chilean mine is barely five percentage points better than the worst mine in the benchmark countries (75% versus 70%). Unlike the benchmark countries, no local mine has complete compliance.

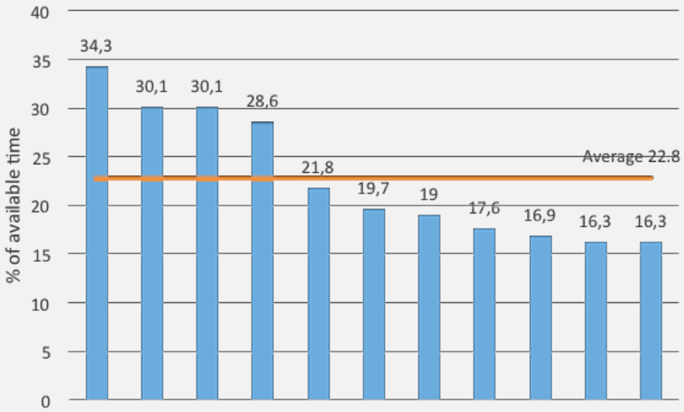
Figure A.19 Compliance levels of maintenance plans, 2015 (% of compliance)



Source: MatrixConsulting

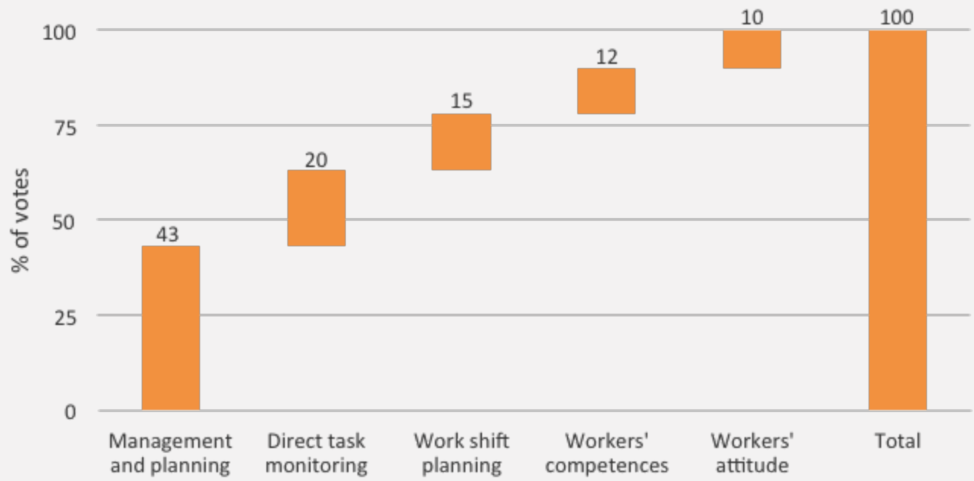
On average, mines lose 22.8% of their time due to poor planning, and in some cases, this figure can be over 30% (Figure A.20). According to the workers, 43% mentioned that non-adherence to planning and direction deficits are jointly the main reasons for the unproductive times. The second cause, mentioned by 20% of workers, is the responsibility of the direct supervisors. In third place, work-shift planning accounts for 15% of the mentions as the cause of unproductive times at local mining sites (see Figure A.21).

Figure A.20 Unproductive time (Non Scheduled Operational Stops), 2015 (% available time)



Source: MatrixConsulting

Figure A.21 Causes of unproductive times

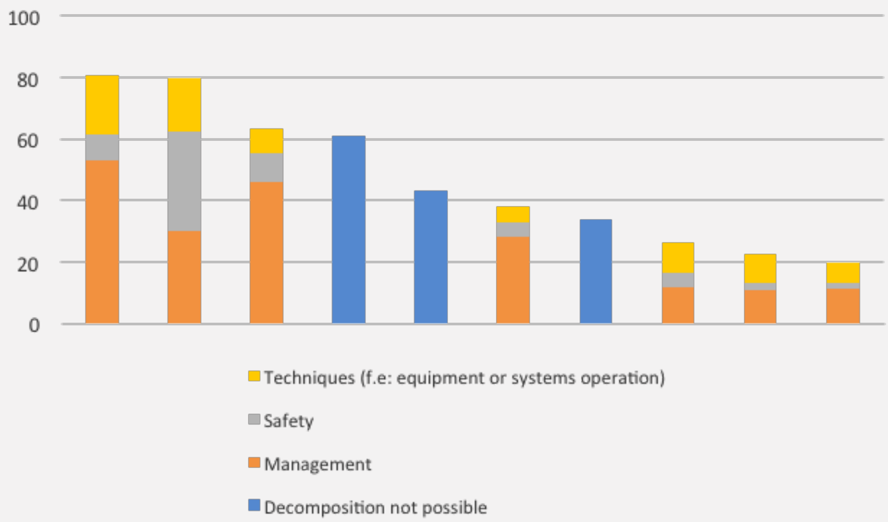


Source: MatrixConsulting

8. Training

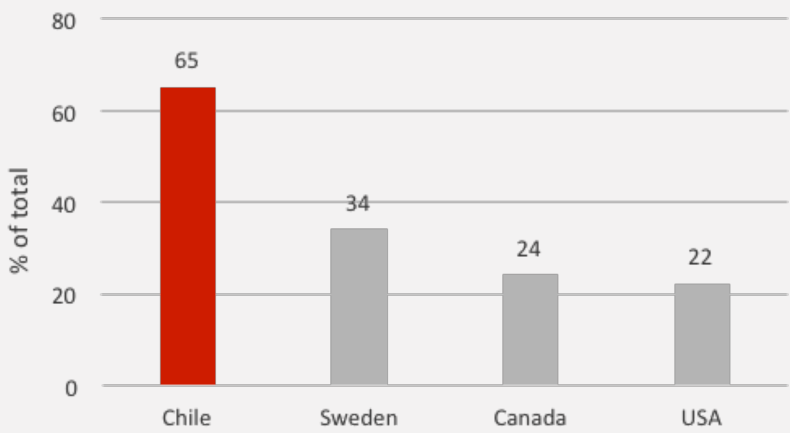
National and international figures show that domestic operations have much room for improvement in this area. For example, training plans on national mines currently differ in both duration and content, indicating a lack of standardized criteria for training workers (see Figure A.22).

Figure A.22 Distribution of training hours per worker, 2015
(hours per FTE=2190 person-hours per year)



In addition, when compared with other mining countries, Chile is perceived as one of the countries that assigns less importance to training programs in companies. This also impinges on the fact that workers often recognize the lack of on-the-job training (see Figure A.23).

Figure A.23 Workers that acknowledge needing more training in their job
(% of total)



Chapter 4

Suppliers: Characterization and Productivity

Source: MatrixConsulting

Abstract

The development of a mining productivity agenda should consider the supplier's sector as an essential and inseparable pillar of the industry's productivity. A characterization of the mining supplier industry was carried out and a significant deceleration was found from 2013 to 2014 in the sales to mining companies. Amongst the factors that account for this deceleration a considerable heterogeneity in the accreditation times in Chilean copper mines is identified. The most efficient mine takes 15 days, while the most inefficient 75. In addition, findings suggest there is ample room to improve the available effective working time in Chile by 10% to 20%. Strengthening the supplier sector would have a positive impact on the mining industry, and in addition, be, in itself, a source of future exports.

Key points

- Mining companies' purchases from supplier companies reach US$20,000 million per year.
- There has been a significant slowdown from 2013 to 2014 in supplier companies' sales to mining companies, especially sales associated with projects.
- Mining suppliers are highly concentrated. On average, the two leading suppliers gather around half of the sales in the seven categories analyzed.
- Most of the Chilean mining industry suppliers have their main office in the Metropolitan Region.
- Mining suppliers increased their labor productivity in the period 2013-2014.
- Large suppliers have higher levels of labor productivity than small and medium-sized suppliers do.
- Studies suggest room for long-term improvement of 10 to 20% of the effective working time inside the mining operation.
- Accreditation times for large copper mining operations in Chile are very heterogeneous. The most efficient company takes 15 days, while the least efficient takes 75 days.

4.1. Introduction

The fall in mining productivity shown in Chapter 2, and the labor productivity and capital utilization gaps presented in Chapter 3 involve not only mining companies but also a group of agents related to the industry that is determinant at the level of aggregated productivity. In the case of Chile, the importance of subcontractors and suppliers is fundamental, as mining companies have outsourced different functions to a significant number of suppliers, concentrating their efforts on the core of the business, i.e., ownership, operation, and management[1]. About 65% of mining employment is outsourced. Therefore, an important part of the past and future success of the national mining industry depends directly on the productivity and competitiveness of the supplier sector (Fundación Chile, 2012). Undoubtedly, this shows the complexity of the industry.

Mining suppliers have increasingly attracted government attention since they are perceived as an opportunity to increase exports, diversify and sophisticate the economy, and move towards the development of a knowledge-driven economy. Mining-related activities can be developed, aimed at supplying national and international companies through the development of new knowledge and technology intensive solutions, which are scalable and exportable to other industries and countries. Korinek (2013) conceptualizes this opportunity as the "mining's multiplier effect."

Development around natural resources was central to economic and industrial growth in countries such as Australia, Canada, Finland, New Zealand, or Sweden. This evolution is partly a continuous and increasing process of densification encompassing the natural resource, producing agglomeration and complexing the industry. They are usually called clusters and have been present in the natural resource debate for almost ten years in our country. [2]

The idea is the development of mining suppliers in Australia is considered an example for the Chilean case (Meller and Gana, 2015). Regarding its mineral wealth, Australia has been able to develop a robust sector of services, equipment and technologies for the mining industry (METS), achieving international leadership in several niches, with sales estimated at US$92.8 billion and exports estimated at US$15,463 million, in 2012 (Austmine, 2013).

The importance of the sector has been recognized since the 1990s. In 2012, the first "Characterization Study of Chilean Mining Suppliers" (Fundación Chile, 2012) was published, a document that was later updated in 2014 (Fundación Chile, 2014)[3] . Funda-

1 It is important to note that analysis during the previous chapters used the total employment on the mining operations which includes their own-workers and its subcontractors.
2 See CNIC (2007).
3 For an earlier study, focused on innovation capabilities of mining suppliers, see DICTUC (2007).

ción Chile and ProChile released the first Export Report of Chilean Mining Suppliers in 2015, which describes the magnitude and composition of exports of goods and services linked to the mining industry. This chapter complements and updates these previous efforts, this time within the framework of the presidential mandate of Productivity in the Mining Industry led by the National Productivity Commission (CNP). Its elaboration is a result of the joint effort of the CNP, Fundación Chile, Achilles and Cochilco. [4] The previous characterization studies of suppliers (Fundación Chile, 2012 and 2014) used a probabilistic survey to obtain information from the sector. This study has a broader information base, which allows greater depth and precision in the analysis. Section 4.2, "Expenditures and Suppliers of Goods and Services" aims to measure the size of the suppliers market and their concentration levels according to the type of products. Cochilco collected the data through a survey of 18 mining operations producing copper, a copper smelter, and a gold operation, which altogether account for 85% of the national copper production and 17% of gold production during 2014. For the analysis, all the operations surveyed were considered without distinction by type of ore or process. Sections 4.3 and 4.4 were developed by the Regic registry of Achilles, which contains information on 4,438 mining suppliers in Chile. Of this total, for analysis purposes, 3,184 companies were selected with updated information for at least one of the years 2013 or 2014. The analysis also distinguishes within suppliers and their intensity of sales to the mining sector (about 50%).

Chile has an important sector of companies supplying the mining industry, which have a relevant local market of over US$20 billion annually. Currently, the national industry produces and supplies 60% of the inputs (Fundación Chile, 2014), and the number of suppliers increased 50% (from 4,000 to 6,000) between 2009 and 2012 (Fundación Chile, 2012, 2014). As of 2015, according to Regic registration information, the country has about 4,500 supplier companies.

The chapter is structured as follows. Section 4.2 examines expenditure and suppliers of goods and services. Section 4.3 characterizes Chilean mining suppliers. Section 4.4 analyzes the sector's productivity and section 4.5 presents the results and conclusions of the chapter.

4.2 Expenditure and Suppliers of Goods and Services[5]

4 See Comisión Nacional de Productividad y Fundación Chile (2016). Support from Cochilco and Achilles was crucial for the development of that study.

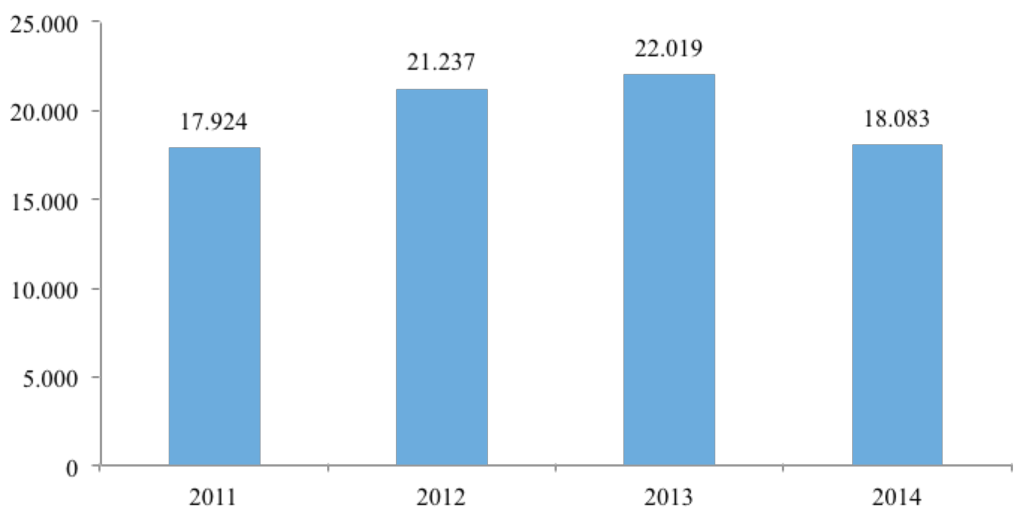
5 This section is based on Cochilco (2015) “Encuesta de participación de empresas proveedoras de la minería - 2014”

According to the sample, the mining suppliers market is $20 billion per year approximately. There has been a significant decrease in the mining companies' spending on goods and services since 2013. Additionally, when quantifying suppliers, we observe that they are highly concentrated, with dominant suppliers in different areas.

4.2.1 Expenditure on Goods and Services

During 2014, spending on goods and services declined from a reported peak of close to US$22 billion in 2013. It fell by approximately US$4 billion (down 18%) (See Figure 4.1). Most operations display this decrease separately.

Figure 4.1: Expenditure on goods and services
in surveyed operations 2011-2014 (US$ millions)



Source: National Productivity Commission

Operation purchases associated with projects contracted (see Table 4.1). In fact, operation spending on goods and service decreased by 8% between 2013 and 2014 (from US$16,279 million in 2013 to US$15,018 million in 2014), while purchases associated with projects fell by 47% (From US$5,740 million in 2013 to US $ 3,066 million in 2014). The completion of ongoing projects and reduction of new projects development accounts for this. If in 2013 the purchases for projects represented 26% of the total expenditure, in 2014 they represented only 17%.

Table 4.1: Expenditure on Goods and Services in Operation and Projects 2011-2014 (US$ millions)

Category	2011	2012	2013	2014
Operation	12.951	14.854	16.279	15.018
Projects	4.973	6.383	5.740	3.066
Total	17.924	21.237	22.019	18.083

Source: National Productivity Commmission

Finding 4.1: There is a significant deceleration from 2013 to 2014 in sales to mining companies, especially sales associated with projects.

Table 4.2: Categorization of Expenditure on Goods and Services

Category	Description
Purchases, contracts and leases	Purchase of equipment, machinery, plants, supplies, spare parts, materials; leasing equipment, machinery, real estate, personal property and vehicles.
Maintenance and repair services	M & R service: industrial, movable, equipment, machinery and others.
Transport and communication services	Transport services: personnel, mining products, various loads and other types.
Other Services	Support services to HR management, production, laboratory, inspection and control, drilling, administrative, computational, health, food, maintenance, architecture, surveying, training, hotel, telecommunications, geology, measurement, and others.
Category	**Description**
Studies and evaluations	Engineering (Conceptual, basic, details, and industrial), feasibility studies and industrial evaluations.
Construction and Assembly	Construction of infrastructure works, mining and others; construction of small and special installations, material movements.
Counseling	Consultancy: legal, auditing, planning, communication, geology and mining, IT, HR, risk control, assembly / operation / maintenance of equipment, training for certifications, inspections or audits, project management, supply, plants, in maintenance of infrastructures, and others.
Fuel and Energy	Purchase of energy and fuels.

Source: National Productivity Commission.

Since the distribution of expenditure on goods and services is sensitive to the classifications used by each mining company for its purchases, expenditures on goods and services were grouped (for each operation) into seven predetermined categories (see Table 4.2).

Table 4.3 presents the amounts associated with each category, for both Operations and Projects. In Operations, the item "Purchases, contracts and leases" has a higher impact on expenses with 31%, followed by "Other services," "Fuel and Energy" and "Maintenance and repair services" with 26%, 21%, and 15% respectively. In Projects, 30% goes to "Construction and Assembly."

Table 4.3: Distribution of expenses in Goods and Services of Operation and Projects 2014 (US$ millions and %).

Category	Operation		Projects	
	US$ MM	%	US$ MM	%
Purchases, contracts and leases	4.654	31,0%	711	23,2%
Other Services	3.828	25,5%	1.014	33,1%
Maintenance and repair services	2.277	15,2%	146	4,8%
Transport and communications services	687	4,6%	30	1,0%
Construction and Assembly	254	1,7%	929	30,3%
Counseling	156	1,0%	35	1,1%
Studies and Evaluations	81	0,5%	194	6,2%
Fuel and Energy	3.082	20,5%	7	0,2%
TOTAL	**15.018**	**100%**	**3.066**	**100%**

Source: National Productivity Commission

4.2.2 Supplier Quantification

In operations, "Purchases, contracts, and leases," which considers inputs and spare parts, concentrate most of the suppliers in number, and "Other services" follow. In both cases, there is a relationship between expenditure and the number of suppliers (see Table 4.4). Expenses for "Transportation and communication services," and especially "Energy and Fuels" appear concentrated in a smaller number of suppliers. Dominant suppliers capture over 30% of the expenditure for all categories, possibly due to the need for economies of scale and specificity of knowledge.

Tabla 4.4: Supplier distribution per category 2014

Category	% average purchases at:		Average number of suppliers
	2 main suppliers	Rest of the suppliers	
Purchases, contracts and leases	24%	76%	740
Maintenance and repair services	29%	71%	116
Transport and communications services	55%	45%	35
Other Services	29%	71%	306
Studies and Evaluations	47%	53%	22
Construction and Assembly	48%	52%	56
Counseling	34%	66%	51
Fuel and Energy	82%	18%	8

Source: National Productivity Commission

Finding 4.2: Suppliers of the Chilean mining industry are concentrated. On average, the two leading suppliers concentrate around half of the sales in the seven categories analyzed, implying the existence of economies of scale.

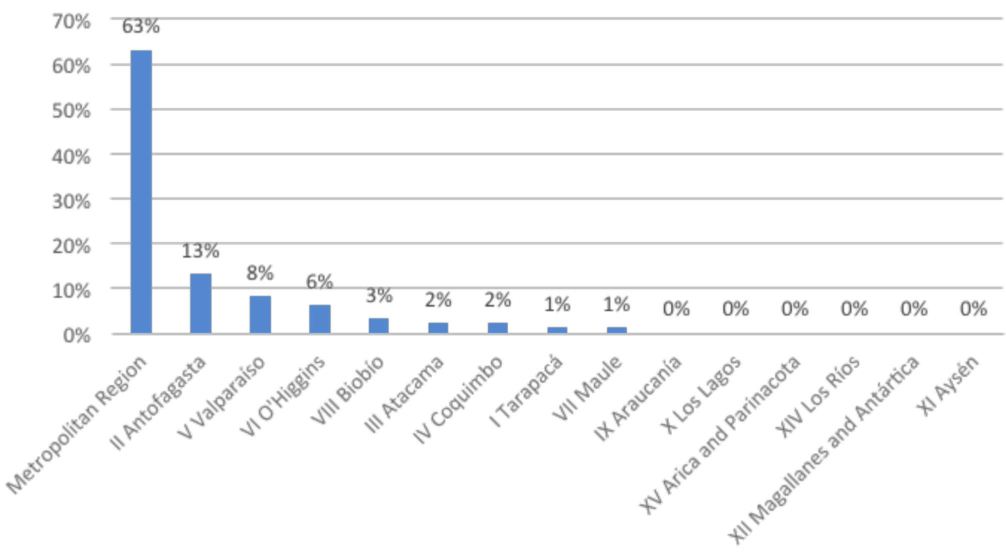
4.3. Characterization of Chilean Mining Industry Suppliers

In this section, Chilean mining industry suppliers are characterized according to their geographical location, size, composition and variation of employment, and composition and variation of sales and exports.

4.3.1 Location

Of the 3,184 companies analyzed, 97% have their headquarters or a subsidiary in Chile. Of the remaining 3%, 17 are from North America, 16 from South America (excluding Chile), six from Asia, 25 from Europe and 3 from Oceania. [6] Of the national companies (or with a subsidiary in Chile), 63% have their headquarters in the Metropolitan Region (see Figure 4.2), followed by the Region of Antofagasta (13%), the Region of Valparaíso (8%) and the Region of Libertador Gral. Bernardo O'Higgins (6%). Considering there are no significant differences on the data reported in previous studies (Fundación Chile, 2012 and 2014), we conclude that the sector's regional composition has not changed during the last five years.

Figure 4.2: % Mining Suppliers per Region (main branch/office)



Source: National Productivity Commission

6 There is no country information for 29 firms.

If we consider only companies whose sales to the mining industry represent over half their total sales, we observe no greater changes concerning the total sample (see Figure 4.2). Except for Antofagasta, where the proportion increases to 19%; and the Metropolitan Region, where it decreases to 54%. In any case, the concentration of companies in the Metropolitan Region reveals the country's low level of decentralization, and some other factors such as the proximity to service networks and supply chains, the shortage of skilled labor in mining regions, and the high cost of land in the north (Fundación Chile, 2014). Information on regional subsidiaries is not available, which may underestimate the level of decentralization of the economic activities of mining suppliers.

> **Finding 4.3:** Suppliers of the Chilean mining industry concentrate their main offices in the Metropolitan Region. However, those with greater mining sales intensity have a more significant presence of their parent companies in mining regions.

4.3.2. Size of Supplier Companies

Suppliers can be classified by size, either according to the number of fixed-term workers[7]or annual sales.[8]

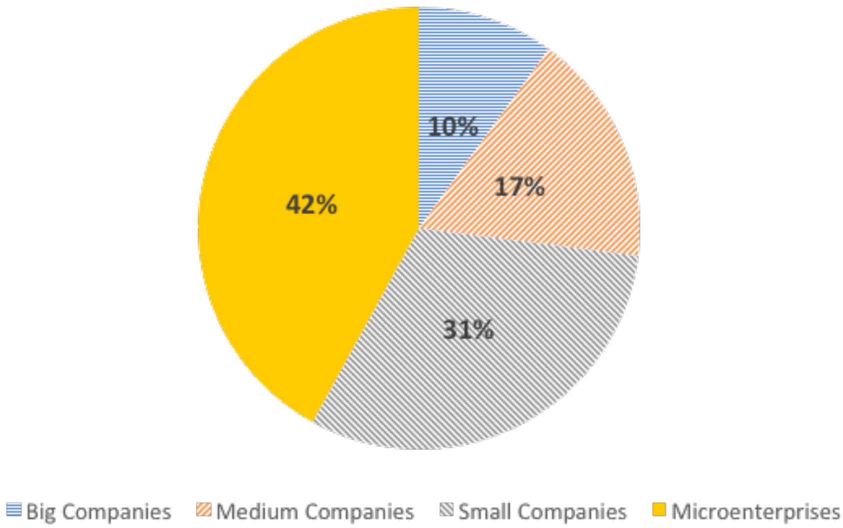
When suppliers are ranked by size according to the number of employees, 42% are considered micro-enterprises (less than 10 workers); 31% are small enterprises (between 10 and 50 employees); 17% are medium-sized enterprises (50 to 199 workers); and only 10% are considered large companies (over 200 workers) (see Figure 4.3). In short, by employment level, 90% of the sector would be classified as SMEs.

When ranking suppliers according to their sales, 34% are considered big business (sales over 100,000 UF per year), 26% medium, and 40% small or micro enterprises.

7 Micro companies: less than 10 workers, small companies: between 10 and 49 workers,, medium companies: between 50 and 199 workers, big companiers: 200 or more workers.

8 Micro companies: less than 2.400 UF, small companies: between 2.400,01 UF and 25.000 UF, medium companies: between 25.000,01 UF and 100.000 UF, big companiers: more than 100.000 UF.

Figure 4.3: Company Size according to number of employees.



Source: National Productivity Commission

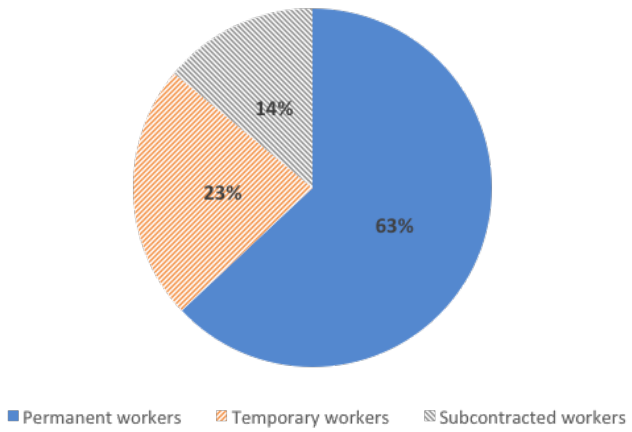
Finding 4.4: One-third of Chilean mining industry suppliers are large companies under the sales classification. However, ranked according to employment level, 90% are medium and small.

4.3.3 Composition and Variation of Employment

When companies with up-to-date information in the Regic register (2013 and 2014) are analyzed, we observe that the supplier companies employ 730,368 workers. Of these, 63% are permanent employees, 23% temporary workers and 14% subcontractors (See Figure 4.4).[9] In contrast, the mining companies' (their clients), have about 65% of workers classified as subcontractors (Pérez and Villalobos, 2010).

[9] It is not feasible to identify how many of these workers are providing goods and services to the mining sector. Many mining suppliers are also suppliers of other sectors.

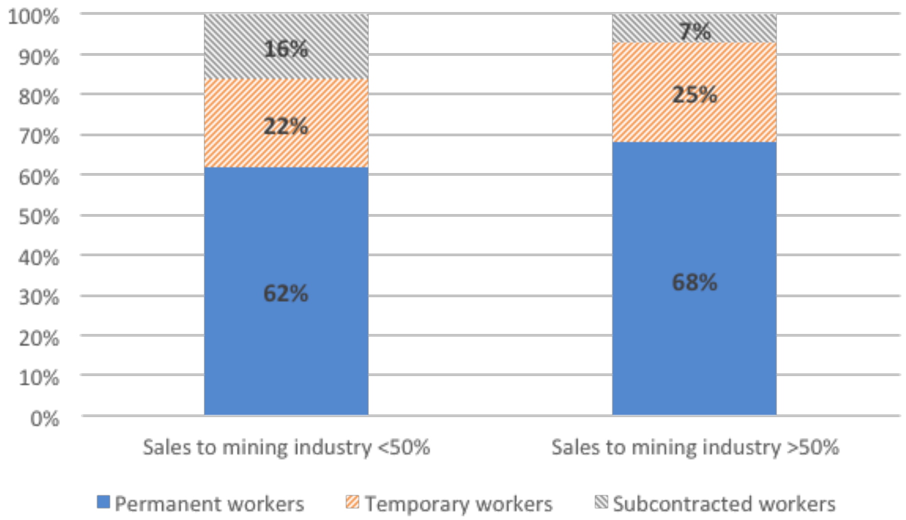
Figure 4.4: % of permanent, temporary workers and subcontractors



Source: National Productivity Commission

Suppliers with less than 50% of their total sales to the mining industry have a higher proportion of subcontracted employees and, consequently, a lower proportion of permanent and temporary employees (see Figure 4.5).

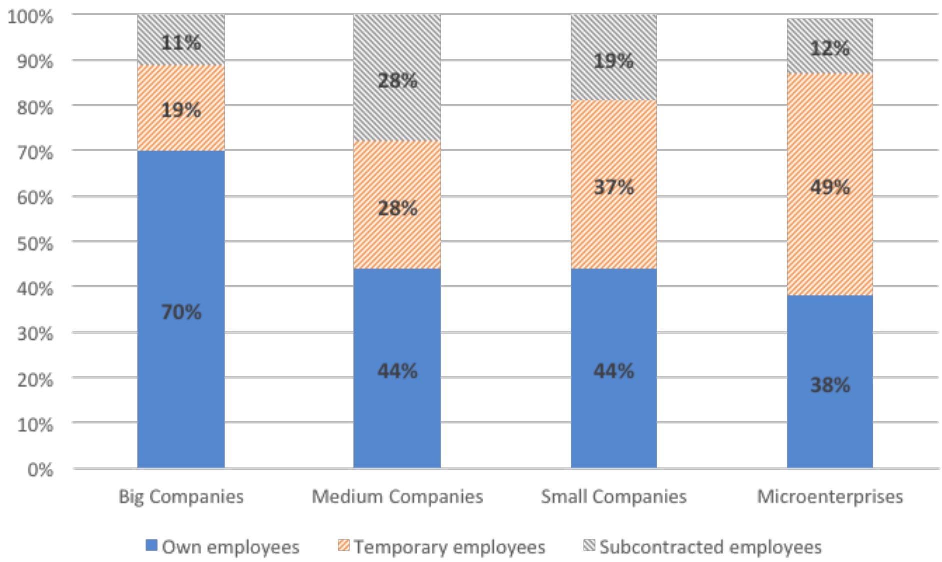
Figure 4.5: % of permanent, temporary workers and subcontractors, according to mining sales intensity



Source: National Productivity Commission

When analyzing the composition of employment by size (according to number of employees) (see Figure 4.6), large enterprises employ a greater proportion of permanent workers: 70%. This ratio decreases to 40% for medium-sized, small and micro-enterprises. Medium sized enterprises present the highest relative percentage of subcontracted workers, 28% of the total. Meanwhile, temporary workers are more important in small and micro enterprises, with 37% and 49% respectively.

Figure 4.6: % of permanent, temporary workers and sub-contractors, according to supplier size per employees



Source: National Productivity Commission

In short, for each permanent job in the sector, the supplier companies subcontract 0.2 workers. Subcontracting is lower in businesses that are more intensive in mining sales: 0.1 in companies that have more than 50% of their sales to the mining industry, and 0.3 in those that have less than 50%.

When disaggregating subcontracting by company size (according to number of employees), medium-sized enterprises stand out, with 0.6 subcontracted workers for each permanent employee, higher than the rates observed in the rest of the segments (see Table 4.5). The cyclical nature of the mining industry, which would allow medium-sized companies to adjust their number of workers to cope with larger projects, could explain these results.

Table 4.5: Sub-contracting ratio according to company size by number of employees

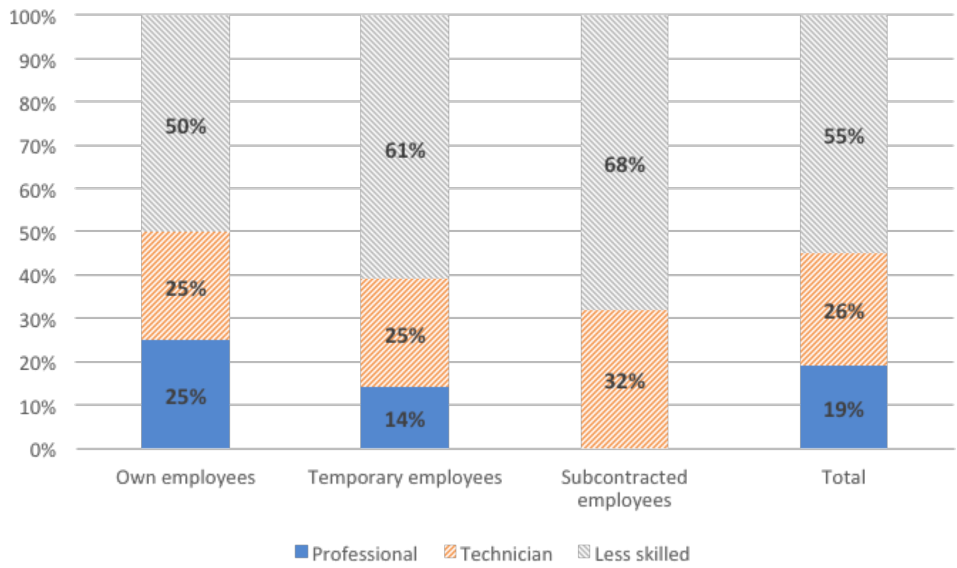
Company Size According to number of employees	Subcontracting Rate
Large Company	0,2
Medium Company	0,6
Small Company	0,4
Micro Enterprise	0,3

Source: National Productivity Commission

Figure 4.7 shows the percentage of professional, technical and less-skilled[10] workers according to the type of employment. Concerning the total employment generated by the sector (permanent, temporary and subcontracted employees), 19% are professional workers, 26% technicians, and less skilled workers are 55%. Of permanent employment, half is less skilled; one-quarter are professionals and another quarter technicians. On the other hand, for temporary employees, 14% are professionals, and 61% are less skilled.

Figure 4.7: % of workers per human capital and employment type

10 "Less skilled" refers to workers without higher education.

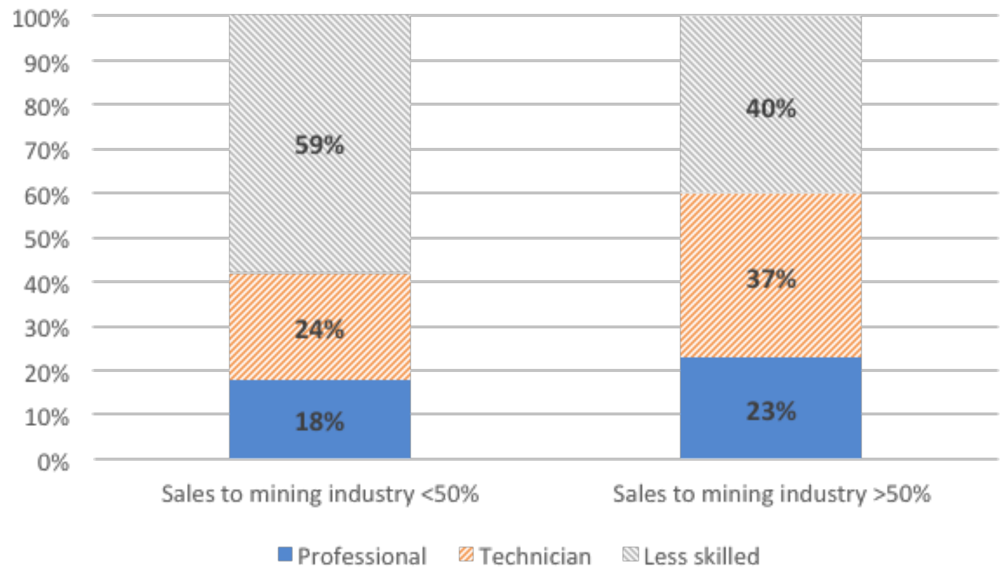


Source: National Productivity Commission

There is no information on the number of subcontracted professionals. With the information available, the segment's configuration of subcontracted workers according to qualification level is distributed as follows: 32% technician employees and 68% less skilled employees. This represents a ratio of 2.13 less skilled employees for each technician, which is similar to the segments of permanent workers and temporary workers, with 2.00 and 2.44 respectively.

Highly intensive companies in mining sales (over 50%) have more qualified human capital than the less intensive ones: 23% professionals and 37% technicians. This is significantly above companies that have less than 50% of their sales to the mining industry, which have 18% and 24% rates, for professionals and technicians respectively (See Figure 4.8).

Figure 4.8: % of workers per human capital and mining sales intensity



Source: National Productivity Commission

Table 4.6 shows employment variations of the mining industry suppliers sector for the 2013-2014 period, towards the end of the last copper super cycle. The sector's total employment increased by 5% over the period, permanent employees rose by 11%, the number of temporary workers grew by 7%, and the subcontracted workers decreased by 18%.

Table 4.6: Variation in employment 2013-2014, according to type of employment

	2013	2014	Var %
Permanent employees	417.839	462.128	11%
Temporary employees	154.064	164.532	7%
Subcontracted Employees	126.875	103.708	-18%
Total employment	**698.778**	**730.368**	**5%**

Source: National Productivity Commission

As shown in Table 4.7, mining-intensive supplier companies experienced further falls in employment: -10% change in total employees, versus an increase of 8% in companies with less than 50% of their sales to mining. The segment of subcontracted employees registered the greatest decrease, which, in mining-intensive companies, implied a reduction of 48%.

Table 4.7: Variation in employment 2013-2014, according to type of employment and intensity of sales to mining

	Mining Sales <50%	Mining Sales >50%
Permanent employees	13%	2%
Temporary employees	16%	-18%
Subcontracted Employees	-13%	-48%
TOTAL	**8%**	**-10%**

Source: National Productivity Commissio

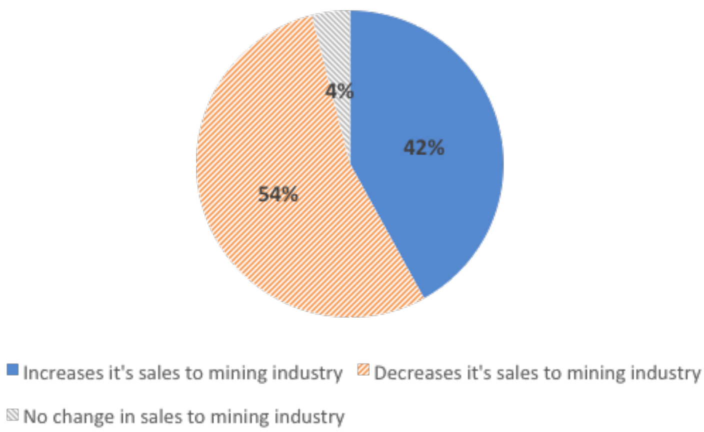
4.3.4. Supplier Companies Sales Variation and Composition

As specified in section 4.2, expenditure on goods and services reported by mining companies decreased by 18% between 2013 and 2014. According to our sample, suppliers sales to the mining industry decreased by 28%.

The less mining-intensive companies (with under 50% of sales) showed a larger decline, with a 39% decrease in their sales to the mining industry. In contrast, the most mining-intensive companies (with over 50% of their sales) recorded a 22% drop in their sales to mining. Therefore, diversification seems to have a positive effect on employment, (see Table 4.7) as diversified companies can sell to other sectors when the demand from mining companies falls.

At the company level, 42% increased their sales to the mining industry during the 2013-2014 period, 54% decreased their sales to this industry, and 4% maintained them (see Figure 4.9).

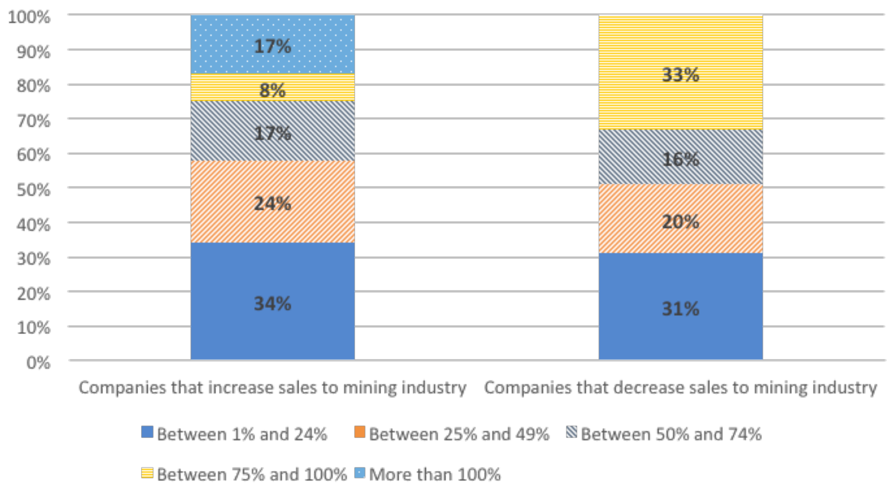
Figure 4.9: % of suppliers according to mining sales variation



Source: National Productivity Commission

Figure 4.10 shows the proportion of companies that increased and decreased their sales to the mining sector, according to the range of change in sales. Of the suppliers that increased their sales to mining, 34% did it between 1% and 24%, 24% between 25% and 49%, and 25% between 80% and 100%. Among the companies that decreased their sales, 33% report falls between 75% and 100%.

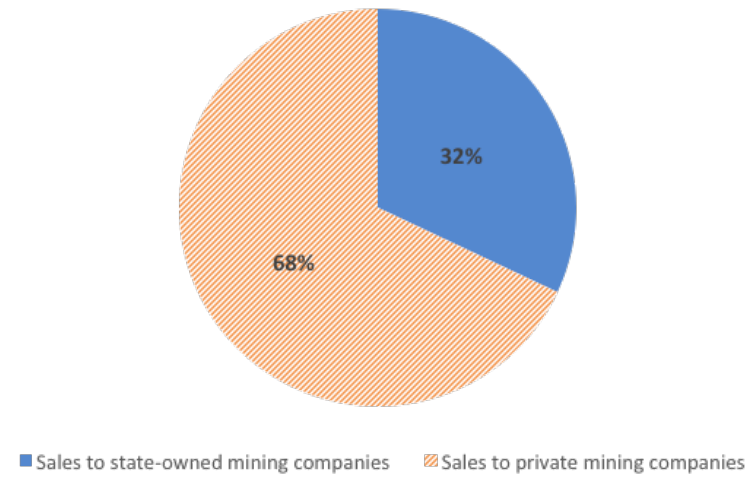
Figure 4.10: % of suppliers according to range of variation in sales to mining



Source: National Productivity Commission

Private mining companies capture 68% of the sector's sales; while 32% goes to public companies (see Figure 4.11). These percentages are consistent with the copper production share of both public and private companies in the mining industry.

Figure 4.11: % of suppliers mining sales to private and public companies



Source: National Productivity Commission

Sales to public mining companies decreased by 25% in 2013-2014, while sales to private mining companies declined by 30% (see Table 4.8). Total sales decreased by 28% in the available sample of suppliers.

Table 4.8: Change in sales to mining 2013-2014

	% Var 2013-2014
Sales to Private Mining Companies	-30%
Sales to Public Mining Companies	-25%
Total Mining Sales	-28%

Source: National Productivity Commission

4.3.5 Mining suppliers' exports

The sector's goal is to reach US$4 billion a year in exports from mining supplier's by 2035, from at least 250 "world class" suppliers (Fundación Chile, 2016). Although efforts to internationalize local suppliers go back to 1993 with the "Chile Exporta Minería" program, it has only been since the last decade that there is systematized information available on the sector´s export performance. The data suggested a boom in the 2000s when exports from a group of suppliers went from US$16 million to US$505 million, between 2002 and 2011 (Korinek, 2013). It is also worth mentioning ProChile's "International Promotion of Suppliers of Goods and Services for Mining Industry" initiative, with funding of US$4.6 million from the Strategic Investment Fund under the Ministry of Economy. However, as with other projects, it should be evaluated and revised in the medium term.

Fundación Chile and ProChile (2015) carried out the first study on supplier dynamics between 2010 and 2014. The following findings were obtained: (i) supplier companies exported approximately an average US$500 million per year, (ii) more than 300 companies exported during 2014 (iii) 83% of the sales correspond to goods and 17% to services; (iv) there is a substantial concentration: 5% of companies exported over US$1 million, and 2% of companies account for 61% of sales volume, (v) the main exported goods are supplies for explosive manufacture, and grinding articles and balls (53% of the volume in 2014), (vi) the main services exported are engineering design and consultancy for extractive mining installations (90% of the 2014 volume), and (vii) 75% of exports are destined for Latin America.

Compared to benchmark countries -such as Australia- where supplier exports represent a larger share of exports (Meller and Gana, 2015), we see there is room for improvement. Also, half of the Australian suppliers export their goods or services, while in Chile this percentage is less than half. For example, only 65 companies sustained annual exports of over US$1 million dollars between 2012 and 2014 (Fundación Chile, 2016), still far from the goal of 250 companies.

The Chilean mixed model, with public and private enterprises, favors a larger scale and amplifies the possibilities of having a strong supplier sector. It remains to be seen how favorable its greater internationalization is, considering that, in the case of Australia, a fundamental role is attributed to the foreign projects of domestic mining companies (Meller and Gana, 2015), which has not happened in Chile due to the abundance of copper reserves. This may change over the next decade due to some international projects of Codelco and Antofagasta Minerals.

4.4. Productivity in the Suppliers Sector

This section explores the evolution of the productivity of Chilean mining industry suppliers. To this end, firm-level data from Regic of Achilles Chile are used. To our knowledge, this is one of the first approximations to the productivity dynamics of the mining industry suppliers' sector at the firm level. Productivity is measured using the total achieved production and the total employment inputs, i.e., a partial productivity measure. No productivity measurements are made within the operation. [11]

4.4.1. Labor Productivity

We considered labor productivity (A_t) as the productivity indicator, defined as the ratio of sales (Y) to the number of workers (L). However, as in other cases, this indicator presents problems. First, an increase in prices, given everything else constant, would show a (false) increase in productivity. Second, it assumes that the growth in value added per worker (the desired data) varies according to the increase in the gross value of the employee's production (the available data). Third, it does not consider the effects of capital accumulation or the effective use of capital. Nonetheless, considering that only sales data are available at current prices and that it is an easy way to understand the productivity measures, it is the simplest way of describing productivity at the supplier level and should be interpreted as the income level generated by each worker during one year. (For an equal number of workers, if a company sells more than another does, it is considered more productive given it obtains greater value with the same inputs.)[12] Additionally, the change in the average labor productivity of the supplier companies is:

$$\Delta\%A_{it} = \frac{\Delta A_{i,t+1}}{A_{i,t}}$$

During the period 2013-2014, and with the complete sample, the suppliers' labor productivity increased by 9.6%. If we consider companies with sales to mining companies

[11] In this sub section, the annual results of the supplier firm is observed but not its productivity inside the operation (for example: contractors). Therefore, productivity bottlenecks inside the mining operations aren't analyzed here.

[12] Due to its partial productivity index, it cannot be assumed exclusively as workers productivity. A supplier firm can have higher labor productivity than another with equal amount of workers, but that could be explained because it may be working with more (and better) machinery and equipment. However, labor productivy is easily comparable and, in general, tends to move in the same direction as total factor productivity.

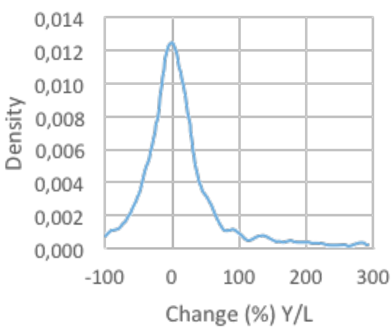
of over 50%, labor productivity increases by 11.4%. Thus, labor productivity increases approximately between 9% and 12% (see Table 4.9).

Table 4.9: Average change in Labor Productivity 2013-2014

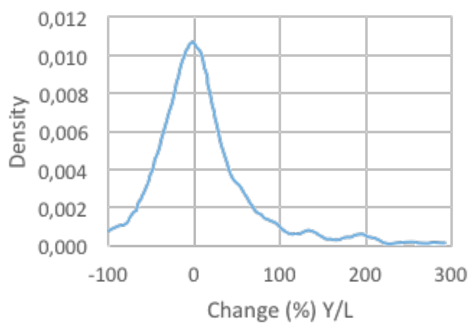
	All	Companies with Mining Sales over 50%
Change in Y/L	9,6%	11,4%

Source: National Productivity Commission.

Figure 4.12: Labor Productivity Variation Histogram 2013-2014



Whole Sample



Sales to mining industry over 50%

Source: National Productivity Commission

The distribution of labor productivity (see Figure 4.12) is centered around zero. That is, the representative company had no changes regarding labor productivity during the period 2013-2014. However, there is a significant dispersion within the total sample, as well as in the subset that sells over 50% to mining companies. Since productivity of mining industry suppliers increased by around 10% (on average), it is necessary to review how this productivity varies when we condition it on a series of relevant variables.

Table 4.10 shows the elasticity of labor productivity concerning an increase in sales to mining companies, distinguishing between public and private enterprises. A 1% increase in sales to private mines is associated with an increase in labor productivity of 0.77%. Instead, for public mines, this magnitude is 0.54%. The results are greater for companies with intensive sales to the mining industry, than the total sample of suppliers, by a difference of four percentage points.

Table 4.10: Labor Productivity-Sales Elasticity to Mining Companies 2013-2014.

	All Suppliers	Suppliers with Mining Sales over 50%
Private Mining Companies	7,7	11,9
Public Mining Companies	5,4	9,6

Source: National Productivity Commission

When analyzing productivity, company size is a fundamental aspect due to the presence of economies of scale. Two criteria are considered in order to classify the size of a company: employment and sales.

Tables 4.11 and 4.12 show the results of the labor productivity levels and the variation in the 2013-2014 period for the job size classification. Greater productivity in larger companies is observed when analyzing the total number of businesses. However, if companies intensive in sales to the mining industry are analyzed, small, medium and large firms present similar levels of productivity and are surpassed by micro enterprises. This may reflect a suppliers' high level of specialization, where few workers generate much value, or a company that sells mainly imported goods and services. Regarding variation, the results indicate that the larger the size of the company, the lower the productivity increase. This could be consistent with misallocation of resources; similar to the evidence found by Syverson (2015) for Chile, regarding the general firm productivity and the level of employment.

Table 4.11: Labor Productivity by Size of Company according to number of employees- 2013-2014 (Millions of Chilean Pesos)

	All Suppliers	Suppliers with Mining Sales over 50%
Microenterprise	84,4	95,5
Small	70,0	63,9
Medium	73,5	68,2
Large	110	62

Note: Employment and sales correspond to the average of both periods.

Source: National Productivity Commission

Table 4.12: Variation in Labor Productivity by Size of Company according to the 2013-2014 Employment (%).

	All Suppliers	Suppliers with Mining Sales over 50%
Microenterprise	16,4	19,0
Small	10,0	11,2
Medium	5,3	3,4
Large	7,5	8,9

Source: National Productivity Commission

Using the sales size classification, we observe that the larger the company, the higher the productivity per worker (see Table 4.13 and 4.14). Regarding variation, smaller firms show greater fluctuations, due to the fall in sales suffered by the sector during the period (see Table 4.15).

Table 4.13: Labor Productivity by Size of Company according to Sales 2013-2014 (Millions of Chilean Pesos)

	All Suppliers	Suppliers with Mining Sales over 50%
Small	4,1	3,9
Medium	11,8	11,2
Large	81,8	75,7

Note: Employment and sales correspond to the average of both periods.

Source: National Productivity Commission

Table 4.14: Variation in Labor Productivity by Size of Company by Sales – 2013-2014 (%)

	All Suppliers	Suppliers with Mining Sales over 50%
Small	35,5	-30,0
Medium	16,7	-8,8
Large	10,2	12,5

Source: National Productivity Commission

Table 4.15: Change in sales to mining 2013-2014

	% Var 2013-2014
Sales to Private Mining Companies	-30%
Sales to Public Mining Companies	-25%
Sales to Total Mining Industry	-28%

Source: National Productivity Commission

The analysis results are: (i) labor productivity increases in all segments during the period 2013-2014; (ii) firms with greater diversification (less than 50% of sales to the mining industry) improve their productivity to a lower extent than lesser diversified firms (with over 50% of sales to the mining sector), (iii) larger company size (in sales) means higher productivity levels, (iv) a higher drop in labor productivity is observed in smaller companies (with over 50% of sales to the mining industry) but it increases in large firms (by employment), (v) there is a positive relationship between sales to the mining industry and labor productivity, which is higher for companies that are intensive in mining sales.

Finding 4.5: Mining suppliers increased their labor productivity from 2013 to 2014 with greater variations in smaller suppliers. This is due to this segment's greater variation in sales.

Finding 4.6: In general, larger suppliers have higher levels of labor productivity than small and medium-sized suppliers do.

4.4.2 Productivity within the Operation

Available working time in the operation/project

A measure widely used for labor productivity at work corresponds to the available working hours: the effective time where the worker is either performing activities that add value or supporting other activities that add value.

The Technological Development Corporation, which is part of the Chilean Chamber of Construction, has carried out a series of measurements in recent years on levels of mining activity (see Figure 4.13). According to their estimates: about 50% of the time is spent on activities that add value, either directly or indirectly (support). Between 22% and 27% of the working hours are spent in authorized detentions (which do not add value but are required to meet regulations and breaks according to law). Between 17% and 26% of the time is used in activities that do not add value nor are they required by statute or by operational needs.[13] That is, work that adds value is around half the time available. This study estimates that rising effective working time from 50% to 60% (by 2020) would save 10,000 working hours and US$300 million. [14]

Aligned with these saving estimates, the Chilean Chamber of Construction presented at public hearings the results of a pilot project in Mining Construction. Seeking to improve coordination, results showed an increase in available time from 46% to 54% in labor and from 44% to 53% in machinery and equipment. This highlights the importance of good management and dialogue practices among contractors (suppliers) and the mining companies and confirms that a significant part of the labor productivity and capital gap reported in Chapter 3 of this report can be solved within the companies. [15]

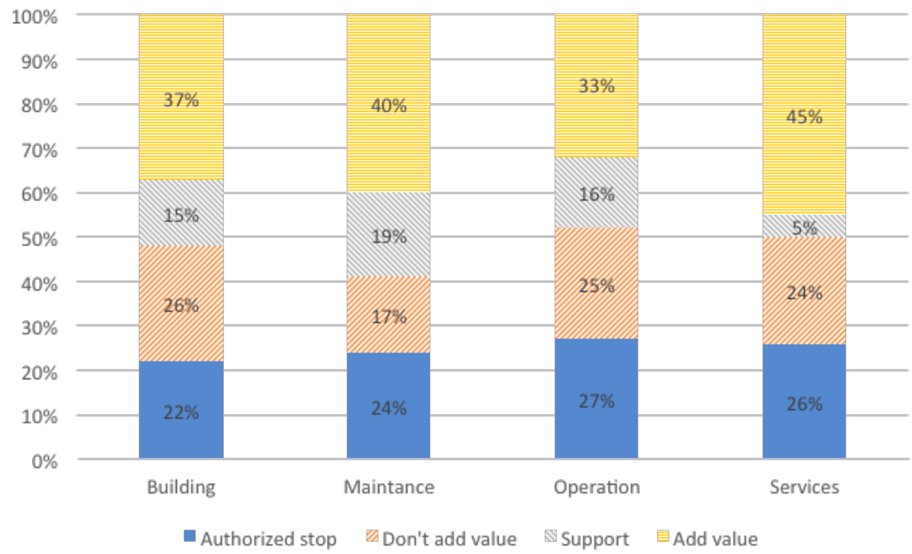
In sum, there is an important space for improvement regarding the availability of work time in Chile. In the mining operation, if activities that do not add value were halved within the operation, about 9% to 13% of the total time for productive activities would be released. The time available can be increased for the mine construction, releasing between 8% and 9% of the time currently used. If this were achieved, the gaps identified in Chapter 3 would be partially overcome.

13 This evidence is consistent with a case study realized by APRIMIN, a suppliers' organization that gathers over 100 of the biggest mining suppliers, with Foraco, an international drilling supplier, in 2014. This study showed significant gaps in available working time: Chile used 46% of the workday, Canadá 76% and Australia 80%.

14 See Corporación de Desarrollo Tecnológico (2015, 2016).

15 See Corporación de Desarrollo Tecnológico (2016).

Figure 4.13 - Activities Distribution per working time (%) 2010-2016



Note: Mine Construction process has the highest number of measurements with 25, the rest have at least five measurements taken during the period .

Source: Corporación de Desarrollo Tecnológico.

Finding 4.7: In the long term, there is room for improvement regarding the availability of effective working time in Chile which could increase between 10% and 20%. Part of these gains can occur within companies, without public action.

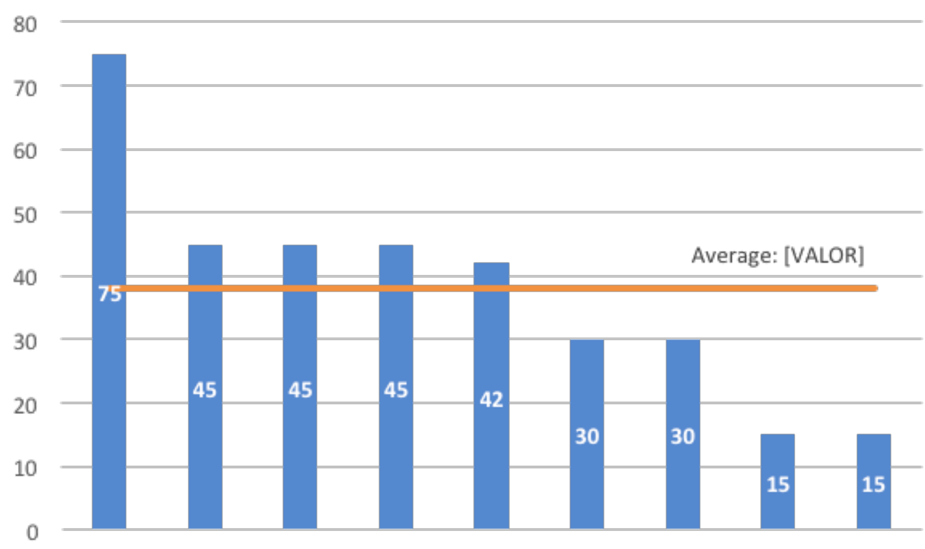
Accreditation Times

An important part of the improvement in the supplier-mining company link is in the accreditation times and in the variety of requirements that suppliers must comply for the mines. Entrance to each mine (even those belonging to the same owner), exhibit significant differences of requirements and certification process, which generates inefficiency regarding efforts and resources. This is amplified considering that the sector has a subcontracting level of around 60%.

Figure 4.14 shows the variation in the accreditation days required for the 12 mining operations of the benchmark study in Chapter 3 (reported by companies). The most efficient mines require 15 days to certify its contractors, while the least effective takes 75 days, five times more. The average is 38 days. These huge gaps reveal different practices within companies, which, if they converge to the best national practice, could save up to two months of time spent by companies in internal procedures. Specific measures in this area are addressed in Chapter 10.

These figures are relevant. As an example, a large mining company estimated in half a million dollars the potential annual savings generated from a reduction of one accreditation day. Reducing internal accreditation deadlines by one month could save an operation about US$10 million per year.

Figure 4.14: Accreditation days for contractor workers (2015)



Source: National Productivity Commission based on Matrix Consulting.

Finding 4.8: There is a considerable dispersion in the accreditation times of large-scale copper mining industry operations in Chile. The most efficient company takes 15 days, while the least efficient takes 75 days.

4.5. Conclusions

The mining suppliers sector is a pillar of the Chilean mining industry, and its performance affects the overall performance of mining companies. In addition, the supplier sector itself could become a source of exports. Therefore, characterizing it, and identifying the areas of strength and weakness is fundamental to enhance the future of this industry, and therefore the mining industry of Chile as a whole.

Summary of Findings

Finding 4.1: There is a significant deceleration from 2013 to 2014 in sales to mining companies, especially sales associated with projects.

Finding 4.2: Suppliers of the Chilean mining industry are concentrated. On average, the two leading suppliers concentrate around half of the sales in the seven categories analyzed, implying the existence of economies of scale.

Finding 4.3: Suppliers of the Chilean mining industry concentrate their main offices in the Metropolitan Region. However, those with greater mining sales intensity have a more significant presence of their parent companies in mining regions.

Finding 4.4: One-third of Chilean mining industry suppliers are large companies under the sales classification. However, ranked according to employment level, 90% are medium and small.

Finding 4.5: Mining suppliers increased their labor productivity in the period of 2013-2014 with greater variations in smaller suppliers. This is due to this segment's greater variation in sales.

Finding 4.6: In general, larger suppliers have higher levels of labor productivity than small and medium-sized suppliers do.

Finding 4.7: In the long term, there is room for improvement regarding the availability of effective working time in Chile, which could increase between 10% and 20%. Part of these gains can occur within companies, without public action.

Finding 4.8: There is a considerable dispersion in the accreditation times of large-scale copper mining industry operations in Chile. The most efficient company takes 15 days, while the least efficient takes 75 days.

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Second part

Productivity Analysis of The Chilean Copper Mining Industry

Chapter 5

Energy and Water Resources

Abstract

Energy and water resources are strategic for the mining sector. During the last decade, about 30% of the country's electricity consumption was allocated to the mining industry, which represented approximately 10% of total energy consumption. Over the next decade, the industry will increase its consumption of electric energy by 34%, due to both the fall in mineral ore and the aging of the deposits, and to the emergence of new projects and further expansions. Any event that threatens water provision or optimal water consumption for the operation processes jeopardizes the productive performance and, in the long term, the viability of the project.

Key points

- Compared to its international competitors, Chile's large-scale copper mining industry is relatively efficient concerning the use of fuel and electricity.
- Mining concessions used only for speculative purposes on sites destined for electrical generation or transmission projects raise energy costs.
- The copper mining industry uses the water resource efficiently.
- At the national level, the mining industry extracts substantially less water than other sectors (agriculture and industry).
- Enabling the use of seawater implies significant investment and operating costs, due to the altitude of the mines and the distance from the extraction areas.
- Nearby mining operations can generate economies of scale for the construction of desalination plants, electricity generation plants, and pipelines.
- The sector requires clear governmental policies on desalination and the installation of plants as well as a clear and transparent regulatory framework.
- There is a regulatory gap regarding brine expulsion from desalination plants.

5.1. Introduction

Energy and water resources are strategic for the Chilean mining sector. The focus of this chapter is on proposals that incentivize efficient water and energy use within the large-scale copper mining industry, and ensure adequate resource availability in the long term.

The resource's availability and its impact on costs are critical factors due to the growing need for energy, even if it is to maintain current levels of production. During the last decade, the sector's energy expenditure accounted for 15 to 20% of the direct cost. Under prevailing technological constraints and the incidence of factors such as the mineral's grade and the aging of the mining site, keeping production implies an increase in energy consumption for each ton of copper.[1] Increasing production involves an even greater energy requirement, due to factors not controllable by companies.

According to the National Energy Commission (CNE in Spanish) and the Chilean Copper Commission (Cochilco in Spanish), the mining sector accounted for approximately 30% of the country's electricity consumption during the last decade and around 10% of total energy consumption.[2] Cochilco's projections (2016a), which consider new and expansion projects; as well as structural factors such as the fall in the mineral grade and the aging of the mineral deposits, suggest that during the next decade the sector will increase its consumption of electric energy by 34%. Although there is no projection for fuel use, the electricity and fuel consumption ratio of the last 15 years suggests an increase between 25 and 30%.[3] The increase in use will mainly correspond (54%) to the Sistema Interconectado del Norte Grande, the Northern Interconnected System (SING in Spanish), and to a lesser extent (46%) to the Sistema Interconectado Central, the Central Interconnected System (SIC in Spanish).[4]

Similar to energy, water resources are also a strategic input into the mining industry. Without water, the concentration or electro-generation processes cannot happen, and the copper extraction is therefore impossible. Any event that reduces the provision of water or threatens the optimal water consumption for the course of an operation threatens the productive performance and, in the long term, jeopardizes the viability of the project.

1 Older mining operations have harder material and longer hauling distances.

2 See Cochilco (2016c)

3 For each unit of electric energy, 0.85 units of fuel were used during the 2000-2014 period and 0.92 for the 2010-2014 period.

4 Cochilco's projected values do not include the connection between the SING and SIC nor energy efficiency aspects. Therefore, they could be considered as an upper range of the mining sector's energy requirements.

In addition to the increasing consumption, the water availability can be affected by climatic effects, which restrict the current sources used by the sector - especially inland waters. Therefore, to maintain the current production levels, it is necessary to find alternatives that allow the resource's efficient use, as well as expanding them for raising production. In this sense, the use of seawater, the effective consumption of water and its re-use, are the most viable options to overcome the growing restrictions. Cochilco (2016b) confirms significant increases in the use of seawater,[5] better efficiency rates,[6] and greater re-use of the resource. In 2015, 72% water use in mining came from re-circulation,[7] 24% from fresh inland water,[8] and 4% from the sea (Cochilco, 2016b). This seawater consumption implies an eleven-fold increase compared to 2009 levels and is expected to grow at a rate of 14% per year in the future decade. Meanwhile, Cochilco (2015) estimates that fresh water consumption for these mines will drop by 1.9% per year for the same period, a trend that suggests the convergence of continental water and sea water use (around 11m3 / sec) by 2026.

The increase in seawater use poses a new challenge from a technical point of view, since transporting significant flows of seawater (either treated or untreated) from considerable distances and altitudes have important implications. It is necessary to evaluate the challenges that arise with the energy consumption required in desalination and transport processes, challenges with its normative regulation, as well as those regarding the public order.

The chapter is structured as follows. Section 5.2 discusses energy use in the mining industry. Section 5.3 examines water resources, and section 5.4 presents results and chapter conclusions.

5.2. Energy

Mining is a highly energy-intensive industrial process, for both electricity and fuel. Its impact on companies' expenditure is relevant since the consumption of electric energy

5 Between 2014 and 2015, the growth in sea water usage in productive processes was 33%.

6 Between 2009 and 2014, the quantity of water used per processed ton diminished in a 21%, to 0.53 m3 per ton.

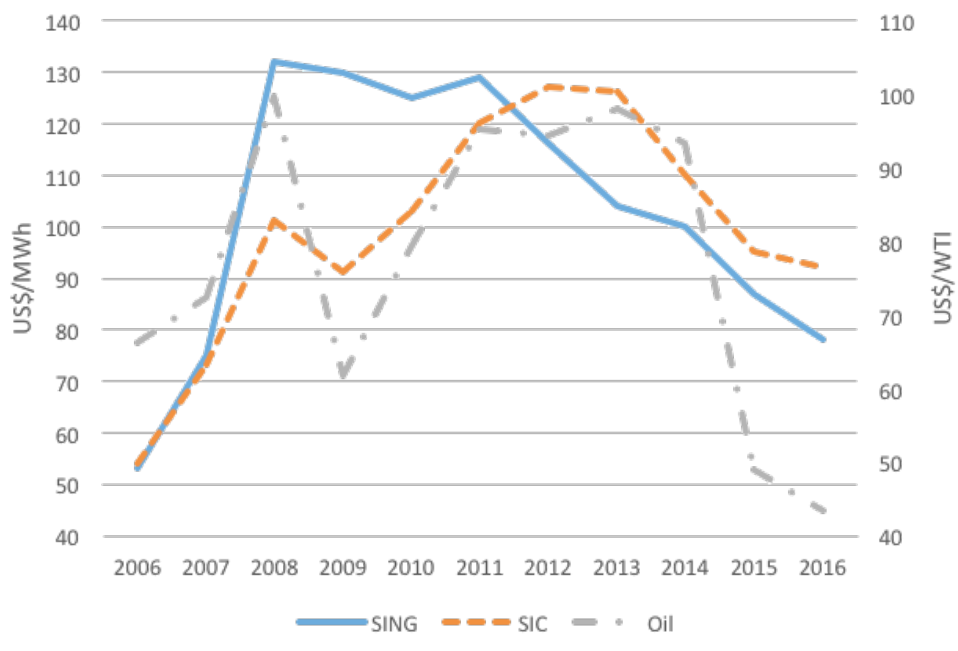
7 This average hides a high heterogeneity since some operations have a 30% recirculation rate and some have over 80%. This is explained mostly by the distance from the concentrator plant to the tailings dams.

