

Knowledge-Intensive Mining Services: a Regional Approach for their Development in Chile

Autores:

Claudio Bravo-Ortega
Leonardo Muñoz

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Claudio Bravo-Ortega^{a,*}, Leonardo Muñoz^b

^a School of Economics and Management. Department of Economics. Universidad de Chile, Santiago, 8330015, Chile

^b National Council of Innovation for Development, Santiago, 8320215, Chile

Abstract

Governments in every country are concerned about the local economic development within each country's region. In this vein, the case of mining industry draws attention in its trend of establishing enclave economies rather than cluster dynamics at the local level. In the case of the mining industry one might state that there is no room for local economic development based on a strong industrial fabric if no directed policies are set and implemented. This paper's objective is to understand how the backward and forward linkages approach is a key argument to inform regional industrial and vertical initiatives that aim to upgrade mining suppliers' technological capacities. Based on the strategic design revision of the public-private programs for mining suppliers' development and five case studies, we explore whether those implemented initiatives are being locally translated into mining regions. We find that the regional approach is nearly nonexistent in public policies implemented in the last 12 years. From our perspective, this lack of the regional approach makes it difficult to visualize direct effects from public-private policies on local firms' performance. All these issues contribute inputs for scoping the design and deployment of policy tools for local economic development.

Keywords

Backward and forward linkages, innovation, natural resources, mining industry, Chile

* Corresponding autor

e-mail addresses: cbravo@fen.uchile.cl (C. Bravo-Ortega), lmunoz@cnid.cl (L. Muñoz)

1. Introduction

The mining industry in Chile is one of the most dynamic and challenging economic sectors of the country. In fact, this economic sector represents one-third of global copper production and represented more than 8% of the national GDP in 2016, with an average of 13% between 2006-2016. The national proportion of mining exports represents approximately 55% of the total, where Chilean copper represents 90% of worldwide shipments (Consejo Minero, 2016). Considering the 2016-2025 period, projected investments show that mining in copper will lead to direct investment, representing more than US\$ 43 billion or approximately 87.8% of the total projected mining investments, including CODELCO, the state-owned copper company in Chile. Thus, during the next decade, the projected investment in copper mining will be greater than the total amount that was invested in the previous ten years (2006-2016), which represented US\$ 34 billion (COCHILCO, 2016a).

This paper survey whether the regional approach has informed the public-private programs implemented in Chile to upgrade mining suppliers' technological capacities in the last 12 years. For this analysis we combine the assessment of strategic guidelines of public-private programs for mining suppliers' development with cases of studies of mining suppliers that have been expose to those policies. Results are related to the opportunities derived from the current dynamics of the mining sector worldwide and the possibilities of mining suppliers regionally-based to respond to increasing demand of outsourced services from mining companies located in mining regions in Chile.

Indeed, the internal dynamic of the mining industry plus the expected demand of copper

products from China, this sector offers unique opportunities for related stakeholders in achieving greater levels of productive diversification based on the services and labor requirements of the local industry. Eventually, the development of solutions targeting those needs will enable the development of technological capabilities and innovative experiences and the social insertion of actors along the value chain. Indeed, the vertical disintegration within the mining industry creates new business opportunities for the suppliers of services. This movement is expressed in the outsourcing of non-strategic services to third parties; therefore, mining companies are more progressively focused on their core business. In fact, in 2014, approximately 70% of the operating costs in mining companies were related to the purchase of goods and services from providers (Fundación Chile, 2016a).

Nonetheless, the Chilean mining industry is encountering important challenges related to technological inputs and operational factors. For instance, Fundación Chile (2016b) notes that the age of mines and the declining ore grades imply that there are important investments to be made. Otherwise, the industrial production will decrease from the current 6 million metric tons (MT) to 4 million MT in 2025. In contrast, to maintain the leading position in copper production and export levels worldwide, the production must rise to 8 million MT during the same period. This increase involves solving different technological challenges, from the availability of funds and related investments to the enhancement of continuous schemes of human capital qualifications, both specialized and advanced, with a strong focus on strengthening the possibilities of regional actors in mining regions taking active roles in developing solutions suited to localized mining firms.