8 Refers to all the permanent water inside of the country' landmass. In those sources, we have rivers, lakes, flood plains, reservoirs, and saline interior systems.

and fuel represented between 15 and 20% of direct production cost (Cash Cost 1).[9] Usually, energy problems in the mining industry are due to their cost (competitiveness) rather than productivity, so, in recent years, industry concerns focused on the high price of energy (see Figure 5.1). New energy projects (mainly non-conventional renewable energies), the fall in the price of diesel, and efficiency improvements to existing processes have all allowed a price reduction of electric power during the past two years, which partly relieves this problem but does not overcome it.

Although it is beyond the scope of this chapter to analyze the problems of the electricity market not linked directly to the mining sector, it is worth mentioning that all initiatives that come from the public and private sectors towards securing the power supply at competitive prices will favor the development of future mining projects. The SIC-SING interconnection, and specifically Law No. 20.936 (Transmission Law), which establishes a new Electric Transmission System and creates an independent coordinating body of the national electricity system, are an improvement in this aspect.

Figure 5.1 Energy Prices for Electricity and Fuel 2006-2016



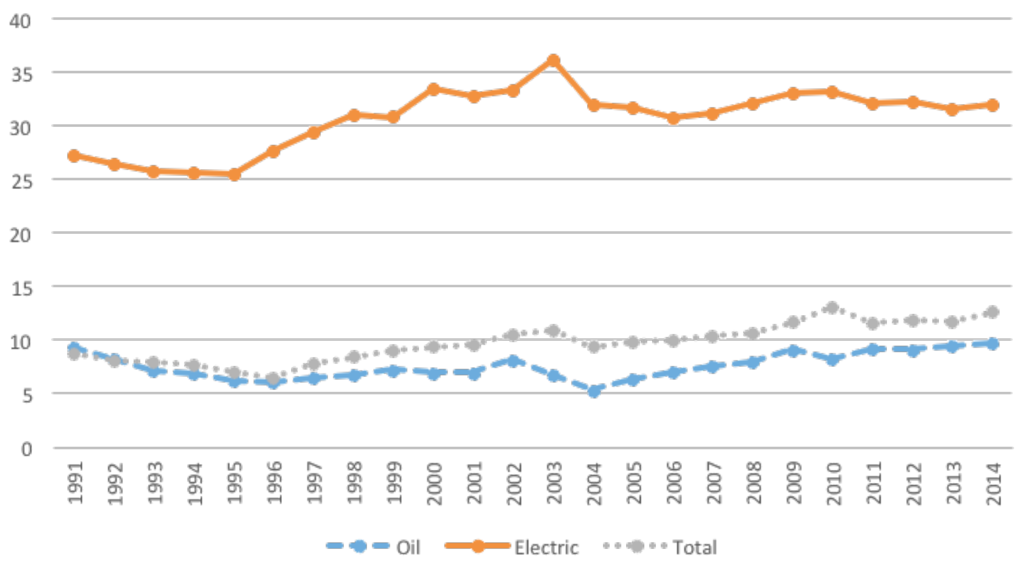
Source: National Productivity Commission based on CNE and Central Bank

9 Includes the main cost components: electricity, fuel, wages, services, etc.

The copper mining industry has increased its share in domestic energy consumption. According to the CNE, since the end of the 90s, the sector went from accounting for 25% of national electricity consumption to account for more than 30% today. It also represents around 8% fuel usage derived from petroleum. In fact, copper mining went from consuming 8% of the country's total (electricity and fuel) energy (1991-2003) to more than 10% (2004-2014), a 20% increase (see Figure 5.2).

Between 2002 and 2015, electricity consumption in the copper mining production process accounted for about 50% of the total energy consumed, and the concentration and leaching processes account for two-thirds of that consumption. As mentioned, most of the increase of the expected consumption in the concentration processes is due to the natural aging of the mineral deposits: in 2016 it represented 55% of consumption, and estimations indicate that in ten years it will reach 68% (Cochilco, 2016a). The leaching process (LX-SW-EW), being second in consumption, shows a reduction due to the closing of several operations. In fuel consumption, more than 60% corresponds to the transport process in the open pit mine, which increased from 56% (2001) to 77% (2015) due to the deepening of the pits (greater distance and slope).

Figure 5.2 - Copper mining share in total domestic energy consumption (%)



Source: National Productivity Commission based on CNE (2015)

The structural challenges in mining are global and not exclusive to the Chilean mining industry. In the future, differences in competitiveness and even the viability of operations will have to deal with these challenges more efficiently. The efficient use of energy, not only the capacity to draw more production per unit of energy consumed but also in the source of such energy, is paramount. This last point is critical, considering that, a significant increase in energy consumption can lead to a rise of products harmful to the environment and poorly valued by society. For example, coal generation accounts for about 40% of SING's electricity generation.

Mixed results are seen when comparing the Chilean mining industry to other copper-producing countries (Cochilco, 2014). On the one hand, the actual (and projected) consumption of diesel per ton of moved material (in a pit mine) in the 2000-2014 period in Chile is slightly more efficient (0.53 liters) than the rest of the world (0.56 liters). Projections from 2015 show that the world would reduce its consumption to 0.51 liters of diesel per ton; however, there would be stagnation in Chile, which shows a slight relative loss of efficiency in our country.

Similarly, electricity consumption in concentrating plants predicts that the Chilean industry's efficiency compared to that of the rest of the world will worsen. From 2000 to 2014, the Chilean copper mining industry consumed around 21 kWh per ton of processed material, against a 23 kWh consumption of the rest of the world. Estimates indicate that the Chilean industry's efficiency will worsen reaching 25 kWh per ton of processed material by 2030, while the remainder of the world will continue at 23 kWh. The United States, Mexico, and Peru will be the most competitive countries with 20 kWh per ton of processed material, while Australia and Canada will be the least competitive with 25 to 30 kWh.

The industry has made valuable efforts regarding Energy Efficiency (EE) in recent years. In 2015, the Mining Council and the Ministry of Energy signed an EE partnership agreement, and the mining sector was the first to commit to a systematic progress in this area.[10] Large mining companies were subject to Energy Audits, which submitted 226 improvement opportunities that, according to the Ministry of Energy, would reach a potential saving of 5% (Cochilco, 2016a).[11] Legislative changes in this direction, such as the Energy Efficiency Law, can support the sector's energy challenge.[12]

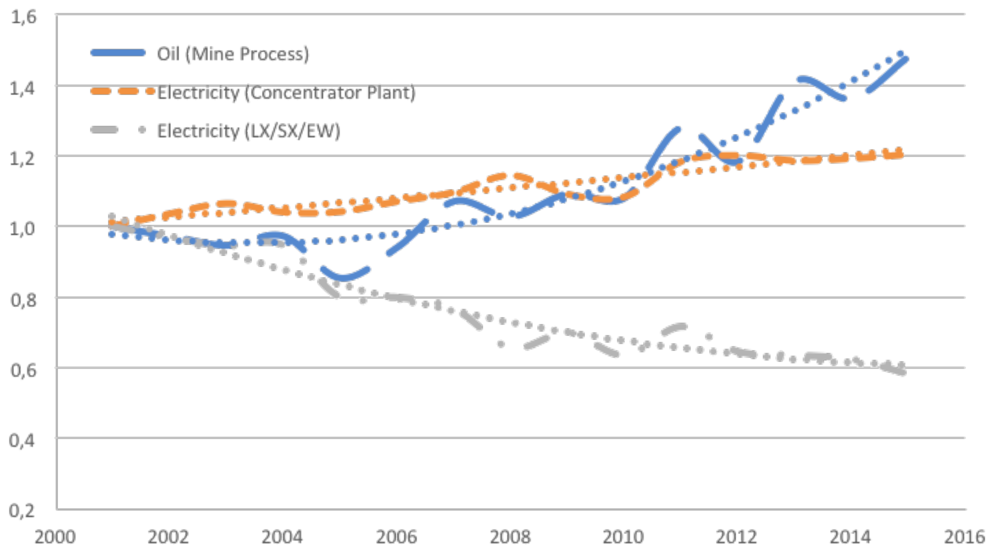
10 The agreement required that mining companies make independent energy audits in order to identify EE opportunities at different levels. With those results in mind, plans of EE were developed for the short, medium and long term.

11 In line with Cochilco (2016a), sources from the industry suggest that the saving potential in an average mining operation ranges from 5% to 10% in the long run, conditional to specific characteristics of the operation.

12 Being their main components the Systems for Energy Management and the Energy Audits.

Since 2000, the fuel consumption per ton of moved material in a pit mine has increased by 50%, while the electricity consumption per ton processed in the concentration process has grown by 20%. The consumption at the leaching processes is the only one that drops (about 40%) due to the closure of some production lines (see Figure 5.3). In fact, the large-scale copper mining industry is transitioning from the reduction of oxide processing to the increase in the sulfide processing, which allows anticipating additional increases in the use of fuel (transport) and electricity consumption (concentrator plant).

Figure 5.3 - Unitary Coefficient Index for Energy Consumption per ton of material



Source: National Productivity Commission based on Cochilco

Along with the increase in direct energy consumption, there is, in the medium term, a substantial increase in seawater use, which will require a significant expansion in the electricity consumption for its treatment and transportation. The expected increase is so large that Cochilco's projections (2016a) place it as the second process of highest consumption after the concentration process: by 2027, 9% of the total electric energy consumption will be due to seawater use in the sector.

In short, it is possible to conclude that the Chilean large-scale copper mining industry uses both electric and fuel energy relatively efficiently, compared to its international competitors. However, the medium-term scenario implies a substantial increase in energy consumption, which will have to be supplied as efficiently as possible (including sustainability) and that will affect Chile's competitive position vis-à-vis some mining competitors.

Finding 5.1: Chile's large-scale copper mining industry is relatively efficient in its use of both electrical and fuel energy, compared to its international competitors.

5.2.1 Electrical Transmission

Although electricity generation faces its challenges, the expected increase in mining consumption does not impose a problem regarding availability. The energy problem for mining has mainly been due to costs rather than availability.

However, concerning availability, the installation of electric transmission lines that transport energy from the backbone lines to the operations - colloquially called "the guitar" - may encounter difficulties in the future, opening up opportunities for improvement in the current situation. On the one hand, the authorization to install an electric transmission line, considered as a concession under the Electricity Law,[13] (electric concession) does not have the same level of legal protection as other concessions considered to be immovable property (i.e., mining or water concessions).[14] Hence, before or during the implementation of an electric transmission line, the electric concessionaire is driven to constitute mining concessions for the sole purpose of obtaining protection derived from their legal regime as immovable property, consequently reducing potential costs in litigation.[15]

13 Law Ranking Decree No. 4/2007, O.J. February 5th, 2007.

14 In their respective legislations, these concessions are defined as immovable property. The concept of "immovable property" is established in articles 566 and seq. of the Chilean Civil Code in the following terms: "Property or immovable things are those that cannot be transported from one place to another; such as land and mines, and those that adhere permanently to them, such as buildings, trees. - The houses and inheritances are called buildings or funds. " In the case of mining, it is of special interest that the civil law, generally applicable in subsidy to any special rule, considers the mine as an immovable property.

15 Although Article 34 Bis of the Electricity Law (amended by Law No. 20,701) has provided a procedural instrument for the litigation caused by the possessory action of suspension of new works (regulated in articles 565 and seq. of the Civil Procedure Code) in order to avoid stopping the construction of an electric transmission line, this instrument has not been effective. When the owners of the electric transmission line are required by this action, the construction is effectively paralyzed, since the determination of the bond to lift this blockage leads to another judgment within, thus increasing the costs of implementing the project. Therefore, in order to avoid this procedural impasse, the electric concessionaire becomes, in parallel, a mining concessionaire with the sole purpose of defending the layout of its transmission line in front of the legal framework that today allows

On the other hand, the special protection granted by concessions equivalent to property is important since it allows a simple use of easements.[16] They are a domain limitation regulated in articles 820 and seq. of the Civil Code and in the specific regulation regarding the type of concession, allows transit or use of some superficial part of the land for certain purposes. However, one of the main assumptions for easements is that it should be a useful relationship between land rights,[17] as determined by law. In the case of mining and water concessions, this is evident (and even expressly regulated), since they are positioned on a land surface. However, in the case of electric concessions, this is not so evident, since they are at the mercy of holders of greater rights (i.e., mining concessions) thus, being affected by the impacts on the costs of implementation, maintenance, and termination of the projects.

In practice, an electric concessionaire may find that the land intended for his electric transmission line is cut open or surrounded by mining concessions. These have, by their Constitutional Organic Law and specific legal regulation, the power to request all the necessary easements to carry out their works (even though, eventually, they do not execute them). Thus, when used for speculative purposes, legal mining easements block the development of any electric power generation project or transmission. Hence, the electric concessionaires (even before they are authenticated as such), must ascertain the state of the mining concessions in the area when reviewing the feasibility of the project. They are also compelled to constitute mining concessions on their own to not be affected by third party legal mining easements (i.e., those formed between the mining concessionaire and the soil's owner without concessions). For, as a mining concessionaire, they can impose their easements (either judicially or extra judicially) against the surface property's owner or other mining concessionaires, which hold a better right than merely the administrative electric concession. In fact, the Association of Electrical Companies confirms that most of its partners have mining concessions for defending the use of soil from this kind of practices.

third-party mining concessionaires (executing mining Works or not) to interfere with their electrical project.

16 Since mining concessions are the cheapest and easy to constitute, it generates a speculative focus on the use of mining property (discussed in detail in Chapter 8 - Mining Exploration). For example, a speculator may request mining concessions by completely encircling an electrical substation for the sole purpose of obtaining potential rent via easements. This practice also applies to the construction of pipelines from desalination plants to mining sites.

17 They are two kinds of land rights in this figure. The servant land right (land that suffers the burden of being cut or used) and the dominant land right (land that executes the burden on the former).

Those who wish to become an electric concessionaire may encounter two potential opponents: the owner of the surface land,[18] and a local mining or water concessionaire,[19] increasing the costs of the line operations and risking a future litigation.[20]

The recently promulgated Law No. 20.936 presents several areas of improvement for this.[21] Likewise, recent jurisprudence has favored the development of non-conventional renewable energy projects over pre-existing mining rights on state-owned lands that were destined for the development of these activities by the State (allocated through concessional administrative acts, such as tendering for the development of these projects). In this case, the execution of the "social function" of the right of ownership prevails over the mining concessionaire's interest.[22]

18 This owner is the natural opponent to any kind of projects executed on or crossing through their soil.

19 Since its concession is an immovable property, it will also oppose any installation that affects the area of the concession, whether it is actually using it or not.

20 Particularly, arbitral litigation that arises from difficulties between mining, electric and hydric concessionaires according to article 31 Bis of Electricity Law.

21 Currently, although this regulation does not offer alternatives to solve the speculative use of mining concessions that compels the electric concessionaire to execute in order to defend its project, it does propose some criteria for the valorization of the electric project that are useful for the topic in discussion and which, we estimate, should be extended to cases such as disputes arising between mining and electric concessionaires under articles 31 Bis (common litigation between concessionaires) and 34 Bis (action to denounce new work) of the Electricity Law. At the moment, as the law did not decide on the widespread applicability of this valuation, it would only serve as an antecedent that can bring the interested party to the process, but, like the bond to lift the stoppage caused by the action of suspension of new works is at the judge's discretion without any legal parameter, its determination during a trial allows the procedural entrapments already detected.

22 The cited judgement corresponds to an unprecedented ruling by the Supreme Court, case number 8133-15, entitled Compañía Minera Arbiodo con Fisco de Chile. This ruling, confirming what was decided by the Court of Appeals of Antofagasta in relation to a mining easement claim by Minera Arbiodo, constitutes itself a precedent in order to reorganize the priorities that may exists on the development of different projects (miners , wind power) in the same area. Because of this ruling, which did not give rise to the mining easement demanded since the concession area was being used for the development of ENEL Green Power wind project, the affected mining concessionaire has deduced an action for nullity from public law and damages against the administrative acts that gave rise to the development of this wind project, since these are infra-legal and unconstitutional mechanisms, causing them damages (cause code C-31539-2016, 12th Civil Court of Santiago). At the beginning of 2017, this lawsuit was in progress.

It is necessary to facilitate the lines' procurement and resource provision to further the synergy between the mining operations and their need for electrical energy. For this, it is important to avoid forcing the electric concessionaire to also become a mining concessionaire under the Mining Code regime. As mentioned before, these types of practices occur to easily constitute easements on surface lands for electric project development.[23] In addition, they add protection against third-party concessionaires that may affect their rights.[24] It is worth mentioning that once a mining concession is constituted, the costs of maintaining the electric transmission line increase, since the mining rights granted must be preserved through the payment of annual patents to avoid litigation. Therefore, it operates as a supplementary insurance for the labor of the electric concessionaire.[25]

For these practices, electric concessionaires are regularly exposed to potential litigation. The legislation provides protection in case there are complex mining operations in the area of interest of the electric concessionaire. However, the speculative use of exploitation and exploration mining concessions[26] is well known, since there are no obligatory legal or technical requirements to demonstrate the need for establishing such concessions to the authorities, and even less for the future execution of a sustainable mining plan over these same concessions. To favor the efficient use of resources, reduce costs and make large projects attractive for future investments, it is necessary to design mechanisms that discourage the speculative use of these concessions, and that, at the same time, do not limit the development of other activities.

In addition to the mining easements constitution already described, the misuse of possessory action of immovable property regarding the suspension of new works -when his/her possession has been disturbed by a new construction- encourages the speculation over land use that includes a mining concession. As envisaged by law,[27] it favors a speculator

23 Articles 120 and seq. of the Mining Code allow the constitution of mining easements by means of an expedited judicial procedure where the only question between the parties is the amount of compensation to the servant property. Because it is a very special easement, its constitution grants additional protection to the dominant property (the mining concession that would exercise the legal easement requested) by enabling it with a right of a real nature (easement), independent of whether it carries out mining works.

24 See article 34 Bis of the Electricity Law.

25 This practice denatures the institution of the mining concession, developed to protect the exploration or exploitation of a mineral resource in a specific area, by transforming it into a tool of legal defense for third party interventions in the area.

26 For surface work (soil pits, minor excavation, etc.), only the permit granted by the exploration concession is required, but for the speculator -not the miner- this is irrelevant because what interests him is to constitute the mining concession. See Chapter 8 - Exploration in Mining.

27 Designed to protect the owner of a property (whatever it is, whether it is built or that is a mere exploration concession that does not require surface construction) from interventions of third parties. In the case of mining concessions, see Articles 9 of the Constitutional Organic Law on Mining Concessions and Article 94 of the Mining Code.

concessionaire to negotiate compensation with the project developers.[28] This action is a legal tool[29] that does not depend on the mining concession as property, but rather as a general possessory action of common use applicable to any construction based on property owned by a person.[30] The property owner files it before the Civil Courts of Justice, as soon as constructions commence, to either restrain its development or order its demolition, unless it results in compensation for damages caused in their land. The person executing the project is notified as soon as the Court gives proceed to the claim, and all works must immediately cease until reparations for damages are settled. This forced detention implies a suspension of all construction projects including mining operations and electrical projects. This phenomenon of common occurrence extends to the mining industry and the resources needed for its functioning, like electrical projects.

Article 34 Bis of the Electricity Law refers to this particular legal practice and has devised a mechanism to avoid the effects of this stoppage, allowing the continuity of the operation, a prior provision of a sufficient sum of money, to account for either demolition or compensation for the damages that may arise due to the continuity of the operation, as would be the case of electric concessionaires. This mechanism was later extended to non-conventional renewable energy concessionaires through the article 97 of the Law No. 20.936. Its general application was unsuccessfully attempted on other concessions that require constructions for their development, through the Bill contained in Bulletin 9169-08.

In short, just as easement constitutions, the possessory action of immovable property regarding the suspension of new works -when his/her possession has been disturbed by a new construction, transcends both theoretically and practically the purely mining aspect; and impacts the sector both directly and indirectly, particularly concerning costs of implementation and maintenance of projects, especially in medium-sized mining operations.

Since mining concessions (both exploitation and exploration) enjoy an immovable property status,[31] their constitution is frequent, without this translating into an actual use of the land for the purposes determined in the norm. These are constituted for the sole purpose of taking advantage of the litigious instances offered by the current regulation, thereby pressuring negotiations between different kinds of concessionaires or filing claims for their interests into judicial proceedings, all of them tending to paralyze the development

28 This was also indicated in public hearings by trade associations such as the Mining Council.

29 Regulated in the articles 930 and 931 of Civil Code and articles 565 and seq. of Civil Procedure Code.

30 Considered as construction any kind of work built on the ground.

31 Reinforced by the Constitutional Organic Law on Mining Concessions (Law No. 18.097, O.J. January 21st, 1982).

of new projects and the correct use of both electric and hydric resources. This is known as "hidden mining" for, although it does not exploit minerals, it is a source of income for its owners. Its existence enables them to deduct legal actions (i.e., possessory actions, demand legal mining easements, among others) that, despite constitutional provisions,[32] oblige extrajudicial negotiations and, ultimately, the purchase of the mining concession in order to end a current trial or avoid future litigation.

In summary, the speculative use of mining concessions can affect the development of electric transmission projects (whether ERNC or not), through demanding legal mining easements on the area of interest to the electric concessionaire. They are also affected by the misuse of the legal instrument that allows the possessory actions (which was originally designed for any property). When dealing with mining concessions, legal modifications to the requirements may mitigate the improper use of these tools, although this entails significant legal difficulties.[33] Another option would be to discourage ex-ante that mere speculators (without interest in developing mining activity) become mining concessionaires with the sole purpose of hindering the development of other activities through its judicialization. Specific recommendations for the latter are addressed in Chapter 8 of Exploration in Mining, which, given the sector´s nature regarding investment and project time horizons, considers all implications of changes in legal status.

Finding 5.2: There is room for improvements in electricity supply costs due to the speculative use of third-party mining concessions where electrical generation or transmission projects are to be installed. Costs increase due to both land use rights negotiations as legal proceedings, and the protection of mining rights considered as property (legal mining easements, possessory actions).

32 Article 34 Bis of Electricity Law, which is based on the principle of guaranteeing the results of the electric project's development, paying a provisional sum to the Court to lift the suspension of the works. Before this payment is made, the course of the trial itself generates a natural wear and tear on the parties involved, encouraging them to negotiate extra judicially with the purpose of giving direction to their projects.

33 E.g.: Establishing that, prior to resolving the action of suspension of new works, the judge verifies the effective development of the activity that is affected with the new work whose construction is suspended. Another alternative would be for the plaintiff to provide antecedents that prove his good right or the potential direct harm that an attempted stoppage of the new work would mean.

5.3. Water

Water is essential for copper production. It is critical in the processing of sulfides and oxides, especially in concentrator plants, pipelines, and leach pile irrigation, in the open pit to mitigate suspended dust, and in extra services. Simply put, without water, there is no mining activity. The increasing restrictions faced by the country and the mining sector on the use of continental waters[34] have led to the efficient use of the resource and the search for alternative sources. In recent years, the industry has advanced in improvements that maximized water recirculation and increased seawater use.

Bearing in mind the sector's goal of producing 7.5 million metric tons of copper per year by 2035, ensuring the availability of the resource is a key challenge that implies determining the combination of optimal sources for efficient resource consumption over the next 20 years.

By 2015, the use of recirculated water reached 40.4 m3/sec, continental water was 13.1 m3/sec, and maritime water consumption was 2.3 m3/sec (Cochilco 2016b). These aggregate figures hide the high heterogeneity that exists concerning water resources, which depend on the location of the operation. According to Cochilco (2016b), only in Regions II and III is seawater used as part of their water sources. In addition, Region II has one of the highest rates of recirculated water, with 75% of total consumption in mining regions.[35]

Another relevant factor when improving the efficiency of water reuse is the tailings treatment in the sulfide deposits. In recent years, thickening of tailings has allowed a better water recovery, among other benefits.[36] This technology has already been tested in Chile (e.g., Centinela Sulfuro ex-Minera Esperanza), although its escalation has faced particular difficulties. With current technology, the economic feasibility of having completely dry and harmless tailings is too costly for the large-scale copper mining industry, but could be considered in the future for medium-sized mining.[37]

When analyzing water consumption in the production process, focusing on the continental source (which is the least available water source), 70% is used in the concentrator plant, while 15% in hydrometallurgy. The remaining 15% is destined for smelting, refining, and other services. Given that the future of the sector is in sulfide processing over oxides

34 Refers to all the permanent water inside of the country' landmass. In those sources, we have rivers, lakes, flood plains, reservoirs, and saline interior systems.

35 This subset includes the XV, I, III, IV, V, VI and XIII regions.

36 It also increases the project life cycle, reduces water pollution risks, increases seismic stability and optimizes land use.

37 During public hearings, it was suggested that although nearly dry tailings exist in Mexico (15-20% humidity), those operations process a much lower amount of mineral compared to a large mining operation in Chile. Thus, the economic cost in Chile isn't feasible for larger scales.

(due to the mentioned aging of the deposits), an increase in the consumption of water in concentration processes and less use in hydrometallurgy is expected. Using m3 of water consumed per ton of treated copper as an efficiency parameter, Cochilco data shows a more efficient use of the water resource in the more intensive stages: concentrator and hydrometallurgy. Since 2009, the consumption of water per ton of processed mineral has dropped by 25% in the case of the concentrator plant, and 33% in hydrometallurgy (see Table 5.1), which signal a focus in guaranteeing the optimal use of the resource.

Table 5.1 – Unitary Consumption of Fresh Water (m3 per processed ton)

Process	2009	2010	2011	2012	2013	2014	2015
Concentration	0.67	0.69	0.65	0.61	0.57	0.53	0.52
Hydrometallurgy	0.12	0.12	0.12	0.10	0.09	0.08	0.08

Source: Cochilco (2016b)

At the regional level, regions II and III are the only ones that show a downward trend in water consumption per processed ton. It is worth noting the reduction of a third of water consumption in the concentrator process in Region III, from 0.85m3/ton (2012) to 0.48m3/ton (2015). In the rest of the regions, efficiency either decreases or is maintained. Large-scale mining, on average, is 30% more efficient in water use than medium-sized mining (concentration), which highlights the importance of economies of scale and the availability of appropriate technologies.

Recirculation is crucial in the water resource management in the mining industry. Depending on the operation's design, the surplus can be reused within the same process, or in others, according to the requirements of quantity and quality of the water. The latest data shows that the reuse rate (the consumption of recycled water over the total) in the copper mining industry is around 73% (2011-2015) (see Table 5.2). Comparatively, recirculation of water in the concentration process has increased from 57.3% in 2009 to 73.2% in 2015.

Table 5.2 – Recirculated Water in Copper Mining (%)

	2011	2012	2013	2014	2015
Recirculation	68.7%	74.0%	73.0%	73.9%	72.5%

Source: Cochilco (2016b)

At the regional level, the IV and Metropolitan regions have the highest rate of reuse (over 80%), no doubt due to greater restrictions and competition with alternative uses (agriculture and human consumption). It is worth mentioning that in 2015, the mining sector represented about 3% of the consumptive use of water at the national level, less than industry (7%), human consumption (8%), and agriculture (82%).[38] Therefore the challenge for the efficient use of water in the mining sector is double: to overcome the desert conditions where most operations are located and, secondly, mines located in zones of smaller water restriction, must compete with other sectors, whose relevance in the consumption of water surpasses significantly that of the mining industry.

Finding 5.3: The copper mining industry uses water efficiently. This efficiency increased in the period 2009-2015 with a 25% reduction in the consumption of fresh water per processed ton of copper in the concentrator and 33% in hydrometallurgy. Water recirculation increased from 68.7% to 72.5%.

"Miner's water"

In spite of the low proportion of mining water extraction (3% of the national consumption equivalent to 14.3 m3 / sec in 2015), there is an issue on these extractions corresponding to the so-called "pit waters" or "miner's water." These are waters found during the mining works[39] that can only be used so long as it is necessary for exploration, exploitation, and profit, and in accordance with the temporary extension and type of mining concession that covers its finding.[40] In 2015, the "miner's water" accounted for 8% of the total water withdrawals from mining, equivalent to 1.3 m3/sec. These waters are heterogeneous both in quality (often highly mineralized) and in quantity, are not tradable, and represent more of a problem than an asset due to the risk of slope stability in open pit mines or floods in underground mines. Due to this, the surfacing of miner's water affects both the safety of workers and the productivity of the mine, so they must be extracted as quickly as possible.

Water found in the development of a mining operation has not lacked controversy over its regulation, which, although scarce (three legal articles), has generated an extensive

38 See National Water Bureau (2016)

39 See Article 8 of the Constitutional Organic Law on Mining Concessions (final section) and articles 110 and 111 of the Mining Code and 56 second paragraph of the Water Code. These waters are defined as "the waters found in the work of a mining concession, to the extent that such waters are necessary for the exploration, exploitation and benefit that they can perform, depending on the type of concession in question" and whose rights thereto are ancillary to the respective mining concession.

40 It should be noted that other waters necessary to explore, exploit or benefit mineral substances would be subject to the provisions of the Water Code.

judicial jurisprudence in charge of impartially specifying its key edges.[41] Specifically this type of water must be fortuitously found in mining operations, and may not be used for any other purposes other than what pertains the specified concession where they are placed. Additionally, they must not be used to a disproportionate extent for such purposes and, although its usage flow is not determined, a minimum flow must always be used. Under all circumstances, this water must be used within the mining project (e.g., tunnel construction product from which waters emerge, environmental mitigation work) and may be restricted in cases of drought. Extraction of the water outside these boundaries is a criminal offense.

The "miner's water" is currently subject to the general statute of all water usage rights. In this respect, the National Water Bureau (DGA in Spanish) does not grant the right to use them (as law grants it), but checks for misuse, and may impose further control systems[42] and declare them as Prohibition Zone for new water usage through founded resolution.[43]

There is an ongoing process to reform Article 56 of the Water Code whereby this matter is specifically regulated (Bill Bulletin No. 7543-2012). It is worth mentioning that this reform proposes that the discovery and extraction of miner's water must be reported to the DGA, and creates a usage authorization by this entity. Informing the DGA on water findings in mining operations is considered reasonable since its mission as an administrative bureau lies in the administration and sustainable management of water resources. However, the times required for authorization to use the extracted resource and the deadline for its approval (which are approximately three years) are a problem, due to the safety and productivity implications discussed above.

As of December 2016, the proposed reform limits the possibility of using the miner's water for the benefit of minerals and adds legal requirements. Contradicting Article 110 of the Mining Code, a DGA authorization must be obtained to use the miner's water, which determines by resolution the manner and requirements for its usage through a simplified procedure for small-scale mining (being, as a general procedure, the current application of the right of actual water usage). Thus, the "miner's water" becomes another particular type of water use right, generating uncertainty for projects that currently use or will use it

41 To that end, see the rulings: Court of Appeals of Santiago. Minera Melón con Dirección General de Aguas, Rol No. 11115-2015; Supreme Court, Consejo de Defensa del Estado con SCM Cía. Salitre y Yodo Soledad, Rol No. 5826-2009; Supreme Court, DGA con Sociedad Legal Minera NX Uno de Peine, Rol No. 4914- 2011; Supreme Court, Minera Los Pelambres con DGA, Rol No. 6997-2012; Supreme Court, Consejo de Defensa del Estado con SCM Compañía de Salitre y Yodo Soledad, Rol No. 5826-2009. Note that these rulings are not necessarily favorable to the mining companies, in the case of Tesorería General de la República con Compañía Soledad, the Court rejected the application of the miner's water status with respect to the mining concessionaire.

42 Article 299 of Water Code.

43 Article 63 of Water Code.

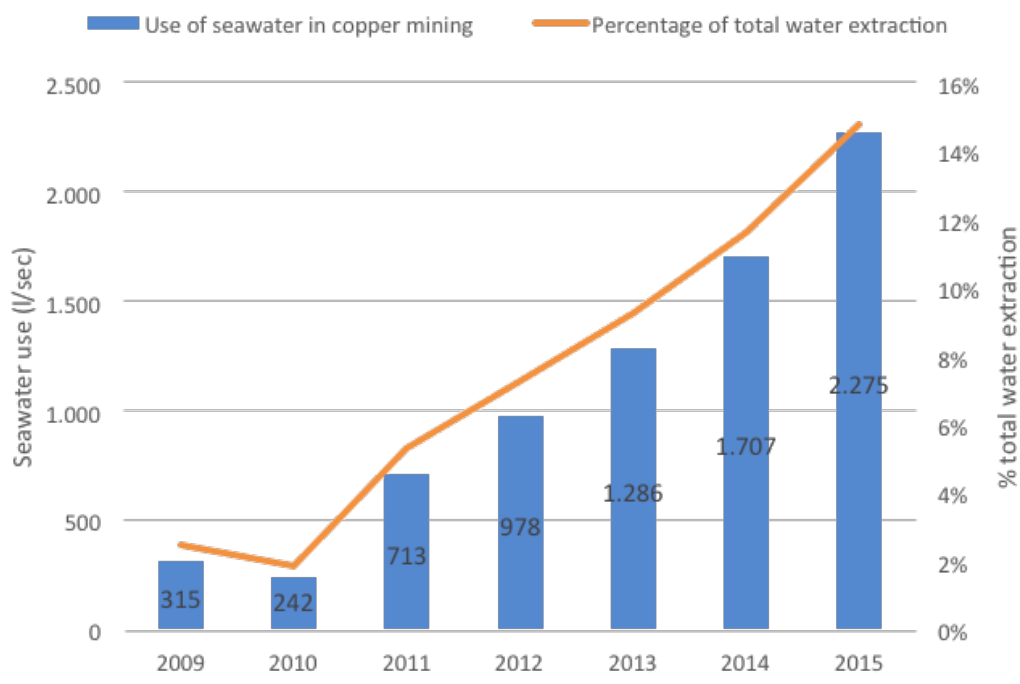
in the future. It also leaves a regulatory void on those waters found during the mining work, that are duly informed and its use is not intended due to the dangers they pose.

> **Recommendation 5.1:** Establish the obligation to inform the National Water Bureau of a miner's water finding, but avoid generating permits for them that allow exploitation.

Seawater

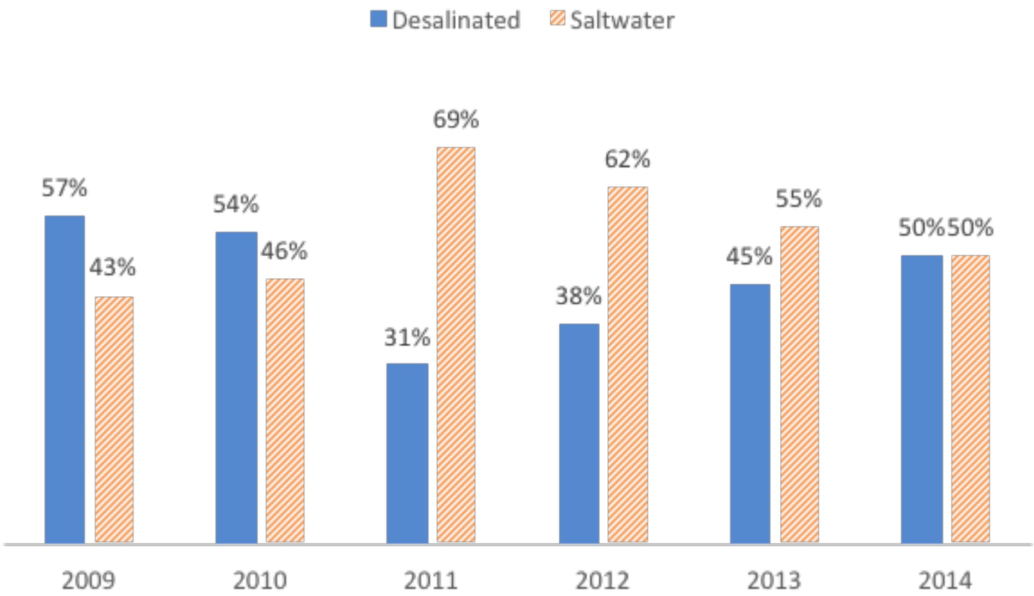
Between 2009 and 2015, the use of seawater in copper mining increased sevenfold, reaching 15% of total water consumption (Cochilco, 2016b) (See Figure 5.4). The utilization of seawater depends on each project. In some cases, the use of saline water suffices, while in others, a desalination process is necessary before sending the water to the mine. In general, the desalted and saline water consumption was around 50/50 in the 2009-2015 period (see Figure 5.5).

Figure 5.4 - Seawater Use in Mining (l/sec; % extraction).



Source: National Productivity Commission based in Cochilco (2016b)

Figure 5.5 - Seawater Consumption Distribution in Mining (%)



Source: Cochilco.

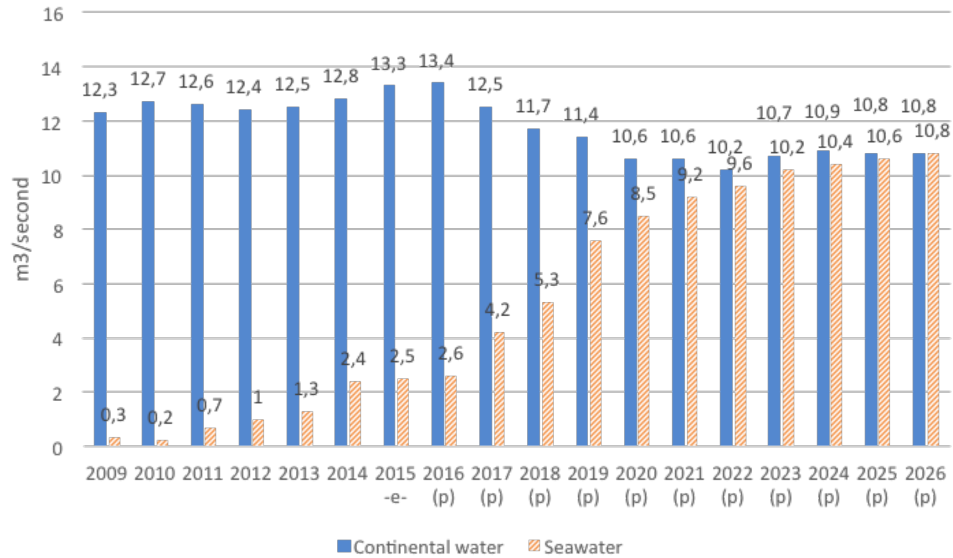
Seawater use is expected to increase considerably, at an additional 14% growth per year, which will allow matching the flow rate used for continental water sources (see Figure 5.6) by 2026. At present, there are ten desalination plants associated with mining projects, of which seven are also capable of sending salt water. Fifteen additional plants are underway (see Table 5.3); although at the administrative level a greater number of maritime concessions applications were detected for the installation of desalination plants, not all of which are related to mining.

Table 5.3 – Installed capacity of seawater use in current and future copper mining.

Operation Name – Owner Mining Company	Expected operational start-up year	Condition	Region	Desalinization Capacity (l/s)	Seawater Impulse Capacity (l/s)
Michilla – Antofagasta Minerals	–	Base	II	75	23
Mantoverde – Anglo American	–	Base	III	120	n.d
Coloso – BHP Billiton	–	Base	II	525	n.d
Mantos de Luna – Minera Tocopilla	–	Base	II	20	5
Centinela – Antofagasta Minerals	–	Base	II	50 a 150	780 a 1.500
Antucoya – Antofagasta Minerals	–	Base	II	50	280
Las Cenizas – SLM Las Cenizas	–	Base	II	9	55
Sierra Gorda – Quadra Chile	–	Base	II	63	1.315
Pampa Camarones – Pampa Camarones	–	Base	XV	5	2,5
Candelaria – Lundin Mining	–	Base	III	300 - 500	n.d
Escondida Water Supply – BHP Billiton	2017	Probable	II	3.200	n.d
Los Pelambres – Antofagasta Minerals	2018	Possible	IV	400	n.d
Santo Domingo – Capstone	2019	Probable	III	260 a 290	355
Radomiro Tomic – Codelco	2019	Possible	II	1630 a 1.950	n.d
Diego de Almagro – Minera Can Can	2019	Possible	III	450	n.d
Spence – BHP Billiton	2019	Possible	II	800 a 1.600	n.d
El Espino – Pucobre	2019	Probable	IV	5	n.d
Quebrada Blanca – Teck	2020	Potential	I	1.300	n.d
Centinela Ampliación – Antofagasta Minerals	2019 - 2024	Possible	II	178	n.d

Source: Adapted from Cochilco (2016b)

Figure 5.6 - Projects for water extraction in copper mining 2015-2026



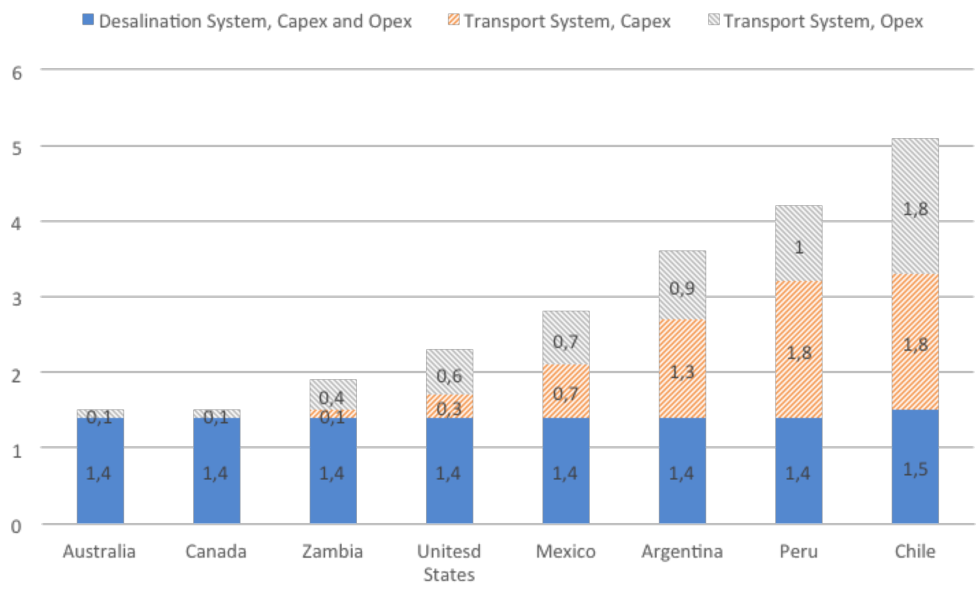
Source: Cochilco (2015)

The increase of seawater use must consider both the energy requirements associated with desalination and water pumping to the mines. Since mining sites are located at altitudes above 2,000 meters, and at distances of up to 400 kilometers from the coast, pipelines (initial capital investment), and the energy required to pump the water (operational costs) impose a significant cost. These costs are higher in Chile compared to similar investments in other mining countries (see Figure 5.7). Like the case of the electric transmission lines, there arise possible easement problems for the transport of water from the desalination plant to the mining site due to subsoil speculative use.

Therefore, the lower the installed volume capacity, the higher the unit cost of seawater, so economies of scale in the desalination process are advantageous. While some large mining companies can solve the problem by investing individually, potential economies of scale suggest sharing investments between various mines. As an example, during 2016, the projects of Relincho (Teck) and El Morro (Goldcorp) were merged into one (Nueva Unión) to take advantage of synergies, including a desalination plant. Likewise, the operations of Quebrada Blanca (Teck) and Collahuasi (Glencore and AngloAmerican) signed a memorandum of understanding for joint use of road infrastructure and a possible desalination plant. An additional alternative is a regional water interconnection system.[44]

44 See Landerretche (2016).

Figure 5.7. Seawater Costs in Mining (US$/m³).



Source: Consejo Minero (2012).

To date, there are three Bills on seawater.[45] The first seeks to enable the State to develop desalination activities. The second one urges the mining industry to incorporate the desalination processes if an operation draws an amount of continental water greater than 150 l / s. The third seeks to tax the use of seawater through a special concession for seawater extraction intended for private use. While the former may generate a greater supply of seawater (and lower prices) by incorporating the State as a relevant player in the desalination activity, the other two projects would produce a cost increase for the mining industry. If the objective is to encourage the use of seawater in the mining industry, it is a contradiction to impose a tax, especially when seawater is not scarce.

Moreover, the Government should establish regulations leading to the massification of seawater use. Territorial systemization would be a desirable public role, evaluating the impact of the installation of a plant of these magnitudes. Moreover, it is worth considering that the location of a desalination plant can benefit one company to the

45 Bill No. 9862-33: empowers the State for the creation of desalination plants. Bill No. 9185-08: establishes the desalination of sea water for use in mining production processes, consolidated with Bill No. 10038-08: Modifies the Mining Code on the water usage in mining productivity processes, and Bill No. 10319-12: Modifies the Law-Ranking Decree No. 340, on Maritime Concessions, to regulate the extraction of sea water.

detriment of another because it affects the costs of investment and operation.[46] For example, in Spain, the regulations include directives that specifically target the location of private desalination plants. [47]

It is important to mention that a positive externality of seawater use by the mining sector is that the required infrastructure (desalination) can be of community use and other productive activities if an extra capacity is considered or once the mine ceases to operate. Most of the mining activity is in water-stressed regions, and, despite using water efficiently compared to other activities (such as agriculture), according to Cochilco and the National Water Bureau (DGA in Spanish), the population is not necessarily aware of this. Bearing this in mind, the use of seawater can play a significant role in the acquisition of the social legitimacy currently required by the mining industry.

Finding 5.4: Investment and operating costs for enabling the use of seawater are significant, due to the altitude of the mines and the distance from the extraction areas, which implies that there are advantages in economies of scale among nearby mining companies for the construction of desalination plants, electricity generation, and pipelines.

Recommendation 5.2: Promote greater use of shared infrastructure in water matters (desalination plants, pipelines, among others), either through the coordination amongst mining companies, through a third party that builds the infrastructure and assumes the costs of coordination, or using another feasible alternative, such as a water interconnection system.

46 For instance, closeness and sea currents could cause brine expelled to the sea by a desalination plant to increase the processing costs of another plant nearby.

47 Royal Ordinance No. 1327/1995, July 28, on the desalination of marine or brackish water. In the public domain, the regulation of the installation of these plants is given by Law No. 12/1990 of July 26th, on Waters of the Autonomous Community of the Canary Islands. Spain is interesting because at an Administrative Law perspective, it is very similar to Chile. It is also relevant to note the case of the United States, where the Florida Water Resources Act of 1972 (sec. 373.019) sets out guidelines for the installation of these projects. Although there is no federal legislation on that matter in the United States, the closest principle to establishing the desalination plant is in line with the theory of littoral rights, which strictly refers to the right of coastal owners to waters adjacent to their properties.

In leading mining countries, such as Australia and Canada, there is a tendency to establish a general reference framework for water quality standards, whose purpose is to protect the resource and prevent its pollution (Cochilco, 2008). The discharge of liquid industrial waste, due to its volume and toxicity, must be treated in a specific way for each project through the granting of permits, where the competent authority considers all site-specific factors through environmental impact studies. In our country, this analysis is done by the SEIA. Hence, to reduce costs and encourage new desalination projects, it is necessary to establish general guidelines on waste from water treatment plants, devoting a chapter to the desalination plants, in compliance with international standards.[48]

Finding 5.5: The sector requires a clear policy on desalination by the Government and a speedy and transparent regulatory framework.

Improving the clarity and speed with which permits are processed is a general challenge for the State administration. Several sources indicate that obtaining a maritime concession can take up to 4 years. It is, therefore, necessary to have a roadmap specifying both the permits required for the development of the desalination activity and its sequence, including those necessary to obtain a maritime concession and the start-up of a desalination plant. Although the Coastal Border Integrated Management System is a contribution in guiding the establishment of a maritime concession (DFL 340/1960), it does not include compliance rules required by a concessionaire interested in the installation of a desalination plant. It is also necessary to resort to organisms like the SEIA, Registry of Emitters and Transfers of Contaminants, Superintendence of Sanitary Services, etc.

Finding 5.6: There is no clear road-map on permits and procedures for the installation of desalination plants.

An important aspect to consider when enabling the potential of supplying seawater is the treatment of waste from desalination plants.[49] There is no clarity as to what the impact of the expulsion of brine on the environment could be, especially when the number of

48 For in depth analysis, see International Desalination Association (http://idadesal.org/).

49 Although there are desalination technologies where it is not necessary to expel the brine to the sea, this is not the case in most of the desalination projects in our country.

projects increases significantly. Moreover, although the desalination plants are subject to evaluation by the Environmental Impact Assessment System (SEIA in Spanish), which analyzes the impact of brine, in the absence of a specific regulation on these residues, a general industrial waste legislation is applied.[50] There is a regulatory dispersion for environmental issues, adjacent to sanitary enforcement powers and that has a direct impact on the planning, development, and completion of projects, which undermines clarity regarding the procurement of permits and the completion of milestones, aggravating this situation.[51]

Finding 5.7: There is a regulatory void regarding the expulsion of brine from desalination plants to the marine environment, which is attended by general legislation.

Recommendation 5.3: Establish a clear road map of permits and times required for the approval of desalination plant projects.

Recommendation 5.4: Establish a specific chapter on regulations for wastewater treatment plants, concerning desalination plants in compliance with international environmental standards.

50 The only norm that regulates the emission in Chile is DS 90/2000 (O.J. March 7th, 2001) that "Establishes emission standards for the regulation of pollutants associated with the discharges of liquid waste to marine and continental surface waters", where in any of its compliance tables associated with the marine environment within and outside coastal protection, chloride is considered to be subject to a maximum discharge limit (which is considered for the discharge of waste into bodies of water), being the common environmental assessment based on the SEIA Regulation (DS 40/2013), the basis for the sectorial review and the delivery of the applicable Sectorial Environmental Permit No. 115.

51 Today there are six different regulations that deal with this matter and, in some cases, their provisions overlap, leaving legal operators to apply general principles (specialty, organic repeal) to give a correct interpretation and application of the provisions involved. Thus, the provisions of DS 40/2013 (Regulation of the Environmental Impact Assessment System), DS 143/2009 (Primary quality standards for surface inland waters suitable for recreational activities with direct contact), DS 209/2006 (Determines the toxicity values of the substances for the purposes of the sanitary regulation on hazardous waste management), DS 148/2004 (Approves sanitary regulation on hazardous waste management), DS 46/2003 (Establishes standards of emission of liquid waste to waters), DS 90/2001 (Establishes emission standards for the regulation of pollutants associated with discharges of liquid wastes to surface and marine waters) and DS 144/1961 (Establishes norms to avoid emanations or atmospheric pollutants of any nature), added to the technical standards indicated in the National Institute of Normalization, must be made compatible.

5.4. Conclusions

Energy and water resources are strategic inputs for the large-scale copper mining industry. Due to the expected expansion of current and new mining projects, substantial increases in the consumption of both resources are expected over the next years. To satisfy this demand, it is necessary to improve both water and energy availability, as well as its efficient use. In addition to the direct impact on the production process, success in this area will have a significant effect on the industry's relationship with local communities.

In the field of energy resources, evidence indicates that large-scale copper mining industries use energy efficiently, even when benchmarked internationally. There are some advances in this area such as the agreement between the Mining Council and the Ministry of Energy, as well as the future law on Energy Efficiency. Although there is room for improvement concerning energy efficiency, it is limited (5%), and it will be difficult to increase in the short term. Regarding supply availability, the copper mining industry will be confronting internationally competitive prices (US $ 50-100 per MW) due to new bids, and the future union of SING and SIC.

Energy supply operating costs concerning transmission lines and land use can be improved. One of the biggest problems faced by the electric concessionaire is the existence of third-party mining concessions, some of which are used for speculative purposes, far removed from actual exploration or exploitation. Thus, costs are augmented regarding both negotiations on the rights that affect land use by the transmission line (towers, cabling, panels) and in lawsuits that may arise under the protection of mineral rights as immovable property (possessory action of suspension of new works).

It is necessary to specify the requirements outlined in the Mining Code and its Regulations for the constitution of mining concessions. Mining concessions are either for exploration (the most common, low cost and easy to acquire in an area of economic interest) or for exploitation. To discourage the speculative use of the ground under the protection of a mining project, the concept of the mining concession must be reoriented towards an adequate use of the land, discouraging speculation and generating a long-term commitment with the concessionaire. Specific recommendations in this matter are addressed in Chapter 8.

Regarding water resources, evidence indicates that the large-scale copper mining industry uses water efficiently in its different processes. The scarcity of the resource strongly encourages recycling and efficiency in its usage. In the future, greater restrictions on the use of inland water and tougher competition with other activities (population and agricultural consumption) will lead to an increasing use of seawater. The mining industry is advancing in this direction, but public policy must define the boundaries to enhance such use. There is a consensus in the country concerning the deficits on the water resource management, due to either lack of coordination between public entities or missing proper institutions.[52] Proposing such guidelines goes beyond the scope of this chapter.[53] However, legal gaps should be addressed to encourage the use of seawater in mining.

5.4.1. Summary of Findings

Finding 5.1: Chile's large-scale copper mining industry is relatively efficient in its use of both electrical and fuel energy, compared to its international competitors.

Finding 5.2: There is room for improvements in electricity supply costs due to the speculative use of third-party mining concessions where electrical generation or transmission projects are to be installed. Costs increase due to both land use rights negotiations as legal proceedings, and the protection of mining rights considered as property (legal mining easements, possessory actions).

Finding 5.3: The copper mining industry uses water efficiently. This efficiency increased in the period 2009-2015 with a 25% reduction in the consumption of fresh water per processed ton of copper in the concentrator and 33% in hydrometallurgy. Water recirculation increased from 68.7% to 72.5%.

Finding 5.4: Investment and operating costs for enabling the use of seawater are significant, due to the altitude of the mines and the distance from the extraction areas, which implies that there are advantages in economies of scale among nearby mining companies for the construction of desalination plants, electricity generation, and pipelines.

Finding 5.5: The sector requires a clear policy on desalination by the Government and a speedy and transparent regulatory framework.

Finding 5.6: There is no clear road map on permits and procedures for the installation of desalination plants.

52 During the last years, the creation of a Undersecretary of Water in the Ministry of Public Works (MOP) has been endorsed to provide a better framework and coordination between public agencies.

53 See, for example, World Bank (2011, 2013).

Finding 5.7: There is a regulatory void regarding the expulsion of brine from desalination plants to the marine environment, which is attended by general legislation.

5.4.2. Summary of Recommendations

Recommendation 5.1: Establish the obligation to inform the National Water Bureau of a miner's water finding, but avoid generating permits for them that allow exploitation.

Recommendation 5.2: Promote greater use of shared infrastructure in water matters (desalination plants, pipelines, among others), either through the coordination amongst mining companies, through a third party that builds the infrastructure and assumes the costs of coordination, or using another feasible alternative, such as a water interconnection system.

Recommendation 5.3: Establish a clear road map of permits and times required for the approval of desalination plant projects.

Recommendation 5.4: Establish a specific chapter on regulations for wastewater treatment plants, concerning desalination plants in compliance with international environmental standards.

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LAW NO. 20,701 on procedure for granting electric concessions (D.O. 14-10-2013).

LAW NO. 20.936, which establishes a new electric transmission system and creates an independent coordinating body of the national electricity system (D.O. 20-07-2016)..

Cited International Legislations:

Spain:

- Royal Decree No. 1327 (28/07/1995), on the desalination installations of marine or brackish water.
- Law No. 12 (26/07/1990) of Waters of the Autonomous Community of the Canary Islands

U.S:

- Florida Water Resources Act of 1972 (Chapter 373, Florida Statutes).


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Chapter 6

Mining and Communities

Abstract

This chapter provides an analysis of the relationship between mining companies and communities in Chile, highlighting the role and importance of the State. Early, continuous, accurate and reliable information are key factors for building trust between parties. Likewise, both the state and local governments are major actors in the company-community relationship. The transparency and credibility of these institutions, in addition to their management capacity, are decisive for the feasibility of long-term solutions and mutual benefit.

Key points

- It is not enough to have all environmental permit, mining companies must also manage their social license to operate.
- Regulatory clarity and early, continuous, accurate and reliable information between the parties is fundamental to building trust between communities and mining companies.
- State and local governments are key players in the company-community relationship.

6.1. Introduction

This chapter presents information on the relationships between mining companies and local communities[1]. The role of the State is analyzed, and part of the relevant literature is reviewed. Three case studies are also examined: Minera Los Pelambres, Minera Cerro Colorado, and RockWood Lithium.

Over the last decade, and worldwide, citizen demonstrations concerning the legitimacy of large investment projects have been increasing (Ortiz, 2013). The reasons vary from flaws in the political system to claims for social rights and the environment. Chile has not been oblivious of this trend, and mining, in particular, has had to confront conflicts, both with those communities that live in its area of influence, as well as at the national level. Some conflicts have escalated internationally, increasing in visibility and actors involved (Urkidi, 2009).

The future of the Chilean mining industry, and in particular the materialization of the 7.5 million metric tons of annual production projected for 2035, depends on the expansion of existing mines and the materialization of new projects. However, the viability of both is highly dependent on the so-called "Social License to Operate."[2]

Mining in Chile has been located mainly in the northern desert area, which given its characteristics, includes few communities.[3] However, half of the copper reserves, and consequently, the country's future deposits, are located in the central zone (Regions IV, V, VI, and RM). Therefore, there will be an increase in the amount and complexity of conflicts between the mining sector and high-density communities located near future projects. At the same time, the future mining area will compete with other economic activities for the use of land (for example, agriculture), and for strategic resources such as labor supply, water, and energy. Therefore, relationships between mining companies and communities, and their environment will be increasingly more important, and strategic for the sector and its sustainability as a pillar of the national economy.

Better relationship with communities implies greater legitimacy and potentially less conflict. There is also less possibility of external influence on communities. A constructive relationship can also generate benefits for communities. In the absence of a good company-to-community relationship, companies assume higher explicit and implicit

[1] "Community" refers to the population located nearby the mining operation and its influence area. Elements such as tailings dams, dumps, mineroducts and others that can be located far from the exploitation site (the open pit) are also included.

[2] The Social License to Operate (SLO) refers to the acceptance of the mining companies and their projects by the local communities.

[3] See Annex - Figure A.6.1 Main Mining Operations in Chile Map as of March 2016.

costs, and accumulate a growing social liability, while communities lose job and material opportunities. Often, achieving a balance where both parties benefit may be elusive.

The chapter is structured as follows. Section 6.2 examines different conflicts and their costs. Section 6.3 lists the primary impacts of the mining industry that can lead to conflicts. Section 6.4 discusses the "Social License to Operate" and its implications. Section 6.5 addresses current initiatives in Chile for a better business-community relationship. Section 6.6 presents three case studies. Lastly, section 6.7 presents the results and conclusions of the chapter.

6.2. Conflicts and their Costs

Davis and Franks (2014) discuss various conflicts with communities and their associated costs, grouping them into four categories (Table 6.1), depending on the level of violence and the parties involved. The escalation in violence implies the participation of different players, different strategies and the parallel increment in costs, especially for the company.

Table 6.1 Conflicts

Based on Procedures (generally non-violent)	• Requests: to the government (local / regional / national) or company (subsidiary or parent) • Administrative: formal claim through state or other mechanism (eg: international organizations) • Legal: actions in the jurisdiction of the mine / parent company, group actions, court orders. • Publicity: use of media, campaigns, NGOs
Physical Protests (can be violent or not)	• Demonstrations: at local / regional / national level; with mining workers (strike) and / or the community. • Blocks: to the mine, access routes, roads, railways, ports.
Violence towards people	• Injuries: members of the community, company workers, public and / or private security forces. • Deaths: community members, company workers, public and / or private security forces.
Property Violence	• Private property: damage or destruction of equipment / facilities / buildings; interference with private infrastructure; small / large scale. • Public property: damage or destruction of equipment / facilities / buildings; interference with public infrastructure; small / large scale.

Source: Adapted from Davis and Franks (2014)

A conflict with the community in the area of influence of a mining operation can affect productivity and operating costs through several channels (see Table 6.2).

Regarding productivity, there is a loss of operational continuity, unplanned detentions, restrictions on changes in plant design, limitation of project expansion possibilities, interruption of operations, obstruction of roads, decreasing of moved or processed material, and an increase in person-hours for solving the conflicts, among others.[4] Other explicit costs that also affect productivity, both in the short and long term, are due to higher resource requirements to produce the same amount of ore. For example, projects may have to be modified; risk management, capital, and financing concerns will have to be addressed, among others.[5]

Table 6.2 Cost types for mining companies due to conflicts with communities

Less Productivity	• Operational discontinuity; voluntary/obligatory closure due to judicializations; • Temporary closure of operations; • Lost opportunities for expansion and / or new projects; • Disruptions to production: temporary or indefinite delays, absenteeism, "square wheels"; • Delays in deliveries of inputs; • Greater scrutiny and regulatory burden
Staff and Workers	• Time of personnel and teams dedicated to risk and conflict management; • Remediation costs: meetings, negotiations, mediators; • Kidnappings: payments and rescue operations, compensation; • Detentions of personnel; • Injuries to workers and fatalities;- Low mood and effects linked to stress; • Higher retention costs: wages, compensation, bonuses; • Recruitment: promotion, selection, interviews, inductions

Source: Adapted from Davis and Franks (2014).

According to Davis and Franks (2014), a world-class mining operation loses about US$20 million per week as a direct cost of the shutdown. However, the indirect cost of a conflict can be even greater, considering that, it affects expansions, new projects, and involves an additional charge concerning human and financial resources necessary to carry them forward and recompose the social relationship. To estimate the total cost, the uncertainty factor for the feasibility of future projects should also be considered.

Some of these costs are hard to perceive clearly, so companies tend to underestimate them, along with the importance of a good relationship with the local communities.

4 Loss of operational continuity implies less tons of processed material relative to the optimum. In terms of expansion of the mine, it can turn into a sub-optimal design, which implies a less efficient process.

5 See Annex Table A.6.1 - Costs to mining companies because of community conflicts (cont.).

6.3. Challenges for the Mining Industry in its Relations with Communities

As an extractive activity, mining can deeply affect the environment. These effects can be minimized,[6] mitigated[7] and compensated.[8] As can be seen in countries visited for this study (Sweden, Canada, Australia and the United States) mining can become a cleaner and more sustainable industry, and relatively free from conflicts with communities.

According to the International Institute for Environment and Development (2002), the impacts of extractive projects can be:

1. Environmental.

The impact of mining on the environment exists, and it tends to be the biggest problem when dealing with communities. This impact is broad, although it varies according to the stage of development and the productive process. There are disturbances during the stages of exploration, construction, and development of a mine site, but the greatest impact occurs in operation (open pit) processes due to the release of particulate material. The plant processes (concentration or hydrometallurgy) can affect the use of water, as will the disposal of tailings, liquid industrial waste and gravel. Foundries and refineries generate emissions of CO_2, arsenic, and H_2SO_4.

In addition to the controlled impact of the operation, the risk of accidents exists, although again, they can be reduced. The case of the Samarco mine (owned by Vale and BHP Billiton) in Minas Gerais, Brazil, is as extreme as it is emblematic. In 2015, two tailing dams gave way, releasing 62 million cubic meters of toxic mud in the surrounding communities. The fluid killed 19 people, and traveled 600 kilometers to the Atlantic Ocean, becoming the worst environmental disaster in Latin America history. The Brazilian government sued the companies for US$43,550 million for repair costs.

2. Demographic

Mining generates demographic changes. During the construction of a mine, usually, the number of workers cannot be supplied by the surrounding communities, both because of the number of employees required (sometimes several thousand) and the skills

6 For example, reducing the CO_2 and HS_2SO_4 emissions to the minimum feasible levels.
7 For example, supporting the reforesting of the zone.
8 For example, monetary or non-monetary contributions to the community.

needed. In this period (of at least two years), there is a temporary demographic expansion (migration) of workers from other zones. On the positive side, new economic activities such as accommodation, security, and food services, arise among others. But, on the other hand, prostitution, drugs, and violence (World Bank, 2002), may also occur, a fact which is aggravated when the State and its structures are absent, and when the affected population sees their culture undermined, or fears the loss of their traditional source of income.

This condition, although minor, continues throughout the operation of the mine. Non-resident workers may have a particular work mode (fly-in fly-out), which avoids part of these conflicts but leaves less economic benefits in the area.

3. Management and use of land

The mining industry tends to expand over time. It competes for land with other activities such as agriculture or tourism, for it requires large extensions of land for the construction of tailings dams or dumps for sterile material, and the visual impression aggravates its potential environmental impact.

Other economic sources may be affected in different ways, in particular, competition for land or water. They also compete for inputs and labor affecting the job market. Advantages may arise through higher wages and new business opportunities.

> **Finding 6.1:** Regulatory clarity, in aspects such as water rights, land, etc., is fundamental to establish a framework for future debates.

4. Resource Flight

An increase in potential risks of conflict occurs when communities perceive that the negative externalities of the project are mostly assumed by them, and are geographically excluded from all the benefits. Thus, communities are "paying the cost" without enjoying the dividends. Beyond compensation for environmental or visual externalities, this aspect is linked to the distribution of the benefits generated through salaries, taxes, and royalties.

Commonly, a percentage of the company's income and taxes generated by the activity stay in the project's location. There are several examples of such practices, such as the Canon Minero in Peru (2001) whereby taxes are transferred to local and regional governments to be invested in infrastructure projects. Similarly, in Indonesia (2009) companies must pay the 4% to the central government, and 6% to the regional government. In turn, the latter is distributed as 1% to the local government, 2.5% for the district or city where the profits originate from, and 2.5% for the rest of the provinces. In England, 1% of the benefits will go to communities around future fracking wells[9] (Finlayson et al., 2016). These models seek to ensure that part of the taxes paid, return to the area of exploitation and directly benefit communities living in the zone.

The current model in Chile allocates part of the proceeds of the Specific Tax on Mining Activity (the "royalty"), to the Innovation Fund for Competitiveness, of which 25% is transferred to regional governments for innovation activities,[10] and the Investment and Regional Reconversion Fund.[11] For these purposes, and considering the diagnosis made by the Presidential Advisory Council against Conflicts of Interest, Influence Peddling and Corruption concerning local governments, it is necessary to strengthen the institutional framework so that these resources are transparently and adequately used, in favor of the community.

Recommendation 6.1: Implement the proposals of the Presidential Advisory Council against Conflicts of Interest, Influence Peddling and Corruption regarding the funds received by local governments, so that local governments establish a better institutional framework, with greater transparency and efficiency.

5. Information assymetries

Communities are at a disadvantage when negotiating with mining companies because they lack the technical knowledge to understand the effects of investment projects (Social Economic Environmental, 2006).

Therefore, timely communication of the stages and the impact of the project, considering external advisers chosen by the community, increase the trust among the parties. Effective communication is crucial, as well as holding public meetings where concerns can be expressed and reported (Hilson & Murck, 2000). Specialists, both in Chile and abroad, offer counseling and mediation services to the community, although with different results. Additionally, the educational gap between professionals and communities is also a

9 Fracking is a technique to enable or increase gas and petroleum extraction from the subsoil.
10 Operating since 2008. Since 2013, a bigger share has been allocated to mining regions.
11 For the 2011-2016 period, Antofagasta Region leads with 12%, followed by Metropolitan Region with 10%, Atacama 9%, Tarapacá 9%, and Coquimbo 8%.

source of problems. Although information reports and transparency have increased, few are verifiable (International Institute for Environment and Development, 2012), implying that the problems arising from information asymmetries persist and are a challenge for both companies and communities.

6. Governance

In places where the State's presence is weak, the community chooses to resort to the company to meet needs regarding infrastructure, education, health, and other expenses considered social, or public goods, exacerbating expectations and the costs of business relationships. Although financially it is possible for the company to take care of such benefits, there are apprehensions about their sustainability in the long term. The most sensible thing would be to contribute to the provision of assets that allow the community to receive resources not only during the time of the operation but also after its closure.

In short, mining generates impacts and negative externalities in its environment, land and inputs competition, demographic changes, etc. It also faces challenges including resource flight, information asymmetries with communities, and governance issues due to the State's absence, factors that can generate conflicts with communities.

6.4 The Social License

Usually, the relationship between companies and communities has been transactional through the delivery of monetary resources or assets to the community. However, this does not guarantee that resources are used in the best way, it does not facilitate the development of a shared long-term vision that lessens the possibility of future conflicts, nor does it ensure that other groups (even within the same community) challenge the results of that relationship.

A good relationship between companies and communities involves the development and maintenance of the so-called Social License to Operate (SLO). The SLO is a tacit-and, therefore, fragile-license that is "issued" or "granted" by those most affected by the operation: usually the surrounding communities. This concept has gained recognition in the mining sector and is characterized mainly by the level of social legitimacy that a company holds to operate in the long term.

The lack of such legitimacy is one of the five biggest risks of mining today (EY, 2015), and even considers reputational damage when closing a mine. A mining company's business is extracting minerals and not its relationship with its neighbors. However, this is no longer perceived as the company's "social responsibility," but rather a fundamental issue that ensures the operation's continuity, the present value of future expansions, and the "brand" associated with the company (Kemp and Owen, 2013).[12]

The SLO establishment is determined by different factors: (i) the context, (ii) the engagement, (iii) sustainability, (iv) local benefits, and (v) adaptability (Prno, 2013). In addition to adequate impact mitigation, it is essential to maintain fair treatment and a quality relationship with communities (Moffat and Zhang, 2013).[13] The mix between expectations and risk aversion of the parties can lead to confuse the SLO spirit and focus efforts on reducing-in the short term-opposition to the company, and not to work on long-term development (Owen, 2012).

The development of trust between the company and the communities is one of the main challenges for obtaining the SLO, augmented in countries such as Chile that have low levels of interpersonal trust, and high educational gaps. Particularly in Chile (Moffat et al., 2014; MORI, 2015), society considers the mining sector important but perceives that citizens have little influence over the sector and that inhabitants surrounding the mining operations benefit less.

In summary, the country recognizes the relevance of the industry but distrusts both the companies and the government, which involves efforts to build the necessary trust, and greater legitimacy of the mining company's operation to obtain its SLO. This increased legitimacy can generate ample benefits for the communities and companies allowing the operational continuity of active projects and enabling new expansions.

6.5 What is being done in Chile?

There are several ways to approach conflict resolution and company-community engagement. Conflict resolution can be classified as (i) administrative, through public institutions with specific functions and competencies (ii) informal, between communities and enterprises through tacit agreements,[14] and (iii) judicial, through courts.

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[12] It is not core business, but its core to the business.

[13] This engagement could be more or less difficult depending on the context (for example, an indigenous versus a non indigenous community).

[14] Even if formal agreements might exist, SLO is re-evaluated constantly by the community making it hard to formalize permanently.

The optimal way for resolution will depend on the type of conflict, while the manner companies relate to communities will rely on the characteristics of the operation and its location. The international trend aims to reduce the burden of the (informal) company-community relationship and transfer part of it to new local, regional and national instances.[15]

The first recent initiatives in Chile to strengthen the institutional framework for communities and companies have been accomplished by Valor Minero and the Presidential Advisory Commission for the Environmental Impact Assessment System (SEIA in Spanish).

Valor Minero is a public-private partnership[16] in charge of the institutional innovation project "Permanent Dialogue for Large Projects."[17] This project seeks to solve the institutional deficit for the resolution of conflicts that block large projects (not only in the mining industry). In 2016, the project received funding for three years through the Strategic Investment Fund (FIE in Spanish) for US $ 2.2 million and two pilots were introduced to test the model.

The project consists of three parts: to (i) establish a system of permanent dialogue with communities, inserted in the environmental assessment mechanism, so that the effects of the project can be quantified;[18] (ii) implement a conflict resolution system whereby players can request a mediation, arbitration or conciliation; and (iii) establish a certifying entity that empowers and enhances participating organizations.

In January 2017, a first analysis of the gaps in social investment management in Chile (EY, 2017a) was presented along with a text on the community's vision over this matter (EY, 2017b). Both studies show the current state of the relationship between mining companies and the affected communities' perception of these efforts, in the Sierra Gorda (II region) area. The results reveal that communities have high expectations of the investments made by the mining companies, which do not necessarily align with reality.[19] In addition, companies do not always effectively communicate their investments, so the community

15 National regulations should set a common framework between regions, independent from the regional preferences in order not to have a regulatory overlap.

16 The council includes ministers from different areas, public agency representatives, big mining companies, trade unions, NGOs, labor union leaders, indigenous organizations, think tanks and representatives from local governments.

17 A "permanent dialogue" requires not only periodic meetings but also the existence of a person in case of unlucky or extraordinary events.

18 This option is considered because the Environmental Evaluation Service (SEA in Spanish) has capacity (that can be strengthened) to engage communities. During interviews, the communities -especially indigenous ones- highlighted that of the few interactions they had with the State, most of them were with the SEA.

19 Which proves the need of community advising in this area.

has no clarity as to who is implementing the projects. Additionally, the existence of different leaders who are not always recognized by the entire population[20] has created a complex scenario for the mining sector. In response, mining companies have reviewed their strategies and strengthened their social investments teams.

On another hand, the Ministry of Energy has made a significant effort to create a guide for overcoming problems between communities and generating companies.[21] Its methodology entails the (i) inclusion of stakeholders, (ii) early and continuous dialogue throughout the project, (iii) transparent delivery of information, (iv) social dialogue in decision-making, and (v) the project's contribution to local development.

The Environmental Assessment Service (SEA in Spanish) created in 1994 is the public agency in charge of managing and implementing the Environmental Impact Assessment System (SEIA in Spanish). In July 2016, the Presidential Advisory Commission to reformulate SEIA[22] delivered 25 far-reaching proposals to improve the system. These proposals aim to optimize the quality of the initial evaluation of externalities in mining projects, to allow a quicker assessment. Better relationships with communities would be highly favored by a good and timely operation of SEIA, which is aligned with Valor Minero, the Ministry of Energy and the international literature. However, even if the legitimacy of the SEIA process and the information it provides are critical to enabling dialogue, the SEIA is not a forum for interaction with communities. It is a technical forum for evaluating the project's environmental impact. It is a significant contribution, but not enough to settle the relational problems of the mining sector that do not consider permanent dialogue.

Another topic of interest is the indigenous consultation. Chile has signed some relevant international agreements such as the International Labor Organization (ILO) Convention No. 169, ratified in 2008, which entered into force in September 2009. This treaty provides for consultation on legislative and administrative measures that may affect native population. It must be noted that the framework of the relationship between mining companies and communities, is directly dependent on the form and possibility of approving investment projects that have indigenous communities within their area of influence.

Finding 6.2: Early, continuous, accurate and reliable information between the parties is critical to building trust between communities and mining companies.

20 Which reflects, partly, the lack of a formal and adequate institutional framework.

21 See Ministerio de Energía (2016).

22 See http://comision-seia.mma.gob.cl/

Finding 6.3: State and local governments are key players in the company-community relationship. The transparency and credibility of these, in addition to their management capacity, are decisive in enabling long-term mutually beneficial solutions.

Recommendation 6.2: Through the Ministry of Mining, promote and encourage permanent dialogue models for large projects between companies and communities through the development of a participation standard guide for large mining projects similar to that carried out by the Ministry of Energy for energy projects.

Recommendation 6.3: To implement the 25 measures from the Presidential Advisory Commission for the Environmental Impact Assessment System (SEIA) with the aim of having the best possible environmental assessment, facilitating a better dialogue between companies and communities. In particular, we emphasize the proposals of Early Relationship, Indigenous Consultation and Strengthening Citizen Participation in SEIA.

Recommendation 6.4: Implement a dispute and conflict resolution system, such as that promoted by Valor Minero, in which the parts can request mediation, arbitration or conciliation, as well as establish a certification entity that empowers and enhances the organizations that participate in the dialogue process.

6.6. Case Studies

In this section, three national experiences are considered: Minera Los Pelambres, Minera Cerro Colorado and Rockwood Lithium. Primary information was collected through more than 20 interviews with different stakeholders: government entities, mining companies, affected communities, consultants, academics and non-governmental organizations (NGOs), complemented by sources of secondary information.

Our cases consider operations located in different regions, with metallic and non-metallic mining, the presence of indigenous communities, and a difference in ownership (see Table 6.3). A synthesis table of the analysis is presented in the Annex.[23]

[23] See Annex Table A.6.2 - Case Study Synthesis

Table 6.3 - Case Study Operations					
	Region	**Ownership Nationality**	**Output**	**Mining type**	**Indigenous Communities**
Los Pelambres	IV	Chilean	Cobre	Metalic	No
Cerro Colorado	I	Foreign	Cobre	Metalic	Yes
Rockwood Lithium	II	Foreign	Lithium	Non metalic	Yes

Source: National Productivity Commission.

Los Pelambres

Los Pelambres belongs to the Chilean mining group Antofagasta Minerals, located in the valley of Choapa in the fourth region 45 km from Salamanca. It has been in operation since 1999, and now ranks as the seventh largest copper mine in the world, producing 363,200 tons of copper in 2015. Its tailings dam, port, and pipeline are located close to urban communities with which it has had various conflicts. The most relevant case is the conflict with Caimanes, a community located near the El Mauro tailings dam and which, through judicial processes, has sued for its demolition.

Pelambres' relationship with the communities has not been easy, and its engagement model has evolved with time. The beginnings were quite complicated, especially concerning the El Mauro dam. Initially, the model focused on the creation of the Minera Los Pelambres Foundation through which communities and non-mining entrepreneurship were supported. Beginning in 2013, it evolved through the creation of the "Somos Choapa" program, focusing on creating and implementing sustainable development plans for the area, along with local authorities.

At the end of 2013, baseline information was collected through consultants. The results of this study confirmed that it worked on the contingency of the incidents, mitigating and repairing the short-term environmental impacts. There was no long-term collaboration for local development, even though the company had taken about 600 voluntary commitments, but with low visibility and no specific focus.

Currently, the focus is on both social and infrastructure investments. In addition, open forums for dialogue have been held to raise community concerns and their views on the future development of the Salamanca valley. The discussions have been made in specific local areas, understanding that the needs of the areas do not necessarily coincide. The population can approach select places to ask about the program.

This increased visibility has improved the confidence in the company since the population has greater clarity of contributions and goal fulfillments. The company shares information directly, openly and transparently with interested parties through a unified communication channel.

In addition, past practices have been preserved, corresponding to the monitoring of the valley conditions, as well as the relationship and contributions to certain institutions such as the Water Resources Monitoring Board.[24]

The municipality of Salamanca[25] has actively participated in the association process and has made a greater effort to approach the more remote areas, which do not necessarily feel represented by the local government.

All the agents interviewed agree on the need for the regional government to assume coordination work between communes, since currently the relations with the company are handled separately. In many cases, small areas coincide with diagnoses and needs, but projects are not viable due to their scale. The union of several communes could achieve the minimum size required, and bring about economies of scale for larger projects. They argue that, if the State were actively present in these processes, the use of a common public good that serves the entire area could be coordinated.

One of the main observations that emerge from the communities is that there is a scant relationship between state agencies. State agencies have difficulties to work coordinately, which means that some projects are not implemented. The root of this problem can be incompatibility with ongoing (or future)[26] projects or regulatory gaps (since it is unclear as to which is the problem-solving agency(s)).

State agencies are perceived as rigid and not prone to discussing issues that are not directly related to projects. Considering the heterogeneity of the company-community relationship, this tends to hinder the development of the initiatives. However, it is necessary to take into account that part of this rigidity is because the institutional framework establishes that State agencies can only act within the limits of their competencies.

24 Water use is a constant issue in the area, especially due to past years' drought.

25 Municipality is the basic form of administrative division in Chile. The mayor is the leading authority in charge of the municipality's commune. The legal hierarchy is Nation, Region, Province, and Commune.

26 For example, in one of the communities permits were extended for modifying a common infrastructure. However, when works started it was found that members of the communities had special privileges over that infrastructure, which the local government had never notified.

As viewed by external consultants, the State could help in this type of situation as a mediator, which would favor an integrated portfolio of projects between the municipality and the mining company. However, if the formal and administrative processes are perceived as impediments, the community will not accept their participation, affecting the company-community relationship.

Cerro Colorado

BHP Billiton is the owner of Cerro Colorado. Located in the region of Tarapacá, it has been in operation since 1994. In 2015, it produced copper cathodes with 74,482 tons of copper. Originally it was due to close by 2016, but the operation's lifetime was extended by another seven years. This required water extraction from a wetland and its extension to the sector of Lagunillas. Therefore, the company approached the communities to obtain the corresponding environmental permit with the authorities.

There are four indigenous communities of Aymara and Quechua origin within the operation's area of influence. The relationship process was carried out in a timely, participatory and horizontal manner. Even though the project was effectuated before the indigenous consultation, the standards of Article 169 of the International Labor Organization were used.[27]

The communities had certain expectations: to be consulted, to have veto capacity and, through the Environmental Assessment Service (SEA), to solve community development issues. The fundamental challenge for the mining company was to build trust with the communities. With this in mind, they focused on closing information gaps through three measures: (i) to grant access to the mine site; (ii) to monitor regularly the area conditions; and (iii) to pay the expenses of advisers chosen by the communities, hired to familiarize them with the processes of the operation.

Retroactive compensation was also negotiated, which eventually led to a collaborative agreement that includes dispute settlement mechanisms and a monetary contribution allocated directly to community development. The expense of this amount must be presented annually to enable the next payment, allowing transparent accountability. A percentage was fixed through a contract to determine the maximum expenditure destined to the money's administration.

Initially, the communities did not favor the project's extension. There was a history of bad relationships due to damage of geoglyphs, aggravated by the ignorance of the actual

[27] Subscribed by Chile in 2008.

amount and location of archaeological elements in the area. In addition, citizen participation processes were made before the indigenous consultation, handling less information. Negotiations had been carried out in separate working groups with communities, excluding indigenous groups. Additionally, groups that reached different agreements, generated conflict when obtaining different conditions. For example, some negotiations were held behind closed doors without consulting the affected communities. Additionally, the transient population and other impacts directly affected the communities. Eventually, the community leaders prevented the signing of the consultations results considering that the process had been carried out incorrectly.

When the indigenous community was established, the previous transactional engagement gave way to new development programs. An archaeological cadastre was made allowing the reconstruction of the zone's history and, therefore, favored a greater valorization of the indigenous communities. The objectives included tourism development for the region (displaced by mining), and the production of agriculture and local goods, with the intention of reversing migration to cities and retaining local identities.

There is a consensus on the lack of the State's presence in the area. Specifically, communities request more resources for the SEA, which has a limited endowment in extreme areas. Also, areas near mining companies receive even fewer resources because they have the "sponsorship" of these businesses. ONEMI[28], for example, designated Cerro Colorado to help nearby local areas in the case of emergency (earthquakes or other disasters). The State's scant presence in certain areas is noticeable also because there are problems for funding applications,[29] lack of order or clarity in the consultation processes and limited access to skills training.

Rockwood Lithium

The American company Albemarle owns Rockwood Lithium. In operation since the 1980s, it has been dedicated to the processing of brines and their transformation into lithium salts. Its plant is located at the southern end of the Atacama Salar.

The company has maintained relations with the neighboring town of Peine. However, in 2010 its intention to increase its brine extraction quota was rejected. Therefore, before introducing a new project, relations with the Salar communities were improved. In 2012, a dialogue was initiated with the Atacameño Peoples Council (CPA in Spanish), which

28 The National Emergency Office.
29 This occurs because they are not landowners. The land where they live is owned by the State.

gathers 18 communities, with permanent round tables, an environmental monitoring plan and a contribution based on gross income. In 2014, a protocol was established with the communities, and in 2016, a contract was signed with binding agreements. The settlement includes participatory monitoring - including community-driven points of interest, delivery of environmental information,[30] environmental training four times a year, and a commitment to share a percentage of the benefits. In November 2016, CORFO approved the agreement.[31]

The sum of 3.5% of the profits was agreed upon, an amount not negotiated with the company, but determined in the Lithium Commission (where CPA participation was authorized). This percentage is then split, with 3.0% for the communities and 0.5% for innovation. The CPA is developing native products as a complementary economic activity,[32] which favors the sustainability of the community in the long term.

In parallel, the CPA, with funding from the Inter-American Development Bank (IDB), plans to build two photovoltaic plants to feed Rockwood and San Pedro de Atacama, increasing not only the area's development but also, enabling long term income. By November 2016, the IDB and the CPA were working to strengthen agreements to sign and enhance the allocation and use of funds. The CPA criticizes the State's absence but considers the IDB's work as a third party beneficial.

Finding 6.4: The State is not the only one that can safeguard a process of company-community relationship; other institutions can fill that role.

6.7. Conclusions

Implementing policies relating to communities is a complex task due to many factors, among them the heterogeneity of the territories. The complexity is intensified by the presence of indigenous groups, with urban or densely populated areas, and areas of agricultural, livestock or tourist activity.

There are some key principles to consider. Our three case studies (Pelambres, Cerro Colorado and Rockwood) started out with an initial rejection by the surrounding communities. In all cases, increasing information between companies and communities enhanced trust.

30 For example, water use from mountains.
31 CORFO is the owner of the mining property that will be leased to Rockwood.
32 Such as quinoa energy bars, potato agriculture and alcohols from carob and Chañaral trees.

The reduction of information asymmetries can be carried out in different ways: continual monitoring, substantial investments, visits to the mine, and unification of communication channels, among others.

However, there are relevant requirements for successful dialogue. Ideally, the community should be constituted as a unique and distinct entity (Cerro Colorado), while in other cases, the local government can help group together the different communities (Los Pelambres). In one of the cases studied, the dialogue began to bear fruit once legal advisors were withdrawn, which, as pointed out, are perceived as groups or persons that seek to arbitrate with the ultimate purpose of obtaining part of the benefits. Finally, a good company-community relationship results in binding agreements.

Sometimes mining companies have several communities in their area of influence. The recognition of different communities with specific needs allows for a better targeting of efforts by the mining company and reduces internal conflicts between communities. It is essential that the agreed development plans be advanced through community consultation. Going beyond the standards furthers the attainment of the SLO. For example, Cerro Colorado used indigenous consultation standards despite being an operation before the signing of the treaty. However, the fragmentation of efforts can reduce economies of scale in interventions that would be of direct benefit to the communities. It is, therefore, necessary to have an institutional framework capable of balancing the specific needs of each community with the general requirements of the area.

Both companies and communities highlight areas of improvement for the State. In particular, there is a lack of coordination and dialogue between public entities, which leads to fragmented efforts in the projects. Therefore, the role of “honest brokers” such as the Inter-American Development Bank in the case of Rockwood Lithium, as guarantor for establishing a long-term transparency framework for the delivery of funds, is critical.

It is essential not to confuse the role of the company with the role of the State. It is possible that in regions far from the country's economic activity, where the State is scarcely present, communities require companies to fill gaps in the provision of certain public goods (for example, health and education). Although businesses can make contributions to improve the general social conditions of the environment, this role in the long term pertains to the State. Likewise, one of the greatest challenges is the government's ability to manage-efficiently and transparently-the investments of resources contributed by companies (IIED, 2012).

The dialogue model for large mining projects and the revision of the SEIA are actions that point in the right direction and consolidating and improving them based on experience will favor a better link between companies and communities. However, one of the main concerns of the communities is: what is left in the territory once the project is completed?

At best, this problem is solved by building capacities that generate economic activity by the community, such as investment in photovoltaic energy at Rockwood Lithium, or long-term product development projects.

Ideally, this model should enter into a broader framework, such as that proposed by Valor Minero, which takes into account the Ministry of Energy Agenda 2050 and its focus on citizen participation and dialogue processes. Initially this initiative contemplates supporting and advising large investment projects. However, the initiative could also be implemented for projects carried out by the State.

6.7.1. Summary of Findings

Finding 6.1: Regulatory clarity, in aspects such as water rights, land, etc., is fundamental to establish a framework for future debates.

Finding 6.2: Early, continuous, accurate and reliable information between the parties is critical to building trust between communities and mining companies.

Finding 6.3: State and local governments are key players in the company-community relationship. The transparency and credibility of these, in addition to their management capacity, are decisive in enabling long-term mutually beneficial solutions.

Finding 6.4: The State is not the only one that can safeguard a process of company-community relationship; other institutions can fill that role.

6.7.2. Summary of Recommendations

Recommendation 6.1: Implement the proposals of the Presidential Advisory Council against Conflicts of Interest, Influence Peddling and Corruption regarding the funds received by local governments, so that local governments establish a better institutional framework, with greater transparency and efficiency.

Recommendation 6.2: Through the Ministry of Mining, promote and encourage permanent dialogue models for large projects between companies and communities through the development of a participation standard guide for large mining projects similar to that carried out by the Ministry of Energy for energy projects.

Recommendation 6.3: To implement the 25 measures from the Presidential Advisory Commission for the Environmental Impact Assessment System (SEIA) with the aim of having the best possible environmental assessment, facilitating a better dialogue between companies and communities. In particular, we emphasize the proposals of Early Relationship, Indigenous Consultation and Strengthening Citizen Participation in SEIA.

Recommendation 6.4: Implement a dispute and conflict resolution system, such as that promoted by Valor Minero, in which the parts can request mediation, arbitration or conciliation, as well as establish a certification entity that empowers and enhances the organizations that participate in the dialogue process.

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Annex

Figure A.6.1 – Main Chilean Mining Operations in Chile (as of March 2016).

Source: Mining Council.

Table A.6.1 – Types of costs to mining companies due to conflicts with communities

Capital and Financing	Loss of property value: discounts, other depreciations, sales at loss, theft
	Inability to pay debts, fall into default
	Difficulty in raising new financing
	Instability in the price of shares and / or loss in value (in a relevant period of time)
Compensation and Fines	Compensations (outside court)
Remediation	Greater social and environmental obligations: health, education and training, provision of other services, cleaning and remediation
	Administrative costs of proceedings or judgments: costs of the process itself, final settlement payments
Material Damage	Damage and destruction of private property and infrastructure
	Damage and destruction to public property and infrastructure
Risk Management	Insurance: higher premiums and coverages, risk classification
	Need for legal and conflict experts: specialized and additional personnel
Project Modification	Costs of change in design: application, redesign, legal expenses
	Additional works
Security	Payment to police force or private guards
	Higher operational costs of security: grids, patrols, escorts, transport, alarms, less mobility
	Increased training and effort in safety: time, lower production, cost of programs
Reputational	Increased expenditure on public relations: consultants, dissemination of information
	Loss of competitiveness: impact on brand and investor confidence

Source: Adapted from Davis and Franks (2014)

Table A.6.2 – Case Study Synthesis

	Los Pelambres	Cerro Colorado	RockWood Lithium
Environmental impact	Pelambres has a network of measurement of environmental variables within the Choapa valley to which the community has access. This is a fundamental issue for the community. The El Mauro dam has been the focus of attention due to conflict with the Cayman community.	Cerro Colorado has, within its area of influence, multiple archaeological sites that have been quantified along with the surrounding communities. The use of water remains a sensitive issue but related agents have been involved.	The main concern is the water drainage that come from the mountain range. Measures have been implemented to monitor their status.
Demographic Change	Since the company has been in the territory for many years, the inhabitants have become accustomed to demographic change. However, the passage of dangerous goods and trucks remains a major problem.	Problems with contractors in Mamiña due to the demographic impact significantly reduced when instructing collaborating companies to not stay in the villages.	This point was not considered relevant by the agents involved.
Management and use of land and water	The use of water is a constant problem, especially due to the droughts of the last years. The company seeks to build a desalination plant to meet its water needs.	Neither the mine or its facilities are located on arable land, so this is not a major problem.	There seems to be no conflict in this regard.
Resource leak	Much of the workforce is external to the community, but there are preferences when it comes to hiring staff.	Although the personnel belonging to the communities are small, the company has created plans in conjunction with local groups to boost the development of these areas.	Rockwood has committed 3.5% of the profits to boost the development of salar communities.
Asymmetries of information	Although there are still important information asymmetries, constant treatment with formal entities within the community has allowed for easier information exchange	Aware of these asymmetries, Cerro Colorado has funded advisors and courses in Chile and abroad for community leaders. This has allowed bringing together wills and understanding the motivations and restrictions of both groups.	The Council of Pueblos Atacameños has advisers to help them understand the processes and plan the use of the money delivered.
Governance	The Municipality of Salamanca has made an effort to approach communities that do not feel represented. In addition, the company has been concerned not to interfere in its chores.	Support programs have been addressed to each community separately, communicating with each other's leaders independently.	The company communicates with the Council of Pueblos Atacameños, which represents 18 communities. The IDB has advised them for carrying out the programs and projects.

Source: National Productivity Commission.

Chapter 7

Labor Aspects and Mining Security

Abstract

While production and employment increased significantly, the large scale copper mining industry was able to reduce the accident rate, ranking as one of the lowest among Chilean economic sectors. The challenge remains to reduce fatality rates, which are the highest among industrial sectors. This chapter refers to the challenges of developing activities over 3,000 mts. It also discusses labor market institutions and possible changes that may allow greater efficiency.

Key points

- Indicators of accidents at work show that the mining industry has improved its results compared to the year 2000.
- The fatality rate is the highest relative to other economic sectors.
- Exposure to altitude levels above 3,000 meters requires special care and monitoring of workers' health.
- In Chile, there are more hierarchical layers, higher breadth of control between layers, and reduced labor mobility between layers.
- Variable remunerations tend to encourage production over productivity.
- In the Chilean large-scale copper mining industry, the usual working period is an exceptional 7x7 12-hour workday shift, which, for each case, must be approved by the Labor Directorate .[1]
- Operational continuity is a perpetual challenge, especially in the mining area.
- There is a significant human capital gap in the mining industry, both qualitatively and quantitatively.

[1] This institution is responsable for the inspection of statutory labor and employment standards, preliminary mediation of workplace disputes and interpretation of labor and employment laws.

7.1. Introduction

This chapter analyzes labor aspects within the large-scale copper mining industry. Mainly, it examines copper workers` insertion in mining companies' organizations, and their working conditions, reflected both through health and safety aspects.

This chapter is structured as follows. Section 7.2 examines occupational safety; section 7.3 analyzes work under high altitude conditions; section 7.4 considers diseases miners are exposed to; section 7.5 addresses organizational aspects in the mining industry; section 7.6 discusses types of work-shifts; section 7.7 addresses mining issues associated with human capital; and lastly, section 7.8 presents the results and conclusions of the chapter.

7.2. Security

In mining, as in other sectors, job safety is a critical issue. Unlike other industries, the chances of accidents in mining operations resulting in fatal consequences are considerably high. In fact, according to statistics from the Superintendence of Social Security (from now on SUSESO),[1] of all national economic sectors, the mining industry has the highest annual mortality rates for occupational accidents during the period from 2011-2015; 21.6 fatalities per every 100,000 social security protected workers.[2] For this reason, companies, especially mining operations, as well as public entities, union federations, and company unions prioritize this issue on an ongoing basis.

According to the same source, the evolution of the mining industry accident rate shows a significant fall in work-related accidents.[3] In 2015 this rate was 1.5 per every 100 workers (a drop of 50% since 2006), ranking this industry as the one with the lowest accident rate in the country. In contrast, with 21.6 fatalities per every 100,000 workers, it remains the sector with the highest death rate.

1 Annual report. Social Security Statistics (2015).

2 The calculation was done considering the sum of fatal accidents (both at the mine and at commute) in 2011-2015 as the numerator, and in the denominator the average number of workers protected by mutual societies (protected workers) and ISL (insurance workers in spanish). Social Security Statistics 2015. Note that for the entire economy this rate is 5.2%.

3 There is only data from mutual societies (ACHS, IST, MUSEG) since there are no work accident data for the insurance workers (ISL). The sample with which the calculation is made represents approximately 75% of the protected workers. In addition, it does not distinguish between direct employees and contractors. See Social Security Statistics 2015.

However, it is it is one of the few sectors that displays a downward trend in the fatality rate during this period.[4] Specifically, the Fatal Labor Accident Register shows 29 deaths for the mining industry in 2011, while in 2015 there were 10. These figures do not make any distinction according to the size of the mine, although both indexes (accidents and fatality) tend to be lower (in proportion) in the large-scale mining industry, in comparison to the medium or small-scale mining industry.

Another aspect worth mentioning is accidents that occur commuting to (and from) the workplace. In mining's case, this issue is important, taking into account the industry's shift dynamics.[5] SUSESO statistics show that for the analysis period going from 2006-2015, this was one of the sectors with the lowest rate of journey accidents (0.3 accidents per every 100 protected workers).

However, according to the same source, it also presented the largest proportional increase between 2014 and 2015, with 51%. In addition, it is one of the sectors with the highest average growth for the 2006-2015 period (1.3% per year).

Another source for accident statistics is the National Balance of Mining Accidentability (SERNAGEOMIN, 2016). As in the previous case, this report states a clear downward trend in the mining industry's accident rate[6] and number of fatalities[7] between 2000 and 2016.[8] Figure 7.1 shows the accident rate measured over one million working hours. By the year 2000, 7.3 accidents per million of person-hours worked were reported, with a reduction of 47% in 2009 (3.9), and a decrease of 54% in 2015 (1.8). On the other hand, the decline in the fatality rate ranges from 0.18 to 0.04 fatal accidents per million working hours (a 77% reduction). Figure 7.1 also adds data from the Mine Safety and Health Administration (US Department of Labor, 2016) regarding the fatality and accident rate of metal and non-metallic mining for the 2000-2015 period.[9] The conclusion is that, in comparison, the accident rate in the United States is higher than in Chile, with 22.3 (versus 7.3) in 2000, and 10 (versus 2.1) in 2015, for the entire period, however, the fatality rate is lower in the United States. Towards the end of the period, Chile converges to North American standards. Specifically, as of the year 2000, the fatality rate in the United States is 0.11 accidents per million working hours (versus 0.18 in Chile), while in 2015 the rate turns out to be 0.04, just as in Chile.

4 See Social Security Statistics 2015.

5 The bulk of the mining workforce works in two shifts per day of 7x7. This implies peak transfer and exit times.

6 Accidents that cause temporary disabilty or are fatal per million person-hours.

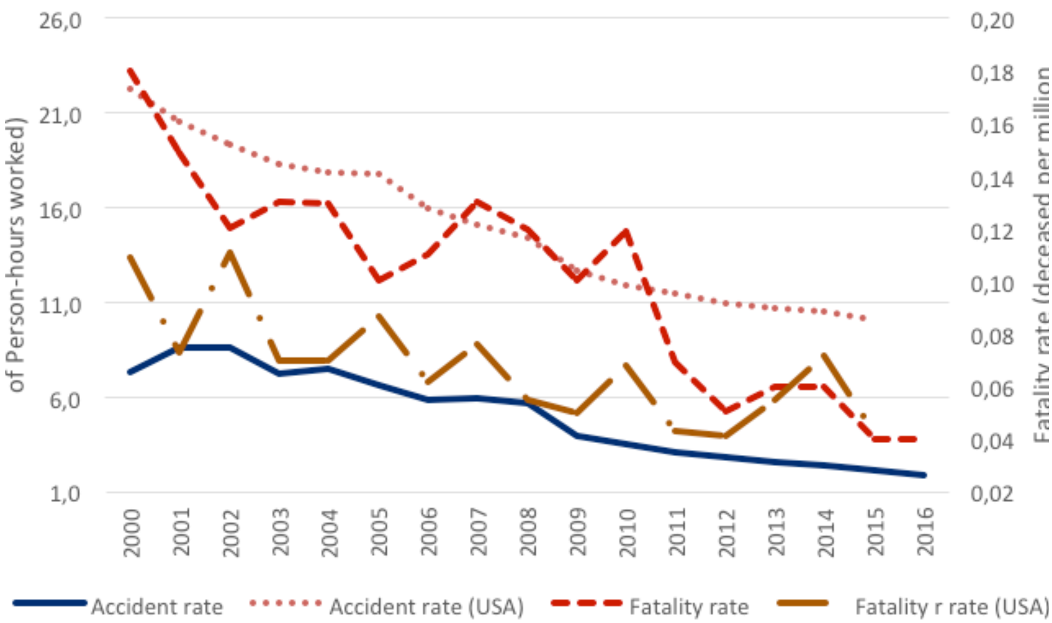
7 Deaths from work-related accidents per million person-hours.

8 Like the previous case, these statistics show no distinction between direct employees and contractors.

9 As in the Chilean case, the figures consider both contractors and direct employees.

It is worth mentioning that both the SUSESO and the SERNAGEOMIN surveys and statistics do not reflect any distinction amongst employees and subcontracted workers.[10] However, in SERNAGEOMIN's case, concerning fatalities, the proportion of deaths of the companies' own employees exceeds that of contracting companies' workers.[11] On the other hand, according to comments received in the development of this report, the accident statistics related to subcontracted workers and contractors seem to be higher than the values reported here.[12]

Figure 7.1. Accident and Fatality rate 2000-2016



Source: Balance Nacional de Accidentabilidad Minera (2016) and Mine Safety and Health Administration (2016).

10 In the Superintendence's survey, there is no mention of the issue. Regarding Sernageomin, there is a brief description, but without detail.

11 The proportion of deceased directly employed workers ranges from 48-77% for the 2000-2016 period.

12 The figures presented here can be considered as a simple average of the rates of hired workers and contractors. Therefore, if the figures associated with contractors were higher than the official figures, then the figures associated with directly hired workers should be lower than those of SUSESO.

During the same period that accidents and fatalities were analyzed, the mining sector significantly increased both its number of workforce and the amount of transported mining material ("moved material"). When comparing their evolution (see Figure 7. 2), there is a substantial drop in deaths concerning the variables mentioned above. Specifically, regarding the level of employment, in 2000 the numbers show one fatal accident per every 2,289 employed workers, while in 2014; it is one for every 6,960 employed workers. This reduction is a significant achievement,[13] which highlights the concern and willingness everybody in the area displays regarding this issue,[14] since the increase in mining's level of employment (as in moved material) during the period, could have induced a more substantial number of accidents. A similar exercise, concerning moved material, shows a fatal accident for every 132 million tons of material moved in 2000, versus one fatality for every 342 million tons in 2014.[15] In summary, these figures reveal an industry focused on avoiding accidents, which has improved measures to protect workers and reduced the severity of potential accidents, while, on the other hand, has more than doubled its endowment and volume of moved material.

Comparing the sample of twelve Chilean operations with the benchmarked countries of Chapter 3 (Australia, Canada, and the United States), we observe similar accident rates per million hours worked (see Figure 7.3). This is proof that large Chilean mining industries have converged towards international best practices in the past years. With the information gathered at company level (2015), the indicator that Chilean operations display is better than the considered international operations' indicator, and only three national mines show rates above the global rank. Notice that the values of the range of the international mines visited were below the US accident figures observed in Figure 7.1 (in the aggregate), which may confirm the fact that the international sample used employ best practices in their day to day operation. [16]

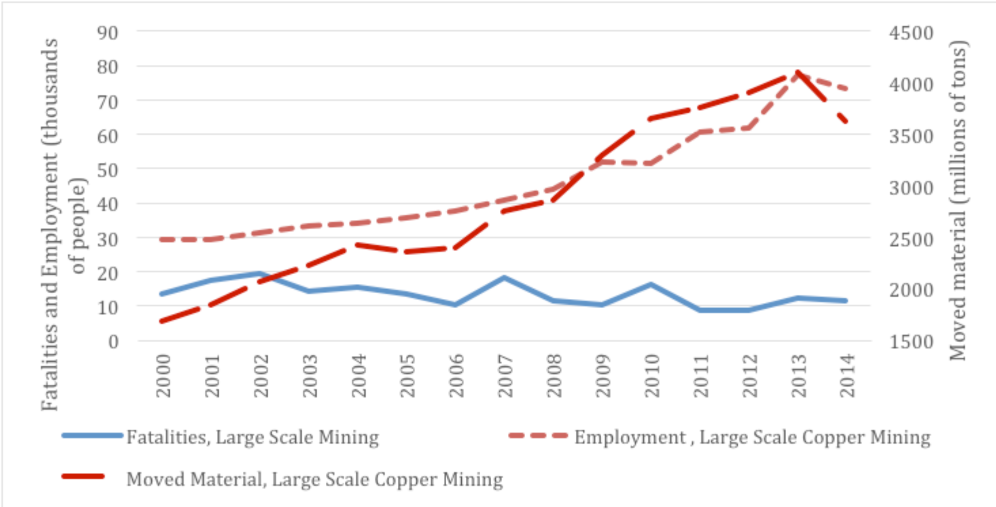
13 For example, the focus on production due to the price cycle might have generated less concern for safety, or, for reasons of agglomeration, generating more accidents. In this sense, it is necessary to consider that the first cause of fatalities, according to SERNAGEOMIN, turns out to be the detachment of rocks, and if the moved material increased significantly this would have increased the fatalities. However, the figures show otherwise.

14 Put another way, the increase in employment (for example) could have led to a greater number of fatalities (or accidents) thus maintaining the proportion. However, both fatalities, and accidents were reduced.

15 During this period, the volume of moved material increased by 119%.

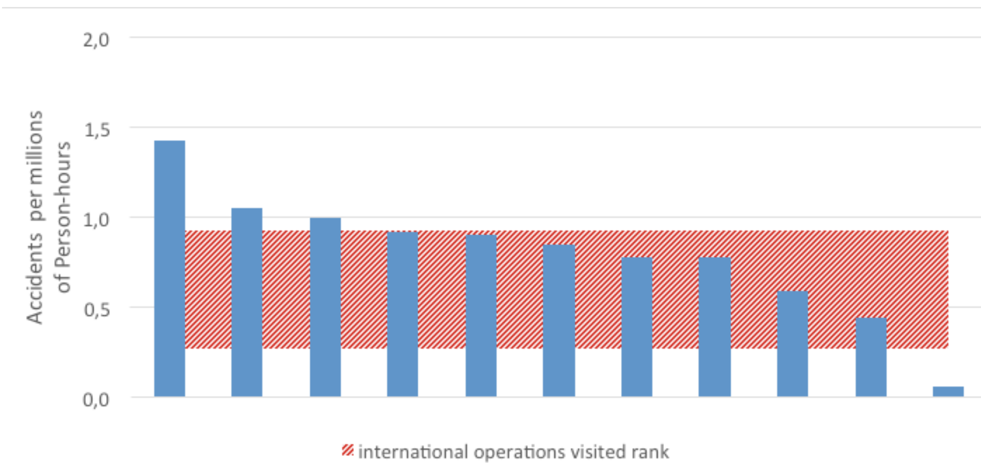
16 Note that the same domestic figures are lower than Sernageomin's average balance.

Figure 7.2. Fatalities, Employment, and Moved Material 2000-2014.



Source: National Productivity Commission based on Cochilco and Balance Nacional de Accidentabilidad Minera (2016).

Figure 7.3. Accidents frequency rate with stoppages per million of worked hours 2015



Source: Nationl Productivity Commission based on Matrix Consulting.

The Labor Code art. 184 establishes that "The employer shall take all necessary measures to protect the life and health of workers effectively..." The same requirement extends to the responsibility of the principal over that of a contracting company.[17] Both requirements are reasonable and do not differ in spirit from other legislations: the employer has all the mechanisms to identify hazards and control risks and must be liable for negligence or willful misconduct. In recent years, the companies' safety efforts have generated a positive impact regarding accident reduction and its severity, allowing large-scale mining to reach international best-practice levels. The current challenge is to continue to improve indexes while increasing both production and productivity.

According to Chilean law, in case of a work-related accident, the worker is entitled to economic benefits whose coverage comes from two sources: 1) accident and occupational disease insurance administered by Workmen's Compensation agencies and hired by the company,[18] and 2) from the primary employer by way of compensation. The former is determined by the insurer according to the loss of capacity of the affected worker, and the second by a court of law.[19] Workers criticize the first case, claiming insurance companies have a conflict of interests, who additionally determine accident or illness coverages since they are also in charge of determining whether a disease or injury is work-related.[20] In the second case, the public hearings carried out during the development of this report mentioned the excessive documentation that must be elaborated and delivered by companies in order to demonstrate their preventive actions and thus leave a record of the mentioned security efforts.[21]

Compared with the international experience of Australia, Canada, Sweden and the United States, the Chilean industry seems to invest in more security-oriented resources. There are two kinds of resources. The first, of higher importance, refers to the time and

17 Article 183-EA of the Labor Code.

18 Law No. 16,744.

19 Law No. 16,744, Article 69: When the accident or illness is due to the negligence or willful misconduct of the employer or a third party, notwithstanding any criminal actions that may arise, the following rules shall be observed: (...) b) The victim and other persons to whom the accident or illness causes harm may claim compensation to which they are entitled from the employer or third parties responsible for the accident, in accordance with the provisions of the civil law, including moral damages.

20 Once the occupational disease is determined, the eventual loss of capacity or permanent disability of the worker must be determined. The Preventive Medicine and Disability Commission (COMPIN in spanish) must carry out the evaluation of an occupational disease. The worker (or other party) may complain to the Medical Claims Commission of Law No. 16,744, an agency belonging to the Ministry of Health. The latter's resolution may be appealed to the Superintendence of Social Security, whom will ultimately resolve.

21 According to interviews in mines, sometimes it is excessively documented to have better legal protection.

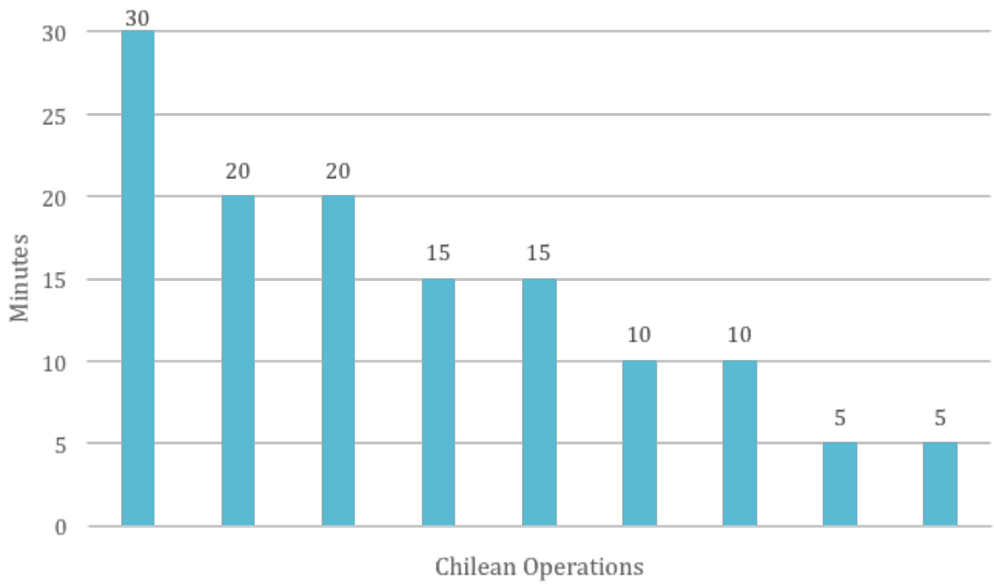
effectiveness of personnel training and formation in order to prevent accidents. The latter relates to the time used in confirming that the first took place. According to the qualitative information collected in the comparison study,[22] results show that Chile highly emphasizes validating the protection and risk prevention measures that have been taken (through forms and protocols). On the other hand, the international sample shows that the greatest efforts rely on creating awareness of the hazards and risks in the workplace. As an example, before performing maintenance in Chile, the time spent in filling out forms (or protocols) can take 40 to 60 minutes, which does not necessarily ensure a safer work performance but reduces the effective time of work and equipment use. In the international mines visited, this procedure takes between 5 and 15 minutes. Besides, there are mandatory safety certifications for workers (either employees or subcontracted workers), governmentally regulated as to their minimum content, duration, and frequency. Therefore, any employee holding a valid certification requires only a short talk related to that particular mine. However, considering the accident and fatality figures of SERNAGEOMIN and the Mine Safety and Health Administration of the United States, the different safety management strategies may explain the lower accidentality and similar death rates in Chile in comparison to the United States.

The international mines visited also show an ongoing concern for safety and low rates of accidents and fatalities, though focused on the workers' self-care and based on previous safety training (regulated by the Government in coordination with the industry). It consciously seeks to reduce the burden associated with workplace talks, documents and registration, thus avoiding redundancy and bureaucracy. Currently, in Chile, mines and suppliers are working together to standardize security talks and other actions, which would be an opportunity for improvement in this area (see Chapter 10).

Figure 7.4 shows the duration of safety talks conducted by the national study operations. The observed variation is consistent with the accreditation time required for suppliers and contractors (Chapter 10). Again, some domestic operations report indicators comparable to international best practices, while others require six times more for an analogous safety talk. Obviously, a criteria approval and workers' prior certification would be of the sector's interest.

22 See Chapter 3.

Figure 7.4. Average duration of safety talks for truck maintainers (daily)



Source: National Productivity Commission based on MatrixConsulting Study.

Finally, it is worth mentioning that the work currently being carried out by the public sector on miner's labor security is the institutional strengthening of SERNAGEOMIN regarding the control of mine site safety. For this consolidation, three concrete actions have been established. The first has to do with the bill intended to amend D.L. No. 3,525. The project grants SERNAGEOMIN new regulatory and supervisory capabilities, establish new sanctions, and raises the penalties for fines in case of violation of mining safety standards. This project also seeks to raise the rank of law certain matters that are currently only regulated by statutes. Finally, through the project, it aims to provide SERNAGEOMIN's sanctioning power with a particular procedure that fully complies with modern standards on due process. The second action has to do with the amendment to mining safety regulations. Specifically, adjusting the standards set by the regulations to the current reality of the mining industry, overcoming regulatory deficiencies, improving the drafting and structure of the rules, and incorporating new issues to introduce the necessary changes at the managerial level in order to strengthen SERNAGEOMIN's functions.

Finding 7.1: In a context of increased production and employment, the mining industry, and in particular large-scale mining, has improved its results in work-related accident indicators compared to the year 2000. However, the fatality rate remains higher than in other economic sectors. The rate of journey accidents, although one of the lowest among sectors, has also been increasing. The challenge is to improve its safety indicators while increasing production and productivity.

Recommendation 7.1: To continue strengthening the joint effort carried out by companies, workers, suppliers and the government in the field of occupational safety, in order to keep reducing accident and death rates, while allowing production and productivity increase.

7.3 Geographic Altitude in the Mining Industry

A consistent issue that arose in this study's public hearings corresponds to the effects of working at high altitude since several sites are located over 3,000 meters above sea level, including copper and gold deposits.[23] At high altitudes, there is less oxygen, which causes hypoxia or "altitude sickness," a state of oxygen deficiency in the blood, cells, and tissues of the body, compromising their function.[24] Hypoxia can be acute (by transient exposure), or chronic (by prolonged exposure), and its main symptoms are headaches and insomnia. Hypoxia symptoms occur more intensely during the first two days of altitude exposure.[25]

In Chile, Supreme Decree 594 regulates the levels of exposure associated with altitude sickness (Ministry of Health).[26] It requires ad hoc health before entering a mine and during the term of the contract.[27] Failure to comply with these health levels forces the employer to relocate the workers at an altitude that does not endanger their health, and without affecting the employees' salaries. Therefore, in Chile, it is necessary to establish an adequate level of health for workers at mines set at over 3,000 meters

23 Main operations over 3,000 meters above sea level (masl): Quebrada Blanca, Salar Surire, Collahuasi, Escondida, Zaldívar, El Abra, Chilean Lithium Society, SQM Salar, SQM Lithium Carbonate, Can Can Mine, Maricunga, Nevada, Los Pelambres, El Indio, Andina and Los Bronces.

24 Institute of Public Health (2015), Work in Geographic Altitude in Chile.

25 The lack of oxygen also affects the efficiency of internal combustion equipment (trucks, shovels, etc.), which have a yield of between 20 and 30% less at heights over 3,000 masl. The gap analysis in Chapter 3 suggests that this affects the cost of mining operations, but not the equipment's productivity. That is, trucks can carry the same load, but consume more fuel.

26 Decree 28 (2012) and Technical Guide of the Ministry of Health, which establishes the concepts of "high altitude" (over 3,000 masl) and "extreme height" (over 5,500 masl), and the requirements for work.

27 Through yearly surveys and evaluations.

above sea level by carrying out a series of examinations (higher standard than the tests for workers not exposed to height). The Ministry of Health defines 33 pathological conditions that contraindicate work at height, including hypertension, cardiovascular diseases, pregnancy, and body mass over 35, etc., most of which are present in the adult population of the country.

Subject to shifts, workers who work at mines above 3,000 meters receive intermittent exposure to altitude. Although there are current studies on the impact of altitude exposure, the evidence regarding its intermittent and cumulative effect is inconclusive.[28] Therefore, the Superintendence of Social Security commissioned the University of Chile[29] with the development of a five year study.[30] The study presented the results for the first year. The prevalence of acute mountain sickness on the first day of the shift reached 23% in the upper stratum (over 3,900 masl), while in the middle levels (between 3,000 and 3,900 masl) and lower levels (under 2,400 masl) it was 3 and 8% respectively. At the cognitive level, there were significant differences in motor skill measures between strata, although with mixed results. There was also a marked effect of altitude on sleep disturbance, being three and four times higher in day and night shift, respectively, in the upper stratum to the lower stratum. However, the cumulative and long-term impact of the effects requires follow-ups for several years for proper understanding.[31]

Since intermittent exposure over 3,000 meters is particular to the mining industry,[32] practices associated with reducing the risks of "altitude sickness" and occupational health criteria should be adjusted over time as the results of the study come out. Among the international mines consulted for this study, mines located at altitudes above 3,000 meters are found only in Peru, but no specific regulations were identified for comparison. Neither does the United States have a specific provision, even though it has had some mining activity at high altitudes.

28 A study conducted in 2013 by the Department of Public Health of the Catholic University (funded by SONAMI and the Mining Council) found no prevalence of risk factors for chronic diseases in workers at height compared to the general Chilean population.

29 See Superintendence of Social Security (http://www.suseso.cl/607/articles-40199_archivo_01.pdf

30 Occupational Health Program (2015). Effects of intermittent exposure to high altitude on the health of workers in mining operations. School of Public Health, Faculty of Medicine, University of Chile.

31 In another study, 30 Chilean mining workers who had no previous occupational history at geographical altitudes were followed during the first 3 years of intermittent 7x7 shifts at altitudes of 3,800 to 4,500 meters. Results showed that during the first 12-18 months hemoglobin, blood pressure, erythropoietin, pulmonary artery pressure and renin increased and that between 19-31 months these signs showed a significant attenuation, approaching the pre-exposure values.

32 People working in astronomical observatories are also being included.

Finding 7.2: There is evidence that intermittent exposure to altitude levels above 3,000 meters requires special care and monitoring of workers' health.

Recommendation 7.2: Adapt Supreme Decree 594 of the Ministry of Health regarding work at heights, as the results of the Social Security Superintendence studies come out in the future.

7.4. Occupational Diseases

Although the aspects associated with both job security and work at high altitudes are issues of prime importance to the national mining industry, these are not the only issues relevant to the workers' health. Like the previous aspects, occupational diseases have an impact on the productive capacity, subtracting hours of work and reducing the employee's capacity to perform suitably.

According to SUSESO statistics, the proportion of diagnosed diseases on the number of the sector's protected employees shows that by 2015 mining was among the industries with the highest frequency of occupational diseases, with 0.16 per every 100 insured workers.[33] The national average was 0.13 per every 100 covered workers.[34] With data from SUSESO, we observe that in 2014 there were some diagnosed diseases that tended to be absent in mining (dermatological conditions), some present in several areas (mental or osteo-muscular ailments), and others that tend to be more prone to mining (respiratory diseases). The same source reports that around 3,300 days a year are lost in the mining industry because of occupational diseases. This amount is significantly lower than the amount of days lost due to work and travel accidents, which exceeds 40 thousand days.

In sum, the mining industry tends to have a high fatality rate, but a low accident rate and has a slightly higher rate of occupational diseases than the national average.

33 2015 data may differ from previous figures because currently, diseases that cause permanent disability or death without lost time are now incorporated into the register of occupational diseases.

34 Industry reports the highest rate (0.21) while Electricity, Gas and Water has the lowest (0.07).

7.5. Organizational Aspects

This section presents a description of organizational aspects in Chilean mines. The lack of uniformity observed in several areas may explain part of the differences found in productivity within Chile, related to the international sample. These findings are the result of interviews carried out in the mines considered in Chapter 3 and information compiled by the Mining Competencies Council (CCM).

7.5.1 Organization and Incentives Design

Hierarchical levels

Distinguishing hierarchical levels in operation, supervision, and management,[35] the majority of the operations visited in Chile present, in average, seven levels, eight being the maximum and five the minimum (see Figure 7.5). In the case of the international mines visited, these levels range between 4 and 5, with lower levels of supervision and greater autonomy of workers. This is relevant in mine operations because at higher levels there are higher organizational costs, mainly due to coordination difficulties, dilution in the definition of responsibilities, and internal bureaucracy. With more levels, the autonomy of the worker is reduced, and consequently, his ability to react to random events is impaired.[36] Practically, in the end, more time is devoted to interruptions or activities not related to the operational process.

The high amount of hierarchy levels may be due to the work skills of the mining labor force (a cross-sector problem). On the one hand, comments gathered from the public hearings performed for this study pointed at the real planning capacity and assignment of responsibilities of the middle and upper levels,[37] as well as the capacity for coordination and degree of skills of the lower levels.[38] In this regard, one of the recommendations of the Council for Mining Competencies CCM (of the Mining Council) 2015 report recognizes the first line supervisor as a productive lever for the operation.[39] In the short term, the

35 Management: general manager, operations, area and process. Supervision: superintendents, area heads and shift chiefs. Operation: operators and maintainers.

36 For example, unscheduled interruptions within the unit process analysis in Chapter 3. Lost exogenous time in the unit processes associated with online interruptions can also be associated.

37 University professionals.

38 For example, certain mines have been replacing contractors for direct employees because the former have lower capacities for particular tasks. This has occurred mostly in the maintenance area.

39 Note that the CCM updated the profile and skills required for the position, and considers that the professionalization of technical roles points to greater autonomy and responsibility in the execution of tasks.

challenge to improve this area resides on the companies' side; however, it is evident that the problem lies structurally in the national training system. Therefore, public policy in this area is essential.

Figure 7.5. . Hierarchical layers in visited Chilean operations.

Source: National Productivity Commission based on MatrixConsulting Study.

An important difference between Chile and international operations concerning training and skills is related to labor mobility at the different levels within the mine: supervision, and management. In Chile, every worker remains within his/her work level,[40] whereas in the global sample (Australia, Canada, and the United States), companies have a policy of identifying high potential employees and promoting them to higher levels. Thus, workers with additional training in leadership and soft skills manage to be promoted to supervisor, which in turn can rise, after further studies, to management levels. These actions seek to align objectives between the parties since workers who perform better,

40 However, there are practices at the domestic level that are replicated and promoted within the industry, such as the detection of talents carried out by some of the mining companies.

access larger benefits.[41] Also, it provides the operator with greater responsibility and operational knowledge of the mine.[42]

It is necessary to have meritocracy within the organization to implement these incentives at a national level. On a regular basis, Chilean companies tend to replicate internally a high social stratification, where it is common to find university graduate supervisors who manage workers with decades of experience in the industry. In fact, in the Chilean large-scale mining industry, about 75% of the supervisors are university graduates, while in other countries, 75% are promoted technicians or operators. In Chile, experience is undervalued, while professional titles are overvalued.

Outsourcing

Another difference between Chilean and international mines is the proportion and targeting of outsourced contractor workers in the mines. According to the Workforce Report of Chilean Large Scale Mining Industry (2015-2024), elaborated by CCM and Fundación Chile's Innovum, in Chile the average outsourced contractors per employee is 1.7, although there is a significant dispersion amongst mines. Of the studied mines, four are above average, while one trebles the average (with 5.8 outsourced contractors per worker). In the United States, the proportion is 0.5 outsourced contractors per employee.[43]

Regarding subcontracting, the industry has benefitted from it in recent years, which is why the share of these workers over the total has increased from 40% to 65% in the past decade.[44] Contractual flexibility, specialization in certain activities and lower costs for the company have justified the requirement of their services. However, currently, there are higher costs, higher levels of conflict, decreased commitment towards the operation, and, in some cases, the decline in human capital has motivated some mines to reduce subcontracting in activities they consider key to operational continuity.[45] In addition, workers (either a direct employee or outsourced contractor) conclude their bargains with

41 Pecuniary and non-pecuniary.

42 The CCM considers necessary retention initiatives, with training programs and certifications based on sectoral standards, which allow engaging workers and keeping them in the sector.

43 See statistics from the Mine Safety and Health Administration of the United States Labor Department. This figure is approximately one contractor per direct employee when subgroups associated with metallic and non-metallic mining are considered.

44 Consider as well that total employment more than doubled in this period.

45 Especially when it comes to maintenance. This is very relevant considering that according to Chapter 3, half of the non-productive time is allocated to maintenance (corrective and planned). Low competencies in this area have an impact on the operational performance of the mine.

their direct employer, which means carrying separate collective bargaining negotiation processes,[46] even for similar mines, with different results.

The role of outsourcing in international operations tends to differ from the one in Chile. Nationally, maintenance concentrates most outsourcing,[47] but in the international mines, it is more heterogeneous, and overall, much less used. In some Australian, Canadian, and American mines, subcontracting is usually used in specific and highly qualified processes (e.g., environmental consultancies), or in processes of lower qualification (e.g., cleaning and meals). In one of the mines visited, the entire plant and mine activities are subcontracted; in another, its direct employees carry out the whole process. The interesting thing about the heterogeneity in this area is that all these mines tend to be more productive than Chilean operations. That is to say, regarding productivity, it does not seem to matter whether the workers are direct employees or from outsourced contractor firms. Apparently, human resource management and organization of a skilled workforce are more important. In order to validate this, according to information gathered for Chapter 3 of this report, no robust correlation between productive capacity and degree of subcontracting has been found nationally.

Breadth of Control

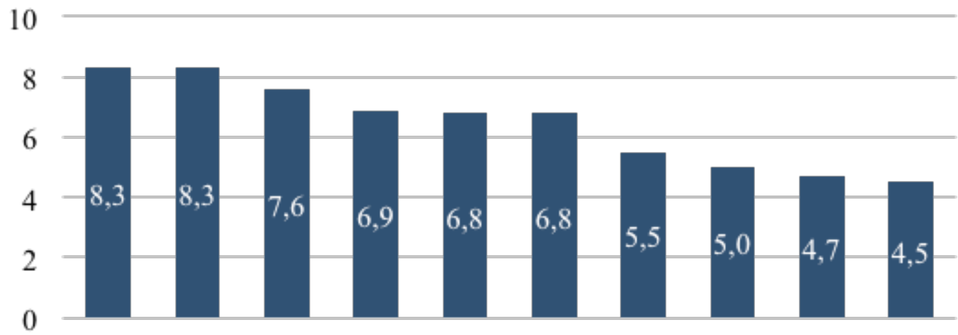
The breadth of control (or "span" of control) is a relevant indicator regarding the ability to manage and organize work, measured as the number of supervised workers (e.g., operators and maintainers) per supervisor. A smaller number of employees per supervisor means that the organization has a lower management capacity, reflecting the need for greater control. This also leads to more bureaucracy and time spent on tasks that do not add value. On the other hand, supervisors with more workers will have a larger focus on the coordination and day planning, and the employees will enjoy greater autonomy.

Figure 7.6 shows the proportion of workers (operators and maintainers) per supervisor in the national operations mine area. On average, each supervisor has 6.4 employees,[48] with 8.3 being the maximum and 4.5 the minimum. According to the CCM,[49] Chilean supplier companies have followed an undesirable trend: they had an average of seven workers per supervisor (2012); by 2015, the control range fell to five (i.e., more supervisors in relative terms).[50] While in mining companies, this ratio fell from 11 workers per supervisor (2012)

46 Company, contractor, direct employee and contractor.
47 By 2015, 61% of contractors focus on maintenance.
48 Median of 6.8.
49 Labor Force of Large-scale Chilean Mining Industry 2015-2024.
50 Recall that these employees currently represent just under 2 of every 3 jobs in mining.

to 9.6 (2015). International best practices show ranges of control between 10 and 15 subordinates per supervisor. Regulatory aspects,[51] as well as skills and competencies of the workforce, may account for some of the differences observed.[52]

Figure 7.6. Number of operators/mantainers per supervisor



Source: National Productivity Commission based on MatrixConsulting Study.

Remuneration and productivity

The remuneration composition is necessary to design incentives aimed at aligning the company's objectives with that of the workers. Both inside and outside the country, there are different proposals. For example, in the United States, the workers do not receive bonuses, while in Peru, by law, 8% of the profits of the company are distributed to the employees. Aside from these extreme cases, the usual practice considers a fixed payment and a variable component linked to the productive performance (cost savings, safety indexes, or other key indicators) associated with the worker's performance, but also to the complete result of the operation.

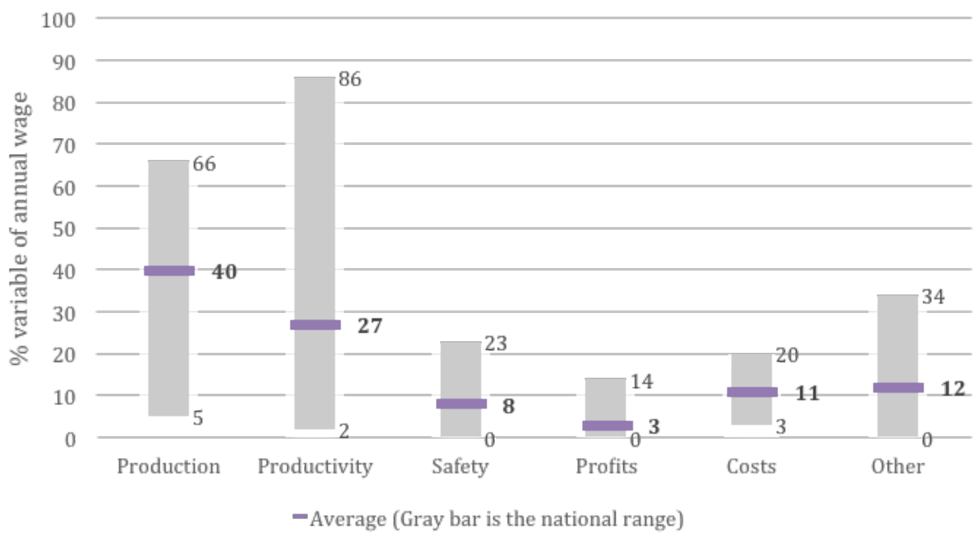
From the information obtained in Chapter 3 regarding the components of wages, we conclude there is a significant dispersion in national mines regarding this area. Figure 7.7 shows that, on average, 40% of variable remuneration is determined by production objectives, which range from 66% to 5%. The second critical component is productivity,

51 For example, in Chile, the regulations lead to a separation between personnel dedicated to risk prevention of a direct employee and a contractor. Otherwise, it would imply that the contractor considers himself a direct employee if he has a superior of the mother company.

52 For example, the lack of skills that allow greater independence in decision-making.

with 27% on average, although it has a significant dispersion: between 86% and 2% of variable remuneration.[53] Considering that the values are a simple average, it is clear that most operations assign a small importance to the productivity component.[54]

Figure 7.7. Wage composition in operations (operators and maintainers)



Source: National Productivity Commission based on MatrixConsulting Study.

Finding 7.3: Organizational practices differ amongst mines within Chile, and also significantly concerning international mines. In Chile, there are more hierarchical levels, lower levels of supervision, and poor mobility between levels. At the national level, variable remuneration tends to encourage production over productivity.

53 In this case, the component considers factors such as equipment performance, utilization, availability, maintenance times, and first-hour production, among others.

54 If the distribution were symmetrical, an average of 44% would be expected for productivity and 36% for production.

7.5.2 Food and Mobile Dining Areas

Chilean legislation requires the employer to provide food to his workers when they cannot acquire it on their own, due to distance or transportation difficulties.[55] Such is the case in Chilean mining, which operates in 12-hour shifts and away from urban centers, typically in mining camps. When workers have their meals at their job site, a catering service is required,[56] for there are no other possibilities for food consumption in the workplace.[57]

Considering the distances within Chilean operations,[58] workers' travel time between the job site and the dining rooms is relevant. Therefore, travel time must be added to the statutory dining time, which, in the case of the sample, is 26 minutes on average for mine maintainers, but, in some cases, may exceed 40 minutes. According to the analysis in Chapter 3, travels (to dining rooms, at the beginning and end of the shift, change of clothes, talks, etc.) account for (on average) a quarter of the time not used by workers in tasks pertaining to the mining operation (e.g., use of available equipment).[59] The time allocated to food consumption is a right,[60] but the transfer times associated with it can be managed. There are two options for the mines: dining rooms can be taken to the job site, which implies the establishment of more than one dining room within the same operation, therefore attending different areas of the operation in a shorter time. A second option is to implement mobile dining rooms,[61] allowed by regulations.[62]

The health authority must approve the existence and operation of dining rooms (fixed or mobile) with a catering service.[63] The interviews carried out for this study indicate that, in some cases, the authorization process may take over a year.[64] The interpretative

55 This requirement is not laid down in the legislation for all productive sectors, but it is for seasonal workers in article 95 of the Labor Code. The Labor Directorate, regarding administrative decisions, has extended the application of this rule to other activities.

56 Supreme Decree No. 594, article 28 et seq. The requirements for dining rooms essencially demand them to be completely isolated from work areas and sources of environmental pollution; maintained in adequate hygienic conditions; having washable table and chair surfaces; floor of solid material of easy cleaning; and provide drinking water for washing hands and face.

57 For example, consumption of food at the workplace is permitted in the US.

58 The Large-Scale Mining Industry in Chile surpasses the standard size of production worldwide, which is why the distances within the same mine are important compared to the world average.

59 This applies when there are no interruptions due to factors exogenous to the particular activity. For example, climatic issues or upstream or downstream interruptions.

60 A 12-hour day considers 1 hour of rest, which should at least include feeding time.

61 In a number of cases, there are sporadic expansion projects, which means an increase in the amount of workers to be transferred, so the implementation of this type of solution is ad-hoc.

62 Supreme Decree No. 594, article 29.

63 Supreme Decree No. 594, Article 31

64 This span of time may exceed the project's term if, for example, the project is an extension of the plant in which the activity is carried out.

scope for this norm is proof of the dispersion regarding the delivery of permits. In fact, the National Productivity Commission mentioned this issue while referring to streamlining and improving the process of granting sanitary authorizations in its review of productivity agendas of previous governments. Specifically, among the recommendations in this area was to objectify, through regulations issued by the Ministry of Health, the criteria used by the Health SEREMI to grant sanitary permits and their audit work.

The main difference with regards to the international mines visited, is the possibility of food consumption in the workplace, something that Chilean regulations prohibit. Seven of the international operations use mobile dining rooms. Only in the US, the dining time in twelve-hour shift days is not allocated to the working day.