The mining industry has accumulated knowledge and achieved some advantages inherited from previous sectoral crises that it has encountered since the XIX century in Chile. Indeed,

several authors (Aroca, 2001; Urzúa, 2011; Fundación Chile, 2016b) differentiate stages in which the national mining industry evolved and achieved greater levels of competitiveness. Some of those conflicting issues are the need to overcome the economic crisis due to the loss of nitrate competitiveness (1930s), the political tension during the process of nationalization of mining property, which was formerly foreign-owned (1970s), and the pressure to increase productivity and competitiveness with international standards (1990s). Recently, the fall in commodity prices and the need to make the mining operation more efficient through the development of technological solutions have also become conflicting issues.

Throughout this process, in the last 50 years, the Chilean mining industry has gone from a competitiveness based on abundant high-quality mineral resources to the possibility of producing innovative solutions in alliance with all the value chain actors of the mining industry. This switch is due to the importance that Chile has acquired within the world copper market. Then, the following question is raised: how has the backward and forward linkages approach informed public policies targeting local capabilities for innovations developed by suppliers of mining services? When this perspective is considered, what must be considered to make it possible for regions to overcome the so-called resource curse or the enclave economy? What about establishing strategies for learning and knowledge accumulation targeting the provision of contextualized technologies?

The first step forward is to differentiate how the mining industry is territorially expressed in Chile, beyond the location of mining sites and operational facilities. These locations are fixed in the regional space. An argument to sustain the regional approach for economic development is that horizontal policies are less efficient in building strong industrial fabric

than vertical policies that incentivize local interactions among actors involved in the industry's development. Thus, targeted public-private initiatives are needed at local level.

Chile is definitely not flat, from a geographical perspective and in terms of the development and relative weight that the mining industry has in the country's administrative regions. In fact, as shown in table N°1, the region of Antofagasta appears to be a mountain in terms of copper production, mining exports and related GDP. When we examine the distribution of suppliers of mining services where the Metropolitan Region of Santiago garners huge importance, this trend is the opposite. Several studies (Fundación Chile, 2016a; 2016b; Atienza et al, 2015) indicate that the regional conditions of infrastructure, labor market, and skilled human capital, among others, discourage the location of service suppliers in the regions where mining companies are located.

INSERT <Table N°1>

Thus, interventions to upgrade the technological capacity and innovation performance of local suppliers are at the crux of efforts to facilitate new industrial dynamics where providers can create new or enhanced knowledge-intensive solutions that address major problems in the mining industry. However, in a centralized country, like Chile, the production linkages approach (Hirschman, 1981) and the regional perspective in policy programs is something new and occasionally difficult to materialize in the key initiatives that maintain firms' motivation to take the path of technological and competitive improvements. Though, suppliers in the mining industry are integral to sustaining sectoral and regional development in the areas in which they are located or offer services. However, routine and knowledge distance could lead to a large gap in a natural resources-based

intensive knowledge economy.

Experience teaches that it is possible to undertake the necessary efforts to take advantage of the opportunity that mining offers to local stakeholders. Any initiative and policy implemented must be based on mutual trust and close interactions among local stakeholders through industrial processes. This basis will illustrate and exploit the so-called *untraded interdependencies* (Storper, 1997) that exist at the regional level as those intangible benefits gained by firms when they cluster together in agglomerations.

In our analysis, we developed five case studies to analyze different firms, from those that have a long trajectory of more than 40 years of participation in their economic activity, such as ENAEX, Bailac and Neptuno Pumps, to those that have recently defined their approach to provide improved services and solutions after years of R&D investments, such as INGMAT and MSMIN. Indeed, the five cases will aid in contrasting the innovation experience of service suppliers and the policy programs developed to strengthen industry performance. Among these case studies we will focus on regionally-based suppliers in order to understand their main motivations and difficulties to develop their activities in an industrial environment different to Santiago, the country's capital city.

In Section 2, we explain our conceptual framework that will sustain our policy analysis and cases of study. In section 3 we develop the revision of the strategic design of public-private programs for mining suppliers' development in order to understand whether the regional approach has been considered. In Section 4, we analyze the suppliers' development possibilities in Chile considering mining industry challenges, policies and technological path of local suppliers. In section 5, we explore the suppliers' development experience in

their regional context within the mining industry in order to find whether related development policies show results on firms' performance. In Section 6, we discuss the policy recommendations suggested by our theoretical framework, policy and cases analysis.