Finding 7.4: Due to the characteristics and scale of the Chilean mining industry, travel times affect the productivity of mines, influencing the hours worked and the use of the equipment. It is possible to reduce the times of travel by the use of mobile dining rooms, but delay in the processing of these permits limits the effectiveness of this solution.

Recommendation 7.3: The Ministry of Health should institute unique and explicit criteria for the establishment of mobile dining rooms not subject to interpretation and thus expedite the process of approval/ rejection of the request.

7.6 Work days and shifts

This section describes the types of workdays stipulated by law. In Chilean mining, "exceptional days" are analyzed in detail since they are considered "ordinary workdays". A brief analysis, based on the information gathered for this study, is also focused on how adequate this type of working day is.

7.6.1. Types of Working Times Permitted by Regulations

The Labor Code defines the Ordinary Weekly Working Time,[65] Biweekly,[66] and Special Work Time[67] for various sectors of the economy.

The Ordinary Weekly Working Time has a maximum of 45 working hours per week, with no possibility of a monthly, quarterly or higher consolidation. This working time must also comply with the following rules: (i) the workday may not exceed 10 hours, (ii) the workday should be divided into two, not necessarily equal segments, interrupted by a space of at least 30 minutes that may not count as part of the work day, and (iii) any working time of over 40 hours per week should be distributed between five and six work days.

The Biweekly Ordinary Working Time applies to services rendered in secluded locations. This working time allows up to 12 consecutive work days followed by three resting days, subject also to a maximum of 10 hours a day, and up to 90 hours in the bi-weekly cycle. In other words it accounts for a maximum of 7.5 hours average per day in 15-day cycles (12 workdays per three rest days).

Finally, the legislation provides for the existence of a Special Working Time for certain activities, which allows the use of particular shifts, due to the job the workers perform. Several cases of this special working time allow daily workdays of up to 12 hours. Navy, port workers, flight crews, cabin crews, professional athletes, urban and intercity passenger locomotion drivers, railways, hotel, restaurants and club workers, firefighters, domestic services, etc. all enjoy this type of shift.[68]

7.6.2. Exceptional Working Time in Mining

Despite its peculiarities, mining does not have a "special working time" scheme. For the most part, the large-scale mining industry uses the "exceptional working times," which is an exception to the ordinary schemes described in 7.6.1 above, and allows for

65 Articles 22, 28 and 34 of the Labor Code.
66 Article 39 of the Labor Code.
67 There are certain positions, regardless of the economic sector, that are not subject to the limitation of a work- day, according to the autonomy and work place under which the position is perfomed. Examples of these are those that have no immediate superior control, those not perfomed within the company premises and those who render their services outside the company by means of computer or telecommunications.
68 Labor Code, Book I, various articles.

different working times, provided the Regional Labor Directorate authorizes them.[69] All large-scale mining operations, whether they operate at camps, or near cities, make use of "exceptional working times" for their workers.

The use of an exceptional working time requires compliance with a set of conditions stipulated by the Labor Directorate, which entail: (i) a maximum work-day of 12 hours, including 11 hours of labour and an hour of rest attributable to that shift,[70] (ii) does not allow the use of overtime, (iii) to meet a maximum ratio between work and rest days of 2: 1 in daytime mines located outside of urban centers,[71] (iv) limits the maximum number of consecutive work days to 14 or 20 in mines located outside cities, respectively, depending on whether they are temporary or permanent mines, (v) have the workers' and the union directive's (if there are unionized workers) consent, and (vi) requires authorization granted by the Regional Direcorate of Labor. It is important to emphasize that the mentioned authorization criteria are not detailed by law, rather, it is a result of an internal decision of the Labor Directorate,[72] of administrative hierarchy and therefore modifiable by that same authority.[73]

Until 2016, the exceptional working time authorization given by the Labor Directorate lasted for four years, but as of April 2017, the exceptional working time authorization will be in force for up to 3 years.[74] As of April 1, 2017, due to labor reform, it is also possible to agree on working times of up to 45 hours per week distributed in 4 working days and 3 of rest - 4x3 shift - with a daily maximum of 12 hours. These include the ordinary workday, the extraordinary workday and an hour of rest. According to the law, these agreements: (i) may have a term up to 3 years, (ii) do not require prior sanction from the authorities, (iii) must register with the Labor Directorate, (iv) are only allowed in companies that have at least 30% unionized workers, and (v) may be canceled by the Labor Directorate

69 Article 38, penultimate and last paragraph of the Labor Code states: "In particular cases, the Labor Directorate may authorize, provided the agreement of the workers, if any, and by means of a well-founded resolution, the authorization of exceptional distribution systems for working days and breaks, when the provisions of this article are not applicacle, taking into account the special characteristics of the rendering of the services, and having determined by inspection that the hygiene and safety conditions are compatible with the system. This resolution shall be effective for the term of up to three years. However, the Labor Directorate may renew it if the requirements that justified its granting are maintained. In the case of projects, the resolution effectiveness shall not exceed its term of execution, with a maximum of three years. "

70 The minimum resting period must include, at least, feeding time.

71 In practice this is not an active restriction since most shifts are 7x7, 4x4 or 4x3

72 These criteria have a historical context associated with previous regulations: for example, the applicable 12 hours scheme for employees who work at hotel and restaurants.

73 Labor Directorate Order No. 5, dated 20.11.2009, which "Systematizes and updates the procedures for authorizing and renewing exceptional systems for the distribution of working days and breaks".

74 Article 1 No. 5 of Law No. 20,940, commonly known as the "labor reform".

if they "seriously infringe compliance with health and safety standards at work". [75] It can be expected that this 4x3 shift will replace the exceptional working times of similar duration, especially in mines located near urban centers, and for employees dedicated to administrative tasks, but not to mining operation workers.[76]

In large-scale mining, 85% of the workers have 12-hour workdays, with 7x7 or 4x4 shifts (work x rest). Hence, this implies that the ordinary mining working time is an exceptional working time. Therefore, mining companies, such as subcontractors and suppliers that provide services in mines, must define their working times, agree on them with their laborers, and seek authorization from the Labor Department. This approval process must be carried out for all newly hired employees and must be renewed every four years (every three years as of 2017). This procedure is specific to each mine and job, and must be separately done for employees and outsourced workers.[77] According to the Labor Directorate statistics[78] and the information gathered from the interviewed mining companies, the authorization (or rejection) processes can take up to 40 calendar days and does not always lead to the acceptance of the exceptional working time shift. Under the current system of internal rules of the Labor Directorate, the agreement between company and union is not enough to start applying an exceptional working time shift. According to statistics from the Labor Department, approximately 68% of exceptional working times shift applications are approved.[79] The same source considers that the bottlenecks tend to appear in the Antofagasta Region (exclusively Antofagasta and Calama), where nearly 6,000 exceptional working time applications are filed.[80] According to the Labor Directorate, the process of reviewing a request for a working time shift is mechanical and consists of corroborating whether the above mentioned criteria are met. Even so, with limited budgets and a significant number of applications, human resources are surpassed. Therefore, the Labor Directorate has begun to implement an electronic and automated process of authorization, which allows the streamlining of the process.

75 New articles 374, 375 and 377 of the Labor Code, Law No. 20,940 (the "labor reform").

76 Although in the first instance Congress approved the agreements of exceptional systems of work and rest, by allowing exempt resolutions by the Labor Directorate, Congress ended up vetoing the mentioned article.

77 The current regulations allow a main company to obtain preliminary authorization for exceptional cycles of working hours applicable to workers of contractors. The activation of the cycle to the Contractor Company or subcontractor requires again the authorization of the Regional Directorate of Labor.

78 Department of Labor Inspection.

79 This is the annual-regional average for 2015 as 2016. Source: Department of Labor Inspection.

80 By 2015, the resolutions issued in the region of Antofagasta reached 6344, while for 2016 were 6410. Each represented about 50% of applications at the national level.

Finding 7.5: The usual working time in large-scale mining is an exceptional working time, which must be previously approved by the Labor Department for each case. The recent labor reform modifies this for 4x3 shifts, requiring only registration.

Finding 7.6: The authorization process of an exceptional working time at the Directorate of Labor takes 40 calendar days on average. This affects the speed with which activities in mining can start, affecting especially the mining suppliers

The current regulations of the Labor Directorate that govern exceptional working times allow for a principal to obtain a preliminary authorization framework of up to 10 different exceptional working time cycles applicable to the workers of outsourced contracting businesses that will work at the principal. Even if the contractor company replicates the scheme of cycles used by the main company, the final activation of the cycle for each contractor or subcontractor requires the authorization of the Regional Labor Directorate again.[81] It is worth mentioning that, according to sources from the Labor Directorate, companies currently underutilize this tool.

Mining companies and their subcontractors are well familiarized with the terms and times required for the processing of the exceptional working times authorization. Therefore, they anticipate the delays to their best by incorporating these agreements within collective bargaining procedures. However, each authorization for exceptional working times is particular according to position, task, and company, and is not exportable to contractors or workers. Consequently, a contractor or supplier that attends several mines must request and obtain an equal number of authorizations from the administrative authority, even if the contractor wishes to replicate the cycle scheme that has already been approved for the main company.

Finding 7.7: The current regulations of the Directorate of Labor that govern exceptional working times allow for the dictation of resolutions of special framework systems to be used by contractors and subcontractors working in a particular primary company. Despite

81 Labor Directorate Order No. 5 of 20.11.2009 of the Labor Directorate, item 4.5.

the fact that this instrument offers potential time saving, it is not used on a regular basis.

Recommendation 7.4: Simplify Labor Directorate Order No. 5 of November 20, 2009, from the Labor Directorate regarding the authorization of exceptional systems of distributing work and resting times, expediting the approval of exceptional working time for contractors and suppliers.

In summary, it is desirable to reduce the processing time for the approval of exceptional working time issued by the administrative authority. Also, allow a contractor or supplier to implement exceptional working time in order to adhere to the main company's working time cycle already in place.

Recommendation 7.5: The Labor Directorate should continue efforts to incorporate information technology into the exceptional working time authorization process and thus make the resolution process more efficient.

Finally, it is important to note that none of the countries visited for this study require such prior approval by an administrative body. In all cases considered, the law acknowledges that mining calls for an atypical working time and that in fact, the current "ordinary" mining working day is one of 12 hours, in cycles of working and resting days. These 12 effective hours are those required to ensure operational continuity with two shifts per day, i.e., prevent teams from stopping at shifts. For a definite working time to be considered valid, an agreement between workers and companies, and compliance with current regulations is deemed enough for all mines visited in the international samples. The administration plays a supervisory role later rather than being an entity that grants prior approval.

7.6.3. The Optimal Working Shift in Mining

At the global level, the best practices in the large-scale mining sector ensure working hours that favor operational continuity. The characteristics of the mining process and the enormous amounts of investment associated with the projects explain this fact.[82] All Chilean companies considered in this study, and the vast majority of the national miners operate based on exceptional working time with shifts of up to 12 hours. The cycles correspond to one working day per resting day, that is 4x4x12 or 7x7x12 (total workdays per rest-days per hours). In fact, nationally, 85% of workers in the sector work under exceptional working time, generally 7x7 days x12 hours. Of these, 80% evaluate them positively, because 12-hour cycles allow more resting days for the employee. In turn, they favor the 7x7 cycle over other options, mainly because it allows them to live in cities away from the mines.[83]

Finding 7.8: 85% of the sector's workforce works in exceptional 4x4 or 7x7 days, and 80% evaluate them positively, with 7x7 being the preferred working cycle.

For companies, exceptional working times also respond to a cost analysis. For the same employee work count, an 8-hour shift requires 30% more workers present than a 12-hour shift. That is especially costly considering that most of the sites operate in camps. With total labor costs of around US$ 4,000 monthly per worker[84] and a quarter of the operational costs corresponding to compensation for employees and outsourced contractors and workers,[85] companies seek to optimize the management of their workforce.

In Chile, companies enter into agreement with their employees for working times that partially allow operational continuity.[86] However, most of the companies interviewed emphasize that "operational continuity" is a permanent challenge, especially in the mining area. In this sense, the proposed labor reform tried to reduce obstacles to operational continuity (Article 378 under its original version), clearly establishing the duration of non-working activities[87] (commonly called passive days) and referring to the remuneration of those activities by the agreement of the parties. However, once approved by Congress, the Executive branch eventually vetoed this article.

82 Any type of operational interruption implies an important time to re-operate efficiently. Given the investment amounts associated with the sector (billions of dollars), this investment is expected to be used for as long as possible.

83 Labor Directorate 2011 (http://www.dt.gob.cl/1601/articles-100032_recurso_1.pdf)

84 Average labor cost of working-hours indicated for Chile by Cochilco (2015) and a total of 2,190 working-hours per year.

85 Cochilco (2016).

86 See, in the collective agreements approved between companies and unions, the so-called "bonds of operational continuity," "hand to hand substitution", relief, etc.

87 One hour maximum.

As was estimated in Chapter 3, a quarter of the unused time regarding available equipment is due to scheduled interruptions that include travel (in addition to talks, and feeding time). Reducing these times would allow a more fruitful use of capital, and thereby greater productivity.

Finding 7.9: Despite agreements between companies and unions to ensure operational continuity, this remains a permanent challenge, especially in the mining area.

Recommendation 7.6: Restore the "adaptability pacts" discussed in the recent labor reform, but vetoed in the final text. This would ease the agreement between companies and workers in order to ensure "operational continuity."

Effective April 1, 2017, the law allows the agreement of up to 45 hours a week distributed in 4 workdays with three rest days and a daily maximum of 12 hours of work (4x3 shift). An improvement on the exceptional working times' agreement and information for the mining industry would extend this legal framework to 4x4 and 7x7 shifts. In fact, since the 4x4 or 7x7 shift offers (proportionately) more days of rest per workday than the 4x3 shifts, it should be expected to include the 4x4 and 7x7 shifts under this new legal framework.

Recommendation 7.7: Add the 4x4 and 7x7 shifts to the possibility stipulated in Article 375 of the Labor Code, so that these working times benefit from the exempted resolution by the Labor Department.

7.7.Human Capital

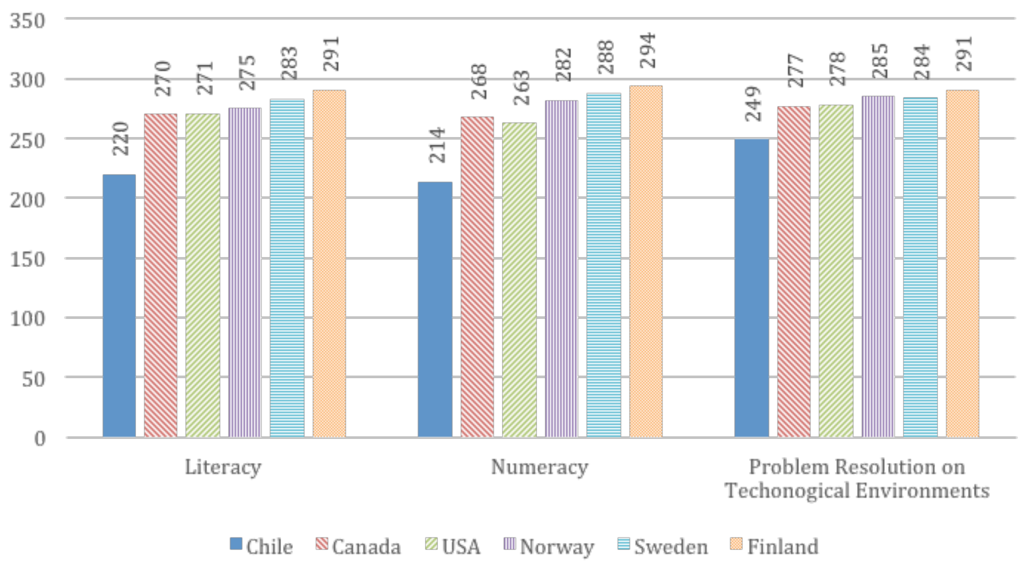
The availability of human capital is a strategic factor for mining, and even more so with the future changes in technology and automation. However, there are significant gaps in this area, both in career-related enrollments in the industry[88] and the relevance of educational programs.[89] The competency gaps observed in extractive industries in the

[88] Excess of demand and supply in different careers associated with the sector.
[89] Curricular meshes that do not match the needs of the industry.

PIAAC study[90] carried out by the OECD (2012-2014) show that Chilean workers have a lower level of reading, numerical and problem-solving skills in technological environments, below Canada, Finland, Norway, Sweden and the United States. (See Figure 7.8) In all cases, Chile has the lowest scores.

Chile has an average rating of 220 points in this sector. This means that the average worker in the industry can understand short and basic texts, with direct and explicit information. The numerical skill of the average worker is 214 points, a basic level that allows mathematical processes such as counting, sorting, and identifying simple figures in graphs. In problem solving, the average is 249 points, a low level of problem-solving ability.[91]

Figure 7.8. Average Scores of Mining Industry Workers [92]



Source: OECD estimations based in the PIAAC (2012, 2015).

90 The PIACC is a test that measures numeric, alphabetical, and problem-solving skills for the adult population aged from 15 to 65 years old.

91 In this case, problem solving has to do with the use of information technologies to unravel the problems posed by the study.

92 In this case, the data were obtained from people who are active in the industry and whose age is between 25 and 65 years old.

In addition to the low levels of these skills, the latest study of the Chilean Workforce in the Large-scale Mining Industry, 2015-2024,[93] carried out by the Council of Mining Competencies[94] (CCM) of the Mining Council and Fundación Chile presents two fundamental aspects of human capital resources for mining. The first is the mismatch between the training received by graduates (or trainees) and the skills required by the sector. The second is the quantitative mismatch between supply and demand of employment in the industry. Both dimensions (formative and quantitative) determine the human capital gap that this sector must address. [95]

Other challenges the report refers to are: (i) Training profiles in secondary and post-secondary technical and professional education graduates do not respond to what the industry needs, leading to re-training, higher levels of control and the recruitment of over-qualified profiles; (ii) there is a permanent tendency to increase labor turnover, not only among companies in the sector but also with other industries, which leads to further re-training and greater control, (iii) current human capital lacks the necessary skills to address the technological changes necessary to meet the challenges of cost reductions and productivity gains. [96]

According to the CCM report, the human capital gap in the training field is essential. This difference corresponds to a mismatch between the requirements of the productive sector and the technical and educational proficiency profiles and competencies in mining specialties, at the intermediate and higher levels, as well as in specialized training organizations (OTEC). The CCM developed the Mining Qualifications Framework profiles required by the private sector. Although the report mentions an adherence to the CCM standard increase by entities in the education area, the level of adherence remain low, especially in professional and technical education institutions at intermediate and higher levels.[97] On the other hand, OTEC has achieved greater adherence with ten CCM quality

93 Composed of the Mining Council, Association of Industrial Suppliers Mining (APRIMIN), Chilean Chamber of Construction and Association of Industrialists of Antofagasta (AIA), 11 mining companies and 2 suppliers.

94 This sectorial initiative seeks to: i) adjust the training offer to the requirements of the industry, in order to ensure future human capital adequate to the challenges facing the industry, ii) develop current human capital according to sectoral standards, iii) improve labor productivity and reduce costs, through adequate human capital.

95 Not only is there a shortage of labor in some profiles, but also, the people available do not have the minimum skills for the current and future requirements of the industry.

96 This largely implies that, although the technology is available and installed, it is not always used. Many of the installed systems in the mining industry are active in its "manual" function, which maximizes the required endowment and human action, and not in the "automatic" option, that minimizes the required endowment and human action.

97 For example, the enrollment in the Professional and Technical Training of a Higher Level Technician has not been adjusted to the information available by the Study of the Mining Labor Force, persis-

organisms. This illustrates why efforts in this field have not yet been able to influence the training programs. The latter may be because the incentive structure of technical training is mainly associated with the accreditation processes rather than with external certifications.

In this case, the FIE project on Transfer Center for Technical Training in Mining[98] appears as the first public-private effort seeking to jointly solve both the shortcomings of training and professional technical instruction. Some of the project's aims are: (i) to convene and articulate a network of vocational technical training institutions for mining; (ii) to develop standards for training and to adjust the technical curriculum at the intermediate and higher levels, based on the Qualifications Framework of Mining; (iii) to develop management abilities in mining and supplier companies based on labor standards; and (iv) to implement a sectoral program of labor practices that contributes to improving the employability of graduates in the mining sector. Among the expected results, it included organizing 20 technical and professional high schools, 7 IES / TNS and 10 OTEC with common standards that ensure relevance and quality of their programs and mining specialties.

There has been more progress in the case of OTECs, for their training system is more flexible and adaptable; mining companies have already begun to adopt the framework aligned to the needs of the sector.[99] In addition, the CCM started to develop a certification process (CCM quality seal), which allows OTECs to certify a quality level in compliance with the new needs of companies.

Another relevant aspect associated with human capital is the skills certification for mining workers (especially currently employed workers). Competency certification could produce greater labor mobility, allowing certified employees access better jobs and therefore, remunerations. Likewise, for companies, it is easier to select personnel and better identify the worker for each particular activity by certifying their competencies, therefore reducing the costs associated with turnover,[100] and overall achieving higher productivity.

In order to appreciate the benefits of certification, it is necessary to intensify it within the industry. However, the extensive adoption of competency certificates is limited due to the high cost of the evaluation and certification processes. The compulsory publica-

ting the growth in enrollment in specialties of lower demand and without increasing enrollments in specialties of greater demand.

98 The executing agency is CORFO with the participation of the Ministry of Labor, Ministry of Education, Mining Council and Fundación Chile.

99 Currently, according to information from the CCM, 9 of the 13 partner companies implement (partially or totally) their human resources management systems to CCM proposals. However, according to another source linked to the training sector, this company adhesion is still partial.

100 Without certification, more people must rotate in the position to find the right worker.

tion of personal data of certified persons further complicates this process, threatening personnel retention, and therefore disincentivizing companies. According to figures from ChileValora,[101] mining is the sector with the fewest certifications made between 2002 and September 2015, with 219 certifications of the approximately 64,000 total certifications.[102] Based on the interviews, we deduce that many of these certifications are of direct employees, and not of outsourced contractors, who could benefit given their expertise due to their rotation between mines. For example, they tend to have more experience in both underground and open pit mining.

Other important human capital challenges involve the incorporation of 20,000 workers due to job rotation (between mines and between sectors), implementing training systems required for the inclusion of new technologies, and increased female participation in the industry.

An additional challenge facing the training system is that the supply of professionals for mining comes heavily from university programs, whereas the sector has greater needs in the fields of maintenance and operation. The study highlights that the increase in first-year enrollment in related careers has also developed without a close connection with the sector's requirements. This quantitative mismatch, according to the study, will generate an excess supply in some careers and a deficit in others. Furthermore, the mismatch is also geographical, although this causes fewer problems thanks to shift dynamics.[103] As an example, in the central and Coquimbo regions, there is an excess supply of 73% and 177%, respectively, while in the regions of Tarapacá and Antofagasta there is an excess demand of around 70%.

The increase in enrollment in related careers is significant, with 26,000 new graduates over the next ten years. However, the aggregate figure is still below the expected 30,000 demand.[104] The estimated quantitative gaps conclude that the profiles with the greatest accumulated deficit for 2024 will be mechanical maintainer (5,664), mobile equipment operator (4,483), fixed equipment operator (3,404), electrical maintainer (799), maintenance supervisor (1,016), and maintenance professional (483). While the surplus profiles are: geology (2,600), geologists (1,900), mine extraction professionals (1,800), extraction

101 Its main function is the formal recognition of people's labor skills, regardless of how they were acquired and whether or not they have a degree awarded by the formal education system.

102 Represents about 0.1% of the sector's workforce.

103 For example, someone who is trained in La Serena can work in mines in Region II due to the 7x7 shift.

104 According to the study, the (accumulated) demand for 2024 is of 30 thousand people. Of this figure, some 18 thousand positions correspond to vacancies that will arise through withdrawals and retirement. However, the figures for 2015 reveal that only 24% of workers over 60 retired from the industry.

engineers (1,600), processing supervisors (1,000), and extraction supervisors (1,000), among others.

The quantitative picture suggests that there are more professionals in the sector, but there is a lack of technicians and operators. For the next ten years, the industry will demand two types of laborers: maintainers (12,420) and operators (10,796). There is a relevant training mismatch, not only concerning the proficiency profiles currently required but also with the skills needed in the next ten years, considering that advances in automation will demand the development of specific skills.

Finding 7.10: There is a significant human capital gap in the mining industry at the qualitative and quantitative level. At the qualitative level, there are differences between the training profiles (groups of competencies) and the needs of the industry. At the quantitative level, there are differences between the number of professionals and technicians offered and required by companies.

Finding 7.11: The provided trainees have a small degree of adherence to the Mining Qualifications Framework. On the other hand, for companies, signs are showing an increasing adherence to the Qualifications Framework, although there is a lot of room for progress.

Finding 7.12: The low level of certification of labor competencies in the mining industry is striking. According to ChileValora figures, approximately 0.3% of all certifications issued between 2002 and September 2015 is for the mining sector.

Recommendation 7.8: Associate the training of mining specialties in high school, technical and professional education, and Technical Training Centers with those defined in the Mining Qualifications Framework developed by the Mining Competencies Council. Moreover, adapt the accreditation of the program, the corresponding subsidy, and the student's exit to its certification.

Recommendation 7.9: Increase the levels of training in the industry, which should be in line with the Mining Qualifications Framework. Likewise, make greater efforts in the industry to certify workers, establishing clear commitments and schedules.

Recommendation 7.10: Update competency profiles by specialty according to the needs of an increasingly automated and digitized world.

7.8. Conclusions

This chapter initially deals with aspects related to job security in Chile's copper mining. For this purpose, different sources were used, like the Social Security Statistics for 2015 of the Superintendence of Social Security, among others. The figures allow us to conclude that the industry - for the past 15 years - was able to reduce the accident rate, ranking as one of the lowest among the economic sectors of the country. However, it has the highest fatality rate, which has nonetheless dropped in recent years. It is worth mentioning that, while the industry has reduced these rates, it has also significantly increased its level of employment and the amount of moved and extracted material. In both cases, there has been a significant drop in the proportion of fatal accidents. The latter speaks of an industry (companies and workers) capable of increasing its extractive process, as well as employment, and at the same time reducing the possibilities of generating accidents with fatal consequences.

When comparing accident rates of the sample analyzed in the benchmark study in Chapter 3 of this report, national mines have rates similar to those of the international sample, considered as good practices. However, strategies to achieve such figures tend to differ between the two. In the Chilean case, there seems to be a greater emphasis on documenting the fact that "all measures of protection" have been taken, whereas, for the international sample, training and good practices tend to be highlighted. Comparing SERNAGEOMIN's and the U.S: Health Administration's aggregated data, a lower accident rate is observed in Chile for the period 2000-2015. However, the fatality rate is lower in the United States during much of the analysis period, and both rates converge by the end of the period. The latter shows, once again, the ability of the Chilean industry to achieve best practices.

Another relevant aspect described in this chapter has to do with occupational diseases. Broadly speaking, Data from the Social Security Superintendence shows that the sector has one of the highest incidences of occupational diseases, with a rate of 0.16 per 100 protected workers. The national figure is 0.13 per 100 protected workers. Although several of the conditions diagnosed in the industry have a similar or even lower proportion to that of other sectors, respiratory diseases are among the most likely to occur within mining.

Regarding the organizational aspects, the gathered information shows an organization with more hierarchical layers than the international sample, as well as a greater number of professionals in the supervision layers. Lower mobility between operators, supervisors, and management is observed. Concerning variable wage components, incentives tend to focus on production rather than productivity. Although the sample that represents good practices shows that the proportion of direct employees and outsourced contractors is not related to the productive capacity of the operation, issues regarding labor relations of direct employees and outsourced contractors, as well as their competencies, could be improved.

The chapter describes the institutionality associated with the industrial relations of the sector. The first conclusion is that the "ordinary working time" within the mining industry proves to be the exceptional working time. There is room to improve the resolution processes. Another conclusion is that, despite agreements between companies and unions in order to ensure operational continuity, this remains a permanent challenge, especially in mining.

Finally, there is a description of the current situation regarding the skills and competencies associated with the sector's workforce. Initially, one conclusion looks at the existence of significant human capital gaps between training and work. On the one hand, the gap has to do with the competence profile currently being developed by the training areas, and with the disparity between the number of enrollments in the different careers and the practical demand for them. A second conclusion is that there is a low level of adherence to training for the framework of mining qualifications. The small certification that is observed today in the sector is a warning sign, for it has the lowest number of certifications between 2002 and September 2015, with 219 certifications out of a total of 64,000, according to ChileValora.

7.8.1 Summary of Findings

Finding 7.1: In a context of increased production and employment, the mining industry, and in particular large-scale mining, has improved its results in work-related accident indicators compared to the year 2000. However, the fatality rate remains higher than in other economic sectors. The rate of journey accidents, although one of the lowest among sectors, has also been increasing. The challenge is to improve its safety indicators while increasing production and productivity.

Finding 7.2: There is evidence that intermittent exposure to altitude levels above 3,000 m requires special care and monitoring of workers' health.

Finding 7.3: Organizational practices differ amongst mines within Chile, and also significantly concerning international mines. In Chile, there are more hierarchical levels, lower levels of supervision, and poor mobility between levels. At the national level, variable remuneration tends to encourage production over productivity.

Finding 7.4: Due to the characteristics and scale of the Chilean mining industry, travel times affect the productivity of mines, influencing the hours worked and the use of the equipment. It is possible to reduce the times of travel by the use of mobile dining rooms, but delay in the processing of these permits limits the effectiveness of this solution.

Finding 7.5: The usual working time in large-scale mining is an exceptional working time, which must be previously approved by the Labor Department for each case. The recent labor reform modifies this for 4x3 shifts, requiring only registration.

Finding 7.6: The authorization process of an exceptional working time at the Directorate of Labor takes 40 calendar days on average. This affects the speed with which activities in mining can start, affecting especially the mining suppliers.

Finding 7.7: The current regulations of the Directorate of Labor that govern exceptional working times allow for the dictation of resolutions of special framework systems to be used by contractors and subcontractors working in a particular primary company. Despite the fact that this instrument offers potential time saving, it is not used on a regular basis.

Finding 7.8: 85% of the sector's workforce works in exceptional 4x4 or 7x7 days, and 80% evaluate them positively, with 7x7 being the preferred working cycle.

Finding 7.9: Despite agreements between companies and unions to ensure operational continuity, this remains a permanent challenge, especially in the mining area.

Finding 7.10: There is a significant human capital gap in the mining industry at the qualitative and quantitative level. At the qualitative level, there are differences between the training profiles (groups of competencies) and the needs of the industry. At the quantitative level, there are differences between the number of professionals and technicians offered and required by companies.

Finding 7.11: The provided trainees have a small degree of adherence to the Mining Qualifications Framework. On the other hand, for companies, signs are showing an increasing adherence to the Qualifications Framework, although there is a lot of room for progress.

Finding 7.12: The low level of certification of labor competencies in the mining industry is striking. According to ChileValora figures, approximately 0.3% of all certifications issued between 2002 and September 2015 is for the mining sector.

7.8.2 Summary of Recommendations

Recommendation 7.1: Continue strengthening the joint effort carried out by companies, workers, suppliers and the government in the field of occupational safety, in order to keep reducing accident and death rates, while allowing production and productivity increase.

Recommendation 7.2: Adapt Supreme Decree 594 of the Ministry of Health regarding work at heights, according to the results of the Social Security Superintendence studies that come out in the future.

Recommendation 7.3: The Ministry of Health should institute unique and explicit criteria for the establishment of mobile dining rooms not subject to interpretation and thus expedite the process of approval/rejection of the request.

Recommendation 7.4: Simplify Labor Directorate Order No. 5 of November 20, 2009, from the Labor Directorate regarding the authorization of exceptional systems of distributing work and resting times, expediting the approval of exceptional working time for contractors and suppliers.

Recommendation 7.5: The Labor Directorate should continue efforts to incorporate information technology into the exceptional working time authorization process and thus make the resolution process more efficient.

Recommendation 7.6: Restore the "adaptability pacts" discussed in the recent labor reform, but vetoed in the final text. This would ease the agreement between companies and workers in order to ensure "operational continuity."

Recommendation 7.7: Add the Exceptional Working Times of 4x4 and 7x7 shifts to the possibility stipulated in Article 375 of the Labor Code, so that these working times benefit from the exempted resolution by the Labor Department.

Recommendation 7.8: Associate the training of mining specialties in high school, technical and professional education, and Technical Training Centers with those defined in the Mining Qualifications Framework developed by the Mining Competencies Council. Moreover, adapt the accreditation of the program, the corresponding subsidy, and the student's exit to its certification.

Recommendation 7.9: Increase the levels of training in the industry, which should be in line with the Mining Qualifications Framework. Likewise, make greater efforts in the industry to certify workers, establishing clear commitments and schedules.

Recommendation 7.10: Update competency profiles by specialty according to the needs of an increasingly automated and digitized world.

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Chapter 8

Mining Exploration

Abstract

This report focuses on the current productive performance of the large-scale copper mining industry. In addition to the improvements to the productive capacity, an important part of the long-term mining sector depends on new deposits coming into operation (regardless of size). Therefore, mining exploration is essential. This chapter studies several areas of improvement in relevant aspects, such as mining concessions, geological information and other areas in order to encourage greater dynamism on mining explorations. Based on best international practices and analysis of Chilean regulations, we propose changes in the current rules regarding the costs of exploration and mining licenses and concessionaire obligations.

Key Points

- Chile's participation in the mining exploration market is lower than its share in production and reserves.
- There is a small availability of territory for exploration in the central metallogenic strips of the country.
- Maintaining mining concessions is effortless due to its low cost.
- There are signals of important levels of concentration in Chilean mining property, which act, in practice, as an entry barrier.
- Some agents misuse mining concessions for speculative purposes, damaging the actual mining concessionaires.
- The procedural periods for establishing a mining concession are very high (6 to 8 months for exploration and 24 to 29 months for exploitation).
- The cost of the Chilean mining patent is small compared to the benchmark countries, especially since in other jurisdictions, a mixed protection regime exists that requires patent and effective mining labor.
- Chile shows a significant backwardness both in availability and quality of pre-competitive geological information.
- There is a lag in the standard of the coordinate system used in mining rights at both national and international levels.

8.1 Introduction

Part of Chile's wealth lies in its mining potential. It has been so in the past and it will continue to be so in the future. This wealth attracted colonizers and investors, and since the sixteenth century,[1] various formulae have been administered to channel the mining activities towards the generation of wealth. Notwithstanding technological advances that maximize the value of this potential[2] and the expansion of current projects, in the long term the ability to generate wealth based on these reserves will mainly be built on the discovery and development of new deposits, and therefore is directly connected to the exploration efforts.

Since the colonial period, mining management has been based on four principles: (i) freedom over mines (anyone can have a mining concession),[3] (ii) the full dominion of the State (formerly the Crown) over mining reservoirs or deposits, whose product is granted to the discoverer under a concessional figure,[4] (iii) taxation of the activity (the protection obligation, and others), and[5] (iv) research and mining explore/exploit regulation. These principles are fully in force in the current legal system.

Mining regulations evolved between 1874 and 1932. The first Mining Code (1874) gave the judges the power to grant mining concessions, and for the first time introduced the possibility of a protection obligation. The protection was replaced by the payment of a patent (1888), as the protection system for labor gave rise to procedural frauds that allowed mining claims to become unprotected. The Mining Code of 1932 perfected the legal procedure for the constitution of mining concessions in two stages: exploitation and measurement, to avoid the uncertainty generated by provisional titles granted in the previous constitutional process. It also established the automatic expiration of the mining concession for non-payment of the annual patent after two consecutive periods and introduced the mining exploration concession, a natural predecessor to the mining exploitation concession (or mining claim).

1 Lira (2007), p. 26 and Ossa (2012), p. 47.

2 For instance, technological advances that allow the transformation of a greater amount of mineral resources into mineral reservoirs (economically feasible to extract).

3 This principle states that, at first glance, there is no prohibition to explore/exploit the surface mining wealth of the mining wealth that lies underground a domain (objective perspective). Likewise, this principle protects the free claimability of all the mines (subjective perspective).

4 In general, concessional models refer to granting someone under certain conditions the use of something that belongs to public domain (e.g.: mines). Hence, mining rights are also referred to as concessions.

5 The protection refers to the obligations of the mining concessionaire in order to maintain its mining rights.

Currently, the following normative bodies in chronological and axiological order constitute the mining property system: (i) Political Constitution of the Chilean Republic in its articles 19 n. 24, subparagraphs six et seq.,[6] and its Second Transitional provision,[7] (ii) the Constitutional Organic Law on Mining Concessions,[8] (iii) the Mining Code of 1983[9], and (iv) the Mining Code Regulation[10]. This framework is intended to define the procedure for the constitution of mining concessions, granting legal security to both the applicants (or claimants) and the current concessionaires. These are the objectives that outline the characteristics of our current mining property system, namely: (i) the constitutional protection of the mining right, both at the level of the Fundamental Charter and its Organic Law, (ii) the obtaining of a concession by a solely judicial procedure (non-administrative), (iii) the concession defined as a real, diverse and independent right of the surface property,

6 For the purposes of this analysis, the provisions of these subparagraphs, particularly: The State has the absolute, exclusive, inalienable and imprescriptible domain of all mines, including guano deposits, metalliferous sands, salt deposits, deposits of coal and hydrocarbons and other fossil substances, with the exception of surface clays, notwithstanding the ownership of natural or juridical persons over the lands in which they are located. Surface properties shall be subject to the obligations and limitations established by law to facilitate the exploration, exploitation and benefit of such mines. The law must determine which of the substances referred to in the preceding paragraph, other than liquid or gaseous hydrocarbons, may be subject to exploration or exploitation concessions. These concessions shall always be constituted by judicial decision and shall have the duration, confer the rights and impose the obligations that the law expresses which will have the character of constitutional-organic legislation. The mining concession obliges the owner to develop the necessary activity to satisfy the public interest that justifies its granting. Its protection regime will be established by this law, it will directly or indirectly seek to obtain the fulfillment of that obligation and will contemplate causes of expiration for the case of non-compliance or simple extinction of the dominion over the concession. In any case, these causes and their effects must be established at the time the concession is granted. It will be the exclusive jurisdiction of the ordinary courts of justice to declare the extinction of such concessions. Disputes arising from the expiration or extinction of the domain over the concession shall be resolved by them; and in case of expiration, the affected person may request from the justice the declaration of subsistence of his right. The owner's dominion over his mining concession is protected by the constitutional guarantee dealt with in this paragraph.

7 Consolidated text in Supreme Decree of General Secretariat of Presidency Ministry No. 100/2005, O.J.O.J.: Sept.22nd, 2005. Original text O.J.O.J. Aug.11th, 1980.

8 O.J.O.J. Jan 21st, 1982. A mention must be made, regarding the nature of the mining concession, to the disposition of the Constitutional Organic Law on Mining Concessions (of COLM). Its rules have priority regarding the Mining Code, the Mining Code Regulation and any kind of regular legislation (Civil Code, Civil Procedural Code, etc.). In this way, COLM regulates the principle of non-discrimination regarding acquisition of mining rights (Art. 5), the easements the mining concessionaire could acquire, the expropriation mechanism and, particularly, the protection regime which quantity determination is delegated to the Mining Code.

9 O.J.O.J. Oct 14th, 1983.

10 Supreme Decree of Mining Ministry No. 1/1986, O.J.O.J. Feb. 27, 1987.

susceptible of any kind of act or contract, divisible, waivable, generally not impoundable, and subject to the primary condition of fulfilling the social function that justifies its granting,[11] (iv) the protection obligation by means of the payment of an annual patent for tax benefit in accordance with the provisions of article 142 et seq. of the Mining Code, (v) the classification of two types of concessions: exploration[12] and exploitation[13] (vi) a differentiated patent for those operating concessions whose main economic interest are non-metallic substances and substances existing in salt flats[14] (vii) a differentiated patent for small miners or artisanal miners mining concessions; (viii) the distribution of the mining concession fee: 70% to the Regional Development Fund corresponding to the region and 30% to the City Hall of the municipality where the concession is located, and[15] (ix) the role of the National Geology and Mining Service (Sernageomin) as a specialized entity in the survey and maintenance of the national mining cadaster and mining role of the country, as well as reporting entity in relation to the technical situation of the concessions (location, overlays, declared minerals, etc.).

This chapter is structured in 7 sections. The first presents an economic view of the mining and exploration activity at the national level, whereby factors that influence the shaping of our national productive reality are observed. The second and subsequent sections refer to the five characteristic axes of the mining exploration activity in Chile: the judicial granting of mining concessions, their protection obligation, the delivery of geological information to the State, access to financing for exploration, and the coordinate system of mining property. In almost all sections the international perspective by comparison with relevant mining countries is taken into account. Finally, in the last part, the recommendations are synthesized in the short, medium and long-term with the purpose of promoting mining exploration by perfecting the current system that governs us.

11 In general, it has been understood that this condition would be fulfilled by solving the obligation of protection, which in the current Chilean case corresponds to the annual payment of a patent.

12 This concession allows its titular only to perform exploration activities on the land, its mainly temporary (2 years since the date of the judgement that declares constituted the concession, extendable for another two years if at least half of the original concessional land is abandoned), with a minimum of 100 and maximum of 5,000 hectares of surface.

13 This concession allows its titular to carry out both exploration and mineral exploitation activities. It is also called mining claim and it has an indefinite duration from the date of the judgement that declares its constitution. Its surface ranges from 1 to 1,000 hectares.

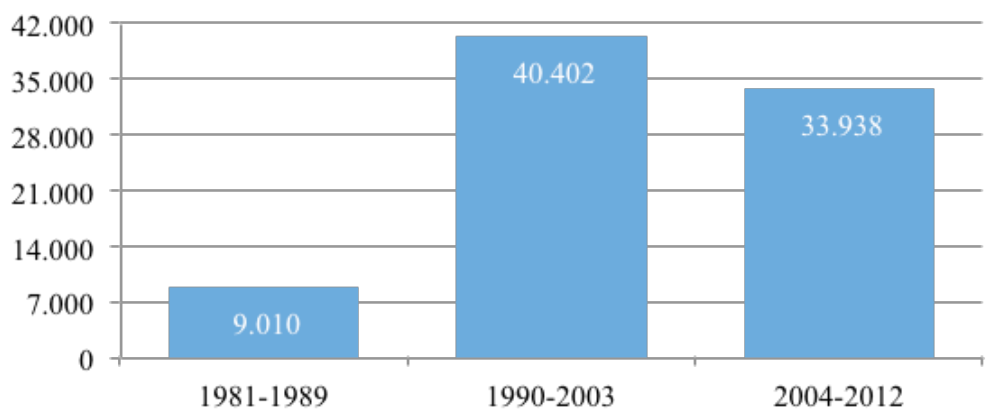
14 Also, called "non-metallic substances patent" regulated in article 142 of Mining Code and 53 and seq. of Mining Code Regulation. See Section 8.4.

15 See article of Law No. 19.143 (O.J.O.J. Jun 17th, 1992).

8.2 Mining Concessions and Copper

The regulatory bodies mentioned above gave mining concessionaires the legal security and stability that allowed them to assume the risks of this activity, reflected in the levels of investment in the sector since 1990 (see Figure 8.1). These institutional bases, together with the entrance of relevant participants in the market, have made Chile one of the most important mining countries in the world. It is the primary producer of copper, lithium, iodine, natural nitrates, and rhenium; third in molybdenum production; eighth in silver production and fourteenth in gold production. Chile also has the primary known reserves of copper in the world, which allows the mining sector to remain connected to the development of the country.

Figure 8.1. Copper-mining investment in Chile (US$ millions of 2012)



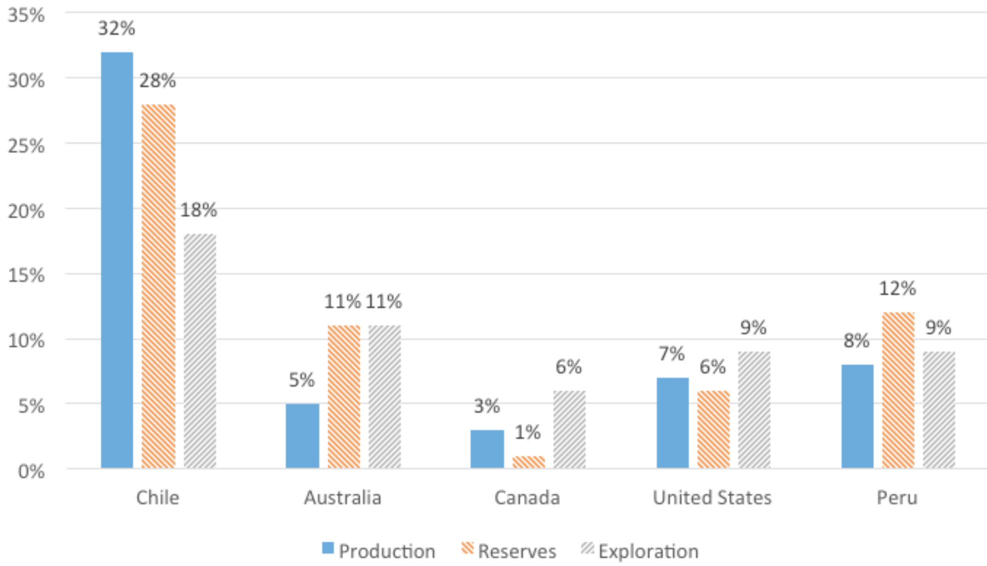
Source: Cochilco and InvestChile

Note: It only includes Codelco's investments and foreign mining investment.

Chile is one of the leading mining exploration destinations in the world, ranking in 4th place, with a 7% share of exploration expenses for non-ferrous metals (including copper) in 2015 (Cochilco, 2015). Yet, when Chilean participation in copper exploration is considered, spending reaches 18%, close to half of its market share as a producer during the period 2010-2015 (see Figure 8.2). Although exploration spending is highly pro-cyclical relative to the price of copper, it is possible to expect the country's participation in the exploration market approaches its production market participation. In other words, Chile now exploits its reserves at a faster rate than its exploration efforts, which undermines the future sustainability of the sector.

Finding 8.1: Chile's share in the mining exploration market is lower than its share in production and reserves.

Figure 8.2. Worldwide Shares on Copper Production, Reserves and Exploration (Average 2010-2015)



Source: National Productivity Commission based on Cochilco, USGS and SNL Metals.

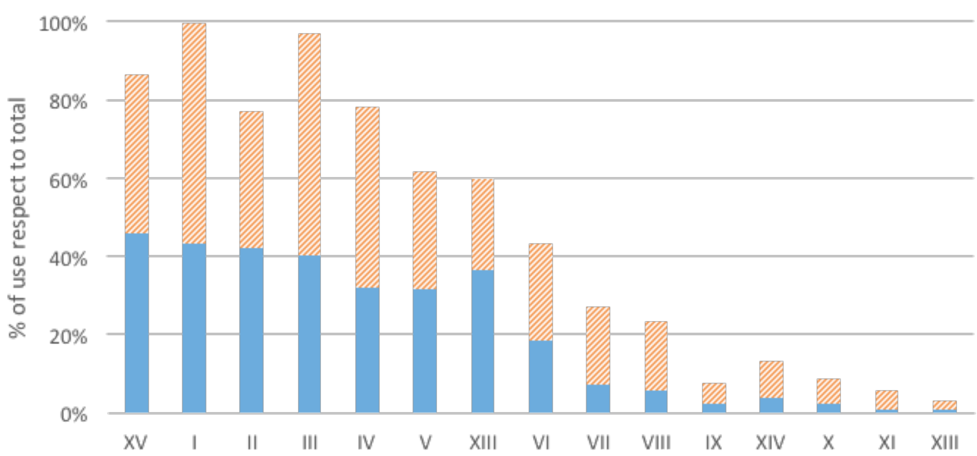
A first approximation to the exploration effort is given by the availability of concessible surface area in Chile. Of the country's surface (excluding the Antarctic territory) 43% is covered by mining concessions (see Figure 8.3), both for exploration or exploitation, bearing in mind that it is possible to have overlaps between them.[16] The northern regions of the country have a larger concession area. Of the total operating concessions

16 There may be overlaps between exploration and mining claims, as they may cover the same area. Such overlaps can coexist peacefully, as long as effective projects in the area (mining, energy, real estate, etc.) are not happening. Particularly in the case of mining, in all events, the right of the so-called "first discoverer" (whoever has first filed and maintains the application for the mining right, whether exploration or exploitation). By express prohibition of article 73 of the Mining Code, it is not possible to overlap mining claims, claiming nullity (Article 95) over the posterior overlapping mining claim.

in Chile, 57% correspond to metallic mining, while the remaining 43% to nonmetallic mining and 0.1% to small-scale mining and artisanal mining.

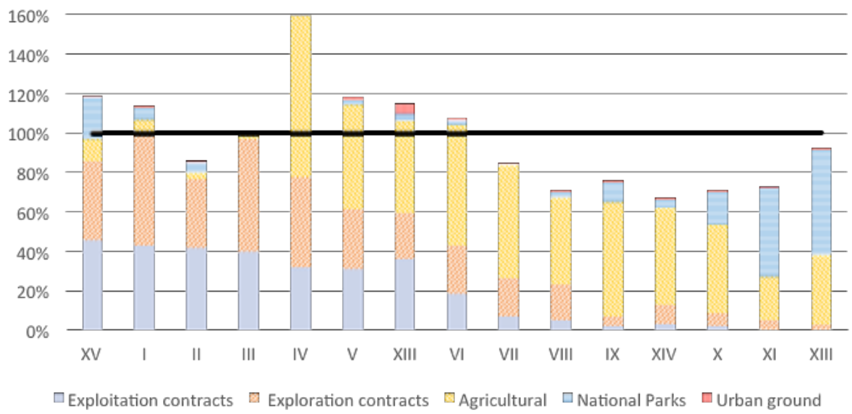
In some municipalities of interest, the concession area for exploration or mining claims exceeds the total area of the respective territory, due in part to the overlap of mining concessions. For example, the municipality of Putre has 100% of its land under operating concessions, and 33% with exploration permits, which means that the concession area is 133%. This also occurs in Iquique (75% mining claims and 45% exploration, for a 120% total), Pozo Almonte (58% mining claims and 52% exploration, for 111% total), Copiapó (45% mining claims and 60% exploration, for a 105% total), Tierra Amarilla (48% mining claims and 68% exploration, for 110% total) or Vallenar (48% mining claims and 68% exploration, for 115% total). Note that this implies that no new company may apply for concessions in any of these areas unless it overlaps them and waits for the predecessor to abandon them. In this scenario, the only option is to buy the mining rights from the previous mining concession owner. This limited availability of land for exploration concessions may constitute a significant entry barrier for the discovery of new deposits. Also, in the context of the regional analysis, the situation of the various uses of soil and subsoil at this level must be taken into account. Thus, in some regions (XV, I, IV, V, XIII and VI), land and subsoil use may be more conflictive due to greater relative scarcity because of agricultural, urban and national use (See Figure 8.4).

Figure 8.3. Percentage of regional territory used by mining concessions in 2013.



Source: Cochilco (2014) based on Sernageomin.

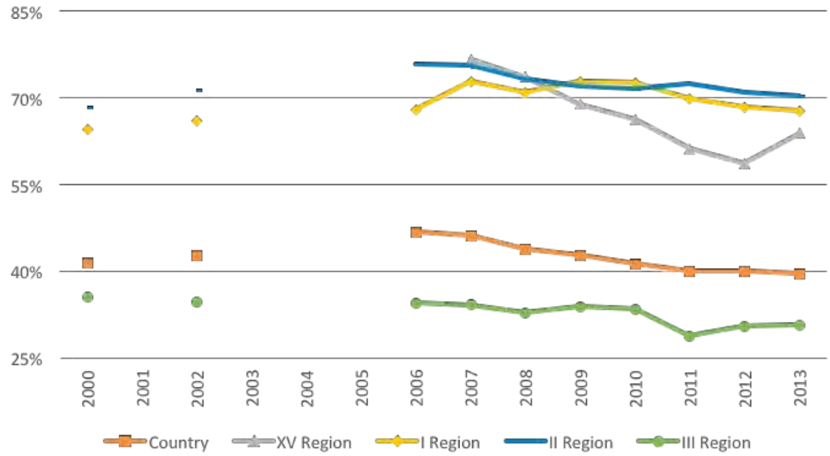
Figure 8.4. Use of land and subsoil territory in Chile



Source: Cochilco (2014) based on Sernageomin, INE, CONAF and Urban Observatory.

In addition to the area under mining concession, the level of concentration of mining property is relevant. In regions XV, II, and I the ten largest holders concentrate about 70% of the mining subsoil, surpassing the average of the country (40%). Region III is under the national average, which is related to a greater presence of small and medium-sized mining. This distribution has been kept since 2000 (see Figure 8.5).

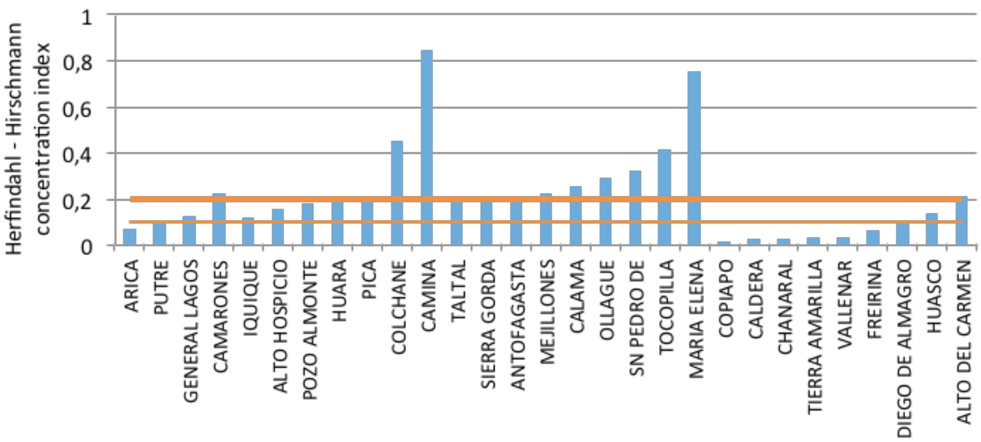
Figure 8.5. Share of the 10 largest owners of mining claims for the period 2000-2013



Source: Cochilco (2014) based on Sernageomin.

Note: There is no information available for years 2001, 2003, 2004 and 2005.

Figure 8.6. Herfindahl-Hirshman[17]
Index on municipalities between Regions XV and III on 2013.



Source: Cochilco (2014) based on Sernageomin.

As of 2013, between the XV and III regions, there are ten municipalities where mining property is highly concentrated (mostly mining claims): Camarones, Colchane, Camiña, Mejillones, Calama, Ollagüe, San Pedro de Atacama, Tocopilla, María Elena and Alto del Carmen (See Figure 8.6).

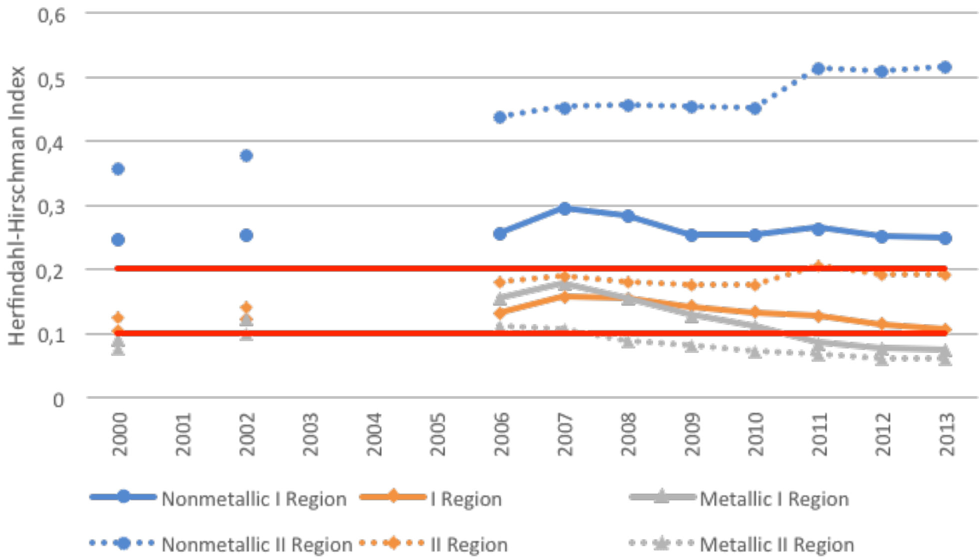
Regarding the mining patent in Chile, it is worth emphasizing that its cost is substantially small compared to other relevant mining jurisdictions (see Section 8.4). Furthermore, there is the additional possibility of reducing the annual patent by two-thirds for non-metallic ore exploitation[18]. In fact, the highest concentration of mining concessions is present in the nonmetallic mining industry (whose annual patent is 66% lower than that of a

17 The Herfindahl - Hirschman index measures the concentration of an industry. It consists of the sum of the squares of the participation of each holder in the market:
$HHI=\sum_{i=1}^{N} s_i^2$
Where s_i corresponds to the market share of the company i.
For analysis purposes, following the European Union standard, those with HHI between 0.1 and 0.2 and highly concentrated while those with HHI above 0.2 are considered to be moderately concentrated markets (see Cochilco, 2014). Note that the magnitudes obtained correspond to a minimum concentration level due to the existence of related persons who register mining claims instead of the true owner.

18 Through the mechanism provided in article 142 of Mining Code and articles 53 and seq. of Mining Code Regulation. The first rule indicates that the annual patent for a mining claim will be equivalent to 0,1 MTU per hectare for metallic exploitation and 0,03 MTU per hectare for non-metallic exploitation, on metalliferous sands or salt flats.

metallic mining[19]). In general, they are in the regions with the highest concentration of mining concessions, as shown in Figure 8.7 for Regions I and II.

Figure 8.7 - Evolution of Herfindahl-Hirschman Index by type of mining exploitation patent in I and II Region 2000-2013



Source: Cochilco (2014) based on Sernageomin.

Note: There is no available information for years 2001, 2003, 2004 and 2005.

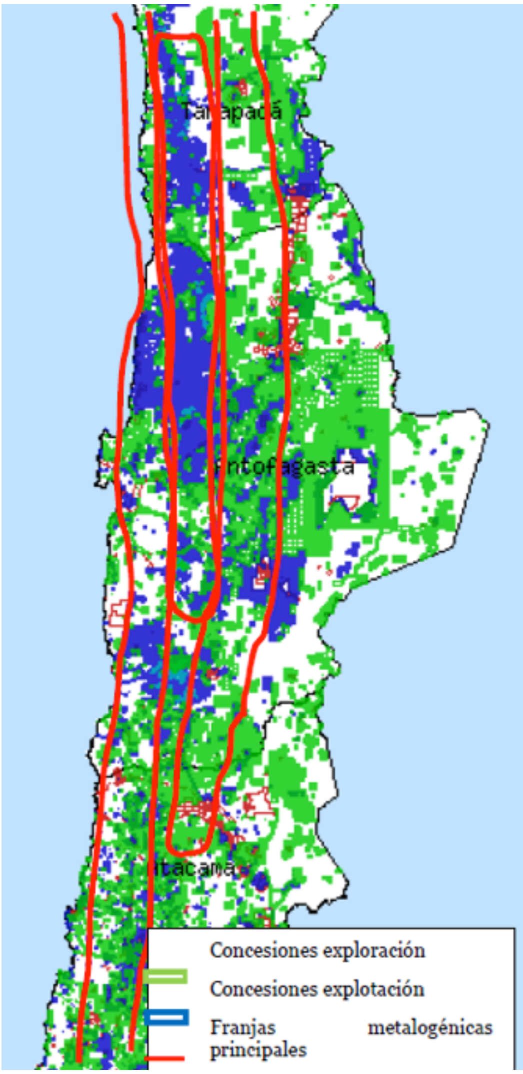
The preceding suggests evidence of heavy concentration in mining property, which can be explained by factors intrinsic to the mining industry, such as scale economics (capital requirements), and the level of geological knowledge. However, given the necessary expenditure level and high risks involved in the exploration activity, it is unlikely that the holders of these mining concessions intend to prospect the entire territory,[20] which implies that there is very little land space for the entry of new participants in exploration

19 In some cases, this may lead to fraud since it only requires a simple statement of the owner of the mining right that is not checked enough by Sernageomin.

20 The main owners of mining property are of two types: larger companies and natural persons / smaller companies. The former have operations in production, an extensive portfolio of projects worldwide and specific exploration objectives (e.g.: world class deposits), which means that they are performing exploration activities in a gradual manner and focused on an organic growth of the company, discarding deposits that do not meet their minimum requirements, thus not prioritizing the full development of our territory's potential. The latter, natural persons or smaller companies, do not have the resources to develop the potential of the acquired mining rights and it is possible to infer that they maintain their property mainly for speculative purposes.

or mining activities (see Figure 8.8). At the same time, concession fees in favor of the State are less than optimal.

Figure 8.8. Mining concession in the central metallogenic strips of mining regions in Chile.



Source: CESCO (2016) based on Sernageomin

Finding 8.2: There is low availability of territory for exploration in the main metallogenic strips of the country due to the area covered by current concessions in force, and the ease of maintaining them at low cost, especially if they correspond to nonmetallic mining.

Finding 8.3: There is evidence of significant concentration levels in both metallic and non-metallic mining properties. In some cases, this may respond to the need for sector-wide economies of scale. However, it nonetheless acts as an entry barrier.

Due to the shortage of mining property open to new participants, policies such as the Law No. 19.137 (O.J. May 12th, 1992) were adopted to allow greater availability of mining concessions to third parties. This law authorized CODELCO, after a favorable Cochilco report, to disregard non-exploited mining claims and whose potential mining resources or scale of production were not within its desirable ranks. These properties were transferred to the National Mining Company (ENAMI), with the purpose of reorienting CODELCO's resources towards the maintenance of exploited mining concessions, while the under-exploited mining rights were made available to other market agents (medium and small mining industries) that were interested in its exploitation. Since 1992, Cochilco has made 77 favorable reports of mining prospects to be transferred to ENAMI who, in turn, places them in public bidding to interested third parties. Under this mechanism, CODELCO has delivered some 300,000 hectares to ENAMI, more than half of them in the region of Antofagasta. However, the mechanism is far from being either efficient or expeditious. Of the total number of prospects in tendering by ENAMI, 30% had no bidders, 40% were still being transferred in 2012, and only 10% were effectively sold to small and medium-sized miners. Part of this flaw can be attributed to a lack of coordination among the various public agencies involved: Cochilco, CODELCO, ENAMI, the Technical Advisory Committee, the Ministry of Mining and General Comptroller of the Republic. There is obvious room for improvement in this area, for example, by establishing deadlines for administrative action or by promoting, where appropriate, favorable consequences for individuals that face administrative silence. The aim is to avoid keeping inactive resources that could be exploited by smaller companies. Notwithstanding its result, this law encourages the transfer of inactive (unexplored or unexploited within a period) mining property, to efficiently allocate the mineral resource in those market agents that will effectively exploit it.

Another economical feature to be considered in this analysis is the fact that the transaction frequency in the exploration or mining concessions lacks dynamism in the mining market, considering how frequent the transactions of mining rights actually are. According to available information, the owners of mining claims tend to maintain their market share and establish a mining area each year[21] ; while exploration concessions show greater variability concerning their holders and the area they cover. This is a natural consequence of both types of concessions: the former requires stability to carry out the expected mining work, while the latter only concerns exploratory purposes in areas that may potentially attract extractive interest according to the world's mineral needs. Furthermore, since mining concessions are legally considered property, the real estate market is less dynamic considering the investment term.

The fundamental economic aspect of mining property is its effective and efficient use. A mining concession that is neither explored nor exploited does not contribute to the wealth of the country. Moreover, the mining concession obliges the owner to develop all the actions necessary to satisfy the public interest that justifies its granting. As mentioned, the State, actual owner of the property, grants the resource in a concessional form in order to be explored or mined, but not its accumulation or to be kept in storage indefinitely. However, our current legal framework allows the use of mining concessions for purposes other than mining development and, therefore, it has a broad room for improvement. [22]

This situation reduces the country's mining potential and future productivity by hindering investment in mining exploration through the maintenance of mining concessions by means of the payment of a low-value annual patent fee (which is also reducible to one-third of its value), that encourages using it for purposes other than mining activities. A typical case is the constitution of mining rights (exploration concessions or mining claims) with the sole purpose of defending the surface activity that is carried out from other agents who seek to impose subsoil rights over soil rights, not being mining entrepreneurs, and with the sole purpose of obtain a financial compensation or damages. As was discussed in Chapter 5 on Water and Energy Resources, a mining right is an attractive defense tool against other agents. Because of its legal condition as property, its constitutional protection (both in the Constitution and in its Organic Law), its rapid constitution and low maintenance costs (annual patents), all of which allow the holders of mining concession owners file judicial actions in order to defend their property.. For example, these actions may be to file a possessory action of immovable

21 Cochilco (2014) indicates that in about 14 years, approximately 65% of the area of exploitation in 2000 will be maintained (17% with a different holder and 48% with the same owner), which accounts for the relative stability of the mining claims market and the long-term tendency of the holders to keep them. In the case of exploration concessions, this rotational ownership analysis is very complex to do because of two factors: the short duration of the concession and the difficulty in identifying the mining right in official records (e.g,: Registry of Mining Property in each Land Registry, Sernageomin).

22 For instance, considering protection through effective labor of exploration/exploitation or some kind of indirect mechanism that encourages mining activity.

property regarding the suspension of new works when his/her possession has been disturbed by a new construction[23]

against third parties that begin energy projects,[24] both traditional and NCRE,[25] with the sole purpose of suspending works unless compensated for the damages caused on their property.

Given the possibility offered by legislation to file a possessory action of immovable property regarding the suspension of new works when his/her possession has been disturbed by new construction and the fact that its sole interposition suffices for the temporary suspension of all works, the constitution of mining concessions counters this. Thus, any major project to be developed on the surface must constitute mining concessions in the area, to avoid facing possessory actions from other mining concession rights located in the same area. In parallel, speculators who, previously knowing the area in which the project will be located, arise in advance requesting a mining right to negotiate with the project holder. In this scenario, real miners are also forced to enter the race to obtain mining rights to prevent others—both speculators and those who defend themselves from the speculators —from getting a head start, preventing them from developing their mining activity in the future. The result is a constant race to constitute mining rights, as a low-cost insurance tool, with the sole aim of avoiding the problems that entail the interposition of possessory actions of immovable property, such as suspension of new works, when a new construction arises.

23 Regulated in article 930 of the Civil Code and in articles 565 and seq. of the Civil Procedure Code, this action was thought at the time (in 1855 for the civil codifier, on 1902 for the procedural codifier) as a particular protection on the soil property that could be affected by constructions of third parties, and that its owner or possessor could suspend those works until compensation for the damages caused by such construction. Thus, the filing of this complaint suffices for the judge to order the provisional suspension of the work, being sufficient solely the notification to whoever is executing the work (foreman, workers) and not the owner. The judge orders that the condition of the work be verified, warning the builder of the demolition or destruction of what has been done since that suspension, calling the parties to a hearing in order to provide evidence as to the origin of this new work. Moreover, if it is necessary to make indispensable works so that the construction does not ruin any the already constructed surrounding areas, a previous expert report is required. Given the practice of the Courts of Justice in this matter, the possible procedural arguments to deploy in this brief procedure (repositions, appeals), the natural delay of the verification of the status of the work and the expert report to determine its entity and potential damages to compensate; makes this complaint procedure, in practice, a real barrier on construction projects in general. For this reason, this legal tool is commonly used in the field of natural resources.

24 It has motivated holders of those energy projects to apply for mining rights in the land in which they are building their facilities, with the purpose of preventing further legal conflicts.

25 Considering Law No. 20.897 (O.J. Feb. 5, 2016) that extended the application of Article 34 Bis analyzed infra, that considers this legal figure for any developer of non-conventional renewable energy projects.

It is worth mentioning that mining rights enjoy, due to its quality of being considered as real estate, of all judicial actions available to protect the possession of their domain (possessory actions). In this sense, Article 9 of the Constitutional Organic Law on Mining Concessions,[26] reinforced by Article 94 of the Mining Code, provides that actions such as recovery of ownership (restitution claim of the domain) and possessory actions (to claim possession restitution) concerning mining rights proceed. Possessory actions brought by a possessor of immovable property as suspension of new works when his/her possession has been disturbed by a new construction are possible to deduct against any third party that threatens possession of the mining right by installing new constructions (e.g., real estate, electrical). Legal disputes between third parties and mining concessionaires proliferated due to this, as did between concessionaires of diverse resources on the same strip of land.

In the case of electric concessionaires, Law No. 20,701, which amends the General Electric Services Law, introduced an Article 34 Bis, which expressly mentions this mechanism. It devised a procedure to suspend the effects of this paralyzation, (allowing to continue with the construction) prior the deposit at the Court's bank account of a sum of money enough to account for the construction's demolition, or for damage compensation if the construction should continue.[27] Bill Bulletin No. 9169-08, attempted to generalize this mechanism modifying several legal bodies (including the modification to Law No. 20,819). However, it unsuccessfully attempted to amend the possessory action brought by a possessor of immovable property when his/her possession has been disturbed by new construction. The amend suggested that the complainant would be required to accompany documents and other means of proof of his immovable right and the construction's actual hazard, opening a chance for lifting the suspension if the builder (whoever it may be) offers sufficient guarantees that it would not cause damage. That is to say, the possessory action brought

26 Article 9 .- Every mining concessionaire can defend its mining right by all means provided by law, both with respect to the State and private individuals; for this purpose, to take actions such as claim, possessory actions and other such as the law indicates, and obtain the pertinent compensation. The concessionaire may request from the judge the appropriate measures for the conservation and defense of his mining right. In particular, the concessionaire is granted the right to visit all the mining works that may affect his mining rights, in the cases, manner and with the effects determined by the Mining Code. This regulation is unique in its class and shields the mining rights from any attack from third parties. This kind of protection, with this imperative nature, is not observable in other types of concessions.

27 Mechanism that, in judicial practice, has become another barrier to continue effectively with the installation of power lines for, in spite of the fact that the judge has a term of three days to determine the amount to be deposited, most of the time this term is not fulfilled. Even when the sum of the bond is set, it is possible to replace it and, if appropriate, appeal the decision, procedurally entailing the reactivation of the works. In several cases, these procedural entrapments lead the final determination of the bond to take months and it is a large practical procedural problem that has an economic impact, with the increase in the judicialization in the execution of energy projects.

by a possessor of immovable property when his/her possession has been disturbed by a new construction, would be considered more as a precautionary measure in the protection of a third party's right, rather than as a demolition order (as it was initially conceived). Like all precautionary measures, it should be granted with strong foundations and only be kept as long as the danger that bore it remains.

The Electric Transmission Law[28] establishes some useful evaluation criteria when determining the guarantee that must be established by the electric concessionaire affected by the measure of work suspension for this kind of complaint. However, these standards are not binding by the Judge in the circumstances set out in Article 34 Bis, which were commented on when determining the bond. An alternative is to limit the scope of the possessory actions that mining concessionaires may file against all third parties. This can be achieved by demanding, in exchange for their interposition, an accreditation for the effective development of mining activity in the area affected by the new construction, among other antecedents that serve as a basis for ordering a precautionary measure (as would be the detention order of new construction in progress) in order to protect the mining rights to operate on the surface.

International practices aim at discouraging ex-ante non-mining speculators, rather than limiting the tools available for the mining concessionaires. The reformulation of the protection obligation may discourage this. We estimate that, even when the possessory actions brought by a possessor of immovable property as suspension of new works were legally modified (which would be an improvement because it is one of the least expensive and most powerful legal tools today)[29], speculators would still have other legal tools remaining in accordance with Article 9 of the COLM.[30] Furthermore, the low cost of the patent would not discourage mining property storage.

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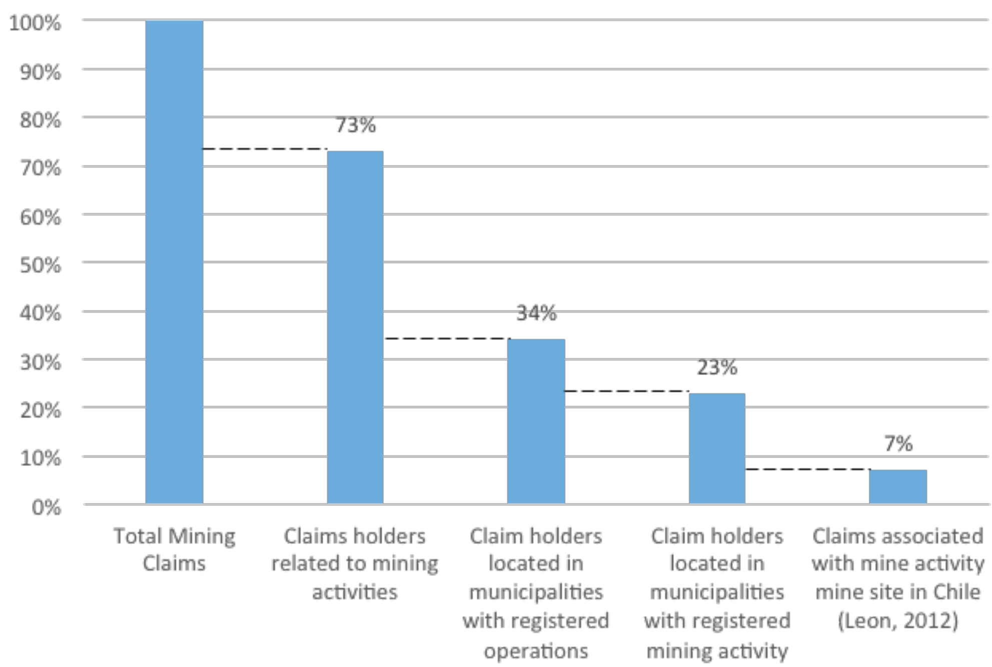
28 Law No. 20,936 (O.J. July 20, 2016) that establishes a new system of electric transmission and creates an independent coordinator organism for the national electric system.

29 Understood as a special precautionary measure and, like all precautionary measures, requires that the person concerned presents a reliable or authoritative record of the danger involved in the continuation of the new work, not merely filing of the action in the Court, accompanying it by sufficient background checks to justify it. See Bill Bulletin No. 9169-08 (Presidential Message, retired).

30 This article states that: Every mining concessionaire can defend his mining right by all means provided by the law, both with respect to the State and private individuals; for this purpose, to take actions such as the claim, possessory actions and other such as the law indicates, and obtain the pertinent compensations.- The concessionaire may request from the judge the appropriate measures for the conservation and defense of his mining right. In particular, the concessionaire is granted the right to visit all the mining works that may affect his mining rights, in the cases, form and with the effects determined by the Mining Code. For this reason, it is not enough to modify the action of suspension of new works, but perhaps a re-study of the measures that can be used by the mining concessionaire in defense of his concession, foreseen in norms such as this, of constitutional organic law rank.

Finding 8.4: Some agents misuse mining concessions for speculative purposes and as insurance against potential litigation, thus harming the effective mining concessionaires. These objectives are different from those that the law considers when granting the subsoil in concession, and by which the State transfers part of its property faculties to private concessionaires.

Figure 8.9. - Estimation of Mining Claims in Chile



Source: Cochilco (2014) based on Sernageomin and León (2012).

Holders of mining concessions related to the mining industry have remained constant at around 73% of the mining area[31] since 2006. That is, either companies with non-mining activities or individuals own 27% of the exploitation concessions. As mentioned, this is due to the application for concessions for speculative purposes, or in reaction to it and as soil insurance for non-mining companies with activities on the surface. Again, this is possible

31 It refers to concessionaires linked directly to the mining activity. The remaining 27% corresponds to concessionaires that could be non-mining companies (construction, agriculture, energy, etc.) or natural persons not directly associated with any mining facilities.

given the current legal framework, the low cost of the patent, and the non-requirement by the State of the use of the patent for the constitutionally assigned purpose. On the other hand, in copper mining, 7% corresponds to the mining site (total area used by the operation) (León, 2012), that is, only one tenth of 73% of the concession area is directly related to mining activity (See Figure 8.9).

In summary, there are four hypotheses that explain an inferior use of the mining property: (i) mining properties that are not in use, but in the past were recognized as such and have geological information;[32] (ii) properties in which the owner does not yet define how to recognize his/her property, or external conditions prevent him to; (iii) properties which are used only for speculative purposes, without carrying out any exploration, extraction or other mining activity (also called ghost concessionaires); (iv) properties that are only used to protect surface activities.[33]

8.3 The judicial granting of mining concessions

A feature of our mining property system has been the judicial granting of mining concessions, which has been part of the Chilean mining tradition since colonial times (see Section 8.1). In our procedure, the Judicial Power, and its court of law, acting as impartial third parties between the interested party and the State, have exclusive jurisdiction to grant these mining rights. In other countries, the granting procedure is carried out before an administrative or technical authority, or also before an administrative authority with the possibility of judicial intervention ex-post (mixed).

In the constitution process of mining concessions, the intervention of the judiciary branch grants certainty of impartiality and objectivity to the applicant. This granting of concessions through the courts, with a legally established and transparent procedure for both the party interested and the administration, provides a much-needed legal certainty for national and foreign investors, thus being a praised feature of our system at an international level.

The process for constituting mining concessions is regulated in Articles 34 and seq. of the Mining Code, with certain differences, in the case of exploration and mining claims. Table 8.1 presents the process of constituting of each mining concession in detail.

32 For instance, mining claims created under the Mining Code of 1932 which, by a transitional constitutional provision remain in force, solely for the purpose of Mining Cadastre in terms of productivity.

33 León (2012) provides geographic-empirical evidence of these last two hypotheses.

Table 8.1. – Process for constituting Mining Concessions in Chile.

Formalities [34]	Exploration Concession	Mining Claim
Voluntary application, made by anyone over 18 years old, before the Court where the central point of the area of mining interest is located.	Complaint called claim.	Complaint called manifestation.
Registration in the Mining Registry of the Land Registry corresponding to the jurisdiction.	Registration of the complaint and its judicial decision within the next 30 calendar days since ordered by the Judge in the corresponding Mining Registry, Discoveries division.	
Publication of the record in the Official Mining Bulletin.	The registration must be published within 30 calendar days since the order of the judicial decision.	
Tax benefit payment.	Per the area and amounts determined in article 51 of Mining Code, payment must be done within 30 calendar days since the filing of the complaint.	
Constitutive Judgement Application.	A writ sponsored by a lawyer in which the applicant mentions the coordinates of the area applying for mining concession (in written and with a referential map) and accompanied by documents showing compliance of legal obligations (registry, publication and tax benefit payment). This writ must be filed within 90 calendar days since the filing of the complaint.	DOES NOT APPLY.
Request for Measurement.	DOES NOT APPLY.	A writ sponsored by a lawyer in which the applicant mentions the coordinates of the area applying for mining concession (in written and also with a referential map) accompanied by documents showing compliance of legal obligations (registry, publication and tax benefit payment). In addition, the applicant must designate an habilitated expert or Civil Mining Engineer for the execution of the measurement operation. This writ must be filed between 200 and 220 calendar days since the filing of the complaint

[34] Here are the most common procedures during the constitution process, bearing in mind that this process can become contentious in case of the allegation of third parties with a better mining right or denouncing any situation of: expiration, nullity, overlap, opposition to the metering request.

Table 8.1. continuation

Formalities [34]	Exploration Concession	Mining Claim
Publication of Request of Measurement.	DOES NOT APPLY.	Request of Measurement and its judicial decision are published in the Official Mining Bulletin within 30 calendar days since it was ordered by the Judge (Art. 60 Mining Code). Since the date of publication, anyone who is affected for this request of measurement (e.g.: by overlap) could apply for an opposition for the measurement, transforming this procedure into contentious (Art. 61 and seq. Mining Code).
Measurement Records and Maps.	DOES NOT APPLY.	Writ in which the applicant accompanies the records and maps from the measurement operation (this operation includes land demarcation, cornerstone buildings, etc.) that was made by the expert or the Civil Mines Engineer, fulfilling all the requirements of the Mining Code and Mining Code Regulation. It must be filed within 15 calendar months since the filing of the complaint.
Technical Report by Sernageomin.	The Court must send the proceeding to Sernageomin for its Technical Report. This report must check that the mining concession is located within the applied soil area and that its geometrical form, dimensions and orientation of its surface are according to the law (Art. 57 Mining Code). Sernageomin must perform its report within 60 calendar days since the reception of the proceeding.[35]	The Court will send the proceeding to Sernageomin for its Technical Report. This report must check the technical aspects of the measurement operation, their records and maps, particularly if they are according to the law regarding the geometrical form, dimensions, orientation and that the mining concession is located within the applied soil area (Art. 79 Mining Code). Also, it must check the existence or non-existence of overlapping mining concessions (Art. 80 Mining Code). Sernageomin must perform its report within 60 calendar days since the reception of the proceeding.

Table 8.1. continuation

Formalities	Exploration Concession	Mining Claim
Constitutive Judgement.	Once received the Technical Report of Sernageomin with a favourable result, and if there is no expiration cause (Art. 85 Mining Code)[36], the Judge will resolve a Constitutive Judgement, declaring the constitution of the exploration mining concession (Art. 86 Mining Code), ordering its inscription and publication in summary.	Once received the Technical Report of Sernageomin with a favourable result, and if there is no expiration cause (Art. 85 Mining Code), the Judge will resolve a Constitutive Judgement, declaring the constitution of the mining claim (Art. 86 Mining Code), ordering its inscription along with the Measurement Record and its publication in summary.
Summary Publication on Official Mining Bulletin.	Summary revised by Court's Clerk published in the Official Mining Bulletin. This summary contains the coordinates and the data of registration in the Mining Registry of the mining concession.. It must be published within 120 calendar days from the constitutive judgement.	
Acknowledgement of receipt by Sernageomin.	Sernageomin must receive an authorized copy of the Constitutive Judgement, its certificate of enforceability and the map of the mining concession. In return, Sernageomin gives the applicant an acknowledgement of receipt that is a regulated requirement for the inscription of the mining concession..	Sernageomin must receive an authorized copy of the Constitutive Judgement, its certificate of enforceability, the map of the mining concession and a copy of the Measurement Record. In return, Sernageomin gives the applicant an acknowledgement of receipt that is a regulated requirement for the inscription of the mining concession.
Registration of the Constitutive Judgement in the Mining Registry (part of Land Registry).	The published summary, the acknowledgement of receipt by Sernageomin, the Constitutive Judgement, its certificate of enforceability and the map of the concession are registered in the pertinent Mining Registry (Discoveries division), recorded as an exploration mining concession (the Constitutional Judgment is transcribed). This registry must be done within 120 calendar days since the Constitutive Judgement.	The published summary, the acknowledgement of receipt by Sernageomin, the Constitutive Judgement, its certificate of enforceability the map of the concession and the Measurement Record are registered in the pertinent Mining Registry (Property division), recorded as a mining claim (the Constitutional Judgment and the Measurement Record are transcribed). This registry must be done within 120 calendar days since the Constitutive Judgement.

Source: National Productivity Commission.

35 Sernageomin has been considerably efficient in the technical review of the proceedings, taking about 43 days on average to carry out this task. However, the technical review of a measurement within the same legal term provided constitutes a problem for Sernageomin due to the lack of staff and budget for the required field visits.

36 The institution of expiration (or lapse) in mining law is a procedural sanction to the applicant that has not performed in time the obligation for which the Mining Code and Mining Code Regulation have deadlines. Article 237 of Mining Code determines as deadlines all the terms that must be completed by the applicant.

Strictly considering the legal deadlines and assuming that all those people and institutions involved in this procedure entirely comply with them (see Table 8.1), an exploration concession constituted in order[37] takes between six to eight months to be fully constituted.[38] This period is comparable to a drilling campaign in copper mining, so it is relevant for the planning and decision process of a company. An operating concession (mining claim) constituted in order[39] takes between 24 and 29 months to be fully constituted, i.e., about three times when compared to its analogous exploration mining concession.

> **Finding 8.5:** The process of constituting mining concessions implies quite long terms, with delays of 6 to 8 months for exploration and 24 to 29 months for mining.

These periods should be reduced, since several terms are remnants of the previous Mining Code (1932).[40] We believe it is feasible—keeping the processing diagram—that terms be modified as presented in Table 8.2. We estimate that it is possible to reduce the time for setting up an exploration mining concession to five months, and a mining claim to 18 months.

[37] Without any technical report observed or noted by Sernageomin.

[38] Registered in the Mining Registry as an exploration mining concession.

[39] Without any technical report observed or noted by Sernageomin and without oppositions to the measurement operation.

[40] Indeed, the term between 200 and 220 days from the date of the presentation of the manifestation to the Court to submit the request for measurement is a term derived from the Mining Code of 1932, which specified a process of ratification that occurred prior to the request for measurement, and delivered a provisional title for the performance of mining works. The legal uncertainty produced by this title led to its elimination in the Code of 1983. However, the period originally indicated for the measurement request persisted.

Table 8.2. – Proposed terms for the procedure of constitution of mining concessions.

Formalities	Exploration Mining Concession	Mining Claim
Constitutive Judgement Application	From 90 to 60 calendar days since the filing of the complaint.	DOES NOT APPLY
Request for Measurement.	DOES NOT APPLY.	From 200/220 to 60 calendar days since the filing of the complaint
Maps and Records of Measurement.	DOES NOT APPLY.	From 15 to 12 calendar months since the filing of the complaint[41].
Summary publication in Official Mining Bulletin.	From 120 to 90 calendar days since the constitutive judgement.	
Registration of the Constitutive Judgement in the Mining Registry (part of Land Registry).	From 120 to 90 calendar days since the constitutive judgement.	

Source: National Productivity Commission.

In the case of operating concessions (mining claims), in addition to its extensive processing temporality by legal mandate, this period is often prolonged due to the poor performance in metering carried out by the interested party's experts. This forces Sernageomin to correct the analysis several times, generating inefficiency due to recursion in the revision, most of which (65%) are due to typing errors or in the maps (aspects set out in the Mining Code Regulation).[42] This is due to three fundamental reasons: (i) any civil mining engineer may act as a metering expert;[43] (ii) there are few incentives to join Sernageomin's qualified annual list of experts; (iii) Sernageomin's expert qualification (those that belong to the annual list and the mining engineers that present measurements) is not public for holders of mining rights who wish to hire them for measurement operation or other

41 Regarding metering, it is difficult to think of a shorter period than the one described here. The execution of a measurement in a high mountain range may well take 6 months of continuous construction works of landmarks (georeferenced concrete cones) and land demarcation. So, if the periods are reduced to smaller values, it is impossible to execute the measurement operation within these terms. The 15-month deadline, also established from the 1932 Code, ensured that in the entire national territory (regardless of its geography) it was possible to physically carry out the measurement operation, an ideal that must be preserved in this proposal. The implementation of new technologies helps determine the coordinates of measurement, but the measurement operation will be, at any event, a physical one.

42 Deeper observations such as improper alignment or positioning of landmarks, errors in geolocation rinex files or errors in relation to overlapping mining claims only account for 35% of the total observations made in a period by Sernageomin.

43 Art. 71 par.2 Mining Code. Usually, experts must apply annually to Sernageomin and be qualified with an enabling exam.

tasks (e.g.: drawing maps for the mining concession). To encourage joining this list and correctly measure the annual qualifications of Sernageomin's experts, as well as those who have submitted three or more measurement operations in the last 18 months, must be made available to the public.

According to its typology, once constituted the mining concession will either have a limited duration or not. Its duration is related to the kind of protection required by the concessionaire in the various stages of the mining activity's development. In general, a mining operation consists of five stages: prospection, exploration, mining construction, mining exploitation activities and closure. In Chile, mining activity is divided into three cycles: 1) exploration (prospection and exploration activities), 2) exploitation (construction and exploitation activities), and 3) closure of the mine.[44] Thus, exploration concessions last two years, starting from the constitutive sentence[45] and may be extended for another two additional years as long as its prorogation judicial procedure states that at least half of the total granted concession area is abandoned.[46] The operating concessions (mining claims), meanwhile, have indefinite duration.[47] It is clear that the combination of a low patent cost and the unlimited duration of the concession severely restricts the possibility of entry and exit for the agents that competitive markets demand, and allows the storage of unexploited property. Along with the information asymmetries, the social interest involved in mining activity is reduced and allows for the use of this kind of immovable property for speculative purposes.

Although the exploration concession has a definite time (two years, extendable by two more), in practice this period does not apply, given the use of repeated petitions of a particular area, or the option of some sort of perpetual exploration license.[48] This prac-

44 Regarding this particular stage, there are some specific obligations of the mining concessionaire in Law No. 20.551 that regulates the closure of mines and its installations (O.J.O.J. Nov. 11, 2011).

45 Art. 17 Constitutional Organic Law on Mining Concessions and Art. 112 and seq. Of Mining Code.

46 The prorogation of the mining concession does not imply its renewal. Although materially similar, both concepts are not technically synonymous. The prorogation of the exploration concession allows to preserve the date on which the application was originally filed in the Court for all legal purposes (e.g., to be able to demonstrate preferential rights in accordance with article 41 of the Mining Code); while the renewal of the concession would mean giving rise to a new term of 2 years, counted from the date of the constitutive judgment.

47 Art. 17. Constitutional Organic Law on Mining Concessions.

48 This practice is also known as "floor creation", in reference to the precedence involved in each concession, the first floor being the one with the oldest exploration concession, the second having the postulated concession and so on. The importance of this floor creation process is that, if someone appears manifesting the same area (that is, requesting concession of exploitation), whosover has the claim or the concession of exploration of the date before the manifestation may oppose it, in order to avoid that the manifestation overlaps his right (Article 61 Mining Code). Hence, the creation of floors by claims is a practice used to maintain the preference in any given area at a very low

tice of re-claims allows the holder of an exploration concession to extend his/her right indefinitely (as long as there are no other applicants in the same area), or to make use of the legal preference in order to transform its exploration concession into a mining claim, whether to carry out mining activities or simply to maintain this kind of property. Shortly before the exploration concession's expiration date, the holder may: (i) submit another claim that covers the same area and coordinates, thus keeping in advance his ownership, avoiding going back to square one by following the two year term regulation, if no one has shown any interest in the concession area or, in case a third party presents a petition for the same area upon expiration; [49] (ii) if a third party shows interest, the holder may transform the exploration concession into a mining claim, expressing it under a pre-emptive right. If a third party presents a claim or a manifestation for the same area, the holder may request it as a mining claim (transforming its exploration concession into an exploitation one) and, since the cost of holding the mining claim is low, mining activities will not necessarily be performed. In this way, the owner does not judicially request prorogation of the previous exploration concession, in which case it would be for another two years but must release 50% of the area that was originally covered by it. The re-claim can be made by both the holder and related persons (work, kinship, etc.) without any kind of restriction.[50] In other words, given the current low maintenance cost, a concessionaire can block the area either by re-requesting the mining right of exploration (if there are no other stakeholders) or by going from exploration to mining claims (in case there are). The problem is not the design of the system, which correctly rewards the "first discoverer", but it is the parameters of the system: the low cost that favors mining property storage.

There are several alternatives for confronting this scenario. The key is to generate conditions that encourage the effective use of the mining concession, either exploration or exploitation, over the blocking of territory caused by agents not interested in the mining activity.

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cost (constituting a concession of exploration has a cost of 1/5 of the total cost of constituting a mining claim, patents considered).

[49] The holder of the mining right knows the coordinates of the area that he wishes to preserve for him/herself, so he/she knows that once the initial two-year period is approaching to an end, it has two options: to put a new claim in the same area or to manifest under the pre-emptive right (transform its exploration concession into an exploitation one).

[50] Art. 5 of Constitutional Organic Law on Mining Concessions. Thus, in the case of manifestation using pre-emptive rights, only the holder has the faculty to do so (Art. 10 Constitutional Organic Law on Mining Concessions, Art. 41 Mining Code).

8.3.1. The international situation

Regarding the granting of mining concessions, there are three possible alternatives in important mining districts: (i) concession granted through judicial proceedings, (ii) a concession granted through an administrative process, and (iii) through an administrative contract. For these three alternatives, there is a balance between discretion and flexibility. The judicial procedure grants greater certainty, but has less flexibility, while the administrative contract is more flexible but also the most discretionary. The administrative procedure systems (with or without the possibility of judicial intervention) is in an intermediate position. An administrative authority predominately grants the concessions in several benchmark countries (see Table 8.3). In Latin America, most of the countries grant mining concessions administratively, except for Colombia, and some Argentinian provinces, where the mining concession is given through a direct Administrative Contract with the State.

Table 8.3. Granting systems of mining rights in selected countries.

Kind of instrument where the mining rights are granted		Chile	Western Australia (Australia)	British Columbia (Canada)	Peru
Concession	Judicial	Tribunal in the geographical area where the concession is located.			
	Administrative		Mining and Oils Department.	Ministry of Natural Resources Operations.	Geological, Mining and Metallurgic Institute.

Source: Cochilco based on Ossa (2012) and Jara (2011).

The general international trend favors limited periods regarding the duration of the mining rights, with the right to extend it subject to requirements. Only in some Latin American countries (Argentina, Chile, Brazil, Peru) can the mining claim last indefinitely. In most cases, the maintenance of the right depends on compliance with the correlative protection obligation.

Table 8.4. Features of mining rights in selected countries.

Features of Mining Rights	Chile	Western Australia (Australia)	British Columbia (Canada)	Peru
Exploration Stage	Two year concession, renewable by 2 more years with limitations.	Exploration License required. It lasts 5 years, renewable for 5 more.	Exploration Request. It has a fixed term and can be proroga-ted if require-ments are met.	Unique type of mining concession with an indefinite duration.
Exploitation Stage	Exploitation mi-ning concession with indefinite duration.	Exploitation public contract for 21 years, renewable on periods of 21 years tops.	Exploitation public contract for 30 years, renewable on periods of 30 years tops.	
Other types of mining rights		Prospection License, Retention License and others.	Exploratory Certificate.	Mining Conces-sion of Utility, Transport and General Labors.
Grid Use	No	Yes	Yes	Yes

Source: Cochilco based on Baker & McKenzie (2013) and Jara (2011).

In developed mining districts, such as Western Australia and British Columbia, other mining rights point to a rapprochement between the mining property and the nature of the activity. For example, the Prospecting License[51] and the Exploratory Certificate, respectively, aim to reduce the risk of mining property being used for non-mining purposes, since only those who have such a license will be entitled to request an exploration concession later. Another qualifying requirement for a mining concession in the case of Western Australia is to submit a mining proposal, a mineralization report, and status of the mining operation certified by a competent person, or a resource and operation progress report. A similar proposal must be submitted to obtain a General Purpose Concession used for sterile material, tailings, machinery, and utility plants. In short, in order to support the applicant's request to constitute a mining immovable property in a particular area, and the intended uses for that property, a statement of grounds must accompany the concession applications.

51 Allows to extract or alter up to 500 Tons of material with the aim of exploring the area in question and extracting samples of up to 20 kg. This is only in certain territories according to the corresponding federal law

In Peru, the Mining Concessions of Utility, Transport and General Labors aim at the peripheral activities developed during a current or future mining activity. Thus, the former refers to the mineral treatment made by the concessionaire and it is paid for by the treatment capacity of its utility plants. The latter relates to the mineral products' transport means, by non-conventional methods (conveyor belts, pipelines, etc.) connecting a mining center and associated facilities (e.g., refinery). The third ones refer to auxiliary mining activities (ventilation, drainage, lifting) awarded to two or more concessions from different concessionaires.

Given the above, according to the activity to be developed, it is possible to infer that the more specific the mining concessions granted to a particular holder, the more accurately they will adjust to the nature of mining industry.

8.4. The protection obligation of mining concessions

The set of obligations pertaining the owner of a mining concession to maintain his property are known as protection obligation. It is based on the fact that in Chile, the mining activity has always been considered a public interest. It is essential for the country's development that mining titles be used for the purpose they were granted for: effective mining exploration and exploitation. The protection obligation is both a promoter of this objective and a preserver of the stability of the mining property right. It allows the necessary certainty to explore and exploit deposits.[52]

In general, the protection obligation can adopt different shapes in the search of a mechanism that allows, at the same time, encouraging mining activities and the assurance of mining property. Given the natural difficulty of this task, some legislations have opted for the protection of mining rights by requiring its owner to initiate mining operations within a period, uninterruptedly and following a project timetable previously approved by the competent authority. Their repeated non-compliance would lead to the loss of the mining right, which would return to the State. This mechanism is known as "protection per work". Although its benefit is that it directly incentivizes mining production, unfortunately, it also depends on the administration's discretion,[53] which undermines the certainty required by the mining activity.

52 See Ossa (2012). Ver Ossa (2012).

53 The administration may have very broad and ambiguous criteria on what is meant by mining work and how to control it, thus reducing the certainty and legal security necessary for the development of this task. For this reason, the countries that use it have clear and non-interpretable rules on the scope of work to be scrutinized, which, in addition, can be brought before the Courts of Justice (as well as labor, sanitary or other fines).

On the other side of the spectrum are those legislations that specify the protection obligation through the periodic payment of a patent, a mechanism known as "protection per patent." The regulatory body determines its amount (as a law or regulation), and the value of this patent tends to be related to the profits derived from the economic activity of the mine. Repeated non-compliance would lead to the loss of this mining right, returning it to the hands of the State. The simplicity of its compliance and the reduction of administrative discretion (minimizing the uncertainty it generates) is an advantage. However, this leads to a minimum (or zero in the case of cheap patents) promotion in the mining activity itself, for as long as the owner of the concession pays for the patent, he/she maintains his/her priority over the area. The problem worsens in case of cheap patents, such as Chile.

Chile is a protection per patent case, which, as already mentioned, has lower patents than other mining jurisdictions. Furthermore, they can still be reduced by two-thirds of their cost for non-metallic patents.[54] In Chile, nonmetallic mining concessions have lower transaction rates than the metallic ones, which is explained in part by the reduced amount of patents that these concessions have. It is important to note that currently, nonmetallic mineral deposits may be worth as much or more in value than metallic substances, for example in silicate, silica and carbonate deposits, or those located in salt flats such as lithium. [55]

Moreover, the regulatory procedure for requesting the reduction of the value of non-metallic patents does not require certification of the actual existence of non-metallic substances in the respective concession. This fact may lead to one of three situations: (i) a concessionaire reports that the materials within its concession are effectively non-metallic; (ii) that in bad faith the concessionaire passes metallic substances as non-metallic substances to benefit from a 66% reduction in the corresponding annual patent; (iii) that the concessionaire declares the actual existence of non-metallic substances even when there is no interest in exploiting these materials, but rather, for the protection of the land intended for other purposes (real estate, eolic or electric projects, etc.)

The Mining Code Regulation requires that in order to avail themselves of the reduced patent, titleholders must attest to Sernageomin "that the primary economic interest lies in the nonmetallic substances or metalliferous placers existing in them or salt flat substances." In this order of requirements (and as it indeed happens), they must certify it

54 0,03 MTU per year per hectare in concession (ap. US$ 2).

55 Note that the mineral wealth of Chile is currently given by both metallic and non-metallic (silicon) minerals and present in salt flats (lithium). For example, 50 years ago silicon was not a mineral considered to form structures, but today silicon chips are part of all light electronic devices.

through "sale invoices of the extracted mineral substances, production reports, shipping documents, geological or technical reports and any other useful means of proof." All that is required to certify that there are only nonmetallic substances in the field covered by these concessions is a simple statement by an authorized expert. This way, the holder of those concessions becomes the creditor of the benefit, without further revision or questioning from the authority.[56]

An alternative would be to equal metallic and non-metallic patents, although there are other alternatives. If the distinction amongst patents is maintained, the reduced patent mechanism can be improved by considering the following: (i) require the holder of the non-metallic concession to carry out advanced geological studies, which can be updated annually, in line with the Regulation of Article 21 of the Mining Code (Law No. 20,819); (ii) to follow the guidelines of the original measurement. The mining concession of any mineral requires for its constitution a cadaster or measurement, elaborated by an authorized expert or a mining engineer. It is necessary for the substances in concession to be displayed on this analysis, under an affidavit of the expert in question.[57] Then it is reviewed on site by Sernageomin, and if it approves the report, with its mineral description, it must abide by it during the complete duration of the concession, avoiding changes in the nature of its primary economic interest to prevent the concessionaire from benefiting fraudulently from a reduced patent; (iii) to require an affidavit with photographs taken by the operating concession's original metering expert or by an expert appointed by Sernageomin from its list of qualified experts for the period. This affidavit must state that no metallic substances were found or that the non-metallic substances already measured were still present. This can be reinforced through the requirement of a notary certification.

While all these proposals imply a higher cost to the mining concessionaire who seeks to benefit from this patent reduction, this would give certainties as to the mineral resource

56 Added to this is the contradiction that results when comparing the requirements made by the Mining Code to small miners to benefit from a reduced patent system. Indeed, Article 142 of the Mining Code provides that small-scale miners and artisanal miners will pay an annual patent of 0,0001 MTU per full hectare exploited, but must prove to Sernageomin that they operate in person or with a maximum of 12 or 6 dependents (respectively) and also have all the permits and easements that are necessary to exploit (a requirement that is not made to mining that is not declared as small or artisanal), having to renew these requirements every two calendar years to access the benefit. This amounts to less than$1 per 100 hectares under concession.

57 Pursuant to Article 37 of the Mining Code Regulation. Many measurement records are inaccurate in this respect, which most of the time are not reviewed or technically ascertained by the authority, either due to lack of personnel or adequate resources. For this purpose, in the section "Deposit" of the measurement records, the experts can put a generic and vacuous phrase like: "concessible substances", which does not say whether they are metallic or non-metallic substances.

present in the country and its evolution. It would also eradicate the malpractice of benefitting from a reduced patent cost without a just cause. It also takes into account the constitutional mandate that states that mining concessions are granted to meet the public interest that justify its granting, which are precisely mining exploration and exploitation.

8.4.1. The international situation

At the international level, all legislations evaluated have a minimum common denominator regarding the protection obligation: protection per work. The degree and demand vary between countries (see Table 8.5). Of the cases examined, only Chile maintains protection per patent.

Internationally there are two regulatory tendencies observed: (i) the requirement to comply with a work plan and/or minimum investments, always in conjunction with the payment of an annual patent and the delivery of geological information; (ii) the progressive increase in the patent's value in case the mining property is not used. Both tendencies seek to discourage the accumulation of property, avoiding generating entry barriers to new agents and obstacles to the development of those already present. Compared to these international best practices, our legislation has a significant margin for improvement.

In Peru, the protection consists of two elements: (i) annual patent payment (Entitlement of Entrance) starting from the year and date the application to the administrative authority that grants mining concessions is submitted,[58] and (ii) achieving a minimum production level per hectare before the tenth year counted from the first payment of the entitlement of entrance (sub surface-fee). Failure to comply with any of these conditions carries consequences. In the case of the sub-surface fee, its non-payment for two periods leads to the concession expiration. In case of voluntary breach of minimum production, an annual penalty per hectare is foreseen from the eleventh year until the year in which the required production is met. If there are no variations by the fifteenth year, the concession's expiration is declared. The sub-surface fee in Peru (the patent) costs between US$0.5 and US$3.0 per hectare depending on the condition of the holder. Instead, in Chile, the

58 The Geological, Mining and Metallurgic Institute (Instituto Geológico Minero y Metalúrgico (INGEMMET)) is a decentralized technical public agency whose purpose is to conduct the ordinary mining procedure, including the receipt of petitions, the granting of mining concessions and their extinction according to the law, ordering and systematizing the georeferenced information through the National Mining Cadastre, as well as the administration and distribution of the Entitlement of Entrance and Penalty. It also carries out the collection, storage, registration, processing, administration and efficient dissemination of geoscientific information and that related to basic geology, subsoil resources, geological hazards and the geoenvironment.

annual patent value is US$1.4 per hectare for exploration concessions, US$6.8 per hectare for operating concessions, and US$2.3 per hectare for nonmetallic mining concessions.[59]

In Canada, the exploration concession's protection is mixed because it requires the payment of a patent along with a minimum creditable investment (amounts vary by provinces). The system has an incremental scheme, which over time increases the patent and/or the minimum level of investment required, with the objective of not leaving both mineral and productive resources vacant. A similar scheme is followed by Australia.

If we compare the differences between patent protection, including the tax benefit payment, we see that Chile has a difference of 2.5 times the international average regarding the payment of the exploration patent.[60] For exploitation, this is evident in the patent payment of 2.5 times the international average (considering only patent).

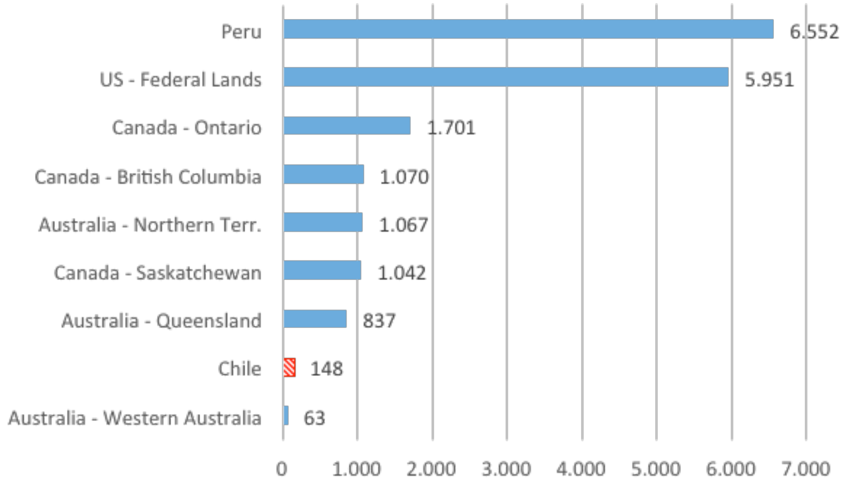
Nonetheless, the level of total protection (patent + labor) that is requested by the jurisdictions to dealers must be compared. Chile has low costs concerning the full protection of both exploration and mining claims (see Figures 8.10 and 8.11). For instance, an initial increase of five to seven times the current value of exploration patents, would mean that the country would reach levels similar to the initial minimum of the other mining districts that require mixed protection (Queensland and Saskatchewan). Regarding exploration, a 13-fold increase would bring the national patent (US$148) to average values of the countries analyzed in the international comparison (US$2,046).[61]

59 Estimated at January 2017.

60 The costs of mining recognition licenses and tax incentives in some jurisdictions could also be considered in this analysis. Mining Recognition Licenses exist in Australia (Queensland and Western Australia) and Canada (British Columbia, Ontario and Saskatchewan). The inclusion of the license fee changes the relative position of Chile, making it cheaper relative to the rest of the world and increasing the difference from the average to 4.5 times (see Annex - Figure A.1). Similarly, there are tax incentives in Australia (Exploration Development Incentive) and Canada (Mineral Exploration Tax Credit). These incentives seek to mitigate the decline in exploration during periods of low prices. However, for the purposes of the analysis, comparability was privileged based on available information, so neither the recognition costs nor the tax incentives were considered.

61 If only values of mining recognition are considered, Chile is the cheapest country regarding costs of full protection (patent + labor). See Annex - Figure A.2.

Figure 8.10 - Full protection costs on Exploration Mining Concessions in selected countries in 2016.[62]



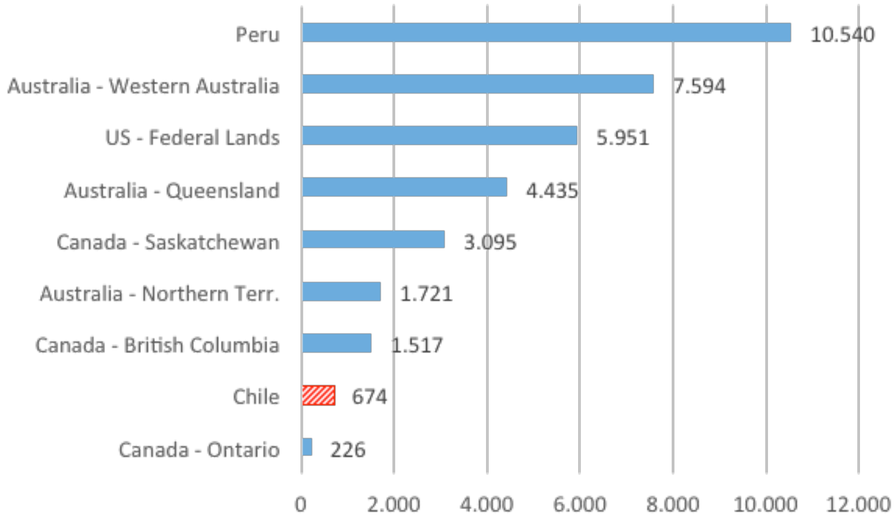
Source: National Productivity Commission based on CESCO (2016)

In the case of the mining claim, the current value of the total protection is also under international standards. A six-fold increase in the present value (US$674) would put it in the middle range of the total value of the districts analyzed in the international comparison (US$3,973). Note that this considers that minimum investments or other elements are required to maintain the mining right[63] so that an increase of the patent in Chile should be accompanied by a rebate mechanism subject to the demonstration of mining labor (direct or indirect) to maintain the country's competitiveness.

62 The full annual protection cost was calculated by adding the payment of the initial application (e.g.: tax benefit payment in Chile), annual patents, minimum annual investments, and minimum annual production for an equivalent area of 100 hectares of concession (1 km2) to homogenize the different concession types in each legislation considered. The average cost was considered over a 10-year time horizon because, in some legislations, the patent payment and minimum investment or production requirements vary according to the grant year. This analysis does not include the cost of recognition licenses.

63 For instance, Western Australia has a patent of A$17 and a mining labor requirement of A$100 per hectare (as full protection mechanism).

Figure 8.11 – Full protection costs on Mining Claims
in selected countries in 2016.



Source: National Productivity Commission based on CESCO (2016)

Table 8.5. Obligations of mining right's holders in selected countries

Key features of the rights.	Chile	Western Australia (Australia)	British Columbia (Canada)	Peru
Exploration Stage.	Annual Patent Payment.	Annual Patent Payment. Provide a mining labor plan, mining results and basic geological information.	Annual Patent Payment. Provide a mining labor plan, mining results and basic geological information	Annual Patent Payment. Duty to fulfill certain mining works. Minimal requirements of mining production and investment. Fines for non-compliance. Provide basic geological information.
Exploitation Stage.	Annual Patent Payment.	Annual Patent Payment. Compliance with mining labor plan and investments.	Annual Patent Payment. Compliance with mining labor plan and minimal investments.	

Source: Cochilco based on Baker&McKenzie (2013) and Jara (2011).

The evolution of international systems towards protection per work and incremental patents suggests that this incentive structure aligns the incentives of the owner of the resource (the State) and its concessionaire. In contrast, Chilean mining concessions, with low-cost protection per patent, can be used for purposes other than those conceived (the exploration and mining of deposits), and to concentrate the mining property.

> **Finding 8.6:** The current protection per patent system does not constitute an incentive to carry out effectively exploration and mining, because it does not require mining labor directly and has a low patent value.
>
> **Finding 8.7:** The cost of the Chilean mining patent is low compared to other countries, even more so, considering that in other jurisdictions, additional obligations to the patent payment are requested to maintain the mining concession.

8.5. Geological information and its availability

Mining is a long-term activity, and mining exploration is a high-risk activity. Therefore, greater availability of geological information implies less risk and more significant mining activity. The mechanism is as follows: (i) it attracts investment in exploration by allowing the industry to identify areas of mineral interest, (ii) it increases efficiency in exploration by preventing companies from duplicating basic information[64] and/or exploring irrelevant areas, (iii) provides useful information for the modeling and making of risky exploration decisions, and (iv) shows the State, areas of potential interest for infrastructure development or territorial planning.

In Chile, pre-competitive geological information is of low availability, and even lower quality, compared to the main competitors.[65] This reduces the internal knowledge on the mineralogical richness of our country. Furthermore, its appeal for investments is lost, considering that the international mining market uses official records of the geological potential to project its investments. In certain stages, geological information becomes a public good, and at an aggregate level it is data that produces knowledge. Moreover, as an accessory and derived from the mining concession, it shares its destiny and constitutional mandate to fulfill the public purpose that justified its granting in concession.

64 It is not desirable or efficient that geological basic information be regenerated since it ends up falling on each one of the sector's actors that use such information. Usually the discovery of a deposit occurs when a series of campaigns have been carried out by different companies in a specific territory.

65 See Fraser Institute (2016) and the previous years of this ranking.

Obtaining geological information is one of the foundations that justifies the granting of a mining concession. At the international level, a mineral occurrence must be demonstrated in a given sector as an enabling requirement to move from an exploration concession to a mining claim. In Chile, this occurrence could be accredited ex-ante by experts authorized by Sernageomin or by Competent Persons,[66] which would allow the mining claims to be granted in concession, the right to have valuable geological information, as well as enable the concessionaire to deal with it clearly and have more information on its true potential.

There are different levels of geological information that could be considered, but a list based on international experience suggests the following:

- Geological, geochemistry, geophysics, and both surface and in depth mineralogy.
- Hydrogeological: phreatic surface, pumping tests, etc.
- Exploration drill holes and representative physical samples: delivering to Sernageomin up to a quarter of those samples of units of geological, economic, scientific interest, etc.[67]
- Radiometric dating.
- Stratigraphic descriptions.
- Calculating mineral resources and mining reserves.
- Financial information on exploration targets, campaign costs/expenditures/investments by geographic location.

To obtain geological information, four aspects must be defined: (i) the type, detail and frequency of the information, (ii) the moment the concessionaire will require it, (iii) the moment in which it goes public, and (iv) the concessionaire receives in exchange, any benefit established by law.[68]

66 See Law No. 20.235 (O.J. Dec. 31, 2007) that regulates the institution of Competent Persons and creates the Competences Rating Committee on Mining Resources and Deposits. As of 2016, there are 329 professionals qualified as Competent Persons in Chile.

67 Battons, cutting or scraps, it refers to hand made samples or crushed samples.

68 For instance: a reduction in the patent costs, access to privileged financing or a possibility to extend the mining claims' duration, if it was limited. Por ejemplo: una rebaja en patente, acceso a financiamiento privilegiado o una posibilidad de prorrogar la concesión de explotación -en caso de que ésta fuese definida.

From the above list, a minimum to consider would be information on surface geology and geochemistry, radiometric dating, resource and reserve calculations, and financial information on exploration. Regarding the second aspect, the geological information raised should cover both the process of constitution of the mining concession (exploration or mining claim) and its conservation and subsequent termination.[69] This should be done to preserve the requested mining right's existence history not only through its registry in the pertinent Registry of Mining Discoveries (or Property) in the due Land Registry (or mining right's identification) but also through a precise determination of its geological content (its substance). For this, the geological information that the authority will require (e.g., geophysics and magnetometry) must be defined objectively, in order forthe concessionaire to be able to project his costs, and also to provide and guarantee legal certainty to third party investors, who may be able to know the type and information and the date since it is made available to public. One way of promoting the collection of such information may be through the procedure of constitution of the mining claim, requesting the concessionaire to provide such information in the corresponding maps and measurement records,[70] just as the requirements of the Mining Code Regulation in this respect are set forth.[71] The Australian experience of collecting information and accrediting the existence of geological operations (through the preservation of exploration drill core samples,[72] aerial photographs, and mandatory records) on an annual basis by the concessionaires could be replicated in Chile through regulatory changes to the cited articles.

As for the third aspect, the moment in which the information is received by the authority is not necessarily the same as the one in which it is presented to the public. The information is made public once the concessionaire releases his land from the exploration concession or mining claim. For this, it is necessary that Sernageomin have storage and processing capacity as well as adequate administrative governance. The geological information is collected as a public good, accessory to the original mining right, which is why Sernageomin's capabilities and obligations must go permanently in that direction. Regarding the last aspect, incentives should be developed for the mining rights holders so that they can perform minimum recognition activities for the obtainment of necessary and relevant

69 Whether by waiver or loss of the mining right due to any legal reason: expiration, nullity, etc. Ya sea por renuncia o pérdida de la concesión minera por cualquier causal: caducidad, nulidad, etc.

70 These include land portfolios, rinex files, georeferenced coordinates and photographs, among others.

71 Art. 21 and seq. For exploration mining concessions, articles 26 to 39 for mining claims.

72 It is a tube of material extracted from the ground, which, in each of its sections, contains a piece of the geological crust to which it refers. This baton can be two mts. Minimum of length and 2 cm. of diameter, freezing a sample of the geological wealth of a mining ground.

geological information. This would enable the fulfillment of the mining concession's ultimate purpose, without generating doubts concerning the granted mining right.

It is necessary to highlight initiatives such as the National Geology Plan and Sernageomin's GEOMIN Portal, and the soon to be promulgated regulation of article 21 of the Mining Code. However, such efforts must be complemented by the generation of an information culture among all stakeholders (private and public) to provide transparent, accurate and up-to-date information on the estimated real content, extent and projections of mining property in Chile.

Chile had an unprecedented mining expansion in the last 25 years but did not take advantage of this development to generate a pre-competitive geological information database at the level of developed countries. In pursuit of the country's future in mining activity, it is imperative to move in this direction.

> **Finding 8.8:** Chile shows a significant lag both in availability and quality of pre-competitive geological information.

8.5.1. The international situation

Australia (Western Australia[73]*)*

Western Australia's mining laws define different types of mining rights and request the delivery of geoscientific information mainly for exploration licenses, although some reports are also required in mineral exploitation concessions (or mining claims). The information to be provided includes geological samples (drill core samples), expenditure reports, reports on the works done, production, mineralization, reserves, and resources. The information obtained during the mining exploration stage is available to the public after a period of confidentiality, and it is even possible to take core samples stored by the geological services.

Australian legislation establishes prospecting and exploration licenses. Both consider the obligation of the mining right's owner to deliver relevant geological information at a given time. In the first case, reports of the work done, the money spent on the mining prospection, and geological samples obtained with details of each mineral type recovered, their quantity and the exact location of the recovery site are provided. A fine is consid-

73 It is the location of over 50% expenditure in mining exploration in Australia.

ered in case of not giving information or giving false information. In the second case, the holder must provide, besides the previous information, studies and operations in the exploration - including probes. Failure to comply with these duties is deemed a felony.

On the other hand, when applying for a mining claim, the application must include a mineralization report by a qualified person and a resource report. A mineralization report is a document prepared by a competent person[74] detailing the results of the exploration, including the type of minerals, the analytical results of the samples and the measurement procedures of mineralization processes. Also, during the validity of the mining concession, periodic reports must be submitted along with geological samples and details of the minerals discovered.

The geological information provided by the concessionaires is released after three months of the concession's waiver, expiration or cancellation, or when the information has been in the Mining Ministry's department for over five years. The information is standardized through regulations that stipulate a set of instructions for each type of information generated and delivered by the concessionaire. A penalty of AUD$ 10,000 is forfeited in the event of failure to produce or provide false or misleading information.

Finally, it should be noted that Australia presents one of the most complete platforms for access to geoscientific information worldwide. Thus, it stores a large amount of geoscientific information and geological samples available publicly and free of charge. The GSWA (Geological Survey of Western Australia) has a compilation and storage of Western Australian Mineral Exploration reports[75] (WAMEX), accessible through a search engine and with a catalog of mineralization and resources reports and reservations of the applications for the operating concessions, which is also public and free. The GSWA also has geological maps, geochemistry information, geochronology, geophysical, seismic and Metallo-telluric studies, and a variety of other products available to the public. Other federal states like Northern Territory also have similar systems. At the national level, Geoscience Australia presents a visualization of geological maps portal, AUSGIN[76] and also a delivery system of geophysical information and digital elevation.[77]

74 Qualified Personnel according to the Mining and Metallurgic Australian Institute, or from Geo-scientists Australian Institute. It is similar to the figure of Competent Persons in Chile (regulated in Law No. 20.235, O.J. Dec. 31, 2007).

75 http://geodocs.dmp.wa.gov.au/document/documentSearchCriteria.do?from=topNav&cabinetId=2200

76 http://portal.geoscience.gov.au/gmap.html

77 http://www.geoscience.gov.au/cgi-bin/mapserv?map=/nas/web/ops/prod/apps/mapserver/gadds/wms_map/gadds.map&mode=browse

Canada

The Canadian case is presented as a relevant example of best practice, particularly in the provinces of Ontario and Saskatchewan. In Ontario, geoscientific information is provided through various detailed reports of studies (prospecting, geology, geophysics, geochemistry, drilling, microscopic, environmental, etc.) with their respective maps, plans, and certifications. Accepted by the administrative authority, it grants credits to the mining rights' owners and allows them to maintain them. In Saskatchewan, the reports of operational expenses and the work done, as well as the results, are summed. In both provinces, the particular retention and storage of drilling cores are regulated, and the authority can request these from its holders.

In the Canadian case, the mining request is the license necessary to carry out exploration activities and also grants a special right for mining activities.[78] Each year the incumbent must credit a minimum expenditure on exploration per mining request' unit[79] and send a report that advocates this expense. These costs include regional and prospecting studies, reports of geotechnical, geological, geophysical and geochemical land and air surveys, as well as drilling and measuring probe reports; and other studies may be added eventually. In the case of mining activities, mine owners must submit an Annual Report containing at least: (i) nature and costs of mining and exploration works, (ii) capital expenditures, (iii) mining reserves to date, (iv) quantity and value of the ore produced and (v) number of employees.

All this information is granted to obtain credits or reductions in the annual payments corresponding to the maintenance of the license. Credit generation incentivizes reporting, and there are no fines associated with these cases. Likewise, the delivered information, once approved by the Ministry of Development and Mines, is available to the public.

Saskatchewan province, for its part, requires mining rights' holders to provide the related records, in both exploration and mining claim cases: samples of minerals and substances found during operations; amount and place of origin of the minerals produced, used, stored and marketed; and any other reported work. However, unlike the province of Ontario, all provided information remains confidential, until the permits or concessions come to term[80] or are waived.

78 In Chile, there also exists the possibility that the mining request, once becoming an exploration mining concession, grants a pre-emptive right in order to constitute a mining claim based on it, according to the provisions of articles 41 and 114 of Mining Code and articles 15 and 18 of Mining Code Regulation.

79 CA$ 400 per year per mining request unit.

80 Whether by the end of the license or concession period, or by the depletion of the mineral in the area (mineral disposal).

Mining right's holders are solely responsible for the accuracy and completeness of all the geoscientific and economic information delivered,[81] in both provinces. If the information granted contains intentional inaccuracies or falsification of the information issued, it is punishable by fines.

The authority stores both the geological information and the drilling cores, and these are available to the public use. Also, the country and the federal states provide information, maps, studies, publications, applications, etc., of all the country's geoscientific information.

In Saskatchewan, there is a sub-surface geological laboratory with a repository of exploration drill holes and cuttings recovered by the exploration industry, which along with rocks and mineral samples from other mappings, are publicly available for review on the Geological Service premises. Also, there is a database with exploration reports (SMAD)[82] and the SMDI, an index containing descriptions of occurrences of industrial minerals in the province.

In Ontario, Geology Ontario[83] provides access to maps, reports, GSO data sets, as well as private sector assessment reports in the AFRI (Assessment File Research Imaging). Geology Ontario also has mineral resource data, underground and surface perforations, lithogeochemical results and information from abandoned and inactive mines. In particular, the drill register (ODHD) contains the details of the data compiled from the evaluation work reports. For its part, the OGSEarth[84] provides the data collected by the Mining and Minerals Division that can be observed from different geographic information programs.

At the national level, the GeoGratis[85] website is available to the Canadian Geological Survey where maps, data, and publications can be found free of charge. Also, mining exploration statistics are available, providing a model for reporting and guidelines for exploration.[86]

81 If mining right's holders sell, transport or ship any mineral or substance removed from the concession area, they must submit a report (in addition to other requested statements) with information regarding the minerals marketed, the method of exploitation and their final customer.

82 These indexes include the information of the drilling logs and their descriptions, maps and reports of geological, geophysical and geochemical studies, and the results of tests.

83 http://www.geologyontario.mndm.gov.on.ca

84 http://www.mndm.gov.on.ca/en/mines-and-minerals/applications/ogsearth

85 http://geogratis.gc.ca/geogratis/en/search

86 http://sead.nrcan.gc.ca/expl-expl/RG-GR-eng.aspx

Peru

In Peru, the mining concessionaire is obliged to grant relevant geological information as part of the protection obligation. In fact, if it performs perforations, it freely disposes of up to 50% longitudinal of each section of core samples. The remaining 50% belongs to the State and must be kept in archives for their easy identification and location by the corresponding authority. The reports are made annually to the Ministry of Energy and Mines, and once the concession expires, it is passed to the Geological, Mining and Metallurgical Institute (INGEMMET) within a maximum period of 12 months.

The information submitted must at least contain mineralization and ore grades per sections of the drilling, surface geochemical information of rocks, soils, technical geological, geochemical, geophysical, hydrogeological, geoenvironmental and other studies carried out within the framework of exploration activities. The files should include studies and technical reports (text) as well as graphs, figures, tables, maps, geological sections, etc.

In Peru, INGEMMET is the recipient and administrator of all geological information in the country and provides free access to all its products and publications.

8.6. Financing for mining exploration

Chile has a financial market that has developed strongly in recent years,[87] though to a lesser degree in the mining sector. According to data from the Banking Superintendency, during the period, the percentage of the annual balance of loans granted directly to the mining industry concerning total new loans fluctuated between 0.6% and 1.4% of the aggregate economy's total, well below all other economic sectors. In short, there is a striking difference between the industry's share of credit and the contribution it makes to GDP.

Companies have different financing alternatives. Bank debts and the issuance of bonds or shares are among the most used tools, a strategic decision that depends on aspects such as the cost of funding, the entity's debt/equity ratio, ownership structure and the possibility of diversifying investments.

87 According to Central Bank data, the percentage of total loans to GDP reached 83% in 2014 compared to 50% in the early 1990s.

Stock market funding allows capital obtainment through the issuance of shares. This leads to financing long-term projects, due to their indefinite character. However, beyond the potential advantages, there are some specific aspects of national mining that represent a major constraint for fostering a public offering. Among the main restrictions are:

- Cultural issues. Mining companies, especially in medium-sized mining, are mainly family-owned. Therefore, they tend to be reluctant to include third parties on the property or to publish company information, indispensable for the market participation of these projects. Furthermore, there is a lack of comprehension in the financial sector regarding the mining industry, which has led over the years to a poor understanding between the two areas.
- Little access to mining property for exploration due to the current concession system, which leads to a small mining rights rotation. The current situation encourages big businesses to take a position on as many mining properties as possible, as a perpetual option to explore at a relatively low cost.
- The absence of geological information. As mentioned in the previous section, access to pre-competitive and high-quality geoscientific information is fundamental to increase the national territory's prospective perception, which the State provides to the industry for free. If transparency were improved, the search for financing would be facilitated.

Besides these restrictions, a hypothesis is that Chilean investors do not invest in mining due to its high risk. In fact, mining exploration is an uncertain, high-risk activity, where the investment is typically carried out in stages. Also, knowledge regarding mineral reserves is modified according to the level of expenditure. In turn, it has a strong pro-cyclical component moving in the same direction as the expectations of the target mineral price. From this perspective, according to various sector's participants, there are financing difficulties, given the alternative uses of capital and the volume of investments required, which have substantial implications for exploration, but also for the development of medium-sized mining.

However, in specialized financial markets of mining countries such as Australia and Canada, where appropriate tools and environments are in place and used to assess and classify such an inherent risk to the activity, expenditure in mining and exploration is significant, reducing the problem of low investment in mining.

It is important to note that efforts have been made in the Chilean stock market to bring mining industry closer to the capital market. In this sense, the Santiago Stock Exchange has had a significant relationship with the Toronto Stock Venture Exchange (TSVX) and signed an agreement that aims to deliver new financing models to local companies in the early stages of exploration or production based on the Canadian model operated on TSXV. This agreement was backed by Chilean capital market regulators, through the Securities and Insurance Commission (SVS) and Canada, and was also promoted by the Ministry of Mining of Chile.

The agreement signed by both stock exchanges allows issuers of the TSXV to opt for a double listing on the Santiago Stock Exchange, which would act as a gateway for these issuers of the Integrated Latin American Market (MILA). The MILA integrates Chilean, Peruvian, Colombian and Mexican stock markets without increasing the disclosure obligations of the issuer, thus bringing these issuers closer to the Chilean capital market. Likewise, the double listing of TSXV instruments on the Santiago Stock Exchange gave rise to the new Venture stock market of the Stock Exchange. This market is still incipient with 11 registered issuers.

All of the above helps to explain the situation of Chilean junior companies exposed in Cochilco (2015): most of the exploration is carried out by large enterprises with 77.9% of the total budget, well above the world average of 48.8%. The participation in the Chilean exploration budget of the junior companies is only 13.2%, well under the world average of 29.3%. Likewise, there are approximately 100 junior companies in Chile,[88] substantially lower than the number of junior companies in Canada (1,200), or Australia (700).[89]

In short, and as Cochilco (2015) indicates, Chile is advancing towards a greater association between mining and the financial sector, but not at the rhythm of the industry's importance in the country.

> **Finding 8.9:** Chile has a significant gap concerning referent countries, regarding both the share of junior companies in exploration spending and the link between the mining sector and the financial sector.

8.6.1. International situation

Canada

Canada is not only a leader in exploration and mining, but also owns the world's largest funding pool for junior companies. As we showed in the previous sub-section, Canada is

88 See Cochilco (2015b).
89 Based on junior companies listed on Venture Capital Exchanges (Cochilco 2015).

our leading international reference, and Chile has significantly approached this country in this respect.

The Toronto Stock Exchange (TSX) is the largest stock exchange in Canada and targets big business, with listing requirements higher than the TSX Venture Exchange (TSXV), a wholly owned subsidiary of the local stock exchange. As a Stock Market, the TSX / TSXV has the largest number of mining companies (1,318), which represented around 8% of the total capitalization. Additionally, the mining companies listed in the TSX / TSXV are diversified as per mining type[90] or geographic location.[91] Also, there is significant mobility: between 2000 and 2015, 50% of the miners that were listed on the TSXV passed to the TSX.

The Toronto Stock Exchange Listing System is divided into two sub-systems: Stage 1 and Stage 2. Stage 1 is focused on senior companies, which have the most significant financial resources, and Stage 2 is for enterprises that are at an initial financing phase. Companies in Stage 2 can move to 1 when they meet minimum requirements to list. There is a differentiation of the list of minimum requirements between stages according to the different sectors of the economy.[92]

The list of minimum requirements to be registered on the TSXV is based on financial performance, research and the stage of development. In addition to the above, the company must have a corporate governance structure, a board of directors and executives that meet TSXV specifications.

It is important to emphasize that in Canada the government's support of the mining sector is broad, which favors the participation of these companies in the stock market, and, consequently, generates interest of local and foreign investors in these companies' capital.

As for tax issues, Canada's mining and oil companies can transfer their tax incentives to shareholders due to investments in natural resource exploration as long as they are listed on the TSX Venture Exchange. Investors can benefit from these incentives if they are equity holders for a minimum period of 18 months. Besides, there is a particular regulatory framework for the sector, with disclosure rules and reserve certifications by its duly accredited professionals. In that sense, if the prospects of the stock market issues are of Greenfield type,[93] they contain a strong warning regarding investments for speculative purposes.

90 The first places are gold mining (22%), copper (15%), silver (14%), zinc (9%) and lead (7%).

91 Of 6,307 projects, Canada leads with 53%, followed by Latin America with 18% and the United States with 12%.

92 Mining, oil and gas, industrial, technology or biological sciences and real estate or investment.

93 Greenfield refers to new deposits and Brownfield to existing reservoir expansions.

8.7. The coordinate system of mining property

All modern mining legislation attempts to use available technology to achieve an efficient system regarding costs, information and processing times, both for management and for those who explore and work in the mines. Currently, it is fundamental to have an online mining property cadastre and mining property insurance systems based on modern technologies such as GPS or GIS.

Within this section, it is necessary to discuss the convenience or inconvenience of subdividing the national terrain into grids, as do Australia, Canada, and Peru. They assign to the mining rights holder one or more grids by which to divide the mining maps of each country. Thanks to this, measurement processes are expedited in the operating mining concessions, and, consequently, reduce their constitution times.

The use of the grid rests on the accuracy of cartography and technological advances that facilitate its implementation and reduce the possibility of overlapping mining rights, however its implementation should be a medium-term goal due to the complexities required by the transition. The grid[94] is not the lowest common denominator for the already constituted concessions' area, so that the transformation to such a system would affect the already established constitutional right of property over existing mining rights, and, therefore, would require the design of an adequate transition.

Also, the grid system is a proposed solution to a technical difficulty (like knowing beforehand the overlap between concessions, no matter the type). However, this system requires that the managing body of the grid will be the one that grants the mining concession's priority and not the court (as is the current procedure for the constitution of mining concessions), which would require changes in legislation (constitutional-organic and simple). In fact, the presentation of the respective application (claim or manifestation) to the Court determines the order of priority of the owners on a particular mining right, since it is a judicial procedure. In the Chilean case, the application's preeminence is not determined by the application of a block in the grid to the agency in charge.[95]

94 A quadrilateral with rectangular shape and North-South orientation.

95 Courts in Chile grant mining rights to the first person that presents at Court the application he/she is deemed, for all legal purposes as "the first discoverer" of the area requested in mining concession (exploration or exploitation). In countries with administrative or mixed systems like Peru, where mining property is granted through an administrative agency, the request for a block of the grid eliminates the possibility that this same block can be requested by others, maintaining the preeminence of the "first discoverer".

Another technical complexity resides in the reference ellipsoid (or datum) by which the system of the constitution of mining concessions in Chile is governed. In fact, the PSAD-56 and SAD-69 ellipsoids are neither geocentric nor compatible with modern positioning systems. Coupled with the fact that the Geographic Military Institute generates geographical charts under the international standard WGS-84, this leads to the necessity of changing the concessions' coordinates of the vertices. The change of datum implies, for some, a re-measurement of thousands of mining properties because this is not only a mathematical conversion from one system to geo-referential units system.[96]

It is clear that both the grid system and the WGS-84 standard are relevant for a better functioning of the mining property system. At the international level, the grid system is used in several countries (Australia, Canada) and is being adopted in other nations (United States). Peru also has a grid system, but, like Chile also has, the coordinate system is the PSAD-56. Significant efforts have been made towards a transition to the WGS-84 system over the last decade. Given the above, this is feasible and should be a medium-term goal for the country.

Finding 8.10: There is a gap in the standard of the coordinate system used in mining rights both nationally and internationally.

8.7.1.The international situation

Australia

In the case of Western Australia, a grid is used whose minimum unit corresponds to a block of 243 hectares, defined as the area between one minute of latitude and one minute of longitude. This system facilitates, for example, the obtaining of Exploration Licenses (similar to Chilean exploration mining concessions) that do not require the field's demarcation and that allow the extraction or altering of up to 1,000 tons of material. This is because, before the design of the licensing process, the system for determining the extent of the mining concessions was unified. This situation did not occur in Chile since the concessions' metric is inherited from the Republican mining Codification and results from our long and narrow geography. In fact, most of the mining claims (exploitation

96 Sernageomin performed a coordinate compatibility study in 2007 and their results showed that simple georeferential transformation implies, in fact, changes in the position of the concessions. Sernageomin (2013).

mining concessions) occur in square shaped areas, whereas exploration mining concessions does so in rectangular form.