2. A local economic development approach for policies in resource rich economies

Until recently, a great many studies and scholarly discussions regarding economic development focused on emphasizing the tension between the terms of trade and the benefits derived from manufacturing economies and those from countries with resource-intensive economic structures. This distinction influenced the vision of policies designed to target the enhancement of industrial manufacturers' development processes, since the exploitation of resources implied lower levels of GDP growth.

Morris et al (2012) surveyed several theories that seek to identify factors that explain the differential growth performance among countries. As a starting point, this review included the research of Prebisch (1950) and Singer (1950) who estimated that in the long run, the prices of manufactured goods tend to be relatively higher than those of commodities. Similarly, in comparing 97 countries, Sachs and Warner (1997, 2001) confirmed the deteriorating terms of trade structure, since they found a negative correlation between the high availability of natural resources and GDP growth; this, in turn, was named the resource curse. Usually, this negative approach to resource-rich economies is linked to enclave activities at the local level (Humphreys et al., 2007) as a means of illustrating that the production of hard commodities occurs in isolation from the local economies of low-income countries.

Nonetheless, the findings from Sachs and Warner's research were contested by several authors (Lederman and Maloney, 2007; Bravo-Ortega and De Gregorio, 2007; Manzano and Rigobon, 2007) who reviewed the economic history of Sweden, Finland, Norway, Denmark, Australia and Canada and found evidence of a positive correlation between resource abundance and GDP growth. These findings are good news for the Chilean economy, since it needs a lower volume of natural resources to access manufactures. For instance, in 1980, 2 tons of copper were required to buy one unit of manufactured good, like a computer; in 2000, one ton of copper could buy 2 computers, while in 2015, a ton of copper could be exchanged for 10 computers (Fundación Chile, 2016b). Thus, the remaining question is how to develop appropriate mechanisms to assure the positive relationship between resource abundance and increasing levels of economic development.

Similarly, it is crucial to remember the key role of China and India in the global economy as both commodity consumers and manufacturing producers (Morris et al., 2012). As the commodity demand from China tends to remain high, this pushes up the prices of commodities. The economic emergence of China is a window of opportunity for resource rich economies, such as Chile. At the same time, current changes in the global patterns of industrial location and the international labor division can be materialized in the new FDI in the local economy or in opportunities for the generation and strengthening of production linkages of local suppliers with MNCs through outsourced services. However, this changing scenario implies a re-thinking of our approach to commodities and industrialization with regional implications through a more proactive perspective that goes beyond the enclave approach of regional leading and large firms.

The mining industry has been a crucial engine of Chilean economic growth and a platform for technological innovation. However, there is a high risk of failure in unlinked regional activities led by local players that may exhibit high levels of market power. The sequence of public policies targeting an improvement in sectoral competitiveness points in the opposite direction to strengthening the articulation among the actors. However, the risk of producing enclave activities is latent at the regional level.

The notion of production linkages was coined by Hirschman (1981) as a way of understanding the dynamic relationships that are established between a leading company and its suppliers of goods and services. In Hirschman's perspective direct linkages would be one of the main factors to promote economic development towards a more diversified structure. The production linkages are differentiated between backward linkages -that comprises goods or services that are inputs for the production of commodities- and forward linkages -where the advanced stages of the value chain are the processing commodities for the final consumption. If we take a closer look at the backward linkages we will see that they are crucial for the industrial development and that they are mostly located in the arrangement of economic activities, in this case to provide goods and services for the mining industry. Thus, linkages can be fostered with locally-based firms, either domestic or foreign-owned. But, usually domestic suppliers generate higher degrees of local added value along the value chain. However, to take advantage of backward linkages it is necessary to develop local capacities in suppliers to shorten the knowledge distance and respond to the challenges and needs of local firms. It is interesting to bear in mind that production linkages perspective is dynamic, since backward and forward linkages can either be enhanced or decay over time, with its relative effect on the geographical space.

One of the challenges confronting the mining industry is to boost the generation of local service suppliers whose knowledge management allows them to respond within certain timeframes and with the quality required by the mining companies. In the absence of incentives or sectoral regulations, large mining companies, primarily foreign-owned, may operate as “enclaves” without consideration of local communities and their economies (Auty, 2006), with weak production linkages to local firms; these are usually mono-producers of goods with low levels of value added (Rodriguez Clare, 1996; Phelps, 2008; Morris et al., 2011). To understand the role of MNCs in the local economy and to determine if there are organizational patterns of local economic activity, Arias et al. (2014) developed an approach to distinguish the characteristics of mining enclaves and clusters. In this research, the researchers found that the Region of Antofagasta (Chile), despite its long trajectory in mining activities, is not related to establishing cluster dynamism as closer to a mining enclave than a cluster.