Canada

In the Canadian case, extension cells subdivide the land. For the constitution of exploration concessions, the interested party must expose a minimum of cells (each cell with an approximate extension of 16 to 21 hectares) and up to a maximum of 100 cells of extension for the concession. The highest ratio between the cells is 6:1, and their shape may or may not be quadrangular. In the case of mining claims, the minimum that the interested party can request is one cell (16 ha) and maximum 16 cells. Depending on the project, it is possible to increase the size of each inner cell.The spatial relationship between the cells is 6:1, and its shape may or may not be quadrangular.

Peru

In Peru, prior carrying out their legal mining regulation, they conducted an extensive geological task to divide the national land and sea territory into 100-hectare grids, aiming at the most efficient resource allocation. Since mining rights share the exploration and mining operation stages, the limits of the extension of each concession are the same as for the previous stage and, in accordance to the grid system of 100 hectares are established throughout the territory. Thus, to constitute an exploration concession, the interested party must indicate a minimum of one grid and a maximum of 10 per concession.[97] A harmonious quadrangular distribution is achieved, which maintains clarity as to the concessions' boundaries relative to the other concessionaires.

8.8. Conclusions

Chile is one of the most important mining countries in the world, and this situation is based both on its excellent mining geological potential and on favorable conditions for investment.

The economic and legal scenario facing mining exploration leads to the imperative implementation of improvements in its various fields, as in the judicial granting of the concession, protection obligations, geological information, financing for exploration and mining property system. This would make the country a more attractive destination for

97 In maritime areas, the maximum is 100 grids.

the mining industry and would boost the exploratory activity and the implementation of new projects.

For its implementation, mining requires rules that are: (i) simple and easy to understand by stakeholders, (ii) viable and expeditious to demand by the authority, and (iii) objective, of general application and impersonal, and not susceptible to arbitrary interpretations, much less corruption.[98]

The development of a comprehensive mining concessions policy also requires: (i) to facilitate exploration and mining activities, but not at the expense of the environment or other stakeholders; (ii) to allow annual recurring income (iii) provide legal certainty, and (iv) create economic incentives to generate exploratory mining activity.

Thus, three major problems have been identified that need to be addressed through legislative and public policy changes: scarcity of available areas for the search of new deposits in the most promising metallogenic strips, a high concentration of mining property, and an improved use of the ownership right of mineral resources by some agents.

Its solution lies in allowing the liberation of areas for exploration and facilitating rotation among the holders of mining concessions, accessing the entry of active agents and revitalizing the activity of the current agents. Additionally, there should be improved availability of geological information and greater access to financing for junior companies, considering that geological information has synergies with improvements to the concession system.

By observing and analyzing international best practices, the most relevant requirements that need to be incorporated in Chile for a mining property system according to international standards emerge. In this sense, the general trend is towards the mixed protection of the mining concession through patent and labor. The latter is creditable both through verifiable minimum investments (and compliance with a suitable work plan) and the obligation to provide reliable geological information, which should eventually be made available to citizens and mining agents as a public good. Also, it is possible to observe replicable implementations in Chile, such as improvements to the coordinate system, grid system, standardization of expert evaluations, and payment and calculation of the patent, among others.

With this in mind, the recommendations set out below are separated into two groups in order of complexity, placing the vast majority of proposals in the first group. All of this is jointly considered, from our current system, to progressively move towards a mixed fulfillment of the protection obligation (patent and labor). Preserving, in every event,

98 See Ossa (2012), p. 554.

the prevailing judicial process of granting the mining concessions since it is deemed an asset of the current system.

However, due to implementation difficulties and associated risks, it is reasonable to distinguish proposals and recommendations according to the hierarchical levels of the legislation involved.

Thus, the first group of recommendations requires changes to the Mining Code and its regulation and legislation of similar hierarchical levels. On the other hand, the second group requires changes to the Constitutional Organic Law of Mining Concessions and legislations of similar hierarchical level. It should be considered that the single implementation of the recommendations of Group 1 would already constitute a substantial advance for the country and would help solve the problems identified.

Group 1: Changes to the Mining Code, its regulations, and legislation of similar or lower hierarchical level

In this group, the primary recommendation lies in the patent protection of the mining right, which should be understood in its complementarity with the next three recommendations. The protection obligation is in the Constitutional Organic Law of Mining Concessions (Law No. 18.097), but the Law delegates in the Mining Code the manner of estimation and cost of the protection obligation. It has been found that the value of the patent, calculated per article 142 of the Mining Code, is low compared to other international mining countries, either comparing just the value patent or the total value of the protection obligation (labor and patent).

Compared to the total protection cost (patent and labor), a 14-fold increase would bring the current exploration patent to levels close to the international average on costs of total protection (labor and patent), while a 6-fold increase would do the same for exploitation patent. The caveat is precisely that in other countries, for example, they are required to prove the execution of minimum investments to maintain the mining right. That is to say, for the maintenance of the concession, compliance with the protection obligation for direct work is required, obliging the concessionaire to inform the authority of the work's execution within the deadlines established for it.[99] This is not possible to implement

[99] Also reducing the need for the authority to exercise constant control over the work carried out by the concessionaire who, by law, is obliged to report the work or lose the benefits attached to the mining right and, eventually, in case of repeated non-compliance, lose it. This self-inspection measure, in turn, allows the authority to allocate resources to other purposes (e.g., collection of geological information in situ during a random visit to a mine site). This is similar to the system used in some jurisdictions in Canada.

with changes at this level of legislation. However, a higher value of the patent in Chile would encourage a greater rotation of the mining property, for mining property storage would be more expensive, and it would discourage the entry of potential speculators.

Specifically, it is recommended that in the short term, there be an increase in the exploration patent of around five times its current value for the first two years of validity, and then an increase from a range between 12.5 times and 20 times its current value during the following two years. Additionally, raise the exploitation patent around five times the current value for the first five years of validity of the right, and then raise it in a range between 12.5 and 20 times the present value since the sixth year onwards. There are other alternatives for patent increases[100] that can be implemented, while maintaining the country's judicial system of mining concessions.[101]

Currently, there is a differentiated patent for small-scale mining and artisanal mining of 0.0001 MTU per exploited hectare (equivalent to one dollar per 100 hectares). This amount should be kept along with the current legal requirements for the rebate (natural person, number of workers, verified exploitation and permits and easements necessary for the development of the activity). With the necessary adjustments, this could also apply to the medium-sized mining.[102]

Under the protection per patent obligation, there is a distortion concerning the price of licenses for nonmetallic mining and metal mining concessions in Chile. The former first is one-third the price of the latter.[103] Both payments should be homologated, considering that the mineral wealth due to the technological advances, comes from both metallic and non-metallic substances located in metalliferous placers and salt flats, thus pushing towards the international market's direction[104] and avoiding current bad practices ge-

100 There are other models to consider: a static one (by changing the base calculation index of patents, from MTU to MTA), according to international standards, and a dynamic one (through the application of a progressive patent, particularly to operating concessions). Although it may be detrimental to small mining companies, this increase may be offset by other benefits that may be granted by the owner of the mining concession, as up-to-date and reliable geological information, in order to reduce the cost of the patent to the current values.

101 The progressive patent model is usually simpler in a system of administrative granting of mining concessions, but it is fully implementable in a judicial granting of mining concessions' system such as Chile. The mining concessionaire pays the patent to the General Treasury, which should request each year the validity of the concession to ensure that the amount is correct. However, it is the concessionaire's duty and, at the same time, an incentive for the differentiated payment, to deliver relevant geological information to the Sernageomin and its certified by it.

102 If this is the case, two segments of medium-sized mining should be distinguished: one medium-sized "minor" mining with production equivalent to 12,000 tons of copper a year and a medium-sized "major" mining with production equivalent to 12,000 to 50,000 tons of copper per year.

103 1/10 MTU and 1/30 MTU yearly per ha. respectively.

104 That perceives wealth in both types of metal.

nerated by this distortion.[105] For subsidy, it is recommended to enable an alternative to reduce the payment of the patent as soon as the mining concessionaire exposes a work plan or related investments.

In the previous paragraphs, we mentioned that the cost of the total protection in Chile is very low relative to reference countries. Given the increase in patents suggested, and at this legislation level, part of the solution would be to allow a reduction in the payment of this raised patent through the concessionaire's consideration, and thus constitute, in practice, an indirect patent per work protection.[106] In particular, it is suggested to allow a reduction in the payment of the exploration patent by up to 90% of its value, by demonstrating expenses in exploration work on the mining property, and the delivery of the corresponding geoscientific information regulated by the Law No. 20.819 / 15 and its regulations. Therefore, this reduction serves as an incentive to improve the geological information available in the country. The applicable expenditure items must be established in the legislation and approved by Sernageomin. Additionally, a reduction of the exploitation patent payment in the first five years of validity of the right, of up to 80% of its value, is recommended, by demonstrating investment and delivery of the required information. The requirements would vary from the sixth year onwards, considering the demonstration of expenses incurred in mining production.

It is important to state the costs that a mining concessionaire, performing activities during the exploration and exploitation phases, may incur. In the initial stages of exploration, the geochemical sampling in laboratory of 1 ha (a 100m x 100m mesh), which is normal in early stages of exploration, after the basic geological mapping, has a cost of US$60-150 depending on the laboratory and the number of elements to be analyzed.[107] Likewise, the reverse air drillings amount to US$80-120 per meter, and in initial stages, four to five boreholes are drilled with ranges from 40-50 meters to 600-800 meters,[108]

105 If the concessionaire protects his mining right through the payment of a patent, he should be forced to deliver to the Sernageomin reliable geological information on his mining right that he owns, in order to certify the existence of a mineral of interest without leaving space to declare other minerals of lesser value: clay, or aggregates. This obligation should be an essential prerequisite for access to the reduced patent, if any. As designed in articles 142 and seq. of the Mining Code and 53 and seq. of the Mining Code Regulation, this obligation is unclear and gives rise to the bad practices already exposed.

106 Although technically the protection system continues to be a protection per patent system, to offer this alternative of deduction of its value in exchange for the accomplishment of mining works and the granting of basic geological information to the authority, in practice, converts this obligation in sort of mixed protection obligation, or a protection per patent and indirect work.

107 This is a lower level because it considers only the geochemical analysis, and does not consider the work of taking the sample that includes the salary of the geologist, helpers, tickets, transportation and accommodation.

108 In the case of diamond drilling, the cost is higher, fluctuating between US$180-250

which are distributed in a "geological target" area of four to five km of diameter. In advanced stages of exploration (third year onwards), meshes of 200x200m are drilled to 75x75m meshes, with similar depth boreholes as the above. In operation, extraction and transportation of 1 ton of material costs between US$1.8-2.5 and processing of 1 ton of mineral material costs US$6-15. In medium and small mines these values can be doubled, so these segments would need to move less material to access the maximum reduction. A small-scale mining operation extracts at least a couple of tons per day. With this, someone who effectively works one hectare, whether in exploration - for example, drilling expenses - or in exploitation - for example, moving material - could easily access the maximum discount of the increased patent of his concession.

Note that when applying for the patent reduction of 90% in exploration and 80% in operation, the patent payment in Chile would be equivalent to or even lower than the levels currently in force.[109] Therefore, the international competitiveness of the country would be maintained, as competing countries usually require a greater protection obligation to keep the concession. Further, the delivery of geological information confirms the concessionaire's active interest in using the mining concession for the purposes for which it was granted, as a kind of protection per indirect work, discouraging speculation and rewarding the miners. Additionally, it has the incremental effect of generating a greater volume of pre-competitive geological information in the long term. Given the above, it is also imperative to consider granting a higher budget and reinforce Sernageomin's supervision faculties in this matter, to carry out this work,[110] regardless of whether the concessionaire provides and facilitates the information.

Recommendation 8.1: Raise the Annual Patent from a linear to a progressive one, which increases over time, both in exploration and in exploitation, but allowing a reduction of the patent payment through mechanisms of consideration by the mining concessionaire (geological information, works, among others).

Recommendation 8.2: Match the Annual non-metals substance Patent with the one for metal substances.

[109] Considering the case of the patent increase to 12.5 times during the second exploration period (last 2 years) and exploitation (sixth year onwards).

[110] As the inspection work is done in other administrative agencies (e.g. Labor Directorate, Internal Revenue Service).

Nevertheless, and without objection to incentivizing the patent reduction in consideration of geological information, it is also important to establish the incentives and penalties for the non-compliance of its deliverance to Sernageomin (Law No. 20.819 / 15). The regulation of Law No. 20.819 must be explicit regarding the mechanism and format of information delivery, which is fundamental to fulfill the stated objectives. For this, the information must be delivered in such a way that it can be compiled and consolidated georeferentially. Likewise, special consideration should be given to sanctions arising from non-compliance with this obligation. Thus, in line with constitutional requirements, in case of fines resulting from non-compliance, they must be established by law (either the Sernageomin Decree Law or the Mining Code).

Finally, the geoscientific information provided by the concessionaire should be initially confidential, to protect property rights and economic exploitation (in line with international best practices). After a definite period, it should be released for public knowledge (minimum: 1 year from the end of the concession, either by expiration or by the owner's voluntary waiver), because such information is a public good in itself.[111] Access to this kind of information (as public information) cannot be limited except under specific grounds provided by law.

> **Recommendation 8.3:** Establish incentives and sanctions for non-compliance with the geological information obligation, laid down in Article 21 of the Mining Code.

A suggestion of an institutional nature arises, linked to the geological information and its compilation: to reformulate the Decree Law No. 3525/1980 that creates the National Service of Geology and Mining, Sernageomin. The purpose would be to proffer it with greater control powers, capacities and clear obligations in the matter of mining, aiming to make geological information available to the public at low or no cost.[112] Following the international example of INGEMMET (Peru) and to render effective the functions granted to this entity by that Decree Law, it becomes necessary to reorganize this Service in its

[111] Relevant geological information must be considered both as a duty (for the concessionaire) and as a right (for the public and interested parties, as to their availability), because it is accessory information to a good that fulfills a clearly and constitutionally established public function (the social function that justifies its granting).

[112] As a reference, the costs of reproduction provided for in Law No. 20.285 (regulates the access to public information) can be considered, always tending to make the cost as low as possible so that it does not constitute a barrier to access a public good from exploration and exploitation of national wealth.

five existing departments: General Geology, Applied Geology, Mining Property, Production, and Administration. The first two departments should be expressly empowered to intervene in the development of geoscientific knowledge of the country, and may directly require the geological information whose regulation introduced Law No. 20.819 and its Regulation (soon to be enacted). Likewise, both departments must have both the adequate capacity to process and publish the information as well as the due protection during the periods before the release of the information to the public.[113] The third department must have supervisory powers not only in matters of technical overlapping of mining claims but also in analyzing the destination and use of the mining property (e.g., supervise the execution of mining works, if applicable).

The Decree-Law mentioned above allows for legal reforms as proposed (e.g., creation of a mining inspection[114]), to deepen and perfect the inspection powers of this Service. It endows it with attributions in accordance to the country's mining reality and the mining property's social function, both for the obtainment and eventual distribution of relevant geological information and for the protection of the mineral heritage of the nation. It is important to emphasize that a budget increase should be considered in line with the institutional strengthening proposed here.

> **Recommendation 8.4:** Strengthen the Sernageomin, granting broader powers and clearer control parameters to its departments, with the purpose of maximizing the impact of each one of its work areas.

Sernageomin's reform should be in accordance to an improvement to the system of field measurement revision made by the metering experts. For mining rights to be built on solid foundations, it is useful to include control over the work developed by both the qualified specialists (enlisted by Sernageomin) and the mine engineers or to equal the conditions between experts and engineers directly.

As stated, the few or no incentives to enter the experts' list, and the possibility that any mining engineer can perform this delicate operation, are factors that influence an inefficient mining property constitution process. Article 71 of the Mining Code and the

113 A legal reform should specify the period of confidentiality for the geological information. Following the example of Australia, this period should not exceed 5 years counting from the constitution of the mining concession. This would make it possible to balance both the investment protection's right by the applicant and the public interest regarding the geological information obtained from mining concessions.

114 Using as a model the Labor Directorate regulated in Decree Law No. 2/1967.

Mining Code Regulation should be ammended for the qualification and inclusion in the proposal for the appointment of specialists (current Resolution 3835, dated 12-19-2003). The conditions among professionals should be equaled, and the annual work qualifications be made available as public information for anybody, in order to work towards an expeditious, transparent and adequately scrutinized revision process of this operation.

> **Recommendation 8.5:** Equate the conditions between specialists and engineers qualified to perform measurement tasks, and make publicly available the yearly qualification to which their work is submitted.

On the other hand, some changes would improve the function of the mining property system. The first aspect is to discourage the floor creations practice, or the request of exploration mining concessions in the same terrain consecutively, between related people (natural or legal), since it threatens rotation mining property levels. Currently, by mandate of our Constitution and the Constitutional Organic Law, it is not possible to prohibit or limit the acquisition of mining concessions (exploration or exploitation in a given area) to any person without distinction. However, restrictions could be applied to these concessions such as a yearly fee equivalent to the number of times (double, triple or more) it is requested by the same person or group of related persons in the same territory.[115] This would motivate a greater rotation in mining property, and would be only an indirect limitation of ownership concentration.

> **Recommendation 8.6:** Restrict the consecutive and immediate request for exploration concessions between related persons.

The second aspect corresponds to the time it takes to constitute a mining right. Our country has the technical capacity to reduce both the terms corresponding to the activities carried out by the applicant for a concession and those related to the development of the measurement operation, which would encourage a greater dynamism of the exploration activity. We estimate that the constitution period for a mining concession could be reduced to 5 months in the case of exploration and 18 months in the event of exploitation.

115 In order to determine the relationship between one or more persons, natural and legal, and economic groups, provisions could be used, such as article 100 of Law No. 18,045 of the Securities Market on the determination of related persons

The purpose of the terms is not only for the voluntary constitution of the mining rights, but also so that third parties can take notice within a reasonable time frame, of what happens on the surface lands exposed to the constitution of mining concessions. In this sense, third parties and other concessionaires may take notice of the mining concessions (their presentation, measurement - if any - and constitutional judgments) through the Official Mining Bulletin. Its current dispersion over provinces hinders the availability of consolidated information at the national level. Hence a positive change in this direction corresponds to the compliance with the provisions of Article 238 of the Mining Code so that the Official Mining Bulletin is effectively a supplement to the Official Journal of Chile. Thus, this Bulletin would become a national electronic publication, which would provide transparent and low-cost information for those interested in investing in mining. The implementation of regulatory provision DS 88/2016 that orders it is expected by July 2017.

Recommendation 8.7: Reduce the times involved in the application, evaluation and constitution procedures of mining concessions.

The third aspect is the design of the auctioning for abandonment of mining concessions process. It is a significant problem since part of the wrong geological information comes from the maintenance in the Mining Cadastre of concessions that, according to the Law, expired for not having fulfilled the protection obligation. The Mining Code mandates the General Treasury of the Republic to auction these concessions, which, if not awarded, become free lands (without owners) and are removed from the records of the Registry of Mining Discoveries (or Property) in the correspondent Land Registry and Sernageomin. However, due to the well-known lack of coordination between these entities, the General Treasury does not proceed in a timely and legal manner to the execution of the auctions, which means that the National Mining Cadastre and the Registry of Mining Discoveries (or Property) in the correspondent Land Registry remains inaccurate and outdated.[116] Due to the precariousness of this information, it is necessary to redesign the enforced judicial procedure of abandonment. In this way, only the record that gives account of the unpaid patents and its publication suffice to auction speedily and transparently, urging

116 Both registries, are the only reliable and official source of geological information available in our country for international investors, if they wish to make investments. To this effect, it is common to ask national consultants are commonly consulted for the feasibility study of an area and for such task the only available information is the one existent in Sernageomin and the Registry of Mining Discoveries (or Property) in the Land Registry of the area as public information. Given its imprecision and outdatedness, this situation is a factor of loss of competitiveness to develop mining activity in our country.

the Treasury and the Courts to remit the information to the Registry of Mining Discoveries (or Property) in the correspondent Land Registry and Sernageomin in full. They can further proceed to rectify their records in the shortest possible time. These changes would allow a better functioning of the granting of the concessions system.[117]

> **Recommendation 8.8:** Redesign the auctioning process of abandoned mining rights, using actions that tend to the coordination and fast transmission of information among all those involved in those processes.

The fourth aspect corresponds updating the coordinates system of Chilean mining rights and their spatial disposition. All global satellite and cartographic information has been updated to this system. Also, all national cartography is also being updated, and there will be no more information generated in the old coordinates system. Therefore, it is necessary to transfer the mining rights system to WGS84, in the medium term. There are experiences of such system migration in other mining countries such as Peru that can serve as a guide for the Chilean case.

In line with the above, we estimate that it is also possible to move towards a grid system that divides the entire national territory into polygons of similar shapes and magnitudes. This requires modifications to the Mining Code,[118] significant resources and significative terms, but would substantially simplify the process of setting up mining concessions and place Chile on a par with international benchmarks.

Although the transition is complex, similar processes have been carried out in recent decades in other countries. Transitional legal provisions[119] that allow the transition from the current system to the grid system must always be considered, in order to avoid overlaps and grant certainty that there will be a process of adaptation to the new regime,

117 While the ideal option would be to have an official, single, national, integrated, public and updated online mining cadaster administered by Sernageomin, this would imply a complete redesign of the registry system for mining property. Since mining property is considered an immovable property or real estate (both for the Constitution and COLMC), it must be registered by the respective Land Registry (Registry of Mining Discoveries or Property, in this case). In short, having a single mining property registry in our country corresponds to a long-term improvement, as it would mean a redesign of the quality of the mining right as a real estate, becoming an immovable property that would be excluded from the Land Registry (where real estate, waters and commerce registers).

118 In this matter, article 4 of Law No. 18.097 specifies that the territorial extension of a mining concession may be divided according to the minimum extensions defined by the Mining Code, delegating in this body the determination to adopt, for example, the grid system for this territorial division.

119 Of the hierarchy of a simple law, drafted in similar manner of transitional article 2nd of Law No. 18.097.

both to current owners and to those constituted previous to this modification, if it were implemented. [120]

Recommendation 8.9: Update the coordinate system and datum of mining rights from PSAD56 / SAD69 to WGS84.

Recommendation 8.10: Adopt a grid system for requesting mining concessions in the medium term.

Of equal importance, it is key to further greater financing to the projects of exploration and mining. Some progress has been made that should allow greater union between the financial industry and the mining sector (e.g., Competent Person Act[121]), but there are still significant differences in the matter with countries such as Canada.

Part of the solution would be to bring both sectors closer together via activities that reduce information gaps and foster a knowledge culture in mining matters providing reasonable assurances to the investor and the concessionaire in equal shares. Examples of such activities would be; (i) regular conferences on financing exploration and exploitation, focused on Chilean mining companies, aimed at showing the advantages and disadvantages of financing with third parties, and get familiarized with the reports mining companies must submit, either when they are listed on the Stock Exchange or if they are already listed, and (ii) regular conferences on financing of exploration projects focused on the financial community, so that they know basic aspects of the analysis and valuation of exploration and exploitation projects.

The above benefits not only junior companies - mainly exploration - but also contributes to improving financing for mining activity in all its forms (medium-scale mining also). It would additionally allow approaching perspectives between two ends of industry, which often have conflicting visions towards the same interest (extracting ore and producing wealth derived from it), but do not have all the necessary information for economic and geological development of the mentioned project.

Recommendation 8.11: Develop a training program in financing projects in exploration and mining with the aim of reducing the information gaps between the financial and the mining sector.

120 This process, for example, could include reductions in the mining patent for those concessions that have to be "remeasured" by modification in the datum and / or in the grid.

121 The existence of professionals qualified and certified as competent person (Law 20.235, 01 Dec. 31st, 2007) allows for an adequate valuation of mining resources and reserves, a fundamental bases to generate confidence in the financial market.

Group 2: Changes in the Constitutional Organic Law of Mining Concessions, and similar or lower hierarchical level legislation

This group's recommendations further those of Group 1 and seek, mainly, to give the mining concessions' protection system a work component (expenses and/or verifiable investment and delivery of geological information), added to the existing patent. Therefore, the protection obligation must be understood as the payment of the patent, the carrying out of effective exploration and mining operations, and the delivery of geological information to the State, all of the above in a joint manner, so this protection obligation is adequate according to current international standards.[122] If all the concessionaires comply with the protection in this way, they would automatically access the patent discount corresponding to Recommendation 8.1, which would maintain the country's competitiveness. It is important to mention that these recommendations (8.12 to 8.15) would apply to the new exploration and mining concessions.

That is why the first additional element corresponds to a change in the protection obligation, provided for in Article 12 of the Constitutional Organic Law of Mining Concessions, generating a protection for direct work (protection per work) by establishing minimum expenses in exploration and exploitation. Likewise, the presentation of minimum work plans for the application and renewal of exploration rights, as well as the evidence of mineralization and minimum work plans for mining rights are considered. It is essential to point out that the requirements must be clear parameters, with the lowest possible interpretations on the concept and scope of the expression "mining works." Additionally, in case the concessionaire meets those requirements, and the corresponding authority does not consider this, its resolution may be liable to be brought before the Courts of Justice. All of the above is feasible, as most of the analyzed countries require a work plan certified by a competent person, with minimum requirements (milestones) in the application for mining rights (following a checklist) and their renewals (if applicable).

In the case of the mining concession, this would be crucial, requiring a report certified by a Competent Person on the mineralization that would justify the development of the work necessary for a mining operation. In this case, a laxer statute should be created for small and artisanal mining (comparable to what already exists today), as well as a similar one for medium-sized mining. This would lead to positive externalities, for it would reduce the chances of fraud through the obtainment of unduly reduced patents for the nonmetallic mining (if such reduction is maintained). Also, it would grant certainty

122 The payment of the patent and the geological information would be annual whereas for the expenses and / or investments a greater periodicity is suggested.

as to the subject of international mining investment contracts (which assure that the investment corresponds to the defined ore).

Recommendation 8.12: Establish a mixed protection system through the payment of a patent, the granting of geological information to the State and the formulation of minimum work plans for the application and renewal of exploration rights, as well as evidence of mineralization and minimum work for exploitation rights.

On the other hand, considering the need for a longer term for exploration activity, a change in the duration of this concession following the standard of countries like Canada is suggested. The initial period, currently considered in the Mining Code, would be three years, renewable up to twice for periods of three years each, totaling a maximum of nine years.[123] At each renewal, the concessionaire must release at least 50% of the mining right area.

Recommendation 8.13: Increase exploration concession periods from two to three years and allow two extensions instead of one, totaling a maximum of nine years.

Regarding the mining claim, it is suggested that it be temporary (30 years maximum), with priority of renewal if certain mining operations' feasibility conditions occur in the area, all of which must be determined by law.[124] This is in line with international practices where the mining claims are limited in time (21 to 30 years) and with the possibility of priority extensions. Chilean ore deposits have a long life (20 years or more), and usually, their life cycles are extended through brownfield investments. An example of this would be the automatic renewal if the concessionaire credits work for a definite number of years (e.g., 10 or 15) since the creation of his/her operating mining concession.[125]

123 Requiring an amendment of Article 17 of the Constitutional Organic Law on Mining Concessions regarding the total term (now 4 years, extension included).

124 It should not be forgotten that, constitutionally, the mining property right is subject to the condition of justifying the interest, which in the mining case is the operational feasibility. It is not an indefinite right, as in the cases of other real estates.

125 Thus, if the concessionaire has credited expenses and / or minimum investment for 10 or 15 years (regardless of whether they are consecutive or not) and ensures the renewal of its operating concession allowing it to project eventual future expansions of the operation with greater certainty.,

Recommendation 8.14: Establish a temporary limit on the mining concession of a maximum of 30 years, subject to priority and unlimited renewals for an equal period.

Finally, there may arise conflict between the owner of a mining concession (subsoil) and the owner of the surface property, if the mining concessionaire wishes to perform reconnaissance or start digging in the particular area. Except in the case of open land (e.g., the Atacama Desert), the owner's o tenant's written permission is required. If the properties are owned either by the State or the Municipality, the permission should be requested from the governor or mayor, respectively.[126] Depending on the characteristics of the surface property, if the owner refuses the authorization to dig, this may be appealable to a Judge, who then would establish the necessary guarantees before authorizing or denying a permit for mineral activities.

However, there is a distortion regarding other productive activities located on the same surface property as a mining concession. This is the particular case of vineyards or fruit trees (groves) where only the owner of the surface land[127] can grant permission for digging, without being overridden by a judicial decision.[128] This distortion is present in Article 7 of the COLMC and specified in Article 15 of the Mining Code.

Given the current possibility of coexistence of both the subsoil and the surface property activities,[129] it is suggested to eliminate the distortion mentioned above. If the permission is denied, submit the authorization to a Judge (ideally, the competent Environmental Court), as in all the other cases. The Court shall settle on the origin of the mining activity, the environmental impact it may generate and evaluate the costs and benefits of granting the corresponding permit. Additionally, in all events, it will ensure the compatibility of the digging activities with the preservation of the forest or vineyard. This permit must be subject to the same provisions outlined in Article 16 of the Mining Code, only as to its duration and the origin of the indemnity guarantee.

126 There are also a number of permits for certain places. For example, to carry out mining work in border areas, permission is required from the Border and Boundaries Division, among many other cases specified in Art 17 of the Mining Code

127 The person that has the real estate registered on its behalf in the Land Registry.

128 Situation that does happen in other cases contemplated in Art. 15 regarding permits.

129 Situation that was not conceivable when the COLMC was enacted.

Recommendation 8.15: Modify the provisions of Article 15 et seq. Of the Mining Code, which exclude certain activities (vineyards and groves) from the general rule of submitting to the competent Judge the request for permission to dig upon refusal by the owner. This action's purpose would be to equate judicial treatment for the resolution of conflicts between all activities, favoring good coexistence in adequate environmental standards and the appropriate compensation.

8.8.1. Summary of Findings

Finding 8.1: Chile's share in the mining exploration market is lower than its share in production and reserves.

Finding 8.2: There is low availability of territory for exploration in the main metallogenic strips of the country due to the area covered by current concessions in force, and the ease of maintaining them at low cost, especially if they correspond to nonmetallic mining.

Finding 8.3: There is evidence of significant concentration levels in both metallic and non-metallic mining properties. In some cases, this may respond to the need for sector-wide economies of scale. However, it nonetheless acts as an entry barrier.

Finding 8.4: Some agents misuse mining concessions for speculative purposes and as insurance against potential litigation, thus harming the effective mining concessionaires. These objectives are different from those that the law considers when granting the subsoil in concession, and by which the State transfers part of its property faculties to private concessionaires.

Finding 8.5: The process of constituting mining concessions implies quite long terms, with delays of 6 to 8 months for exploration and 24 to 29 months for mining.

Finding 8.6: The current protection per patent system does not constitute an incentive to carry out effectively exploration and mining, because it does not require mining labor directly and has a low patent value.

Finding 8.7: The cost of the Chilean mining patent is low compared to other countries, even more so, considering that in other jurisdictions, additional obligations to the patent payment are requested to maintain the mining concession.

Finding 8.8: Chile shows a significant lag both in availability and quality of pre-competitive geological information.

Finding 8.9: Chile has a significant gap concerning referent countries, regarding both the share of junior companies in exploration spending and the link between the mining sector and the financial sector.

Finding 8.10: There is a gap in the standard of the coordinate system used in mining rights both nationally and internationally.

8.8.2. Summary of Recommendations

Recommendation 8.1: Raise the Annual Patent from a linear to a progressive one, which increases over time, both in exploration and in exploitation, but allowing a reduction of the patent payment through mechanisms of consideration by the mining concessionaire (geological information, works, among others).

Recommendation 8.2: Match the Annual non-metals substance Patent with the one for metal substances.

Recommendation 8.3: Establish incentives and sanctions for non-compliance with the geological information obligation, laid down in Article 21 of the Mining Code.

Recommendation 8.4: Strengthen the Sernageomin, granting broader powers and clearer control parameters to its departments, with the purpose of maximizing the impact of each one of its work areas.

Recommendation 8.5: Equate the conditions between specialists and engineers qualified to perform measurement tasks, and make publicly available the yearly qualification to which their work is submitted.

Recommendation 8.6: Restrict the consecutive and immediate request for exploration concessions between related persons.

Recommendation 8.7: Reduce the time involved in the application, evaluation and constitution procedures of mining concessions.

Recommendation 8.8: Redesign the auctioning process of abandoned mining rights, using actions that tend to the coordination and fast transmission of information among all those involved in those processes.

Recommendation 8.9: Update the coordinate system and datum of mining rights from PSAD56 / SAD69 to WGS84.

Recommendation 8.10: Adopt a grid system for requesting mining concessions in the medium term.

Recommendation 8.11: Develop a training program in financing projects in exploration and mining with the aim of reducing the information gaps between the financial and the mining sector.

Recommendation 8.12: Establish a mixed protection system through the payment of a patent, the granting of geological information to the State and the formulation of minimum work plans for the application and renewal of exploration rights, as well as evidence of mineralization and minimum work for exploitation rights.

Recommendation 8.13: Increase exploration concession periods from two to three years and allow two extensions instead of one, totaling a maximum of nine years.

Recommendation 8.14: Establish a temporary limit on the mining concession of a maximum of 30 years, subject to priority and unlimited renewals for an equal period.

Recommendation 8.15: Modify the provisions of Article 15 et seq. of the Mining Code, which exclude certain activities (vineyards and groves) from the general rule of submitting to the competent Judge the request for permission to dig upon refusal by the owner. This action's purpose would be to equate judicial treatment for the resolution of conflicts between all activities, favoring good coexistence in adequate environmental standards and the appropriate compensation.

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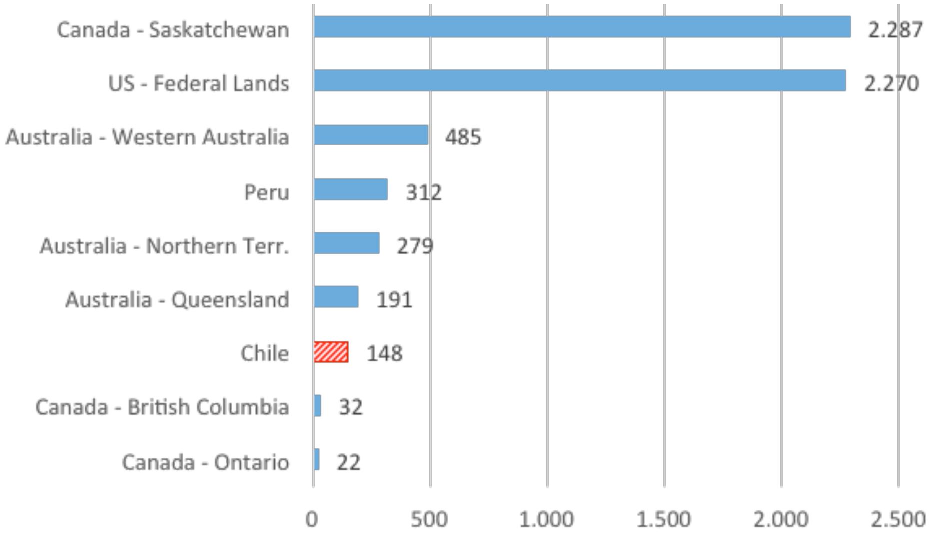
LAW NO. 20.936, which establishes a new electric transmission system and creates an independent coordinating body of the national electricity system (D.O. 20-07-2016).

REGULATION OF THE MINING CODE (D.O. 27-02-1987

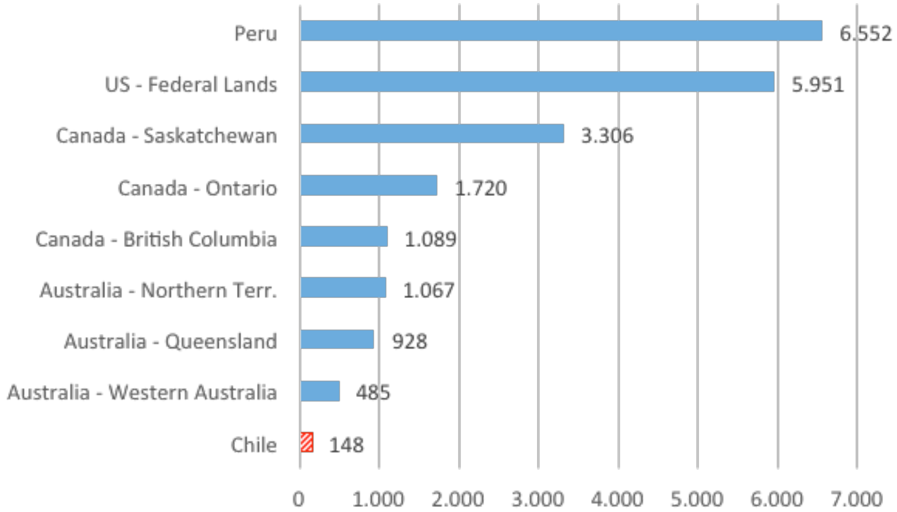
Annex

Figure A.1. Full protection costs on Exploration Mining Concessions in selected countries in 2016 – including Reconnaissance.



Source: National Productivity Commission based on CESCO (2016).

Figure A.2. Full protection costs on Mining Claims in selected countries in 2016 – including Reconnaissance



Fuente: Elaboración propia con base en CESCO (2016).

Chapter 9

Medium-scale Mining

Abstract

This chapter focuses on productivity issues in medium scale mining operations. For this study, we consider medium scale operations mines that produce 1,000 to 50,000 tons of copper per year. These account for 5,6% of total national copper production. Some of the productivity problems are common to the industry, regardless of size, while others are specific to medium-sized mines. Due to differences in scale, even problems that are common to the mining sector as a whole may require different solutions according to the scale of the operation.

Key Points

- The definition of the Institute of Mining Engineers of Chile (IIMCh) is used in this study to describe medium-scale mining and is based on the production level, which defines medium-scale mining operations as those that produce between 1,000 and 50,000 tons of copper per year.
- There is a significant productivity gap - measured as working hours per kiloton of moved material - between medium and large-scale mining. This gap exists since 2000, and since 2007 has become broader. In the past fifteen years, the productivity of medium-scale mining has fallen twice as much as large-scale mining, and at the aggregate level, it has tripled in percentage terms. The largest gap in the available data series is in 2014.
- There is improvement potential regarding modernization in ENAMI, the leading state institution dedicated to the promotion of small and medium-sized mining, according to the principles of public companies recommended by the OECD (2011).
- Competition with large-scale mining in the labor market has led to a shortage of supervisors and middle management in medium-sized mining.
- The main job market for the domestic medium-scale mining industry is found in towns near the mines since few of these mines operate with camps. In these towns, workers are scarce, with little technical and professional training linked to mining.
- In Chile, there is a deficit in local infrastructure, both in quantity and quality (low intermodality) for medium-scale mining. Mainly, the absence of ports reveals the lack of infrastructure supply in Regions III and IV, where most of these mines are located.
- The large-scale mining industry has generated private (individual) solutions to the port infrastructure deficit. They could optimize the size of their ports' operations at more profitable scales by providing access to medium-sized mining.
- A constraint to the medium-scale mining industry is the establishment of financial guarantees for the process of mine site closure.

9.1. Introduction

Chile is an anomaly in the world with its big copper porphyries mining deposits. Other mining countries such as Australia, Canada, the United States and Sweden, have large-scale mine sites that are comparable with Chilean medium-scale mine sites, regarding production. Moreover, these countries' mine sites; considered as medium-scale size sites in Chile, have the best practices of the world, with optimal indicators of productivity, safety, environment, and others.

The future of the mining industry in Chile will have an increasing share at a medium scale, thus analyzing and understanding this segment and its challenges is crucial. In fact, the deposits discovered during the last decade are mainly medium-scale and small-scale mines. Additionally, half of Chile's mining reserves are located in central regions, that are impossible to develop at large-scale mining projects due to high population density and increasing competition for other uses (mainly agriculture). Therefore, the development of a medium-scale mining industry in Chile that converges towards the world' best practices in operation management, sustainability, and relation with local communities is necessary for the sector and a priority for the country. This chapter is based on information collected by the Executive Secretariat of the CNP, and in studies carried out by Cochilco. [1]

The chapter is structured as follows. In Section 9.2, offers a characterization of the Chilean medium-scale mining industry. Section 9.3 describes the sector's primary constraints on productivity. Section 9.4 presents the results of the chapter and its conclusions.

9.2. Chilean Medium-scale Mining industry

This section offers a characterization of Chilean medium-scale mining based on data from Cochilco,[2] Sonami, and Sernageomin, including the evolution of production, employment, and the sector's productivity.

In Chile, there are no systematic statistics of the medium-scale mining sector. The main reason is that different definitions for the segment are used by the industry and the public sector (even within members of the industry and the public sector, there does not exist a consensus for the definition of medium-size mining), so its characterization is the first challenge. There are three classifications to identify medium-sized mining: (i) Institute of Mining Engineers of Chile (IIMCh in Spanish) classification, based on the production level,

1 See Cochilco (2016a, 2016b, 2016c).
2 Using own data and Wood Mackenzie data.

which defines medium-size mines as those that move between 100,000 and 3,000,000 tons of mineral material. (ii) Enami's definition, which considers medium-sized mining operations those that produce more than 10,000 tons of fine copper per year,[3] and (iii) Sernageomin's, which defines medium-sized mining as sites that have between 80 and 400 workers.[4] There is no consensus and no consistency in the classification used.

Finding 9.1: There is no consensus on a clear and precise definition of the medium-sized mining segment. Different organizations use different definitions (labor endowment and production), potentially generating inconsistent productivity statistics.

Recommendation 9.1: To agree among the sector's stakeholders a precise definition of the medium-sized mining segment in order to produce comparable public and periodic statistics. This definition should focus more on production than employment size.

COCHILCO (2016b) uses the definition of IIMCh and Enami. On the other hand, Sonami (2014) uses the definition of IIMCh for production, but, Sernageomin's for employment, making it difficult to construct a consistent measure of labor productivity in the segment. In this chapter, unless otherwise specified, the definition of IIMCh (production between 1,000 and 50,000 tons of fine copper per year) is used, since an output measure is considered to represent the size of an operation better than its number of workers.

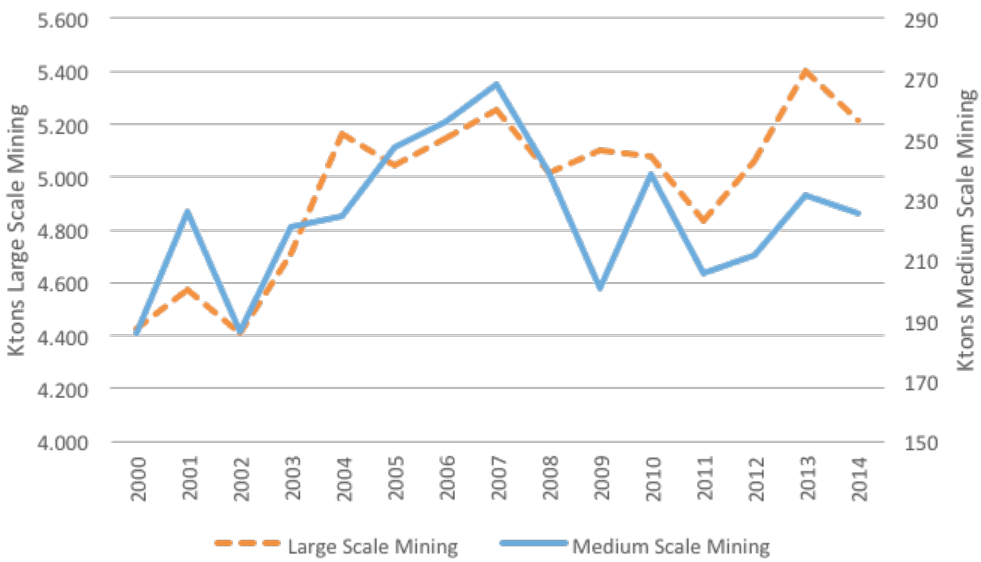
Between 2000 and 2014, the sector's annual production increased from 185,000 tons of copper to 225,000 tons.[5] Similar to the evolution of large-scale mining (see Chapter 2), this increase has two stages. First, with a substantial increase of around 45% (83,000 tons of copper) between 2000 and 2007, and then stabilizing production since 2007 at around 220,000 tons. This growth of 1.4% per year between 2000 and 2014 is slightly higher than the 1.2% annual growth of large-scale mining in the same period.[6] (See Figure 9.1)

Regarding employment (includes both own workers and contractors), there are clear differences between the scale of the medium and large mining industries. However,

3 This definition doesn't set an upper bound for medium-scale mining segment because Enami uses this definition for their services provision, targeted only for medium and small scale mining segments.
4 Between 200.000 and 1.000.000 of person-hours worked per year.
5 Cochilco and Wood Mackenzie.
6 Equivalent to large-sized mining production increasing from 4,400 to 5,200 thousands of tons of copper.

both tended to grow at a similar rate during the period (see Figure 9.2).[7] Large-scale mining increased employment by 160% (from 28,000 to 73,000 workers) between 2000 and 2014, with an average annual growth of 7%, similar to medium-scale mining, which increased employment by 161% (from 2,400 to 6,400 workers).[8]

Figure 9.1 Copper Production Medium and Large Scale Mining 2000-2014 (Ktons of fine copper)



Source: National Productivity Commission based on data from Cochilco and WoodMackenzie.

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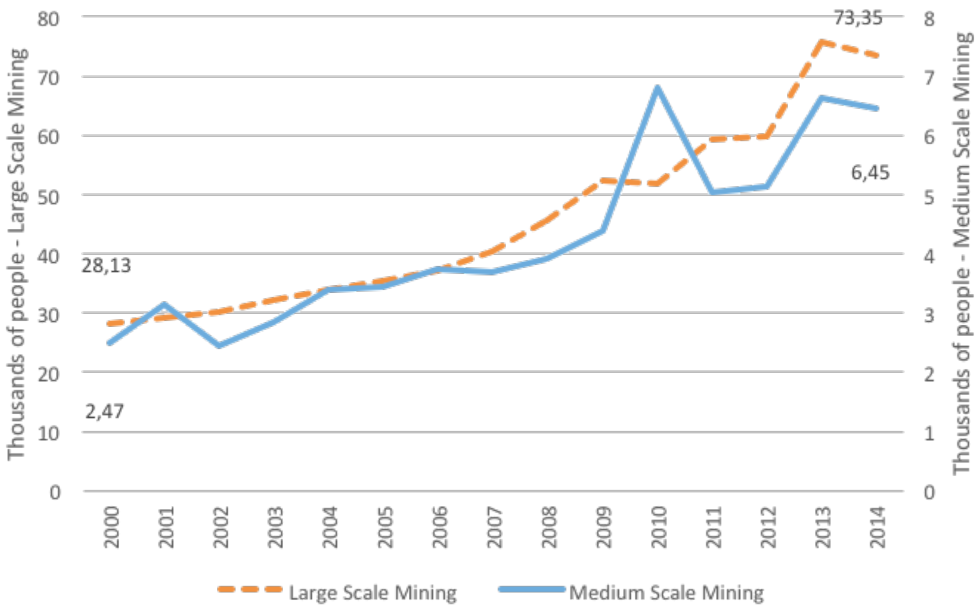
7 Sonami (2014). With Sernageomin criteria: large-scale mining company with at least 400 workers, and medium-scale mining company with between 80 and 400 workers.

8 It is very important to note that the big differences between employment levels are related to the difficulty of having consistent statistics in the segment. Mining Security and Employment reports from Sonami also show similar differences in large and medium-sized mining levels.

Figure 9.2 Total Employment in Large and Medium Scale Mining 2000-2014 (thousands of people)

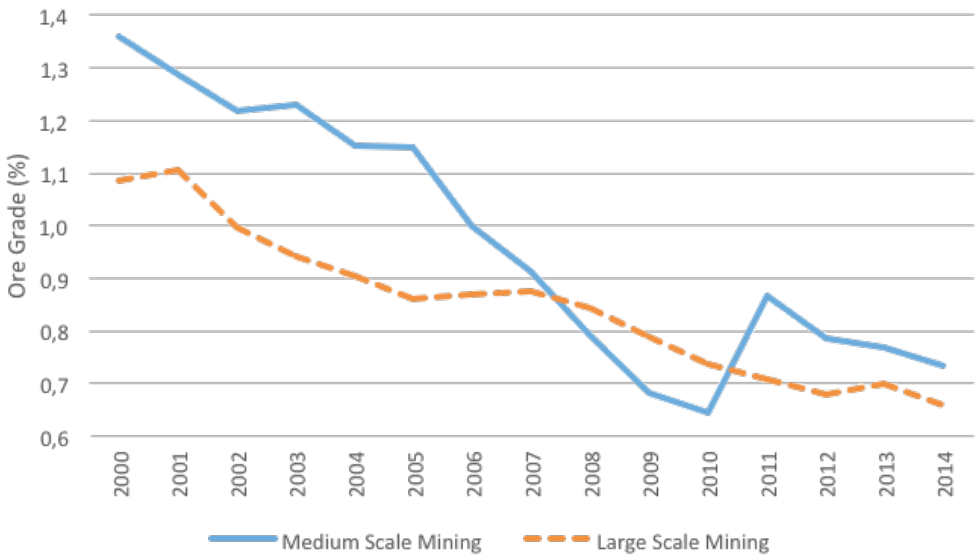


Source: National Productivity Commission based on data from Cochilco and WoodMackenzie

The productivity dynamics (person-hours per tons of copper) between large and medium-sized mining companies do not differ significantly. Using produced copper as an indicator of production, the average annual fall in productivity is 5.7% in medium-scale mining and 5.9% in large-scale mining. Medium-scale copper deposits have a better ore grade than large-scale mining; although both have deteriorated at similar rates of around 44% from 2000 to2014 (see Figure 9.3).[9] It is important to highlight the significant ore grade decrease of the medium-scale mining industry between 2005 and 2010, going from ore grades from 1.2% to 0.6%.

9 In this case, the definitions of large and medium-scale mining are according production levels. Mine sites with production over 50.000 tons of fine copper per year are classified as large-scale mining.

Figure 9.3 Average Ore grade of Large and Medium Scale Mining 2000-2014 (%) [10]



Source: Cochilco based in own reports and Wood Mackenzie.

Considering the bias generated by the ore grade in productivity metrics when using fine copper as indicator for production, and similar to the analysis of Chapter 2 for large-scale mining, we estimate the partial productivity of labor using the requirement of man-hours (per ton of moved material) and material moved,[11] from a mine sites' sub-sample compiled by Cochilco.[12] The results of Chapter 2 indicate that the Large Scale Mining Industry lost 14% of efficiency between 2000 and 2014 (from 38 person-hours to 45 person hours per kiloton of material moved), which implies an average annual fall in productivity of

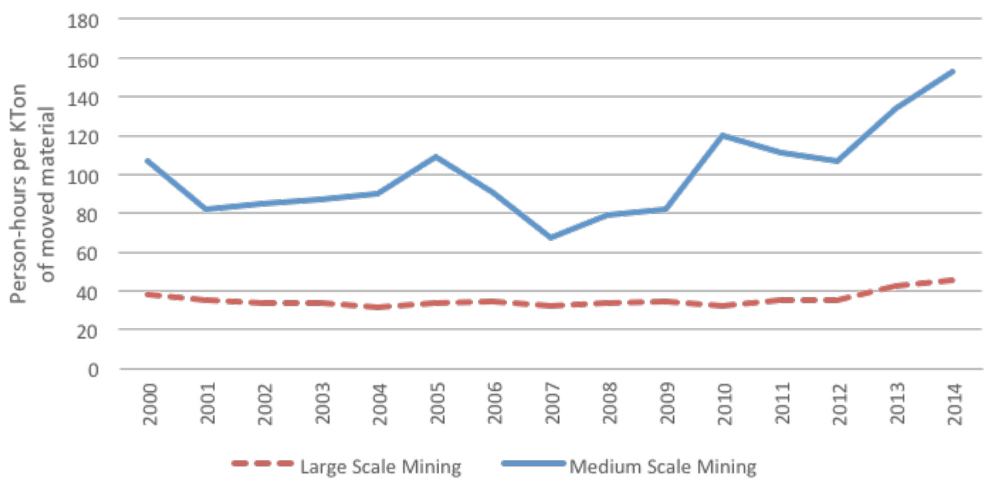
10 In this case, we use a subsample of medium-sized mining that accounts for nearly 75% of production of this segment.

11 The ore grade is an exogenous factor of the mine site's geology as mining operations move not only mineral (to be processed and make copper) but also sterile material that goes to dumps. This situation occurs more frequently in large-scale mining, because almost 75% of medium-scale mining sites are underground mines that generate little waste. However, presented productivity measures include observations of underground and open pit mines for both medium and large sized mining.

12 Medium-sized mining observations account for nearly 75% of production of the segment with production levels between 1,000 and 50,000 tons of copper per year. Likewise, medium-sized mining observations are from major medium-sized mining, sub segment with production levels between 12.000 and 50,000 tons of copper per year. For large-size mining observations, they account for 92% of the production for 50,000 tons or more per year.

1% year. Medium-sized mining lost 43% of efficiency (from 107 working hours per kiloton of material moved to 153 working hours), which implies an average annual fall in productivity of 2.6% (see Figure 9.4).

Figure 9.4 Person-hours per kiloton of moved material in Large and Medium Scale Mining 2000-2014



Source: National Productivity Commission based on Cochilco data.

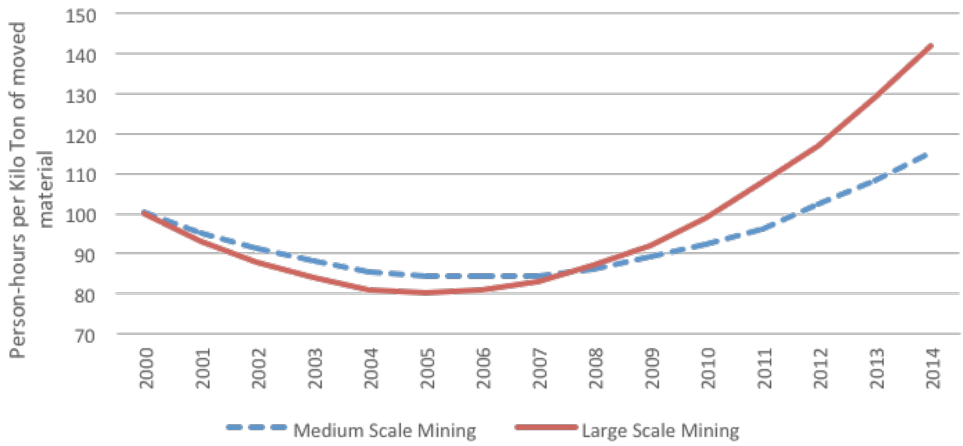
Figure 9.4 presents the huge productivity gap between the two mining segments. There is a recent and increasing fall in the productivity of medium-sized mining, widening the gap with large-scale mining since 2007. Figure 9.5 shows a trend analysis with the same data. The evolution of the productivity pattern of both segments coincides until 2007, although with a slight gap closure due to efficiency gains by the medium-sized mining industry until that year. However, as of 2007 the convergence stops and the segment gap widens to reach its highest level for all the data series in 2014.

In short, the medium-sized mining industry is less productive (by a third[13]) than the large-scale mining industry, with a constant gap since 2000, and growing since 2007. Both segments have faced ore grade deterioration and similar rates of increase in the number

13 Both segments are not perfectly comparable amongst each other, because medium-sized mining is mainly underground mines, and large-scale mining is mainly open pit mines.

of workers and production.[14] Recently the productivity gap has widened due to greater efficiency losses in medium-sized mining. Unfortunately, we do not have information on international productivity of comparable medium-sized companies to improve our analysis.

Figure 9.5 Trend Index of person-hours per kiloton of moved material (Baseline 2000=100)



Source: National Productivity Commission based on Cochilco data.

Finding 9.2: There is a substantial productivity gap - measured as person-hours per kiloton of moved material - between medium and large-scale mining. This gap has existed since 2000 and has increased since 2007. In the last fifteen years, the productivity of medium-sized mining has fallen twice than large-sized mining, and in the accumulated fall, its percentage has tripled large-scale mining. The largest gap available in the series was in 2014.

Recommendation 9.2: To instruct the Chilean Copper Commission to continue with their first characterization of the segment, with the aim of enhancing the understanding of medium-sized mining, given its increasing importance for Chile in the future of mining industry.

14 Both exhibit an improvement between 2000 and 2006 of their productivity and both worsen after 2007.

The international equivalent of medium-sized mining in Chile (which refers to a production of 12,000 to 50,000 tons of copper) is considered as large-scale mining in other countries. In Chapter 3 of this report, there is evidence for the productivity gap in the large-scale national mining and other major international operations. Therefore, the productive difference between global mining and medium-sized local mining is greater than the gap reported for Chilean large-scale mining. However, there are no comparable gap studies in Chapter 3 regarding medium-sized mining with similar firms (focused in output and management capacity) to determine the causes and size of the gap.

Recommendation 9.3: Complement the gap analysis for large-scale mining conducted in this report, with a similar analysis for medium-sized mining in Chile, ideally with similar firms in related countries. This will allow defining a baseline to monitor the evolution of the segment.

9.3 Productivity Constraints

This section is based on Cochilco's studies (2016a, 2016b and 2016c) and analyzes aspects that affect the productivity of medium-sized mining. The studies provide a characterization of the segment and analyze its productive capacity through interviews with six companies and government representatives focusing on the sub-segment of medium-sized mining with production between 12 thousand and 50 thousand annual tons of copper.[15]

Table 9.1 summarizes the main factors affecting productivity according to the previous chapters' discussion. They have been grouped mainly in (i) internal and (ii) external factors.

Table 9.1 – Factors affecting productivity in medium-sized mining

Internal factors	External factors
- Management	- ENAMI
- Organizational Culture and Structure	- Human Capital Supply
- Growth strategy	- Water and Energy Supply
- Financial capacities	- Infrastructure
	- Mine closure
	- Environmental Impact Assessment System

Source: CNP based on COCHILCO (2016c).

[15] COCHILCO (2016c) collected information from interviews to 6 medium-sized mining companies (with high levels of production in this segment) and 7 representatives of public and private stakeholders of medium-sized mining. See Annex - Table A.9.1.

Among the operations' internal factors, there are management issues, which determine how labor and capital are organized. There are cultural aspects in the organizational structure that also affect the possibilities of growth and financing of medium-sized mining.

Regarding external factors, there are areas for improvement concerning the middle miners' relationship with ENAMI, and access and availability of infrastructure. Regarding human capital, the companies point out that the insufficient supply of job training is a challenge, as well as the drain of talents towards the large-scale mining industry. This last point has acquired significant relevance since the expansion in the adoption of 7x7 shifts in the large-scale mining industry which has encouraged greater mobility of workers between regions. The limited number of workers enhances the need for multifunctional workers in medium-sized mining.

The processing in the Environmental Impact Evaluation System (SEIA) is the main external challenge for medium-sized mining. Note that this does not necessarily refer to the system standards, but rather, to its processing procedure, extension, and its requirements from the companies. The workload at each stage of the SEIA process exceeds the capacity of the human and financial resources of medium-sized enterprises. The company must update its licenses each time it extends the life of the operation. Due to the duration of demonstrable mineral reserves and its prospective investment capacity, these updates are regularly required. In short, while large-scale mining can internalize different processes within its functions using dedicated teams or external consultants, medium-sized mining has to do the same, but with less human capital and financial resources, obtaining it by deviating human and financial resources from mine operations.

9.3.1 Internal Challenges to Operations

The first category refers to internal factors and difficulties for operations. In that sense, the solution to these problems does not depend mainly on public policy but depends on management changes, including their convergence to international best practices and the inclusion of international financing in their portfolio of projects.[16] This is especially relevant for medium-sized mining companies, with an annual production of 12,000 to 50,000 tons, where the country could aim to achieve international levels of productivity.[17]

16 For example, establishing a joint venture with multinational mining companies.

17 In this range of production, a site would be considered as large-scale mining in many countries (except Chile).

Some issues specific to the company's management are: the development of an optimal mining plan, the selection of technologies and inputs for the productive process, the balance of capacities between mine and plant, the ability to manage and finance, the organization and supervision of work shifts, managing the operation's sub-contracting levels and employee turnover.[18] They all negatively affect productivity levels, and, although we do not have a gap analysis that could enrich the study, such as the one in Chapter 3, these internal factors should not be overlooked.

There are cultural issues rooted deep within the segment, in particular by the closed origin of the companies. The medium-sized mining companies[19] are mainly family businesses with no corporate structure as was evidenced from the Cochilco (2016c) interviews, and this problem is higher when mining companies are smaller. In contrast, the operations of large-scale mining are specialized corporations in the industry, with international partners, international level corporate structures, and a highly professional management. In addition to the impact on day-to-day management, this organizational structure also limits the possibility of access to obtain financing in foreign markets. Some companies even prefer maintaining their family structure and control, even if it limits their growth options and productivity improvements. In fact, a significant restriction is the guarantees required for loans in the domestic financial market because available financing is indirect to the operations, with loans being granted to owners/partners and backed by their own equity. Smaller mining companies do not have this problem since the National Mining Company (ENAMI in Spanish) provides loans and guarantees minimum prices for small-scale miners.

According to the interviews, medium-sized mining operations works in shorter time horizons than large-scale mining companies, and therefore sub optimal for an industry with large capital requirements. Constraints on long-term planning impose limitations such as the availability of mining property,[20] the quality of the mining plan,[21] and the

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18 Some labor regulation issues like relations with unions and work shifts depend of regulations and aren't fully determined internally by the mining company.

19 Operations with production levels from 1,000 or 1,200 to 12,000 tons per year

20 This limits their production scale and their capacity to make long-term plans. The availability of reserves is linked with a speculative use of mineral patents and a low rotation of mining property in this market. Also, it is determined by the slow and ineffective enforcement of law 19.137 of 1992 (modified by the law 20.392 of 2009) that establish rules on unexploited deposits of CODELCO to a third party. Also, this law authorizes Codelco, with a previous report of Cochilco, to transfer their own assets to Enami, in particular mines with no extraction operations, and where potential mineral resources and the possible production scale are not according to the parameters of large-sized mining. A regulatory framework that rewards mining property owners that are actually doing mining activities encourages a higher availability of mineral property. See Chapter 8 - Exploration.

21 With a short time horizon, strategic decisions related to mineral extraction process aren't necessarily optimal.

productive balance between mine and plant, among other factors.[22] Some interviewees point to the high cost of drilling to test new reserves as an additional factor that limits long-term planning capability. In the segment, most companies work with accredited mineral reserves for less than five years, which restricts the ability to plan, and prevents the possibility of long-term financing. As mentioned, adjustments to the duration of accredited reserves require a process in the SEIA.

A key difference between both large-scale and medium-sized mining are their evolutions and their growth strategies. The large-scale mining industry, considering their time horizons, production scale and financial capacity, structures growth and investment plans organically. Medium-sized mining, unlike large-sized mining, structures short-term plans: it operates in reaction to short-term opportunities, determined by its structure of either family businesses or private limited companies. Inorganic growth is mainly reflected by acquisitions of secondhand mines, plants, and equipment, with some of them coming from companies in economic difficulties or bankruptcy. In other words, the strategic development decisions of medium-sized mining companies are conditioned by the economic situation and opportunities that allow them to acquire and solve these factors (among other factors) and not necessarily by a long-term development plan. Because of the nature of such acquisitions (old artifacts, different brands and models, and various conditions), their use may be costly and complicated. For example, to incorporate old equipment, it is necessary to adapt the operational process of the company, modify the maintenance (frequency, quantity, and requirements), train for the proper use of the equipment, among other actions. In addition, this implies difficulties in receiving efficient and adequate support from suppliers.

Another fundamental aspect is the weak financial capabilities, due to the lack of management capacity, and the corporate structure of medium-size mining. Chilean large-scale mining companies trade bonds and shares in international stock exchanges (except Codelco). However, from 29 medium-sized copper mining companies (the largest in the segment) analyzed by Cochilco (2016b), Pucobre is the only local company that trades shares in the local stock exchange. In addition, eight more trade shares or bonds in stock exchange, only because they have multinational corporations listed on international exchanges as partners or owners. The remaining twenty do not have access to the stock market as a source of financial resources, which limits their capacity to finance long-term projects

22 A mining plan with a poor design or that doesn't consider the mineral reserves adequately, could lead to imbalances between the quantity or the quality of mineral extracted from mine, and the quantity or quality of minerals to process at the plant, generating bottlenecks and productivity drops.

with huge capital requirements. Part of these issues and the differences with Australia, Canada, and Peru, are highlighted in Chapter 8 - Mining Exploration.[23]

9.3.2. External Challenges to Operations

The second category refers to factors external to the company, mainly the provision of public goods and/or regulations, but also club or sectorial goods, where the coordinated action of the sector would benefit stakeholders.

A particular feature of the industry is its relationship with ENAMI, whose mission is to carry out activities to promote both medium and small-scale mining. Such activities require an efficient and adequate use of fiscal resources. In 2011, the OECD proposed a series of guidelines for public companies related to the composition of the board and the transparency in its operation. ENAMI could progress along these guidelines, for example, with their incorporation in the Public Enterprise System. A modernized ENAMI with an adequate corporate government, expanding and improving its interventions, would have a renewed impact on the sector.

Finding 9.3: There are areas for improvement and modernization in ENAMI, the leading state organization dedicated to the promotion of small and medium-sized mining.

Recommendation 9.4: Incorporate the OECD guidelines (2011) for public companies to ENAMI, modernizing their corporate government, and promoting transparency.

The supply and availability of human capital is an additional constraint. Unlike large-scale mining, which can mobilize workers throughout the country and abroad, the medium-sized mining labor market is available mainly from the towns surrounding the mines. Therefore, medium-scale mining companies face limited access to technical skills, and they must compete with the human capital demand of large-scale mining. According to the interviews, the scarcity of labor skills for medium-scale companies includes experience in mining (mainly underground mining), sophisticated machinery operators, and managers with technical knowledge and management of human resources. In other words, there is a lack of both hard and soft labor skills.

23 See subsection 8.6 on financing.

The competition between large and medium-sized mining is unequal. The large-scale mining industries can set wages well above medium-sized mining levels, offering better prospects for professional and career development, allowing them to eventually be better trained and valued. This has intensified since the 7x7 shifts replaced the 4x4 shifts in the large-scale mining industry, enabling workers to move within the country. Much of the increase in large-scale mining employment in the last 15 years (mainly in regions XV, I, II and III) are workers that moved from medium-scale mining, especially from the IV region to the south.

However, on the other hand, medium-scale mining has the advantage of being able to work without camps, employing people who live near the mine, and return home every day. This provides a better quality of life for workers and a better bonding with the local community. Despite this, qualified young people with some accumulated experience in medium-sized mining tend to migrate to large-scale mining, to get better wages. Therefore, wage gap among the cohorts of workers in medium-sized mining arise. On the one hand, there is a group of employees with years of experience, with high prestige within the mine and its environment, who, for family reasons, prefer a job near home. On the other hand, medium-size mining companies have groups of young workers with a lack of necessary experience in mining. The interviews reveal that it is hard to align both groups of workers. The young men trained by the medium-sized mining industry hardly remain in the industry, due to job offers from large-scale mining as middle managers with specialized functions.[24] Medium-sized enterprises are therefore limited in their ability to recruit, and forced to take full advantage of the capabilities and multi-functionality of their more experienced workers.

> **Finding 9.4:** Competition for human capital in the labor market with large-scale mining has led to a shortage of supervisors (middle management) in medium-sized mining.

The limited supply of job training in cities far from regional capital cities increases recruitment and training difficulties for medium-sized companies.[25]There is no offer of formal training courses on mining in the towns near most mines (SENCE courses, OTECs,

24 Medium-sized mining has not incorporated fully the guidelines of the Council of Mining competencies (an initiative of the Mining Council, related to training and human resources) and the guidelines from Chile Valora (an initiative of the Chilean government).

25 For example, in the Coquimbo region, where most of the mining companies belong to medium-sized and small-sized segments, the only town with Technical Training Schools (CFT) with courses related with mining industry is Coquimbo, a long distance from the region's mining towns.

Technical Training Centers for careers linked to mining, etc.). Therefore, workers are trained internally, despite the difficulties to get competent instructors and adequate equipment for teaching mining labor skills.

Finding 9.5: The medium-sized mining industry's labor market is located in small towns near the mines, where workers return after the workday (few sites operate with camps), that with insufficient labor supply in these towns, and with not enough supply of technical and professional training related to mining.

Recommendation 9.5: Establish a local mining training policy in cities where mining employment is relevant, especially in areas where medium-sized mining operates. Local technical schools should further the developing of mining specialties, with infrastructure and equipment support, as well as promoting mining careers in Technical Training Schools (CFT in Spanish) in towns where medium-sized mining is important.

As in large-scale mining, all medium-sized operations have electric power supply contracts that guarantee operational continuity. However, the production scale of medium-size mining does not reach the thresholds to negotiate better prices, being subject to regulated prices. While some mines avoid high-tariff hours with self-generation, according to Cochilco (2016b) this method is more intensively used for medium-sized Gold / Silver / Iron mining rather than Copper. This entails the practice of combining the contracted electricity consumption with self-generation units at peak hours. Concerning energy efficiency, it is harder to optimize in this segment, since the equipment used is older and less efficient than the one used in the large-scale mining industry.

The availability of water supply is even more critical, especially from the III region to the north, limiting production levels and impacting the growth plans of some operations.[26] It is worth mentioning that significant investments are being made in the medium-sized mining industry to apply thickened tailings technology,[27] with the dual target of recovering

26 Because of their flexibility, medium-sized mining companies were the first to use seawater for mining, but their weak financial capacity limits the substitution of fresh water at similar rates to large-scale mining companies. Medium-sized companies like Quebrada Blanca, El Espino, Diego de Almagro, Santo Domingo, Pampa Camarones, Las Cenizas and Mantos de Luna, use seawater. See Chapter 5 (Water and Energy Resources).

27 Tailings generated by the mineral concentration process, where a big share of water is removed from tailings using thickeners, to get a concentrate solute with 65% to 75% of solids. With this

the water that returns to the process and providing more stability and a longer operational life to tailing dams. In addition, medium-sized mining operations such as Quebrada Blanca, El Espino, Diego de Almagro, Santo Domingo, Pampa Camarones, Las Cenizas and Mantos de Luna use or have plans for future use of seawater desalination to supply their operations (See Chapter 5).

Due to the electric and water constraints, partnership and coordination in the medium-size mining sector in order to take advantage of economies of scale is relevant. An example of this could be the provision of desalinated seawater.

Regarding logistics infrastructure, issues in the sector are greater than in large-scale mining. Given its magnitude and financing capacity, medium-sized mining is not able to internalize its needs for transportation, ports, pipelines, etc., and (without access to private infrastructure) it must, therefore, have access to public infrastructure. The report of the National Council for Innovation for Development (2015) on ports and logistics highlights progress since 1990. However, it also shows a current deficit of roads (for new projects or expansion of existing projects) and new programs focused on freight transport and intermodal systems between different means of transport (in particular, ports and railways, through transfer stations).[28] A significant gap persists with the developed countries: the World Bank's logistic performance index (2016) shows Chile below almost all OECD countries, only surpassing Greece and Mexico. Cochilco (2016c) mentions the low standard of industrial mining connectivity in second and third order public routes, with a small capacity for truck traffic due to its design and gravel surface. Additionally, there is an insufficient capacity of bulk (concentrates) shipment in the port of Coquimbo, which also lacks the capacity of containers' shipment, compelling the cargo exports through the ports of Valparaiso and San Antonio.

To confront this deficit, large-scale mining has generated private solutions, with ports such as Punta Patache (Collahuasi), Coloso (Escondida), Punta Padrones (Candelaria) and Punta Chungo (Los Pelambres). According to Cruzat and Reveco (2012), this is not only motivated by the infrastructure deficit but also because of port operations. In fact, there

concentration level, tailings do not separate and the mineral content is homogenous. Because their minimum fluidity, they can be sloped to maximize or eliminate the need of confinement walls and decantation ponds. The remaining water evaporates until it reaches its concentration limit, achieving a dense, non-liquefiable and seismically stable geotechnical state.

28 Intermodal transportation is defined as the articulation between different transport modes using only one cargo unit (like containers), to make cargo transportation faster and more effective. Intermodal transportation for cargo could be improved by implementing infrastructure such as transfer stations between different transportation modes, like trucks, railways and ships (ports).

is a high risk of strikes in Chilean ports (according to ECLAC between 2010 and 2014 Chile had the highest amount of port strikes (in days) throughout Latin America[29]).

Medium-sized mining is less likely to solve the transport deficit privately due to its limited financial capacity. In fact, in regions where medium-sized mining has a high presence, such as Atacama and Coquimbo, ports are scarce, small, and designed for low capacity vessels. However, some initiatives could enable them to access the private ports of large-scale mining companies. For example, the Ultramar group proposed that private mining ports be transformed into port complexes that transfer the cargo of all projects, generating economies of scale (Cruzat and Reveco 2012). For example, it was proposed to use Punta Padrones for all mining companies of Atacama Region, including several medium-sized mining sites (such as El Morro, Relincho, Cerro Casale, Santo Domingo and Diego de Almagro). The study points out that this port is underutilized (given the future projections, it is unlikely that the port would be used at full capacity). The mining company that owns the port would benefit from the generation of efficient economy scales increasing its use, at the same time providing new logistic options for the medium-scale mining industry. This would avoid resorting to public or public-private-partnership ports outside the region in order to export. This model could also be replicated in other infrastructure works, such as intermodal stations and dry ports. At present, the private owned Port of Mejillones (Antofagasta Region) (owned in part also by the Ultramar group) is an example of operation for several mining clients (and non-mining companies). It serves to Suez Energy, Minera San Cristobal (Sumitomo), Polpaico and, for sulfuric acid, Copec, Codelco, Xstrata, and Freeport, among others.

Finding 9.6: There is a deficit in local infrastructure, in both quantity and quality, for intermodality. For medium-sized mining, the absence of ports is the main infrastructure problem in Regions III and IV.

Finding 9.7: Large-scale mining has generated logistic solutions at the individual level, building its private ports to export their production. However, there are chances to take advantage of economies of scale in some ports by providing access to medium-sized mining and increasing the port capacity used.

It is also necessary to strengthen the railway infrastructure, since it is a more efficient mode of transporting large quantities respect to truck transportation. In large-scale mining, operators such as Ferronor and Ferrocarril Antofagasta Bolivia own tracks located

29 See Sánchez and Pinto (2015).

near several large-scale mining operations. For medium-scale mining, connections to the railway network do not exist, and if it does, they are disabled due to abandonment and deterioration. As in seawater supply, large-scale mining may opt for an individual-level solution, but medium-sized mining can take advantage of greater coordination and economies of scale. State investment (either directly or through concessions) could be relevant, in particular with the rehabilitation of the deteriorated sections of the old north rail network or the establishment of new sections connecting mining operations with the nearest ports, introducing new competitors.[30] It is worth mentioning that this not only consists of increasing the network but also of making cargo use compatible with other purposes.[31] Many of these recommendations are similar to National Council for Innovation for Development (CNID in Spanish) proposals (2015).

Recommendation 9.6: Increase the quantity and quality of road, railway, and maritime infrastructure, jointly investing in intermodality between the three modes, according to the guidelines of the National Council for Innovation for Development (2015).

Recommendation 9.7: Facilitate and encourage the incorporation of medium-scale mining to private infrastructure projects of large-scale mining (ports, desalination plants, among others), in that there are potential economies of scale.

The requirements regarding the process of mine closure are another important aspect. In this process, the company takes care of environmental and safety liabilities, generated by the mine's operation, which implies proper mine closure, eliminating environmental waste and rehabilitating the impacted environment. Mining companies must provide financial guarantees for compliance with the plans for the rehabilitation and closure processes.

The legal requirements were initially intended for large-scale mining standards and affect the financial capacity of companies. For example, as the law requires bank warranty bonds[32] whose value decreases with the short time horizons of proven mineral reserves (that is, the life of the operation decreases), these bonds restrict the credit rating and capacity

30 See Corporación de Bienes de Capital (2017).

31 An example where this was not fulfilled is the cargo railway connection with the Port of Valparaiso, where (due to daytime passenger operations) cargo railway transportation was confined only to nighttime.

32 "Boletas de Garantía" in Spanish, refers to a legal document emitted from a banking institution for a client that guarantees commitment towards an obligation. It can be emitted either against a money deposit or a credit.

of the companies. Medium-sized mining companies with a family corporate structure, also affect the credit rating and capacity of its owners.[33] Linked to the previous section, the incorporation of partners with high levels of financial capacity (such as specialized international banking on mining industry) could mitigate this problem, as it would increase exploration activities and reserves, with a longer exploitation horizon. This could cover the requirements associated with mine closure processes. It should be noted that in 2014 the mine closure Law (Law 20,551) was modified to allow mining operations with a capacity to extract between 10,000 and 500,000 gross monthly tons of mineral material (Law 20,819), to calculate its operational life according to mineral resources,[34] and not of reserves.[35] Therefore, the mine's operational life would be increased, and thus the period of guarantee life.

The Chilean procedure doesn't differ significantly from the international procedures (Canada, United States, and Australia), albeit there are some differences. In countries with federal systems, each Province or State has its own requirements, and negotiation with authority defines the amount of guarantee. In the United States and Canada, the amount is calculated based on technical estimates of closure plans, while in Australia the guarantee is set at an amount per hectare (Cifamin 2010).

However, there are significant differences concerning the alternatives to finance the guarantees. In the United States, there is a great variety of financial instruments (private and public) to establish the guarantee.[36] In Western Australia, the Government structured an insurance mechanism, with a fund to which companies contribute. The estimated amount of investment required to recover the land after the closure of the mine, is proportional to the contingent liability of each company, which is activated in case of bankruptcies. The fund also allocates part of its resources to restore abandoned mine sites. Additionally, as mentioned earlier, companies equivalent to medium-sized mining (regarding production) in the other countries considered for the study, belong to multinational businesses or are private companies, with well-defined corporate governments, and their shares are publicly traded, which is relevant for credit access.

In Chile, a mine with more than 5,000 tons of mineral material moved per month should constitute guarantees within 2/3 of the life expectancy of the mine, which is around

33 According to the law, with fewer mineral reserves, less lifetime for the mine site and, therefore, less time limit to establish the guarantees.

34 Mineral estimates that the mine site possesses.

35 Mineral accredited using drillers, economically feasible of extract.

36 In Chile, there are examples of guarantee systems (regulated by government) with a wide variety of instruments in health care industry. For instance, the guarantees required to the ISAPRES (Instituto de Salud Previsional, Health Care Institutes in Spanish).

5 years for medium-scale mining. That is, a mine with five years of proven reserves must constitute the guarantee required for closure three years earlier. As mentioned, the segment operates on a short-term basis, so that most companies must provide insurance in a short time. Considering that they receive indirect financing via credit to the controllers, it is highly possible that these demands exceed the owners' financial capacity (Cochilco, 2016b).

In this context, and considering that the Law is not far from the best international practices, the demands of the mine closure process are not the problem, but rather, the limited financial capacity of medium-sized operations to establish the guarantee bond.[37] The latter does not imply that the process cannot be improved. In this sense, and following the experience of leading countries such as Australia and the United States, more financial options can be developed considering the financial limits of the sector. For example, a fund such as the Western Australia Mining Rehabilitation Fund[38] could be implemented, where companies contribute with a fee according to used infrastructure or land, where the fee is based on the average cost of mine closures. This system has benefits for small miners who cannot establish bank warranty bonds at an accessible cost because the fund operates when all other remediation options have been exhausted. Another option, complementary to the previous one, is to increase the variety of financial instruments, following the example of the United States. An example of an alternative financial instrument (as a guarantee) can be the use of an investment fund (which generates profitability) as a guarantee. Another financial instrument is to test the financial statements of a mining company to evaluate their ability to pay for mine closures, as a guarantee. Cifamin (2010) details the other alternatives of guarantee instruments applied in the United States, as well as their possible application to Chile. Finally, it is important to clarify that in countries with good practices, companies continue to be responsible for each mine complying with the mitigation and management of environmental liabilities generated, so that the socialization[39] of these costs have never been considered as an option for any of the cases above.

Finding 9.8: The process of mine closure in Chile does not differ significantly from international best practices. However, a restriction to the sector is the financial guarantees required for the mine

[37] See Department of Mines and Petroleum (2015).

[38] That means that government, and therefore the nation through its taxes, pay the costs of environmental liabilities generated by a mining company.

[39] Another proposal is to improve the processes for project modifications and the environmental qualification resolution (RCA in Spanish), and strengthen the SEIA's capabilities and functioning, and mediating the relationships with the community during the environmental evaluation process.

closure processes where the only available alternative is the bank warranty bonds.

Recommendation 9.8: Expand the options of financial instruments to guarantee the closure of mining operations. Following the model of Western Australia, analyze the possibility of pooling a common fund of guarantees that also serves to rehabilitate abandoned tailings and dumps.

The Environmental Impact Evaluation System (SEIA in Spanish) processes are a challenge for the middle-sized segment. Cochilco's study (2016c) does not point to the required standards, but to the bureaucratic process, which is too slow and highly uncertain, limiting the management capacities of the companies. Particular emphasis is placed on the difficulties in processing mine expansion or modification projects, where changes of the project (small changes in some cases) lead to restarting the process. In this way, the Presidential Advisory Commission for the Evaluation of SEIA (2016) has proposed that the Environmental Assessment Service (SEA in Spanish) could assume a role of evaluator, coordinator, and administrator of the process, where reports from other public services support the SEA in this role.[40] Improvements in the operation of SEIA have a positive impact on all projects that are evaluated, especially in segments such as medium-sized mining.

Finding 9.9: The Environmental Impact Assessment System (SEIA in Spanish) process exceeds the internal management capabilities of medium-sized mining companies. In particular, this problem is worse for small project expansions, where the benefits are lower compared to the required time and resources of SEIA process.

Recommendation 9.9: Implement the recommendations of the Presidential Advisory Commission for the SEIA Evaluation (2016). Most require only regulatory modifications, which lead to a rapid implementation of recommendations.

40 Another proposal is to improve the processes for project modifications and the environmental qualification resolution (RCA in Spanish), and strengthen the SEIA's capabilities and functioning, and mediating the relationships with the community during the environmental evaluation process.

9.4. Conclusions

This chapter characterizes the medium-sized mining sector and describes barriers to productivity and possible solutions. A major obstacle is linked to the internal performance of companies such as management quality, their capacity to access human capital and financial resources. This is exacerbated by their corporate structure. Other constraints are external, such as the supply of human capital, bureaucracy in procedures and requirements, and access to infrastructure, where public policy plays a leading role.

9.4.1. Summary of Findings

Finding 9.1: There is no consensus on a clear and precise definition of the medium-sized mining segment. Different organizations use different definitions (labor endowment and production), potentially generating inconsistent productivity statistics.

Finding 9.2: There is a substantial productivity gap - measured as person-hours per kiloton of moved material - between medium and large-scale mining. This gap exists since 2000 and has increased since 2007. In the last fifteen years, the productivity of medium-sized mining has fallen twice than large-sized mining, and in the accumulated fall, its percentage has tripled large-scale mining. The largest gap available in the series was in 2014.

Finding 9.3: There are areas for improvement and modernization in ENAMI, the leading state organization dedicated to the promotion of small and medium-sized mining.

Finding 9.4: Competition for human capital in the labor market with large-scale mining has led to a shortage of supervisors (middle management) in medium-sized mining.

Finding 9.5: The medium-sized national mining industry's labor market is located in small towns near the mines, where workers return after the workday (few sites operate with camps), that with insufficient labor supply in these towns, and with not enough supply of technical and professional training related to mining.

Finding 9.6: There is a deficit in local infrastructure, in both quantity and quality, for intermodality. For medium-sized mining, the absence of ports is the main infrastructure problem in Regions III and IV.

Finding 9.7: Large-scale mining has generated logistic solutions at the individual level, building its private ports to export their production. However, there are chances to take advantage of economies of scale in some ports by providing access to medium-sized mining and increasing the port capacity used.

Finding 9.8: The process of mine closure in Chile does not differ significantly from international best practices. However, a restriction to the sector is the financial guarantees required for the mine closure processes where the only available alternative is the bank warranty bonds.

Finding 9.9: The Environmental Impact Assessment System (SEIA in Spanish) process exceeds the internal management capabilities of medium-sized mining companies. In particular, this problem is worse for small project expansions, where the benefits are lower compared to the required time and resources of SEIA process.

9.4.2. Summary of recommendations

Recommendation 9.1: To agree among the sector's stakeholders a precise definition of the medium-sized mining segment in order to produce comparable public and periodic statistics. This definition should focus more on production than employment size.

Recommendation 9.2: To instruct the Chilean Copper Commission to continue with their first characterization of the segment, with the aim of enhancing the understanding of medium-sized mining, given its increasing importance for Chile in the future of mining industry.

Recommendation 9.3: Complement the gap analysis for large-scale mining conducted in this report, with a similar analysis for medium-sized mining in Chile, ideally with similar firms in related countries. This will allow defining a baseline to monitor the evolution of the segment.

Recommendation 9.4: Incorporate the OECD guidelines (2011) for public companies to ENAMI, modernizing their corporate government, and promoting transparency.

Recommendation 9.5: Establish a local mining training policy in cities where mining employment is relevant, especially in areas where medium-sized mining operates. Local technical schools should further the developing of mining specialties, with infrastructure and equipment support, as well as promoting mining careers in Technical Training Schools (CFT in Spanish) in towns where medium-sized mining is important.

Recommendation 9.6: Increase the quantity and quality of road, railway, and maritime infrastructure, jointly investing in intermodality between the three modes, according to the guidelines of the National Council for Innovation for Development (2015).

Recommendation 9.7: Facilitate and encourage the incorporation of medium-scale mining to private infrastructure projects of large-scale mining (ports, desalination plants, among others), so that there are potential economies of scale.

Recommendation 9.8: Expand the options of financial instruments to guarantee the closure of mining operations. Following the model of Western Australia, analyze the possibility of pooling a common fund of guarantees that also serves to rehabilitate abandoned tailings and dumps.

Recommendation 9.9: Implement the recommendations of the Presidential Advisory Commission for the SEIA Evaluation (2016). Most require only regulatory modifications, which lead to a rapid implementation of recommendations.

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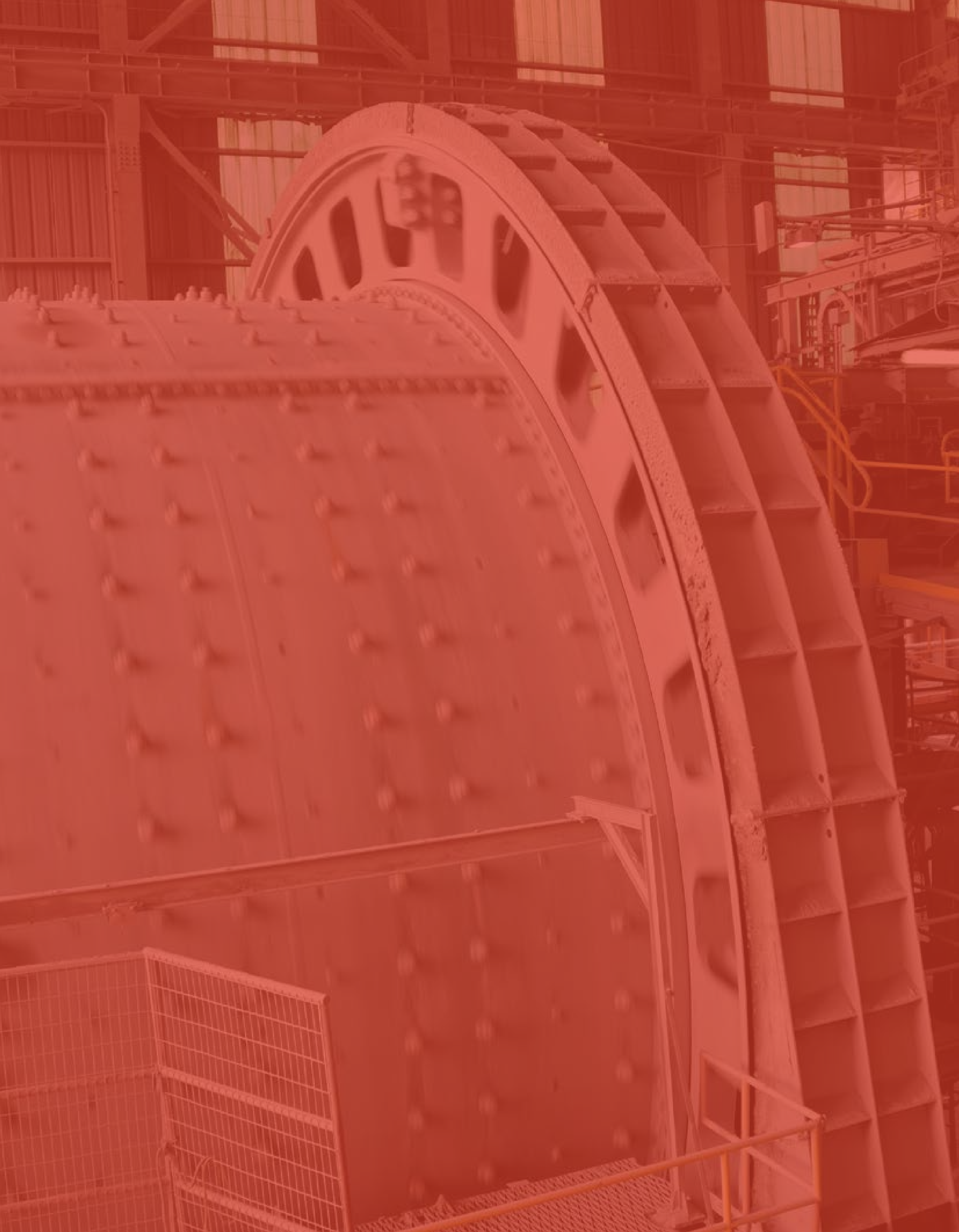
Annex

Table A.9.1 – Impact Matrix – Number of Factors Affected by Constraint Type

Constraints	Structural Constraints				Constraints on Human Resources Management					External Constraints			
	Companies Closed Origin (Familiar)	Credit Warranties	Short term planning	Inorganic Growth	Competition for workers with other companies	Disequilibria in number of workers	Low disposition for multifuncionaliuty	Insufficient Labor Training Supply	Working Shift Systems	Low flexibility in Electric Supply Contracts	Water Availability	Insufficient infra-structure (ports and roads)	SEIA Process exceeding the companies' capacities
Factors:													
Production													
Availability of mining property, resources and reserves			X		X								X
Quality of the Company	X	X											X
Mining Plan			X										X
Technology				X									X
Balance of mine-plant productive capacities			X	X									X
Optimal number of workers with adequate labor skills		X			X	X	X	X	X				X
Sufficiency of systems and equipment available and efficiency in use				X									
Resources Employed													
Financing		X		X									X
Work shifts							X		X				X
Maintenance of personnel					X			X					
Multifunctionality							X	X					
Outsourcing					X	X	X	X	X				
Workers union relations					X		X	X	X				
Training								X					
Other													
Electrical supply										X			X
Water supply											X		X
Supplier environment				X				X					X
Public infraestructure												X	
Associativity			X					X					X
Community relations													X
Compliance with public regulations													X

Fuente: COCHILCO (2016c).

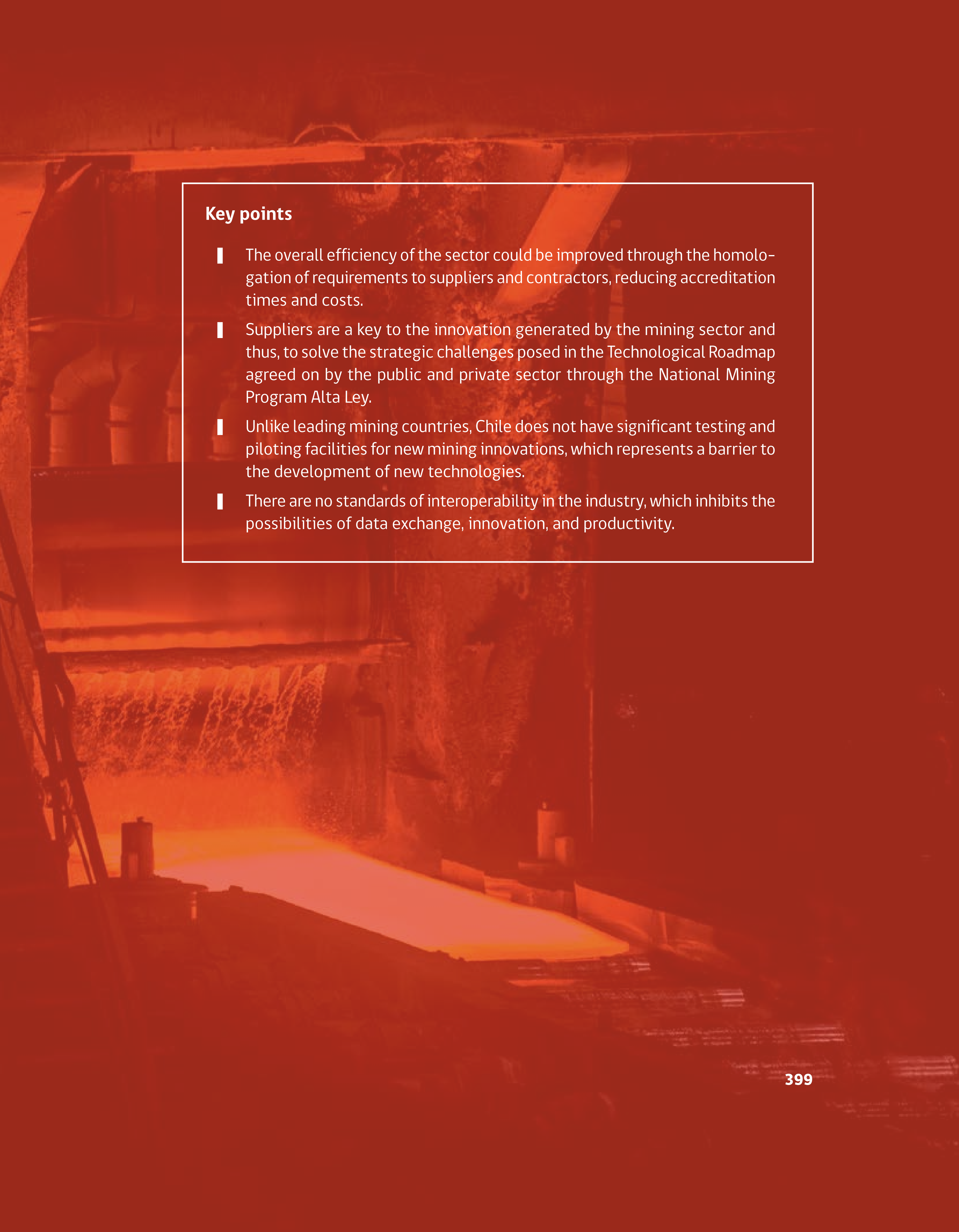


Chapter 10

Suppliers: Barriers to Productivity and Recommendations

Abstract

This chapter discusses recommendations destined to improve supplier productivity based on interviews with suppliers, mining companies, public agencies, and other stakeholders. It builds on chapter 4, on characterization and productivity of providers of the Chilean mining industry.



Key points

- The overall efficiency of the sector could be improved through the homologation of requirements to suppliers and contractors, reducing accreditation times and costs.
- Suppliers are a key to the innovation generated by the mining sector and thus, to solve the strategic challenges posed in the Technological Roadmap agreed on by the public and private sector through the National Mining Program Alta Ley.
- Unlike leading mining countries, Chile does not have significant testing and piloting facilities for new mining innovations, which represents a barrier to the development of new technologies.
- There are no standards of interoperability in the industry, which inhibits the possibilities of data exchange, innovation, and productivity.

10.1 Introduction

Chapter 4 provided a characterization of the mining supplier sector and its productivity. Beyond descriptive analysis, it is necessary to identify barriers to the development of suppliers, emphasizing an increase in efficiency that allows the growth of both the companies and the sector. Chile is the world's largest copper producer, with a third of world production and reserves. However, it has not achieved a relevant position in the mining supplier market as demonstrated by the low level of supplier exports relative to countries like Australia.

The development of local mining suppliers has been a public policy objective of several governments. Recently, the National Mining Program Alta Ley,[1] the development of "world-class" mining suppliers, and other CORFO initiatives demonstrate this interest. The development of local suppliers is an explicit objective in the Productivity Agenda of the Ministry of Economy,[2] and they are a fundamental part of the challenges prioritized in the Technological Roadmap of the Alta Ley program.

The first section of this chapter analyzes existing barriers that affect the accreditation times of supplier companies and seeks to facilitate their linkages with the mining companies. The second part addresses innovation and supplier development issues, analyzing current public policy programs.

10.2. Barriers to Suppliers

Accreditation

The accreditation process consists of certifying working standards in mining operations, for external contractors and their own workers. The mining company (who certifies compliance with the conditions using an entrance certificate) carries out this process. The duration of the accreditation process varies enormously with an average of 38 days and a maximum of 75 days. The process is not only slow; it is in many cases redundant since the same supplier must be accredited each time it starts working for a new mining company. These delays entail significant costs: a large mining company estimates the annual cost of each additional day of accreditation at US$500,000. These times are due to coordination failures and the absence of industry standards, as well as the lack of information exchange (even between mines owned by the same owner).

1 See www.programaaltaley.cl
2 See www.agendadeproductividad.cl

Part of the solution to the delay in accreditation times is the homologation of common standards and criteria for primary issues such as occupational health and work safety, unanimously requested by stakeholders consulted. The accreditation of standards does not necessarily imply that the certification process should not be repeated in each new mine, since there may be specific requirements (for example altitude), but it does imply a shorter time spent in this process. Common accreditation standards should be covered by the entire industry, improving the sector's overall efficiency, as both mining companies and supplier companies would benefit from shorter certification times. Possible solutions can come directly from regulation and public policy, from the private sector's self-regulation or a combination of both. The system can also be implemented at the regional level, granting higher mobility to workers, for example, with Peru, with whom Chile shares both a border and companies and together make up 40% of world copper production and reserves.

Finding 10.1: There is ample space for cost and time reductions in the accreditation of suppliers and contractors through the homologation (or standardization) of requirements between different companies and mines, which would result in important gains in the sector's overall efficiency.

There are some valuable initiatives in this area at the level of mining companies, suppliers, and their organizations, and the industry has made significant efforts in this direction. Aprimin (2016)[3] notes that homologation agreements have been signed with four large mining companies - Antofagasta Minerals, Anglo-American, Codelco, and Collahuasi -, which represent 61% of the national production. These conventions include standards for (1) Basic General Safety Induction, (2) Light Vehicles, and (3) Pre-Occupational Health Assessment. The agreements are at different levels of progress, but when fully implemented, they should represent an estimated US$30 million savings per year for Aprimin. In 2017, two additional mining companies (SQM and Teck) are expected to join.

As for the safety induction field, the Ministry of Mining and Sernageomin developed the Homologated Course of Basic Induction in Mining Operations along with various stakeholders (mining companies, suppliers, and academia). The Ministry of Mining's Supreme Decree No. 99 of 19.3.2015 establishes the duration and minimum attendance of the 16-hour course, the contents and modules, the rating agencies' requirements, and the effect of the course's approval certificate, among others. However, the most relevant

[3] The Asociación de Proveedores Industriales de la Minería (APRIMIN) represents the main supplier organization whose member's accounts for 60% of supplier sales to mining companies.

aspect is the 4-year validity of the approval certificate of the mining operations' basic induction course that would allow entrance to a mine without the need of repeating these courses. In addition to the list of certificates issued to workers by the qualifying entities, Sernageomin keeps a register of the authorized companies that grant the Homologation Course and of the mining companies that wish to join.

As of November 2016, only training entities have been registered, but no large mining company has joined. Consulted companies indicate that, although it is easy to enter the registry, there are difficulties in withdrawing from it; in fact, this option is subject to Sernageomin's discretion since the regulation does not specify the criteria to follow in case the mining company requests to withdraw from the registry. Companies feel uncomfortable over this issue, because, if they raise their standards unilaterally, they would equally have to let suppliers who had taken the course enter the mine. A clear exit criterion from the registry could encourage the entry of mining companies, which could benefit from the potential of this course. The companies participated in the creation of the course curriculum so they do have a voice on the periodic updating that may be required. It should be noted that this course is not among the obligations and functions of Sernageomin, but seeks to support coordination between miners.

> **Recommendation 10.1:** Modify Supreme Decree No. 99 of 19.3.2015 of the Ministry of Mining to establish a clear criterion and the option for companies to withdraw from the registration of the Homologated Course of Basic Induction in Mining Operations.

As for light vehicles (e.g., vans), there is ample room for improvement. According to contractors, the same supplier may need two different color vans if they perform work for two different mining operations; even though both require the same technical specifications (engine strength, load capacity, etc.). This is because each mine (even under the same company) requires a particular color for the contractors' vehicles.

The solution should be achieved through the industry's self-regulation, via standardization agreements between suppliers and mining companies. Another option is for Sernageomin to define - in conjunction with the private sector - similar technical, mechanical, cosmetic and safety standards on the characteristics of light vehicles that mining companies request from suppliers and contractors to facilitate mobility between mines. Concerning color, it would be simply to choose from a list of standard, high visibility colors.[4]

4 A list that allows for exceptions is an option. For example, white color should be banned in a snowy mining operation.

Recommendation 10.2: Establish a universal standard on the technical characteristics and other minimum criteria required for light vehicles. If an agreement between the companies is not possible, settle it through the Mining Security regulations and incorporate it into the Mining Safety Regulation (DS132).

As for pre-occupational[5] and occupational[6] health exams, there are also improvement areas. Often, workers of a contractor company, have their medical exams repeated even if the previous ones are currently valid if they change mines (even within the same company). A significant part of the accreditation times is spent in these processes and improving it would help mining companies, suppliers, and workers.[7] High levels of employee turnover and mining subcontracting amplify this problem.

Current medical examinations (pre-occupational and occupational) should be valid to accredit and allow admission to mining operations. There are no hints of regulations[8] that require a worker to repeat an examination that is currently valid[9] and therefore this point was included in the Aprimin's homologation agreements with the mining companies.

According to the companies, the current regulations do not encourage an employer to rely on previous medical examinations or certifications that a worker brings from other companies due to the requirement to "effectively protect life and health" imposed on the new employer, regardless of previous health history. In other words, if the new com-

5 Pre-occupational exams are those that evaluate the applicant (worker) in relation to the exposed risks in the exercise of their position (functions). The pre-occupational examinations are private responsibilities because, according to the Superintendence of Social Security, they do not correspond to examinations financed by the Social Insurance against Risks of Work Accidents and Professional Illness of Law 16,744, since the applicant to the position has not yet the status of hired worker.

6 Occupational exams allow the detection of pathologies that may worsen by exposure to agents that exist (or have existed) in the work environment. The respective examining body (mutual, also called Worker Compensation Agencies) must cover financially occupational examinations, made to workers based on exposure due to their work function. This includes preventive cases where a hired worker is going to be exposed to new hazards.

7 Due mainly to the time-period between the granting of a contract to a supplier, the appointment and the conduct of the examination.

8 The requirement for pre-occupational health exams is not clearly regulated. As a general principle, the Labor Code (articles 184, 185, 186 and 187) establishes that workers cannot be exposed to hazardous conditions, that the employer is responsible for providing safe working conditions and that the workers will need a fitness medical certificate and that such examinations must be carried out by specialized entities.

9 Except for the exclusive recommendation of a physician, who may, for reasons pertaining the worker's health or other medical criteria, determine that this is convenient.

pany does not verify the existence of a health condition, in the event of an occupational accident, such omission would presumably be used as evidence of the new employer's misconduct. Therefore, the new employer is always required to evaluate the health conditions of the new worker; otherwise, his defense position would be severely undermined if a compensation for damages claim for occupational diseases or accidents is filed.

An additional point to consider would be to define which examinations should be applicable since there is no specific regulation of the mining sector.[10] Most of the initiatives in the area come from within the industry. In 2011, Codelco, in agreement with the Workmen's Compensation Agencies association,[11] succeeded in establishing a set of examinations. More recently, homologation agreements between suppliers and mining companies include this point.

Therefore, there is a representative list of examinations workers are required to have depending on the hazards they are exposed to, used by all Workmen's Compensation agencies. However, this standard should be extended to the rest of the sector, promoting certification and exportability of each individual workers' information. These modifications would change the Mining Safety Regulations, to Regulation No. 594 of the Ministry of Health as well as Law No. 16,744 and its regulations. Greater coordination in the use of health information is consistent with the National Occupational Safety and Health Policy.[12]

As we have seen, the industry's self-regulation through enhanced coordination and awareness of the duplication of efforts provides a solution in the area of health examinations. There does not seem to be significant obstacles for the flow of information between the exam managing agencies (Workmen's Compensation agencies) and mining companies or suppliers.[13] Probably the difficulty lies in the fact that the exam managing bodies

10 A nonspecific regulation that falls mainly on mining workers is the Geographic Height Examination. This is the main pre-occupational health examination taken by workers who work at altitudes of 3,000 to 5,000 meters above sea level. The DS594 of Health, with its modification in 2012, details the risks to workers' health and the general obligations for companies. For more details on working at high altitudes, see Chapter 7 - Labor Aspects and Mining Safety.

11 Consisting of the lists of medical evaluations for each hazard, along with criteria of acceptance or contraindication.

12 Decree 47 of 16.9.2016, of the Ministry of Labor and Social Security. "Regulatory compliance will be promoted in the area of occupational safety and health, for which the supervisory institutions will be strengthened, both in the companies and in relation to the bodies that administer the insurance for work accidents and occupational diseases. These entities should act in a coordinated manner and with procedures aimed at the prevention of occupational hazards, and should also have mechanisms to facilitate technical information and advice to employers, especially in micro and small enterprises, as well as to workers, for the effective fulfillment of the legal disposition".

13 In the case of occupational exams, the employers have the information. In the case of pre-occupational exams, the applicants know if they are suitable according to medical evaluation and to the institution they took the exam.

(Workmen's Compensation agencies) have the medical records in their databases, and the certificates must be requested directly by the worker or by the employer, prior a signed authorization by the worker.[14]

> **Recommendation 10.3:** To take into account all current pre-occupational and occupational exams held by an employee to avoid duplicating efforts.

In short, achieving standardization and homologation agreements, while taking care of improving safety standards, in matters of contractor accreditation, light vehicles, and pre-occupational health assessments would increase the efficiency of the sector. It is worth mentioning that a significant part of the effort and initiatives on these issues has come from the private sector, which acknowledges an awareness of the problems. However, the ongoing dialogue between mining companies, their suppliers and contractors, and the government is fundamental to advance in this area.

Once the homologation process is advanced, the sector should aim to implement a mining passport in the medium term, a site where all of the worker's relevant information, concerning certification, safety, health, etc. is stored. It should be exportable between the different companies and in compliance with the regulations, which requires the public sector's acknowledgment.[15] Adequately safeguarding confidentiality issues,[16] it would represent a consistent improvement concerning information asymmetries, allowing a radical reduction of accreditation times.

> **Recommendation 10.4:** Implement a Mining Passport in the short term that grants mobility to workers of mining companies and contractors with special emphasis on its escalation.

14 Health information is each worker's private data and may not be made public if (1) the worker was not informed of the motives for disclosure and (2) the worker did not consent the disclosure.

15 For example, the Superintendence of Social Security started in 2016 the EVAST program - Evaluaciones y Vigilancia Ambiental y de la Salud de los Trabajadores- that seeks to enable a registry for surveillance and occupational exams. This could be used as a base ground for an online aptitude verification system, which would accelerate organizational processes.

16 That exam-managing bodies report the information only if the worker is able, not the medical exam details, and that the worker must previously consent the company to have access to his health status.

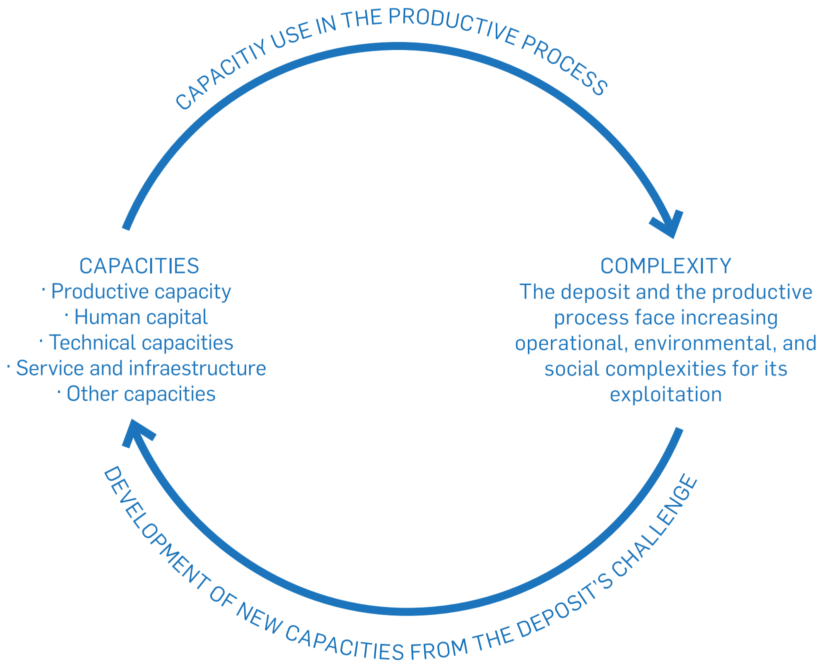
10.3. Suppliers' Innovation

Within the framework of the Alta Ley National Mining Program, a Technological Roadmap was developed. This roadmap determines actions, objectives, and indicators to be implemented in innovation areas. The portfolio of active innovation projects amounts to US$400 million by March 2017 with matched 1:1 private and public funding. Suppliers are key actors in order to solve some of the sector's technological challenges, and a goal was set of achieving US$4 billion in annual supplier exports and 250 world-class suppliers by 2035.

During the initial stages of any sector's development, imports and technology licenses can yield productivity gains. However, in more advanced stages, the use and mastery of technology are necessary for the development of solutions specific to the local productive reality. This can get as granular at operational level. In natural resource industries such as mining, there are particular challenges since the mineral resource is a "moving target" and changes over time. As shown in Figure 10.1, the greater complexity of mineral reserves requires the development of new productive, technological, and institutional capacities to sustain the competitiveness of the sector.

There are several examples of innovations and solutions that have emerged based on problems with mining and other natural resources worldwide. In the early 20th century, the depletion of native copper led to the development of open-pit mining and flotation as a new technology capable of exploiting large low-grade (2%) deposits. More recently, Chilean mining has implemented for the first time in the world the commercial-scale heap leaching at the Lo Aguirre mine. In South Africa, the low quality of the coal mines generated new washing techniques. In other natural resources such as oil, technologies were developed for drilling and extracting at sea depths. The relationship established by suppliers with greater technological and innovative capabilities with mining companies is fundamental for solving the country's challenges since part of the solutions will have to be developed locally due to their specificity.

Figure 10.1 – Link between higher capacities and complexity in Mining.



Source: Fundacion Chile (2016a).

Chile has incubated relevant production capacities and has consolidated a local supply chain during the last three decades. However, the transition to a knowledge-intensive innovative mining ecosystem that allows productivity gains over time is not easy. This process is long-winded, taking 20 years as international experience suggests, and requires resources, actions, and programs capable of aiming towards that goal.

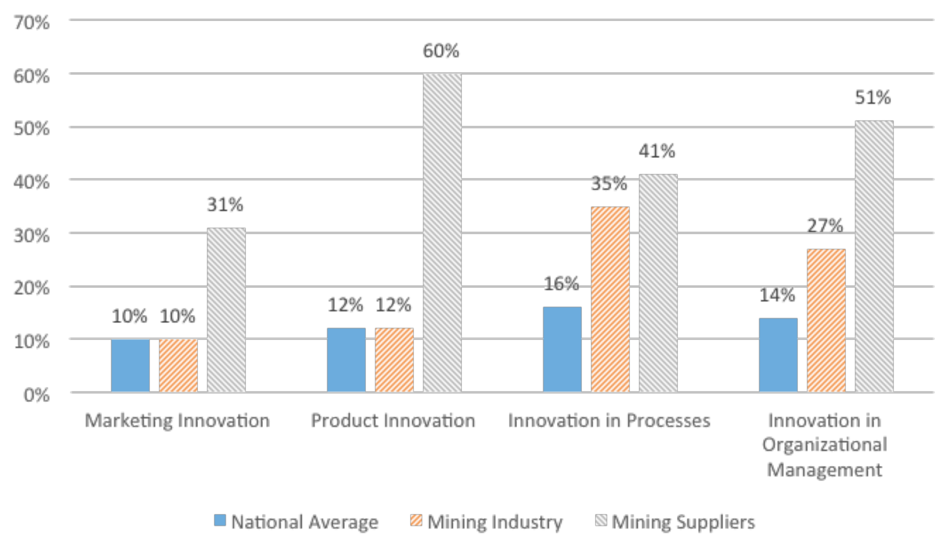
> **Finding 10.2:** Suppliers are relevant to mining innovation, and previously developed early programs are starting to take advantage of this potential.

World Class Supplier Program

The World Class Supplier Program (WCSP) represents one of the main innovation linkages between private companies and suppliers related in mining. It was designed to develop new solutions to mining operational and environmental challenges and to strengthen suppliers. The WSCM is a substantial articulating method of the so-called Mining Cluster.[17]

Compared to the rest of national industry and mining companies, mining suppliers would have a greater propensity to innovate -regardless of the type of innovation- (see Figure 10.2).

Figure 10.2 – Chilean Companies that innovated during 2012 by innovation type (%)



Source: Fundacion Chile (2014)

The WCSP focuses only on those mining suppliers that have the technological capabilities that may solve the proposed challenges (see Figure 10.3). The participants of the WCSP are more intensive in sales to mining; they have more human-capital and a greater pro-

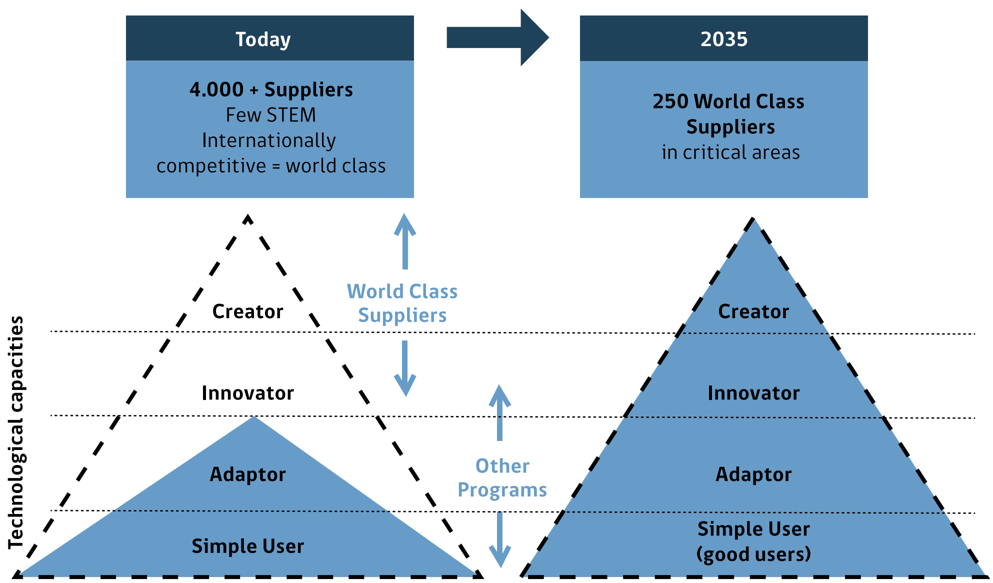
17 Cluster refers to the geographical concentration of companies, which compete and collaborate, increasing the competitiveness of the whole sector. It draws on the relationship between mining companies and suppliers, but it also includes research centers, universities and the public sector. Suppliers include companies that produce mining equipment and parts (e.g.: trucks, hoppers, tires), general inputs (e.g.: sulfuric acid), services (engineering, industrial cleaning), etc. . See Chapter 4 – Suppliers: Characterization.

pensity to export (see Table 10.1). There are, in fact, substantial differences in innovative capacities within the sector.[18]

A world-class supplier is located on the technological frontier and can innovate and export. It is generally measured through a percentage of total export sales (30 %+), as it reflects its technical and innovative capacity, and therefore, a greater competitiveness to export sustainably over time.[19]

Note that the WCSP approach does not focus on R&D expenditure but rather on innovation. R&D is essential, and there are significant gaps between Chile and other mining countries (see Chapter 1).[20] However, suppliers that have technological capabilities (e.g., engineering and design) and that carry out R&D are a minimal subset of the suppliers. Moreover, R&D spending is a reflection of the existence of other less sophisticated technological capacities that allow supplier companies to have R&D activities (see Figure 10.3).

Figura 10.3. World Class Supplier Program's Scope and Capacities.



Source: Fundacion Chile (2016a)

18 Phibrand (2016) reviews these differences in their analysis of barriers to innovation in the II Region.
19 However, capabilities for innovation and for exporting are probably different.
20 If Chile accounts for 30% of world production and reserves, it should aspire to do 30% of copper mining R&D in the country.

Table 10.1: Characterization of Mining Suppliers and WCSP.

	All Suppliers	WCSP
% companies with 60%+ Total Sales to Mining	37%	69%
% of workers with higher education	44%	63%
% that exports goods and/or services in 2012	34%	51%
Innovation Capacities Micro companies (average)	3,3	4,2
Innovation Capacities Small Companies (average)	3,2	4,1
Innovation Capacities Medium Companies (average)	3,5	3,9
Innovation Capacities Big Companies (average)	3,6	3,9

Source: Fundacion Chile (2014)

The WCSP started in 2010 with BHP Billiton and Codelco[21] (53% of national production). By January 2016, more than 100 projects had been carried out with more than 75 suppliers. The WCSP worked (2010-2015) as follows: (i) mining companies present a productive problem without a technological solution available in the market; (ii) the suppliers participating in the WCSP present proposals to the mining company in an open competition; (iii) the supplier signs a contract with the mining company which generally grants at least part of the innovation's intellectual property; (iv) the proposed solution undergoes pilot tests during a given period; (v) If the solution works correctly, the supplier may market it to other mining companies once the exclusivity period has expired (maximum two years). Within the program, there is financial and management support for the participating supplier companies.

The WCSP has been analyzed by several studies, mainly under the approach of a case analysis (Bravo-Ortega and Muñoz, 2015, Fundacion Chile, 2016b, Navarro, 2015, Stubrin, 2016). During the period of 2010-2015, the success rate of the WCSP projects was 12%, considering those projects that performed in-house tests and the validated solution purchased (Meller and Parodi, 2017).[22] Some suppliers have been identified as cases with international projection, among them: Aguamarina, Bailac, Innovaxxion, Neptuno Pumps, among others. In 2012, the WCSP inspired the creation of a similar program in Peru (Antamina mine).

However, criticisms to the program point at the small impact of innovations despite the fact that there are success stories. This would explain why other mining companies have

21 These companies fostered the program focusing on their suppliers.

22 If we consider the projects that reached the stage of prototype development at lab level, but didn't undergo testing in a mining operation, then the success rate would be higher.

not joined the WCSP. Additionally, a supplier company may have innovative capabilities to develop a solution, but not to escalate it into a test in mines or to develop a good or service able for commercialization. In other words, the supplier is only able to develop up to innovative laboratory prototypes. For the WCSP, scale up has been proposed in the following aspects (Urzúa et al., 2016): (i) more collaborative innovation projects, (ii) innovation portfolio with more technologically complex initiatives, (iii) reduced time-to-market[23] of developed innovations, (iv) increased supplier exports, and (v) diversification of suppliers by increasing sale goods and services to other industries.

The current scheme of the WCSP does not allow for the achievement of the multiple objectives due to the individual complexity of each in the scaling of the program. To achieve these targets, some important barriers would have to be overcome. As an example, for a time-to-market reduction, venture capital and test spaces are required. Besides, a greater number of more complex initiatives require both increased technological capabilities and previous successful experiences that will induce mining companies to take on more complex challenges in the program. Likewise, for an increase in exports, management capacities are required as much as innovative capabilities needed to successfully develop and scale a technology project. The achievement of multiple objectives requires multiple instruments. Without scaling, and thus without a visible and consolidated impact, the incorporation of a larger amount of participants will be difficult to obtain.

It is not easy to generate an ecosystem of innovation in a particular sector, but there is a public-private consensus that Chilean mining, by its size and characteristics, can play a fundamental role in the country's innovation. The national availability of 30% of world production, or 40%, considering the Chile-Peru mining area, offers unique market conditions to sector suppliers in the national economy. Furthermore, mining requires it to maintain its competitiveness.

Given the above, a second stage of the WCSP, called the Open Innovation Platform, has been developed under the Alta Ley National Mining Program, substantially funded by the Ministry of Economy, which seeks to address these barriers.

[23] Refers to the period since a good or service is conceptualized until it is available in the market.

Open Innovation Platform

The Open Innovation Platform (PIA in Spanish) aims to accelerate and scale the projects' innovation cycle and facilitate the transformation of the developed solutions for commercial goods and services, with adequate management and after-sales service.

The main differences between the WCSP and the PIA are:

- The participating mining companies (BHP Billiton and Codelco) increase the amount of annual funding by approximately ten times the amounts allocated to the WCSP and is committed to carrying out a specific amount of projects. Total funding amounts to US$8 million over a 4-year period, between the public investment, through the Strategic Investment Fund of the Ministry of Economy, and private contributions from mining companies (BHP Billiton and Codelco).[24]
- - In the WCSP, the suppliers worked mainly with the innovation divisions of the mining companies. In the PIA, technological managers are included in the mines that will cooperate with the operators, supervisors, and managers to detect and handle technical challenges.
- - Suppliers can propose technological challenges ("push"), unlike the WCSP where companies bid the challenges ("pull").
- - There is a funding component for escalation and pilot tests. Note that the supplier companies carry out the innovation development on their own, notwithstanding that they apply to CORFO funds or others.[25]
- - In the WCSP, there used to be a temporary exclusivity of the solution for the mining company with which the project was carried out. In the PIA, this exclusivity does not exist, (although it could exist according to the particular project). Open Innovation is aligned with the changes in Codelco's innovation strategy, which is reformulating its area of innovation in this direction.[26]
- - Large suppliers and medium-sized mining companies can pose technological challenges. It is desirable that Research Centers are incorporated.

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24 This amount is reasonable for a pilot, but should be adjusted upwards or downwards according to the program results within a prudent period.

25 In the 2010-2014 period, 15% of WCSP projects obtained funding from CORFO (Navarro, 2015).

26 Open Innovation considers fundamental the contribution in terms of value and ideas from agents outside the company, whether they be suppliers, universities and/or mining companies. A number of structural changes at the global level (human capital mobility, more venture capital, less hegemony of world powers in innovation, universities that are more qualified, etc.) have led to a higher prevalence of Open Innovation rather than Closed Innovation, a strategy where innovation efforts remain within the organization. See Chesbrough (2008) for more detail.

If the WCSP was fundamentally a mining company-supplier relationship for specific projects, the PIA is a more sophisticated program, similar to a sectorial and public good, focused on connecting supply and demand and allowing escalation.[27] On the one hand, it fulfills a coordinating role by unifying demand requirements (mining companies - large suppliers) and supply requirements (suppliers), facilitates information flows, and fosters management capabilities. On the other hand, although it does not finance technological developments, the platform seeks to connect suppliers with investors and venture capital, solving some of the financing problems. In addition, it encourages associativity because, in complex challenges, no single supplier would have the capacity to address them.

However, the challenges of scaling from the WCSP to the PIA are significant. A critical issue is to increase the number of participating mining companies to expand the number of projects and achieve a larger portfolio, but this takes time. The PIA corresponds to a "club good," which is a necessary, but not sufficient condition to develop the innovation ecosystem alone: mining companies and their involvement are essential in this process. Likewise, the dynamic inconsistency of the political cycle must be overcome for an adequate evaluation of the associative efforts. As an example, the Alta Ley National Mining Program, which circumscribes the PIA, has a portfolio of innovation projects in mining for US$400 million (both public and private funding). There is consensus on this topic, and it is a critical concern for the actors in the sector.

> **Recommendation 10.5:** Continue public-private partnership efforts, such as Alta Ley National Mining Program and its components, evaluating their performance and possibilities for improvement in five years at least.

Difficulties arise implementing an innovation program when identifying in detail the suppliers' capabilities. Both the characterization of this chapter and those made in previous years are a contribution to quantifying the sector but do not allow further analysis. For example, it was not possible to identify which industry each supplier belongs to, in the characterization of the Chapter 4 supplier sector, since several companies report having more than one industrial activity.[28] It is, therefore, necessary to establish indicators in the

[27] Barriers such as coordination between programs, long-term vision, export promotion, and others fall unto other stakeholders and programs. As previously mentioned, multiple objectives are rarely solved by one policy instrument or program -regardless of the program complexity-.

[28] Even at the highest level of industry classification (1 digit), more than half the companies belong to more than one industry (e.g.: there are suppliers with mining and agriculture as their reported industry).

PIA participants, allowing for a better orientation and focus of the programs and detecting the strengths and weaknesses in the innovation of the mining suppliers. Additionally, this allows a better match between supply and demand within the platform.

Recommendation 10.6: Establish clear innovation indicators that allow monitoring the impact of the Open Innovation Platform.

Supplier Exports

Increasing exports of mining suppliers is an additional goal of the PIA. The goal of reaching US$4,000 million annually with 250 world-class suppliers by 2035, implies US$16 million yearly sales per supplier on average.

A requirement to export may be the capabilities that enable productivity increases and/or the development of new goods and services. In addition, the act of exporting induces a competitive pressure to improve productivity and innovation. However, it is necessary to take into account that the capacity to innovate and to export is different.

Currently, mining suppliers export around US$500 million annually (Fundacion Chile, 2015). Few companies concentrate this amount: five export over US$25 million per year and represent 61%. Another 39 export between US$1 and US$25 million per year, representing 31%. Between 2012-2014, 65 companies kept exporting year after year, suggesting a distinction between exporters: the leading exporters (5), those that export in a sustained way (60), and sporadic exporters. It is reasonable to think that the policy instruments required differ between segments since some must deepen their export base, others consolidate it, and others initiate it.

ProChile's "International Promotion of Suppliers of Goods and Services for Mining" with US$4.6 million from the Strategic Investment Fund, under the Ministry of Economy, is pointing in the right direction. Given the complexity of the mining business, specialized mining sales agents may be required, capable of understanding the supply of Chilean suppliers and the demand of foreign miners in the selected countries. In that sense, the presence in international commercial fairs is useful but insufficient. The primary success indicator of the initiative would be both the effective increase in exports, and the amount of exporting suppliers.

Testing Locations

A significant barrier to supplier innovation identified in the study corresponds to the lack of testing sites for the mining industry. Any introduction and development of innovations demand trial and error, but it is very costly for large mining operations to lose operational continuity to test a pilot or innovation, which may or may not work. The situation is aggravated if the expected impact is low or medium. Suppliers report that when offering a product or service to a mining company, the company's primary concern is where such product or service has been previously tested. In this context, the development of world-class suppliers requires the presence of test locations to pilot new technologies and innovations.

Test sites are available in some countries. In Australia, public-private research centers specializing in mining have test sites,[29] such as the Deep Exploration Technologies CRC. A mine outside Adelaide allows field-testing and training. The Chilean company Drillco Tools, a national supplier also participates in the CRC. In Canada, this mechanism has been enhanced with the use of unused mines, both as test spaces and to train workers. The NorCat Underground Center in the province of Ontario has been dedicated to this since 1995. Its business model is a collaborative workspace, with subscription options; pay for rental testing space and/or for participating in its training programs. Part of the investment in this center was in partnership with local and international mining suppliers, who test and display their products in the center. In addition, good practices are disseminated through their training programs.

> **Finding 10.3:** Unlike leading mining countries, Chile does not have appropriate testing and piloting areas for new mining innovations, which represents a barrier to the development of new technologies.

CORFO launched a competition for the implementation of Technology Validation and Pilot Centers for Mining in Chile,[30] in compliance with the Technological Roadmap, where the public matching funds can be up to US$1.5 million per year for a ten years period. This amount may still be insufficient regarding financing due to the scale of the mining sector - in particular for innovations with greater impact, but it is in the right direction for the qualification of test spaces.

An underlying issue in this respect is the relevance of the configuration of the pilot areas to the Chilean technological challenges. It is essential to define the infrastructure according to the type of goods and services it will focus on. Such a configuration should be oriented towards the prioritized gaps of the Technological Roadmap, which already

29 Cooperative Research Centre (CRC).

30 See Call for Proposals: "Creation and Strengthen of Enabling Technological Capacities for Innovation". August 2016.

have a consensus among the sector's participants. But without adequate and up-to-date characterization of the suppliers' innovative capacity (which determines whether there is an offer to cover each gap potentially), it's hard to determine to which goods and services the test spaces will focus on and hence which requirements are needed. This relates closely to the innovation indicators provided by the participants of the Open Innovation Platform.

There is also the possibility of using medium-sized mines as a natural laboratory for the piloting of innovations. The size of medium-scale mining in Chile is comparable to large-scale mining in other countries, which increases its attractiveness in developing validated exportable solutions in operations of similar scale. While local medium-sized mining has other problems, the fact that these companies have a lower opportunity cost and greater idle capacity than large-scale mining can be an advantage. For example, if a process (say, plant) is in maintenance, the entire mine is paralyzed and not producing, providing the space to pilot some innovations. If this were economically and technologically feasible, the use of abandoned sites for this purpose could also be considered.

> **Recommendation 10.7:** Ensure the availability of test, pilot and training spaces for innovations. Encourage the use of abandoned sites and periods of idle capacity in medium-sized mining.
>
> **Recommendation 10.8:** Align the characteristics of these spaces with the gaps prioritized in the Technological Roadmap.

Interoperability

A significant barrier to both productivity and innovation is the lack of interoperability of mining equipment, including those used by suppliers. Interoperability is the ability of information technology systems (ICT), operational technology systems (OTs), and the business processes that support them to exchange data and control transfer, allowing for interoperating amongst systems.

This is a barrier to productivity, but also an opportunity for local innovation. The problem lies in the incompatibility of collecting and interpreting the data generated when operating or monitoring a computer because they all have a particular codification type according to the software used, which makes it difficult to analyze and better plan the activities and make decisions using Big Data. As an example, a mining company may wish to use a truck's operation data, and link it to other data, optimizing its mining plan. Nonetheless, this is also an opportunity since the mining industry has a permanent interest in reducing maintenance, integration and operation costs. Increased interconnection capacity of mining solutions proposed by different suppliers can enable greater increases in productivity, increase worker safety, and improve equipment availability and operational continuity.

Keeping in mind these challenges and opportunities, facilitating interoperability requires standards that support it, which are currently absent in both national and international mining.

> **Finding 10.4:** There are no standards for interoperability in the industry, therefore inhibiting the possibilities of data exchange and innovation.

Consistent with the National Strategic Intelligent Industry Program Roadmap promoted by CORFO, and with the participation and support of important mining companies, the creation of an international standards organization for mining interoperability was proposed. It seeks to develop and promote the adoption and application of open international interoperability standards for efficient and safe mining operations, increasing the ability of companies to integrate and interconnect solutions from different suppliers. The total budget amounts to US$10 million for the first three years, of which 60% corresponds to public funding through CORFO.

This initiative is aimed at increasing the control and capacity of the mining companies to interconnect mining solutions between different suppliers, allowing for increases in productivity and reduction of the operations' costs and risks. One of the first steps is to develop a technical map of mining interoperability, and then continue with prioritization of relevant areas for mining companies. With these results, it will be possible to determine the standards to be adopted and developed, and their adoption would be facilitated through the participation of both the mining industry and national and international suppliers. In Chile, industries such as telecommunications have developed national standards for interoperability. This is true also for the public sector in pursuit of an e-government and a greater number of online services.

> **Recommendation 10.9:** Encourage interoperability between communication and information systems in all mining production processes through the development of instruments (e.g. interoperability standards) in conjunction with suppliers and mining companies in the sector.

10.4. Conclusions

The evidence regarding productivity within the mine exposed in Chapter 4, shows that there is significant room for improvement concerning productive work consistent with Chapter 3. Likewise, areas concerning accreditation times and homologation of requirements on issues of Basic General Safety Induction, Light Vehicles, and Pre-Occupational Health Assessment can benefit both suppliers and mining companies through greater coordination. The development of a short-term mining passport would substantially help the country's competitiveness.

Regarding suppliers and their role in innovation, some relevant initiatives are detected. The World Class Supplier Program is one of the most outstanding linkages, but it faces escalation challenges. In this sense, the Open Innovation Platform constitutes a sectorial and public good that reduces transaction costs by creating a coordination space with multiple instruments to be able to meet the various objectives of the program. The primary barrier to escalation is precisely the connection between productive challenges (mining companies and large suppliers) and capacities to solve them (suppliers). At the same time, a supplier internationalization program is being developed to help boost supplier exports.

At the same time, there are two additional barriers to supplier' productivity and innovation. The first lies in the existence of testing and piloting facilities for mining equipment and services, present in countries like Australia and Canada. Progress is being made in Chile concerning this issue in conjunction with the use of medium-scale mining facilities as a natural laboratory for innovation and testing. The second barrier is the development and adoption of interoperability standards, which would allow the mining equipment's information systems to exchange data and work coordinately.

These public-private partnership programs must go beyond the political cycle to evaluate their continuity properly, most especially since the private sector has committed significant amounts of resources.

Finally, the role of mining suppliers is essential in sustaining competitiveness and the future productivity of the industry. Due to the high level of outsourcing by the mining companies, this situation does not seem likely to change in the future. Considering the critical challenges facing mining, suppliers are an integral part of the solution.

10.3.1 Summary of Findings

Finding 10.1: There is ample space for cost and time reductions in the accreditation of suppliers and contractors through the homologation (or standardization) of requirements between different companies and mines, which would result in important gains in the sector's overall efficiency.

Finding 10.2: Suppliers are relevant to mining innovation, and previously developed early programs are starting to take advantage of this potential.

Finding 10.3: Unlike leading mining countries, Chile does not have appropriate testing and piloting areas for new mining innovations, which represents a barrier to the development of new technologies.

Finding 10.4: There are no standards for interoperability in the industry, therefore inhibiting the possibilities of data exchange and innovation.

10.3.2 Summary of Recommendations

Recommendation 10.1: Modify Supreme Decree No. 99 of 19.3.2015 of the Ministry of Mining to establish a clear criterion and the option for companies to withdraw from the registration of the Homologated Course of Basic Induction in Mining Operations.

Recommendation 10.2: Establish a universal standard on the technical characteristics and other minimum criteria required for light vehicles. If an agreement between the companies is not possible, settle it through the Mining Security regulations and incorporate it into the Mining Safety Regulation (DS132).

Recommendation 10.3: To take into account all current pre-occupational and occupational exams held by an employee to avoid duplicating efforts.

Recommendation 10.4: Implement a Mining Passport in the short term that grants mobility to workers of mining companies and contractors with special emphasis on its escalation.

Recommendation 10.5: Continue public-private partnership efforts, such as Alta Ley National Mining Program and its components, evaluating their performance and possibilities for improvement in five years at least.

Recommendation 10.6: Establish clear innovation indicators that allow monitoring the impact of the Open Innovation Platform.

Recommendation 10.7: Ensure the availability of test, pilot and training spaces for innovations. Encourage the use of abandoned sites and periods of idle capacity in medium-sized mining.

Recommendation 10.8: Align the characteristics of these spaces with the gaps prioritized in the Technological Roadmap.

Recommendation 10.9: Encourage interoperability between communication and information systems in all mining production processes through the development of instruments (e.g. interoperability standards) in conjunction with suppliers and mining companies in the sector.

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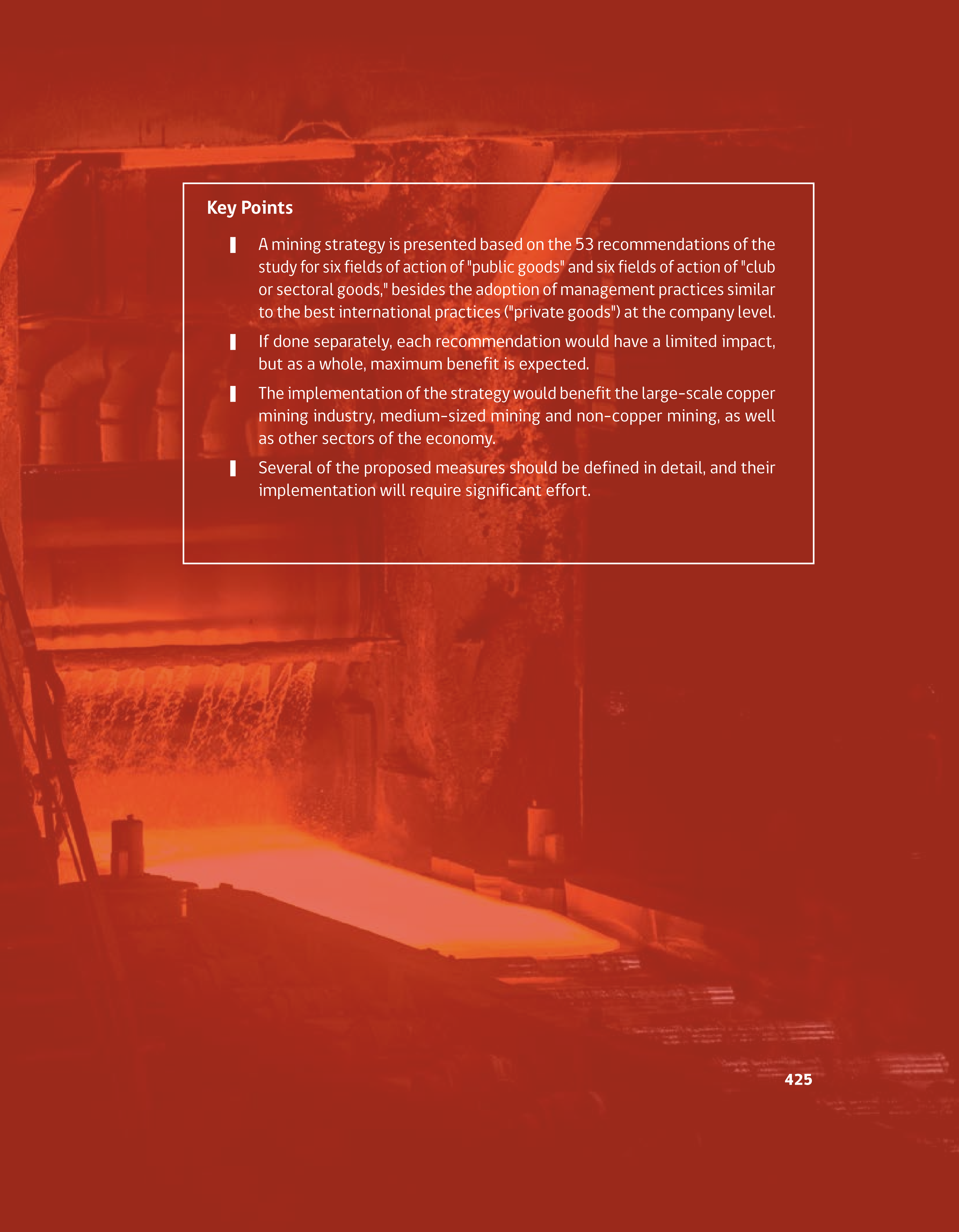
Chapter 11

A Mining Strategy for Chile Findings and Recommendations Summary

Abstract

During the grounding of this report, a series of areas for improvement in the Chilean Copper Mining Industry were identified. These findings lead to the development of a list of recommendations. In this chapter, and based on the 53 recommendations of the study, a mining strategy is proposed including six fields of action of “public goods” and six fields of action of “club goods”, as well as suggestions to private companies in the adoption of management procedures similar to the best international practices (“private goods"). The implementation of the strategy would benefit the large-scale Copper Mining industry, medium-sized mining and non-copper mining, as well as other sectors of the economy.



Key Points

- A mining strategy is presented based on the 53 recommendations of the study for six fields of action of "public goods" and six fields of action of "club or sectoral goods," besides the adoption of management practices similar to the best international practices ("private goods") at the company level.
- If done separately, each recommendation would have a limited impact, but as a whole, maximum benefit is expected.
- The implementation of the strategy would benefit the large-scale copper mining industry, medium-sized mining and non-copper mining, as well as other sectors of the economy.
- Several of the proposed measures should be defined in detail, and their implementation will require significant effort.

11.1. Strategy Pillars

There are three main strategy pillars presented in the recommendations and findings in this report: (i) efficiency in public management and regulatory quality ("public goods"); (ii) greater collaboration and coordination amongst companies with their contractors and suppliers, and with communities ("club or sectoral goods"); and (iii) company management according to best international practices ("private goods"). Since the latter is of sole responsibility of the companies, we will concentrate on the 53 recommendations referred to in the first two areas, where the State has the main responsibility (the "public goods") or has potential catalytic and coordinating role ("club or sectoral goods"). Each of these areas is organized around six action fields.

It is important to emphasize that if Chile regains leadership not only in copper production but also in productivity improvements in all three areas are required, demanding a joint effort of all participants: companies, workers, suppliers, contractors, communities and the State. In fact, rather than the implementation of separate and isolated measures, a mining strategy and design for its further implementation is required.

There are several steps necessary to implement such a plan. First, given the scope of the suggested interventions, implementation requires a joint effort at the State level, with multiple public agencies, ministries, and other entities. Leadership in coordination and implementation should be allocated to a multi-sectoral Ministry. Second, it will be necessary to define an action and implementation plan that assigns responsibilities, priorities, goals, and deadlines. Third, it is appropriate to adjust interventions according to the degree of complexity. Administrative and regulatory actions should be first, and then convincing the main stakeholders of the needs for law reforms.

The overall impact of the reforms will be felt in the long term and will be cumulative, although short and medium term outcomes are expected. (See Table 11.1)

This Commission is available to the State and its agencies to support the implementation of the recommendations and monitoring the realization of the proposed strategy.

Sequence of interventions

In addition to the importance of coordination, implementation of the strategy would benefit from an action plan that prioritizes and sequences interventions. The bulk of short-term gains are associated with improvements in business management according to international best practices. However, there are public interventions that can bear fruit in the short term, such as those that require actions from within the agencies, like management or administrative changes. Examples are the digitization of the exceptional workdays' processes, the drafting of a sanitary regulation for desalination processes, and the updating of several regulations (Sernageomin, Health Regional Secretaries, DGA, Labor Directorate).

Other interventions in the public sphere require legal changes that must be approved by Congress, which demand longer periods for their implementation. Improvements in the area of human resources require not only changes in law and management, but also cultural changes in companies and workers.

Regarding expected impact, the establishment of "adaptability pacts", the simplification of the formalization process of the Exceptional Work Days, and the homologation of criteria for supplier accreditation, would have the greatest impact in the medium term. The institutionalization of the Office of Large Projects, modifications to the system of mining property, the availability of trained and certified human resources, and mechanisms that improve the relationship with the community would have the greatest impact in the long term.

The highest degree of complexity in the implementation of the strategy is found in the modification of the mining concessions system, which requires legal changes and a transition period. It will affect in the long term because it cannot be applied retroactively. Modifications should begin by changing the different patents and their prices, the technical aspects of the geological map and measurement, and continue with the duration of concessions, as well as the implementation of a mixed patent and all its requirements. For this, it will be necessary for some public agencies to change their structure, function, and responsibilities.

Figure 11.1 is a first approximation to identify the probable impact deadlines of our 53 recommendations, grouped into six action fields, for both "public" goods and "club" goods. Figure 11.2 groups the 53 recommendations according to the institutions and agencies that we think should take action. Figure 11.3 summarizes these findings.

This report is the first of its kind carried out in the country, but it should not be the last. Public entities such as the Chilean Copper Commission, or private companies such as the Mining Council and SONAMI should monitor the evolution of high and medium frequency productivity indicators, which would allow a constant evaluation of the development of the sector and the impact of the implemented measures.

Figure 11.1. Policies referring to Public Goods

Scope	Short Term	Medium Term	Long Term
1. Approval or rejection of projects (1.1, 3.1, 5.1,5.4)	Desalination Plants Regulations	Implement the recommendations of the Advisory Board for the SEIA	Major Projects Office
2. Mining exploration (8.1 to 8.15)	Related to measurement and mapping of mining claims.	Standardization of the patent price and its increase.	Implementation of the mixed protection, and requirements to maintain or renew mining claims
3.Operational continuity (7.3,7.6,7.7)	The Labor Directorate should officially record the 4x4 / 7x7 work days.	Adaptability Agreements.	
4. Labor market (7.4, 7.5, 10.4)	Extension of the extraordinary work days by the client to contractors.	Mining Passport.	Training and certification.
5. Human resources (7.8 to 7.10, 9.5)	Multifunctional training.	Training relevance.	Relevance in careers
6. Security (7.1, 7.2)	Common and valid security course.		Work at high altitudes.

Table 11.2. Policies referring to Sectoral Goods

Scope	Short Term	Medium Term	Long Term
1. Innovation (10.7, 10.8, 10.9)			Test spaces. Inter-operability protocols.
2. Infrastructure (5.2, 5.3, 5.4, 9.6, 9.7)		Desalination plants for several mines	Access to private infrastructure for medium-sized mining. Multimodal effort
3. Company-supplier relationships (10.1, 10.2, 10.3)		Criteria standardization for accreditation.	
4. Private intervention with public support (10.5, 10.6)			Alta Ley, Open Innovation Platform.
5. Medium-scale mining (8.11, 9.1 a 9.4, 9.8)		Financial access.	Financing of mine closures.
6. Company - communities relationships (6.1 a 6.4, 9.9)	Participation guide for large projects	Implementation of recommendations of the Advisory Board of the SEIA and of Conflicts of Interest, Influence peddling and Corruption	Valor Minero, relationship and arbitration mechanism.

Figure 11.3. Summary of Recommendations and implementation responsibility

#	Type	Recommendation	Institution
1,1	Public	Establish a Large Projects Office, whose function would be reducing project approval or rejection deadlines, through greater efficiency and coordination among the various public agencies involved in the process at national and regional level. The LPO should be institutionalized and endowed with action mechanisms to those of best international practices, including transparency criteria.	1. Service of Evaluation and Environmental Impact. 2. Ministry of Finance. 3. Sernageomin. 4. Ministry of Public Works. 5. Ministry of Health.
3,1	Public	Through the Chilean Copper Commission, or another agency that the government deems appropriate, produce indicators and periodic studies of productivity in the mining sector similar to those in this chapter, such as to complement the regular studies of competitiveness that the Chilean Copper Commission is already doing.	1. Ministry of Mining. 2. Chilean Copper Commission.
5,1	Public	Establish the obligation to inform the National Water Bureau of a miner's water finding, but avoid generating permits for them that allow exploitation.	1. Ministry of Public Works. 2. General Water Directorate.
5,2	Sectoral	Promote greater use of shared infrastructure in water matters (desalination plants, pipelines, among others), either through the coordination amongst mining companies, through a third party that builds the infrastructure and assumes the costs of coordination, or using another feasible alternative, such as a water interconnection system.	1. Ministry of Public Works. 2. General Water Directorate.
5,3	Public	Establish a clear road map of permits and times required for the approval of desalination plant projects.	1. Ministry of Defense 2. Undersecretariat of the Armed Forces 3. Department of Maritime Affairs.
5,4	Public	Establish a specific chapter on regulations for wastewater treatment plants, concerning desalination plants in compliance with international environmental standards.	1. Ministry of Defense 2. Undersecretariat of the Armed Forces 3. Department of Maritime Affairs.
6,1	Public	Implement the proposals of the Presidential Advisory Council against Conflicts of Interest, Influence, Peddling and Corruption regarding the funds received by local governments, so that local governments establish a better institutional framework, with greater transparency and efficiency.	1. Municipalities 2. Regional SEREMIs (linked to decisions with the community)
6,2	Public	Through the Ministry of Mining, promote and encourage permanent dialogue models for large projects between companies and communities through the development of a participation standard guide for large mining projects similar to that carried out by the Ministry of Energy for energy projects.	1. Ministry of Mining

Continuation Table 11.3

#	Type	Recommendation	Institution
6,3	Public	To implement the 25 measures from the Presidential Advisory Commission for the Environmental Impact Assessment System (SEIA) with the aim of having the best possible environmental assessment, facilitating a better dialogue between companies and communities. In particular, we emphasize the proposals of Early Relationship, Indigenous Consultation and Strengthening Citizen Participation in SEIA.	1. Municipalities 2. Regional SEREMIs (linked to decisions with the community) 3. Evaluation and Environmental Impact Service
6,4	Sectoral	Implement a dispute and conflict resolution system, such as that promoted by Valor Minero, in which the parts can request mediation, arbitration or conciliation, as well as establish a certification entity that empowers and enhances the organizations that participate in the dialogue process.	1. CORFO 2. Strategic Investment Fund
7,1	Sectoral	To continue strengthening the joint effort carried out by companies, workers, suppliers and the government in the field of occupational safety, in order to keep reducing accident and death rates, while allowing production and productivity increase.	1. SERNAGEOMIN
7,2	Public	Adapt the Supreme Decree 594 of the Ministry of Health regarding work at heights, as the results of the Social Security Superintendence studies come out in the future.	1. Ministry of Health 2. Superintendence of Social Security.
7,3	Public	The Ministry of Health should institute unique and explicit criteria for the establishment of mobile dining rooms not subject to interpretation and thus expedite the process of approval/rejection of the request.	1. Ministry of Health
7,4	Public	Simplify the Labor Directorate Order No. 5 of November 20, 2009, from the Labor Directorate regarding the authorization of exceptional systems of distributing work and resting times, expediting the approval of exceptional working time for contractors and suppliers.	1. Labor Directorate
7,5	Public	The Labor Directorate should continue efforts to incorporate information technology into the exceptional working time authorization process and thus make the resolution process more efficient.	1. Labor Directorate
7,6	Public	Restore the "adaptability pacts" discussed in the recent labor reform, but vetoed in the final text. This would ease the agreement between companies and workers in order to ensure "operational continuity."	1. Ministry of Labor
7,7	Public	Add the 4x4 and 7x7 shifts to the possibility stipulated in Article 375 of the Labor Code, so that these working times benefit from the exempted resolution by the Labor Department.	1. Ministry of Labor
7,8	Sectoral	Associate the training of mining specialties in high school, technical and professional education, and Technical Training Centers with those defined in the Mining Qualifications Framework developed by the Mining Competencies Council. Moreover, adapt the accreditation of the program, the corresponding subsidy, and the student's exit to its certification.	1. Ministry of Labor. 2. Ministry of Education. 3. ChileValora.

Continuation Table 11.3

#	Type	Recommendation	Institution
7,9	Sectoral	Increase the levels of training in the industry, which should be in line with the Mining Qualifications Framework. Likewise, make greater efforts in the industry to certify workers, establishing clear commitments and schedules.	1. Ministry of Labor. 2. Ministry of Education. 3. ChileValora.
7,10	Sectoral	Update competency profiles by specialty according to the needs of an increasingly automated and digitized world.	1. Ministry of Labor. 2. Ministry of Education. 3. ChileValora.
8,1	Public	Raise the Annual Patent from a linear to a progressive one, which increases over time, both in exploration and in exploitation, but allowing a reduction of the patent payment through mechanisms of consideration by the mining concessionaire (geological information, works, among others).	1. Ministry of Mining.
8,2	Public	Match the Annual non-metals substance Patent with the one for metal substances.	1. Ministry of Mining.
8,3	Public	Establish incentives and sanctions for non-compliance with the geological information obligation, laid down in Article 21 of the Mining Code.	1. Ministry of Mining.
8,4	Public	Strengthen the Sernageomin, granting broader powers and clearer control parameters to its departments, with the purpose of maximizing the impact of each one of its work areas.	1. Ministry of Mining. 2. Sernageomin.
8,5	Sectoral	Equate the conditions between specialists and engineers qualified to perform measurement tasks, and make publicly available the yearly qualification to which their work is submitted.	1. Ministry of Mining 2. Sernageomin. 3. Council of Mining Competences.
8,6	Public	Restrict the consecutive and immediate request for exploration concessions between related persons.	1. Ministry of Mining
8,7	Public	Reduce the times involved in the application, evaluation and constitution procedures of mining concessions.	1.Ministry of Mining.
8,8	Public	Redesign the auctioning process of abandoned mining rights, using actions that tend to the coordination and fast transmission of information among all those involved in those processes.	1. Ministry of Mining.
8,9	Public	Update the coordinate system and datum of mining rights from PSAD56 / SAD69 to WGS84.	1. Ministry of Mining 2. Sernageomin.
8,10	Public	Adopt a grid system for requesting mining concessions in the medium term.	1. Ministry of Mining.
8,11	Sectoral	Develop a training program in financing projects in exploration and mining with the aim of reducing the information gaps between the financial and the mining sector.	1. Ministry of Mining. 2. Sernageomin. 3. CORFO. 4. Strategic Investment Fund.
8,12	Public	Establish a mixed protection system through the payment of a patent, the granting of geological information to the State and the formulation of minimum work plans for the application and renewal of exploration rights, as well as evidence of mineralization and minimum work for exploitation rights.	1. Ministry of Mining. 2. Sernageomin.

Continuation Table 11.3

#	Type	Recommendation	Institution
8,13	Public	Increase exploration concession periods from two to three years and allow two extensions instead of one, totaling a maximum of nine years.	1. Ministry of Mining.
8,14	Public	Establish a temporary limit on the mining concession of a maximum of 30 years, subject to priority and unlimited renewals for an equal period.	1. Ministry of Mining.
8,15	Public	Modify the provisions of Article 15 et seq. of the Mining Code, which exclude certain activities (vineyards and groves) from the general rule of submitting to the competent Judge the request for permission to dig upon refusal by the owner. This action's purpose would be to equate judicial treatment for the resolution of conflicts between all activities, favoring good coexistence in adequate environmental standards and the appropiate compensation.	1. Ministry of Mining.
9,1	Public	To agree among the sector's stakeholders a precise definition of the medium-sized mining segment in order to produce comparable public and periodic statistics. This definition should focus more on production than employment size.	1. SERNAGEOMIN. 2. ENAMI. 3. COCHILCO.
9,2	Public	To instruct the Chilean Copper Commission to continue with their first characterization of the segment, with the aim of enhancing the understanding of medium-sized mining, given its increasing importance for Chile in the future of mining industry.	1. SERNAGEOMIN. 2. COCHILCO.
9,3	Public	Complement the gap analysis for large-scale mining conducted in this report, with a similar analysis for medium-sized mining in Chile, ideally with similar firms in related countries. This will allow defining a baseline to monitor the evolution of the segment.	1. SERNAGEOMIN. 2. COCHILCO.
9,4	Public	Incorporate the OECD guidelines (2011) for public companies to ENAMI, modernizing their corporate government, and promoting transparency.	1. Ministerio de Minería. 2. ENAMI. 3. Sistema de Empresas Públicas.
9,5	Sectoral	Establish a local mining training policy in cities where mining employment is relevant, especially in areas where medium-sized mining operates. Local technical schools should further the developing of mining specialties, with infrastructure and equipment support, as well as promoting mining careers in Technical Training Schools (CFT in Spanish) in towns where medium-sized mining is important.	1. Ministry of Education. 2. Ministry of Mining.
9,6	Public	Increase the quantity and quality of road, railway, and maritime infrastructure, jointly investing in intermodality between the three modes, according to the guidelines of the National Council for Innovation for Development (2015).	1. Ministry of Transport and Telecommunications. 2. Ministry of Public Works. 3. Company of State Railways. 4. State Port Companies.
9,7	Sectoral	Facilitate and encourage the incorporation of medium-scale mining to private infrastructure projects of large-scale mining (ports, desalination plants, among others), so that there are potential economies of scale.	1. Ministry of Transport and Telecommunications. 2. Ministry of Public Works.

Continuation Table 11.3

#	Type	Recommendation	Institution
9,8	Public	Expand the options of financial instruments to guarantee the closure of mining operations. Following the model of Western Australia, analyze the possibility of pooling a common fund of guarantees that also serves to rehabilitate abandoned tailings and dumps.	1. SERNAGEOMIN. 2. Ministry of Mining.
9,9	Public	Implement the recommendations of the Presidential Advisory Commission for the SEIA Evaluation (2016). Most require only regulatory modifications, which lead to a rapid implementation of recommendations.	1. Ministry of the Environment. 2. Ministry of Mining.
10,1	Sectoral	Modify Supreme Decree No. 99 of 19.3.2015 of the Ministry of Mining to establish a clear criterion and the option for companies to withdraw from the registration of the Homologated Course of Basic Induction in Mining Operations.	1. Ministry of Mining 2. SERNAGEOMIN
10,2	Sectoral	Establish a universal standard on the technical characteristics and other minimum criteria required for light vehicles. If an agreement between the companies is not possible, settle it through the Mining Security regulations and incorporate it into the Mining Safety Regulation (DS132).	1. Ministry of Mining 2. SERNAGEOMIN
10,3	Sectoral	To take into account all current pre-occupational and occupational exams held by an employee to avoid duplicating efforts.	1. Ministry of Labor, 2. Superintendence of Social Security, 3. Ministry of Health
10,4	Sectoral	Implement a Mining Passport in the short term that grants mobility to workers of mining companies and contractors with special emphasis on its escalation.	1. Ministry of Labor, 2. Superintendence of Social Security, 3. Ministry of Health
10,5	Sectoral	Continue public-private partnership efforts, such as Alta Ley National Mining Program and its components, evaluating their performance and possibilities for improvement in five years at least.	1. Ministry of Economy, 2. Ministry of Mining, 3. CORFO
10,6	Sectoral	Establish clear innovation indicators that allow monitoring the impact of the Open Innovation Platform.	1. Ministry of Economy, 2. Ministry of Mining, 3. CORFO
10,7	Sectoral	Ensure the availability of test, pilot and training spaces for innovations. Encourage the use of abandoned sites and periods of idle capacity in medium-sized mining.	Alta Ley, CORFO
10,8	Sectoral	Align the characteristics of these spaces with the gaps prioritized in the Technological Roadmap.	Alta Ley, CORFO
10,9	Sectoral	Encourage interoperability between communication and information systems in all mining production processes through the development of instruments (e.g. interoperability standards) in conjunction with suppliers and mining companies in the sector.	Alta Ley, CORFO

Figure 11.4. Summary of Findings

Number	Finding
1,1	Mining and its suppliers constitute the most important sector of the Chilean economy in a series of indicators relevant to economic and social development. Chile has a clear comparative advantage in the mining industry, particularly in copper mining. The country will not achieve the desired levels of economic and social development if it does not expand the activity of the sector, and this will not happen without the efforts of both the public and private sector.
1,2	The ecosystem around mining is complete regarding organisms and functions, and very complex in its interaction. No other sector can compare at the national level: (i) large, medium and small enterprises; (ii) state-owned, transnational corporations and local capitals; (iii) a significant domestic and foreign suppliers sector; (iv) an organized workers' groups, (v) associations representing companies, providers and workers, and (vi) specialized State and Government agencies. Due to its complexity, the sector is in a privileged position to reach agreements and implement long-term policies in a national mining development strategy.
1,3	The Chilean institutional process of approving or rejecting large projects is unnecessarily long and cumbersome, far from international best practices.
2,1	During the period 2000-2014, the country increased its copper production by 19%; 17% occurred between 2000 and 2004, the remaining 2% between 2007 and 2014. During this period, the partial labor productivity shows a fall of 54% copper produced per worker, but 15% if material moved per worker is considered. Other countries show similar dynamics.
2,2	During the period 2000-2014, energy consumption grew by 79%, labor by 157%, and capital investment by 178%. Between 2000 and 2007, demand growth for capital, labor, and energy was balanced around 5-6% per year. Between 2007 and 2014, energy use grew by 4% per year, while capital investment and labor contracting rose by 7-8% per year.
2,3	The total factor productivity of the copper mining sector, corrected by endogenous and exogenous factors to the operation, shows a drop of 1% per year between 2000 and 2014, accumulating a reduction of 14% in the period.
2,4	The factors that contributed to production were processed ore (3.6% per year), energy (0.9% per year) and labor (0.5% per year). Instead, ore grade (-3%) and factor productivity (-1%) contributed negatively.
2,5	Using a labor productivity indicator that considers the person-hours required to move a thousand tons of material, there are significant gaps in Chilean mines, and a general worsening of productivity is observed throughout the analyzed period (2000-2014). When gaps increase, it is because the less efficient group (in relative terms) increases its inefficiency at a higher rate than the other group. Conversely, when gaps decrease, it is because the more efficient group (in relative terms) worsens its productivity more rapidly.
2,6	The evolution of the gaps, as well as the tendency for productivity to fall in the analyzed period, is a robust result, independent of the sample associated with large scale mining, confirmed even in mines that produce over 100,000 tons per year, mostly exploited by large world-class companies.
2,7	Estimates of total factor productivity (TFP) consistently show significant gaps between Chilean mines, and a permanent drop during the analysis period similar to that given by partial labor productivity, confirming the results found in the previous review.
2,8	The fall in TFP fluctuates at an average annual rate of 1% and 1.9% according to the initial level of productivity of the mines.

Continuation Figure 11.4

Number	Finding
3,1	There is a high dispersion in the productive performance of the evaluated Chilean operations. The most efficient operation uses 43 person-hours per thousand tons of material moved, while the least efficient operation uses 115 hours. On average, it took 67 person-hours to move a thousand tons of material during 2015, although most (median) used 53 person-hours.
3,2	When compared with international operations, there are significant gaps at productivity levels. On average, the international sample operations accomplish the same task occupying 37 person-hours less than the national average (67), and 23 hours less than most domestic operations.
3,3	The results suggest that less productive operations have a more heterogeneous composition of person-hours in different areas. Less productive operations tend to have, either a greater proportion of person-hours at the plant compared to the mine or a higher percentage of support services. On average, a national mine has 1.8 person-hours in the plant and support per person-hour in the mine, while for the international case this indicator is 1.3.
3,4	The productivity gap between the best national (43) and the best international mine (18) is 25 person-hours per kiloton of material moved. That is, the best domestic mine is 139% more inefficient than the best in the international sample. When the best performing national mine is compared to the international average, this difference is reduced to 13 person-hours. That is, the most efficient national mine is 44% more inefficient than the mean of the international sample.
3,5	Productivity at the Mine area shows that, on average, domestic operations use 24 person-hours per thousand tons of material moved. Gaps between local operations are important (221% more inefficient regarding the best performing mines). Concerning the international sample, on average, they carry out the same task using 11 person-hours less, again a gap of over 100%.
3,6	Concentrator Plant productivity shows that, on average, domestic operations use 47 person-hours to process a thousand tons of material. The difference between the most and least productive mine is 62 person hours, i.e., the least productive is 214% more inefficient than the best.
3,7	Hydrometallurgical Plant productivity shows that, on average, domestic operations use 119 person-hours to stack a thousand tons of material. The difference between the most and least productive mine is 116 person-hours, i.e., the least productive is 177% more inefficient than the best.
3,8	Productivity associated with loading shows significant gaps at the national level: as for the asset efficiency, the gap is 28 percentage points. The biggest differences in this gap are due to stops, followed by maintenance.
3,9	On average, the international sample uses the shovels 24% more time than the national average. This would be equivalent to using the asset an additional 49 days a year if the asset was used 24 hours, 365 days a year.
3,10	Productivity associated with hauling has significant gaps at the national level: as for asset use, the gap is 32 percentage points. Stops account for the biggest difference of this gap, followed by maintenance.
3,11	On average, the international sample has 10% more hauling efficiency than the national average. This means that the asset is used 23 more days a year by the international sample if we consider a use of 24 hours a day, 365 days a year.
3,12	The national gap in the efficient use of the Concentrator Plant is 13 percentage points, with an average of 89% of possible time.
3,13	Maintenance is the greatest source of heterogeneity in the efficient use of the Concentrator Plant of the national sample.
3,14	Compared to the national average, the international sample is 13% more efficient in Grinding and 6% more in the Primary Crusher.

Continuation Figure 11.4

Number	Finding
3,15	The national gap in the efficient use of the Hydrometallurgical Plant is 19 percentage points. The greatest source of heterogeneity in the efficient use of the Hydrometallurgical Plant comes from maintenance.
4,1	There is a significant deceleration from 2013 to 2014 in sales to mining companies, especially sales associated to projects.
4,2	Suppliers of the Chilean mining industry are concentrated. On average, the two leading suppliers concentrate around half of the sales in the seven categories analyzed, implying the existence of economies of scale.
4,3	Suppliers of the Chilean mining industry concentrate their main offices in the Metropolitan Region. However, those with greater mining sales intensity have a more significant presence of their parent companies in mining regions.
4,4	One-third of Chilean mining industry suppliers are large companies under the sales classification. However, ranked according to employment level, 90% are medium and small.
4,5	Mining suppliers increased their labor productivity from 2013 to 2014 with greater variations in smaller suppliers. This is due to this segment's greater variation in sales.
4,6	In general, larger suppliers have higher levels of labor productivity than small and medium-sized suppliers do.
4,7	In the long term, there is room for improvement regarding the availability of effective working time in Chile which could increase between 10% and 20%. Part of these gains can occur within companies, without public action.
4,8	There is a considerable dispersion in the accreditation times of large-scale copper mining industry operations in Chile. The most efficient company takes 15 days, while the least efficient takes 75 days.
5,1	Chile's large-scale copper mining industry is relatively efficient in its use of both electrical and fuel energy, compared to its international competitors.
5,2	There is room for improvements in electricity supply costs due to the speculative use of third-party mining concessions where electrical generation or transmission projects are to be installed. Costs increase due to both land use rights negotiations as legal proceedings, and the protection of mining rights considered as property (legal mining easements, possessory actions).
5,3	The copper mining industry uses water efficiently. This efficiency increased in the period 2009-2015 with a 25% reduction in the consumption of fresh water per processed ton of copper in the concentrator and 33% in hydrometallurgy. Water recirculation increased from 68.7% to 72.5%.
5,4	Investment and operating costs for enabling the use of seawater are significant, due to the altitude of the mines and the distance from the extraction areas, which implies that there are advantages in economies of scale among nearby mining companies for the construction of desalination plants, electricity generation, and pipelines.
5,5	The sector requires a clear policy on desalination by the Government and a speedy and transparent regulatory framework.
5,6	There is no clear road map on permits and procedures for the installation of desalination plants.

Continuation Figure 11.4

Number	Finding
5,7	There is a regulatory void regarding the expulsion of brine from desalination plants to the marine environment, which is attended by general legislation.
6,1	Regulatory clarity, in aspects such as water rights, land, etc., is fundamental to establish a framework for future debates.
6,2	Early, continuous, accurate and reliable information between the parties is critical to building trust between communities and mining companies.
6,3	State and local governments are key players in the company-community relationship. The transparency and credibility of these, in addition to their management capacity, are decisive in enabling long-term mutually beneficial solutions.
6,4	The State is not the only one that can safeguard a process of company-community relationship; other institutions can fill that role.
7,1	In a context of increased production and employment, the mining industry, and in particular large-scale mining, has improved its results in work-related accident indicators compared to the year 2000. However, the fatality rate remains higher than in other economic sectors. The rate of journey accidents, although one of the lowest among sectors, has also been increasing. The challenge is to improve its safety indicators while increasing production and productivity.
7,2	There is evidence that intermittent exposure to altitude levels above 3,000 meters requires special care and monitoring of workers' health.
7,3	Organizational practices differ amongst mines within Chile, and also significantly concerning international mines. In Chile, there are more hierarchical levels, lower levels of supervision, and poor mobility between levels. At the national level, variable remuneration tends to encourage production over productivity.
7,4	Due to the characteristics and scale of the Chilean mining industry, travel times affect the productivity of mines, influencing the hours worked and the use of the equipment. It is possible to reduce the times of travel by the use of mobile dining rooms, but delay in the processing of these permits limits the effectiveness of this solution.
7,5	The usual working time in large-scale mining is an exceptional working time, which must be previously approved by the Labor Department for each case. The recent labor reform modifies this for 4x3 shifts, requiring only registration.
7,6	The authorization process of an exceptional working time at the Directorate of Labor takes 40 calendar days on average. This affects the speed with which activities in mining can start, affecting especially the mining suppliers.
7,7	The current regulations of the Directorate of Labor that govern exceptional working times allow for the dictation of resolutions of special framework systems to be used by contractors and subcontractors working in a particular primary company. Despite the fact that this instrument offers potential time saving, it is not used on a regular basis.
7,8	85% of the sector's workforce works in exceptional 4x4 or 7x7 days, and 80% evaluate them positively, with 7x7 being the preferred working cycle.
7,9	Despite agreements between companies and unions to ensure operational continuity, this remains a permanent challenge, especially in the mining area.
7,10	There is a significant human capital gap in the mining industry at the qualitative and quantitative level. At the qualitative level, there are differences between the training profiles (groups of competencies) and the needs of the industry. At the quantitative level, there are differences between the number of professionals and technicians offered and required by companies.

Continuation Figure 11.4

Number	Finding
7,11	The provided trainees have a small degree of adherence to the Mining Qualifications Framework. On the other hand, for companies, signs are showing an increasing adherence to the Qualifications Framework, although there is a lot of room for progress.
7,12	The low level of certification of labor competencies in the mining industry is striking. According to ChileValora figures, approximately 0.3% of all certifications issued between 2002 and September 2015 is for the mining sector,.
8,1	Chile's share in the mining exploration market is lower than its share in production and reserves.
8,2	There is low availability of territory for exploration in the main metallogenic strips of the country due to the area covered by current concessions in force, and the ease of maintaining them at low cost, especially if they correspond to nonmetallic mining.
8,3	There is evidence of significant concentration levels in both metallic and non-metallic mining properties. In some cases, this may respond to the need for sector-wide economies of scale. However, it nonetheless acts as an entry barrier.
8,4	Some agents misuse mining concessions for speculative purposes and as insurance against potential litigation, thus harming the effective mining concessionaires. These objectives are different from those that the law considers when granting the subsoil in concession, and by which the State transfers part of its property faculties to private concessionaires.
8,5	The process of constituting mining concessions implies quite long terms, with delays of 6 to 8 months for exploration and 24 to 29 months for mining.
8,6	The current protection per patent system does not constitute an incentive to carry out effectively exploration and mining, because it does not require mining labor directly and has a low patent value.
8,7	The cost of the Chilean mining patent is low compared to other countries, even more so, considering that in other jurisdictions, additional obligations to the patent payment are requested to maintain the mining concession.
8,8	Chile shows a significant lag both in availability and quality of pre-competitive geological information.
8,9	Chile has a significant gap concerning referent countries, regarding both the share of junior companies in exploration spending and the link between the mining sector and the financial sector.
8,10	There is a gap in the standard of the coordinate system used in mining rights both nationally and internationally.
9,1	There is no consensus on a clear and precise definition of the medium-sized mining segment. Different organizations use different definitions (labor endowment and production), potentially generating inconsistent productivity statistics.
9,2	There is a substantial productivity gap - measured as person-hours per kiloton of moved material - between medium and large-scale mining. This gap has existed since 2000 and has increased since 2007. In the last fifteen years, the productivity of medium-sized mining has fallen twice than large-sized mining, and in the accumulated fall, its percentage has tripled large-scale mining. The largest gap available in the series was in 2014.
9,3	There are areas for improvement and modernization in ENAMI, the leading state organization dedicated to the promotion of small and medium-sized mining.
9,4	Competition for human capital in the labor market with large-scale mining has led to a shortage of supervisors (middle management) in medium-sized mining.

Continuation Figure 11.4

Number	Finding
9,5	The medium-sized national mining industry's labor market is located in small towns near the mines, where workers return after the workday (few sites operate with camps), with insufficient labor supply in these towns, and with not enough supply of technical and professional training related to mining.
9,6	There is a deficit in local infrastructure, in both quantity and quality, for intermodality. For medium-sized mining, the absence of ports is the main infrastructure problem in Regions III and IV.
9,7	Large-scale mining has generated logistic solutions at the individual level, building its private ports to export their production. However, there are chances to take advantage of economies of scale in some ports by providing access to medium-sized mining and increasing the port capacity used.
9,8	The process of mine closure in Chile does not differ significantly from international best practices. However, a restriction to the sector is the financial guarantees required for the mine closure processes where the only available alternative is the bank warranty bonds.
9,9	The Environmental Impact Assessment System (SEIA in Spanish) process exceeds the internal management capabilities of medium-sized mining companies. In particular, this problem is worse for small project expansions, where the benefits are lower compared to the required time and resources of SEIA process.
10.1	There is ample space for cost and time reductions in the accreditation of suppliers and contractors through the homologation (or standardization) of requirements between different companies and mines, which would result in important gains in the sector's overall efficiency.
10,2	Suppliers are relevant to mining innovation, and previously developed early programs are starting to take advantage of this potential.
10,3	Unlike leading mining countries, Chile does not have appropriate testing and piloting areas for new mining innovations, which represents a barrier to the development of new technologies.
10,4	There are no standards for interoperability in the industry, therefore inhibiting the possibilities of data exchange and innovation.

11.2. Summary of Findings and Recommendations

Summary of Findings

Number	Chapter	Finding
1,1	1	Mining and its suppliers constitute the most important sector of the Chilean economy in a series of indicators relevant to economic and social development. Chile has a clear comparative advantage in the mining industry, particularly in copper mining. The country will not achieve the desired levels of economic and social development if it does not expand the activity of the sector, and this will not happen without the efforts of both the public and private sector.
1,2	1	The ecosystem around mining is complete regarding organisms and functions, and very complex in its interaction. No other sector can compare at the national level: (i) large, medium and small enterprises; (ii) state-owned, transnational corporations and local capitals; (iii) a significant domestic and foreign suppliers sector; (iv) an organized workers' groups, (v) associations representing companies, providers and workers, and (vi) specialized State and Government agencies. Due to its complexity, the sector is in a privileged position to reach agreements and implement long-term policies in a national mining development strategy.
1,3	1	The Chilean institutional process of approving or rejecting large projects is unnecessarily long and cumbersome, far from international best practices.
2,1	2	During the period 2000-2014, the country increased its copper production by 19%; 17% occurred between 2000 and 2004, the remaining 2% between 2007 and 2014. During this period, the partial labor productivity shows a fall of 54% copper produced per worker, but 15% if material moved per worker is considered. Other countries show similar dynamics.
2,2	2	During the period 2000-2014, energy consumption grew by 79%, labor by 157%, and capital investment by 178%. Between 2000 and 2007, demand growth for capital, labor, and energy was balanced around 5-6% per year. Between 2007 and 2014, energy use grew by 4% per year, while capital investment and labor contracting rose by 7-8% per year.
2,3	2	The total factor productivity of the copper mining sector, corrected by endogenous and exogenous factors to the operation, shows a drop of 1% per year between 2000 and 2014, accumulating a reduction of 14% in the period.
2,4	2	The factors that contributed to production were processed ore (3.6% per year), energy (0.9% per year) and labor (0.5% per year). Instead, ore grade (-3%) and factor productivity (-1%) contributed negatively.

Summary of Findings		
Number	**Chapter**	**Finding**
2,5	2	Using a labor productivity indicator that considers the person-hours required to move a thousand tons of material, there are significant gaps in Chilean mines, and a general worsening of productivity is observed throughout the analyzed period (2000-2014). When gaps increase, it is because the less efficient group (in relative terms) increases its inefficiency at a higher rate than the other group. Conversely, when gaps decrease, it is because the more efficient group (in relative terms) worsens its productivity more rapidly.
2,6	2	The evolution of the gaps, as well as the tendency for productivity to fall in the analyzed period, is a robust result, independent of the sample associated with large scale mining, confirmed even in mines that produce over 100,000 tons per year, mostly exploited by large world-class companies.
2,7	2	Estimates of total factor productivity (TFP) consistently show significant gaps between Chilean mines, and a permanent drop during the analysis period similar to that given by partial labor productivity, confirming the results found in the previous review.
2,8	2	The fall in TFP fluctuates at an average annual rate of 1% and 1.9% according to the initial level of productivity of the mines.
3,1	3	There is a high dispersion in the productive performance of the evaluated Chilean operations. The most efficient operation uses 43 person-hours per thousand tons of moved material, while the least efficient operation uses 115 hours. On average, it took 67 person-hours to move a thousand tons of material during 2015, although most (median) used 53 person-hours.
3,2	3	When compared with international operations, there are critical gaps at productivity levels. On average, the international sample operations accomplish the same task occupying 37 person-hours less than the national average (67), and 23 hours less than most domestic operations.
3,3	3	The results suggest that less productive operations have a more heterogeneous composition of person-hours in different areas. Less productive operations tend to have, either a greater proportion of person-hours at the plant compared to the mine or a higher percentage of support services. On average, a national mine has 1.8 person-hours in the plant and support per person-hour in the mine, while for the international case this indicator is 1.3.
3,4	3	The productivity gap between the best national (43) and the best international mine (18) is 25 person-hours per kiloton of moved material. That is, the best domestic mine is 139% more inefficient than the best in the international sample. When the best performing national mine is compared to the international average, this difference is reduced to 13 person-hours. That is, the most efficient national mine is 44% more inefficient than the mean of the international sample.
3,5	3	Productivity at the mine shows that, on average, domestic operations use 24 person-hours per thousand tons of moved material. Gaps between local operations are important (221% more inefficient with regards to the best performing mines). Concerning the international sample, on average, they carry out the same task using 11 person-hours less, again a gap of over 100%.

Summary of Findings		
Number	**Chapter**	**Finding**
3,6	3	Concentrator Plant productivity shows that, on average, domestic operations use 47 person-hours to process a thousand tons of material. The difference between the most and least productive mine is 62 person hours, i.e., the least productive is 214% more inefficient than the best.
3,7	3	Hydrometallurgical Plant productivity shows that, on average, domestic operations use 119 person-hours to stack a thousand tons of material. The difference between the most and least productive mine is 116 person-hours, i.e., the least productive is 177% more inefficient than the best.
3,8	3	Productivity associated with loading shows significant gaps at the national level: as for the efficient use of the asset, the gap is 28 percentage points. The biggest differences in this gap are due to detentions, followed by maintenance.
3,9	3	On average, the international sample uses the shovels 24% more assets than the national average. This would be equivalent to using the asset an additional 49 days a year if the asset was used 24 hours, 365 days a year.
3,10	3	Productivity associated with transportation has significant gaps at the national level: as for asset use, the gap is 32 percentage points. Detentions account for the biggest difference of this gap, followed by maintenance.
3,11	3	On average, the international sample uses 10% more assets than the national average. This means that the asset is used 23 more days a year by the international sample if we consider a use of 24 hours a day, 365 days a year.
3,12	3	The national gap in the efficient use of the Concentrator Plant is 13 percentage points. The possible time used: an average of 89% is highlighted.
3,13	3	La mayor fuente de heterogeneidad en el uso eficiente de la Planta Concentradora de la muestra nacional proviene de las mantenciones. Maintenance is the greatest source of heterogeneity in the efficient use of the Concentrator Plant of the national sample.
3,14	3	Compared to the national average, the international sample uses 13% more equipment in Grinding and 6% more in the Primary Crushing.
3,15	3	The national gap in the efficient use of the Hydrometallurgical Plant is 19 percentage points. The greatest source of heterogeneity in the efficient use of the Hydrometallurgical Plant comes from maintenance.
4,1	4	The is a significant deceleration from 2013 to 2014 in sales to mining companies, especially sales associated to projects.
4,2	4	There is a significant deceleration from 2013 to 2014 in sales to mining companies, especially sales associated with projects.
4,3	4	Suppliers of the Chilean mining industry are concentrated. On average, the two leading suppliers concentrate around half of the sales in the seven categories analyzed, implying the existence of economies of scale.
4,4	4	Suppliers of the Chilean mining industry concentrate their main offices in the Metropolitan Region. However, those with greater mining sales intensity have a more significant presence of their parent companies in mining regions.
4,5	4	One-third of Chilean mining industry suppliers are large companies under the sales classification. However, ranked according to employment level, 90% are medium and small.

Summary of Findings

Number	Chapter	Finding
4,6	4	Mining suppliers increased their labor productivity from 2013 to 2014 with greater variations in smaller suppliers. This is due to this segment's greater variation in sales.
4,7	4	In the long term, there is room for improvement regarding the availability of effective working time in Chile which could increase between 10% and 20%. Part of these gains can occur within companies, without public action.
4,8	4	There is a considerable dispersion in the accreditation times of large-scale copper mining industry operations in Chile. The most efficient company takes 15 days, while the least efficient takes 75 days.
5,1	5	Chile's large-scale copper mining industry is relatively efficient in its use of both electrical and fuel energy, compared to its international competitors.
5,2	5	There is room for improvements in electricity supply costs due to the speculative use of third-party mining concessions where electrical generation or transmission projects are to be installed. Costs increase due to both land use rights negotiations as legal proceedings, and the protection of mining rights considered as property (legal mining easements, possessory actions).
5,3	5	The copper mining industry uses water efficiently. This efficiency increased in the period 2009-2015 with a 25% reduction in the consumption of fresh water per processed ton of copper in the concentrator and 33% in hydrometallurgy. Water recirculation increased from 68.7% to 72.5%.
5,4	5	Investment and operating costs for enabling the use of seawater are significant, due to the altitude of the mines and the distance from the extraction areas, which implies that there are advantages in economies of scale among nearby mining companies for the construction of desalination plants, electricity generation, and pipelines.
5,5	5	The sector requires a clear policy on desalination by the Government and a speedy and transparent regulatory framework.
5,6	5	There is no clear road map on permits and procedures for the installation of desalination plants.
5,7	5	There is a regulatory void regarding the expulsion of brine from desalination plants to the marine environment, which is attended by general legislation.
6,1	6	Regulatory clarity, in aspects such as water rights, land, etc., is fundamental to establish a framework for future debates.
6,2	6	Early, continuous, accurate and reliable information between the parties is critical to building trust between communities and mining companies.
6,3	6	State and local governments are key players in the company-community relationship. The transparency and credibility of these, in addition to their management capacity, are decisive in enabling long-term mutually beneficial solutions.

Summary of Findings		
Number	**Chapter**	**Finding**
6,4	6	The State is not the only one that can safeguard a process of company-community relationship; other institutions can fill that role.
7,1	7	In a context of increased production and employment, the mining industry, and in particular large-scale mining, has improved its results in work-related accident indicators compared to the year 2000. However, the fatality rate remains higher than in other economic sectors. The rate of journey accidents, although one of the lowest among sectors, has also been increasing. The challenge is to improve its safety indicators while increasing production and productivity.
7,2	7	There is evidence that intermittent exposure to altitude levels above 3,000 meters requires special care and monitoring of workers' health.
7,3	7	Organizational practices differ amongst mines within Chile, and also significantly concerning international mines. In Chile, there are more hierarchical levels, lower levels of supervision, and poor mobility between levels. At the national level, variable remuneration tends to encourage production over productivity.
7,4	7	Due to the characteristics and scale of the Chilean mining industry, travel times affect the productivity of mines, influencing the hours worked and the use of the equipment. It is possible to reduce the times of travel by the use of mobile dining rooms, but delay in the processing of these permits limits the effectiveness of this solution.
7,5	7	The usual working time in large-scale mining is an exceptional working time, which must be previously approved by the Labor Department for each case. The recent labor reform modifies this for 4x3 shifts, requiring only registration.
7,6	7	The authorization process of an exceptional working time at the Directorate of Labor takes 40 calendar days on average. This affects the speed with which activities in mining can start, affecting especially the mining suppliers.
7,7	7	The current regulations of the Directorate of Labor that govern exceptional working times allow for the dictation of resolutions of special framework systems to be used by contractors and subcontractors working in a particular primary company. Despite the fact that this instrument offers potential time saving, it is not used on a regular basis.
7,8	7	85% of the sector's workforce works in exceptional 4x4 or 7x7 days, and 80% evaluate them positively, with 7x7 being the preferred working cycle.
7,9	7	Despite agreements between companies and unions to ensure operational continuity, this remains a permanent challenge, especially in the mining area.
7,10	7	There is a significant human capital gap in the mining industry at the qualitative and quantitative level. At the qualitative level, there are differences between the training profiles (groups of competencies) and the needs of the industry. At the quantitative level, there are differences between the number of professionals and technicians offered and required by companies.
7,11	7	The provided trainees have a small degree of adherence to the Mining Qualifications Framework. On the other hand, for companies, signs are showing an increasing adherence to the Qualifications Framework, although there is a lot of room for progress.
7,12	7	The low level of certification of labor competencies in the mining industry is striking. According to ChileValora figures, approximately 0.3% of all certifications issued between 2002 and September 2015 is for the mining sector,

Summary of Findings

Number	Chapter	Finding
8,1	8	Chile's share in the mining exploration market is lower than its share in production and reserves.
8,2	8	There is low availability of territory for exploration in the main metallogenic strips of the country due to the area covered by current concessions in force, and the ease of maintaining them at low cost, especially if they correspond to nonmetallic mining.
8,3	8	There is evidence of significant concentration levels in both metallic and non-metallic mining properties. In some cases, this may respond to the need for sector-wide economies of scale. However, it nonetheless acts as an entry barrier.
8,4	8	Some agents misuse mining concessions for speculative purposes and as insurance against potential litigation, thus harming the effective mining concessionaires. These objectives are different from those that the law considers when granting the subsoil in concession, and by which the State transfers part of its property faculties to private concessionaires.
8,5	8	The process of constituting mining concessions implies quite long terms, with delays of 6 to 8 months for exploration and 24 to 29 months for mining.
8,6	8	The current protection per patent system does not constitute an incentive to carry out effectively exploration and mining, because it does not require mining labor directly and has a low patent value.
8,7	8	The cost of the Chilean mining patent is low compared to other countries, even more so, considering that in other jurisdictions, additional obligations to the patent payment are requested to maintain the mining concession.
8,8	8	Chile shows a significant lag both in availability and quality of pre-competitive geological information.
8,9	8	Chile has a significant gap concerning referent countries, regarding both the share of junior companies in exploration spending and the link between the mining sector and the financial sector.
8,10	8	There is a gap in the standard of the coordinate system used in mining rights both nationally and internationally.
9,1	9	There is no consensus on a clear and precise definition of the medium-sized mining segment. Different organizations use different definitions (labor endowment and production), potentially generating inconsistent productivity statistics.
9,2	9	There is a substantial productivity gap - measured as person-hours per kiloton of moved material - between medium and large-scale mining. This gap has existed since 2000 and has increased since 2007. In the last fifteen years, the productivity of medium-sized mining has fallen twice than large-sized mining, and in the accumulated fall, its percentage has tripled large-scale mining. The largest gap available in the series was in 2014.
9,3	9	There are areas for improvement and modernization in ENAMI, the leading state organization dedicated to the promotion of small and medium-sized mining.
9,4	9	Competition for human capital in the labor market with large-scale mining has led to a shortage of supervisors (middle management) in medium-sized mining.

Summary of Findings

Number	Chapter	Finding
9,5	9	The medium-sized national mining industry's labor market is located in small towns near the mines, where workers return after the workday (few sites operate with camps), that with insufficient labor supply in these towns, and with not enough supply of technical and professional training related to mining.
9,6	9	There is a deficit in local infrastructure, in both quantity and quality, for intermodality. For medium-sized mining, the absence of ports is the main infrastructure problem in Regions III and IV.
9,7	9	Large-scale mining has generated logistic solutions at the individual level, building its private ports to export their production. However, there are chances to take advantage of economies of scale in some ports by providing access to medium-sized mining and increasing the port capacity used.
9,8	9	The process of mine closure in Chile does not differ significantly from international best practices. However, a restriction to the sector is the financial guarantees required for the mine closure processes where the only available alternative is the bank warranty bonds.
9,9	9	The Environmental Impact Assessment System (SEIA in Spanish) process exceeds the internal management capabilities of medium-sized mining companies. In particular, this problem is worse for small project expansions, where the benefits are lower compared to the required time and resources of SEIA process.
10.1	10	There is ample space for cost and time reductions in the accreditation of suppliers and contractors through the homologation (or standardization) of requirements between different companies and mines, which would result in important gains in the sector's overall efficiency.
10,2	10	Suppliers are relevant to mining innovation, and previously developed early programs are starting to take advantage of this potential.
10,3	10	Unlike leading mining countries, Chile does not have appropriate testing and piloting areas for new mining innovations, which represents a barrier to the development of new technologies.
10,4	10	There are no standards for interoperability in the industry, therefore inhibiting the possibilities of data exchange and innovation.

Summary of Public and Sectoral Recommendations

Number	Chapter	Type	Recommendation	Public Institutions in charge of implementation
1,1	1	Public	Establish a Large Projects Office, whose function would be reducing project approval or rejection deadlines, through greater efficiency and coordination among the various public agencies involved in the process at national and regional level. The LPO should be institutionalized and endowed with action mechanisms to those of best international practices, including transparency criteria.	1. Service of Evaluation and Environmental Impact. 2. Ministry of Finance. 3. Sernageomin. 4. Ministry of Public Works. 5. Ministry of Health.
3,1	3	Public	Through the Chilean Copper Commission, or another agency that the government deems appropriate, produce indicators and periodic studies of productivity in the mining sector similar to those in this chapter, such as to complement the regular studies of competitiveness that the Chilean Copper Commission is already doing.	1. Ministry of Mining. 2. Chilean Copper Commission.
5,1	5	Public	Establish the obligation to inform the National Water Bureau of a miner's water finding, but avoid generating permits for them that allow exploitation.	1. Ministry of Public Works. 2. General Water Directorate.
5,2	5	Sectoral	Promote greater use of shared infrastructure in water matters (desalination plants, pipelines, among others), either through the coordination amongst mining companies, through a third party that builds the infrastructure and assumes the costs of coordination, or using another feasible alternative, such as a water interconnection system.	1. Ministry of Public Works. 2. General Water Directorate.
5,3	5	Public	Establish a clear road map of permits and times required for the approval of desalination plant projects.	1. Ministry of Defense. 2. Undersecretary of the Armed Forces 3. Department of Maritime Affairs.
5,4	5	Public	Establish a specific chapter on regulations for wastewater treatment plants, concerning desalination plants in compliance with international environmental standards.	1. Ministry of Defense. 2. Undersecretary of the Armed Forces 3. Department of Maritime Affairs.

Summary of Public and Sectoral Recommendations

Number	Chapter	Type	Recommendation	Public Institutions in charge of implementation
6,1	6	Public	Implement the proposals of the Presidential Advisory Council against Conflicts of Interest, Influence, Peddling and Corruption regarding the funds received by local governments, so that local governments establish a better institutional framework, with greater transparency and efficiency.	1. Municipalities. 2. Regional SEREMIs (linked to decisions with the community).
6,2	6	Public	Through the Ministry of Mining, promote and encourage permanent dialogue models for large projects between companies and communities through the development of a participation standard guide for large mining projects similar to that carried out by the Ministry of Energy for energy projects.	1. Ministry of Mining
6,3	6	Public	To implement the 25 measures from the Presidential Advisory Commission for the Environmental Impact Assessment System (SEIA) with the aim of having the best possible environmental assessment, facilitating a better dialogue between companies and communities. In particular, we emphasize the proposals of Early Relationship, Indigenous Consultation and Strengthening Citizen Participation in SEIA.	1. Municipalities. 2. Regional SEREMIs (linked to decisions with the community). 3. Service of Evaluation and Environmental Impact.
6,4	6	Sectoral	Implement a dispute and conflict resolution system, such as that promoted by Valor Minero, in which the parts can request mediation, arbitration or conciliation, as well as establish a certification entity that empowers and enhances the organizations that participate in the dialogue process.	1. CORFO. 2. Strategic Investment Fund
7,1	7	Sectoral	To continue strengthening the joint effort carried out by companies, workers, suppliers and the government in the field of occupational safety, in order to keep reducing accident and death rates, while allowing production and productivity increase.	1. SERNAGEOMIN.
7,2	7	Public	Adapt Supreme Decree 594 of the Ministry of Health regarding work at heights, according to the results of the Social Security Superintendence studies that come out in the future.	1. Ministry of Health 2. Superintendence of Social Security.
7,3	7	Public	The Ministry of Health should institute unique and explicit criteria for the establishment of mobile dining rooms not subject to interpretation and thus expedite the process of approval/rejection of the request.	1. Ministry of Health

Summary of Public and Sectoral Recommendations				
Number	Chapter	Type	Recommendation	Public Institutions in charge of implementation
7,4	7	Public	Simplify Labor Directorate Order No. 5 of November 20, 2009, from the Labor Directorate regarding the authorization of exceptional systems of distributing work and resting times, expediting the approval of exceptional working time for contractors and suppliers.	1. Labor Directorate
7,5	7	Public	The Labor Directorate should continue efforts to incorporate information technology into the exceptional working time authorization process and thus make the resolution process more efficient.	1. Labor Directorate
7,6	7	Public	Restore the "adaptability pacts" discussed in the recent labor reform, but vetoed in the final text. This would ease the agreement between companies and workers in order to ensure "operational continuity."	1. Ministry of Labor
7,7	7	Public	Add the 4x4 and 7x7 shifts to the possibility stipulated in Article 375 of the Labor Code, so that these working times benefit from the exempted resolution by the Labor Department.	1. Ministry of Labor
7,8	7	Sectoral	Associate the training of mining specialties in high school, technical and professional education, and Technical Training Centers with those defined in the Mining Qualifications Framework developed by the Mining Competencies Council. Moreover, adapt the accreditation of the program, the corresponding subsidy, and the student's exit to its certification.	1. Ministry of Labor. 2. Ministry of Education. 3. ChileValora.
7,9	7	Sectoral	Increase the levels of training in the industry, which should be in line with the Mining Qualifications Framework. Likewise, make greater efforts in the industry to certify workers, establishing clear commitments and schedules.	1. Ministry of Labor. 2. Ministry of Education. 3. ChileValora.
7,10	7	Sectoral	Update competency profiles by specialty according to the needs of an increasingly automated and digitized world.	1. Ministry of Labor. 2. Ministry of Education. 3. ChileValora.
8,1	8	Public	Raise the Annual Patent from a linear to a progressive one, which increases over time, both in exploration and in exploitation, but allowing a reduction of the patent payment through mechanisms of consideration by the mining concessionaire (geological information, works, among others).	1. Ministry of Mining
8,2	8	Public	Match the Annual non-metals substance Patent with the one for metal substances.	1. Ministry of Mining
8,3	8	Public	Establish incentives and sanctions for non-compliance with the geological information obligation, laid down in Article 21 of the Mining Code.	1. Ministry of Mining

Summary of Public and Sectoral Recommendations

Number	Chapter	Type	Recommendation	Public Institutions in charge of implementation
8,4	8	Public	Strengthen the Sernageomin, granting broader powers and clearer control parameters to its departments, with the purpose of maximizing the impact of each one of its work areas.	1. Ministry of Mining 2. SERNAGEOMIN.
8,5	8	Sectoral	Equate the conditions between specialists and engineers qualified to perform measurement tasks, and make publicly available the yearly qualification to which their work is submitted.	1. Ministry of Mining 2. Sernageomin. 3. Council of Mining Competences.
8,6	8	Public	Restrict the consecutive and immediate request for exploration concessions between related persons.	1. Ministry of Mining.
8,7	8	Public	Reduce the times involved in the application, evaluation and constitution procedures of mining concessions.	1. Ministry of Mining.
8,8	8	Public	Redesign the auctioning process of abandoned mining rights, using actions that tend to the coordination and fast transmission of information among all those involved in those processes.	1. Ministry of Mining.
8,9	8	Public	Update the coordinate system and datum of mining rights from PSAD56 / SAD69 to WGS84.	1. Ministry of Mining. 2. SERNAGEOMIN.
8,10	8	Public	Adopt a grid system for requesting mining concessions in the medium term.	1. Ministry of Mining.
8,11	8	Sectoral	Develop a training program in financing projects in exploration and mining with the aim of reducing the information gaps between the financial and the mining sector.	1. Ministry of Mining. 2. SERNAGEOMIN. 3. CORFO. 4. Strategic Investment Fund
8,12	8	Public	Establish a mixed protection system through the payment of a patent, the granting of geological information to the State and the formulation of minimum work plans for the application and renewal of exploration rights, as well as evidence of mineralization and minimum work for exploitation rights.	1. Ministry of Mining. 2. SERNAGEOMIN.
8,13	8	Public	Increase exploration concession periods from two to three years and allow two extensions instead of one, totaling a maximum of nine years.	1. Ministry of Mining.

Summary of Public and Sectoral Recommendations				
Number	**Chapter**	**Type**	**Recommendation**	**Public Institutions in charge of implementation**
8,14	8	Public	Establish a temporary limit on the mining concession of a maximum of 30 years, subject to priority and unlimited renewals for an equal period.	1. Ministry of Mining.
8,15	8	Public	Modify the provisions of Article 15 et seq. of the Mining Code, which exclude certain activities (vineyards and groves) from the general rule of submitting to the competent Judge the request for permission to dig upon refusal by the owner. This action's purpose would be to equate judicial treatment for the resolution of conflicts between all activities favoring good coexistence in adequate enviromental standards and the appropriate compensation.	1. Ministry of Mining.
9,1	9	Public	To agree among the sector's stakeholders a precise definition of the medium-sized mining segment in order to produce comparable public and periodic statistics. This definition should focus more on production than employment size.	1. SERNAGEOMIN. 2. ENAMI. 3. COCHILCO.
9,2	9	Public	To instruct the Chilean Copper Commission to continue with their first characterization of the segment, with the aim of enhancing the understanding of medium-sized mining, given its increasing importance for Chile in the future of mining industry.	1. SERNAGEOMIN. 2. COCHILCO.
9,3	9	Public	Complement the gap analysis for large-scale mining conducted in this report, with a similar analysis for medium-sized mining in Chile, ideally with similar firms in related countries. This will allow defining a baseline to monitor the evolution of the segment.	1. SERNAGEOMIN. 2. COCHILCO.
9,4	9	Public	Incorporate the OECD guidelines (2011) for public companies to ENAMI, modernizing their corporate government, and promoting transparency.	1. Ministry of Mining. 2. Enami. 3. System of Public Companies.

Summary of Public and Sectoral Recommendations

Number	Chapter	Type	Recommendation	Public Institutions in charge of implementation
9,5	9	Secto-ral	Establish a local mining training policy in cities where mining employment is relevant, especially in areas where medium-sized mining operates. Local technical schools should further the developing of mining specialties, with infrastructure and equip-ment support, as well as promoting mining careers in Technical Training Schools (CFT in Spanish) in towns where medium-sized mining is important.	1. Ministry of Education. 2. Ministry of Mining.
9,6	9	Public	Increase the quantity and quality of road, railway, and maritime infrastructure, jointly investing in in-termodality between the three modes, according to the guidelines of the National Council for Innovation for Development (2015).	1. Ministry of Transport and Telecommunica-tions. 2. Ministry of Public Works. 3. Company of State Railways. 4. State Port Companies.
9,7	9	Secto-ral	Facilitate and encourage the incorporation of medium-scale mining to private infrastructure projects of large-scale mining (ports, desalination plants, among others), so that there are potential economies of scale.	1. Ministry of Transport and Telecommunica-tions. 2. Ministry of Public Works.
9,8	9	Public	Expand the options of financial instruments to guarantee the closure of mining operations. Following the model of Western Australia, analyze the possibility of pooling a common fund of gua-rantees that also serves to rehabilitate abandoned tailings and dumps.	1. SERNAGEOMIN. 2. Ministry of Mining.
9,9	9	Public	Implement the recommendations of the Presidential Advisory Commission for the SEIA Evaluation (2016). Most require only regulatory modifications, which lead to a rapid implementation of recommendations.	1. Ministry of the Environment. 2. Ministry of Mining.
10,1	10	Secto-ral	Modify Supreme Decree No. 99 of 19.3.2015 of the Ministry of Mining to establish a clear criterion and the option for companies to withdraw from the registration of the Homologated Course of Basic Induction in Mining Operations.	1. Ministry of Mining. 2. SERNAGEOMIN

Summary of Public and Sectoral Recommendations				
Number	**Chapter**	**Type**	**Recommendation**	**Public Institutions in charge of implementation**
10,2	10	Secto-ral	Establish a universal standard on the technical characteristics and other minimum criteria required for light vehicles. If an agreement between the companies is not possible, settle it through the Mining Security regulations and incorporate it into the Mining Safety Regulation (DS132).	1. Ministry of Mining. 2. SERNAGEOMIN
10,3	10	Secto-ral	To take into account all current pre-occupational and occupational exams held by an employee to avoid duplicating efforts.	1. Ministry of Labor, 2. Superintendence of Social Security, 3. Ministry of Health
10,4	10	Secto-ral	Implement a Mining Passport in the short term that grants mobility to workers of mining companies and contractors with special emphasis on its escalation.	1. Ministry of Mining, 2. Ministry of Labor, 3. Superintendence of Social Security, 4. Ministry of Health
10,5	10	Secto-ral	Continue public-private partnership efforts, such as Alta Ley National Mining Program and its compo-nents, evaluating their performance and possibilities for improvement in five years at least.	1. Ministry of Economy, 2. Ministry of Mining, 3. CORFO
10,6	10	Secto-ral	Establish clear innovation indicators that allow monitoring the impact of the Open Innovation Platform.	1. Ministry of Economy, 2. Ministry of Mining, 3. CORFO
10,7	10	Secto-ral	Ensure the availability of test, pilot and training spaces for innovations. Encourage the use of abandoned sites and periods of idle capacity in medium-sized mining.	1. Alta Ley, CORFO
10,8	10	Secto-ral	Align the characteristics of these spaces with the gaps prioritized in the Technological Roadmap.	1. Alta Ley, CORFO
10,9	10	Secto-ral	Encourage interoperability between communication and information systems in all mining production processes through the development of instruments (e.g. interoperability standards) in conjunction with suppliers and mining companies in the sector.	1. Alta Ley, CORFO