Consequently, local firms show weak linkages –mainly backward linkages- to mining activities, thin labor markets and limited knowledge spillovers along the value chain. In turn, in Antofagasta -the major mining region of Chile- the analysis of the regional input-output matrix shows that results tied to these conditions are a mismatch between the regional copper production and the limited backward and forward linkages within the region in terms of output, income and employment (Aroca, 2001, 2002), also there are significant negative effects on regional wages due to the commuting labor force in the regional mining industry, since the majority of mining workers live and work in different regions (Aroca and Atienza, 2011), and the differential effect of production scale for mining companies on regional wages, considering the Antofagasta and Atacama regions (Rivera and Aroca, 2014). The evidence shows that the weakness of backward and forward

linkages in mining regions affects the embeddedness of the local economic activity. Conversely, in the last two decades, the relevance of the change in the global organization of mining, which progressively moves towards a greater degree of outsourcing and sub-contracting of services, is viewed as an opportunity for the generation of backward linkages with service suppliers (Atienza et al., 2015; Morris et al, 2011; Lagos and Blanco, 2010).

Although the promotion of production linkages is a key argument that supports initiatives that target the strengthening of economic development with regional impact, it is also true that its dynamism at the local level has been weakened as a policy instrument (Atienza et al., 2016; Phelps et al., 2015). This decay shows that the successful and virtuous experiences of vertical integration of productive processes between suppliers and leading companies do not occur naturally, and assertive directions are needed. In contrast, it is necessary to agree on the rules of the game and the policy instruments needed to achieve positive results. From the review of certain international experiences, we can confirm that in the different cases, it was necessary for those involved to proactively confront situations related to the development of linkages. Examples include the following: the backward linkages based on knowledge and technology transfer to Norwegian companies in the oil industry and the local content processes in Australia (Ville and Wicken, 2012); the Brazilian learning linkages development through the service role played by large firms, suppliers and local universities (Figueiredo and Piana, 2016); and the relevant role of Government in guaranteeing standards of cooperation along the value chain as a criterial success factor of a Chinese-owned mining company in Zambia (Fessehaie and Morris, 2013).

Chile has not been exempt from experiences related to the technological, productive and competitive capacities of the mining value chain. These initiatives vary in their

implementation from public leadership to other private or public-private experiences. These initiatives all strive to improve the performance of the mining sector; however, it is necessary to examine whether the backward and forward linkages approach is the basis of their design or implementation and to examine how the regional development perspective is included. The following section addresses these issues based on the arguments presented here.

3. The Chilean experience in the promotion of mining services: the national-regional tension

Chile has developed a complex system of public policies focused on economic development at the national level, which have impacts at the regional level. Since the 1990s, policy instruments linked to the promotion of Entrepreneurship, Science, Technology and Innovation have principally originated from the National Economic Development Agency, CORFO, and the National Commission for Scientific and Technological Research, CONICYT. These two centralized public agencies define public policy priorities and the design of related instruments. For the territorial deployment policy instruments, only CORFO has offices in each Chilean region, while CONICYT remains centralized.

This institutional context is relevant when regionally implemented initiatives need to harmonize their claim for regionally suited public policies that are designed from a top-down horizontal approach with instruments to boost the regional economic sectors; this essentially requires a closer approximation to a more vertical and "bottom-up" (Crescenzi and Rodríguez-Pose, 2012; Camagni, 2009; Capello, 2009). Chile has evolved in the design

and implementation of different programs that seek to improve the coordination of policies that better fit the regional requirements from different scopes and methodologies. Progress has been slow, and the results are scarce. However, the evolution in the programs' approaches provides an overview of the learning achieved in the last 10 years. This section presents the different Public Policy Programs that have been implemented to improve the competitiveness and productivity of the mining sector in Chile. All have been conceived by the Central Government but progressively show evidence of regional considerations to improve their scope.

3.1. The National Cluster Program

The National Cluster Program has its origins in the National Innovation Strategy, delivered by the National Council of Innovation for Competitiveness (CNIC) with which, in mid-2005, Chile decided to confront its low rates of economic growth and competitiveness at the international level. This strategy has been supported by the benchmarking analysis of those countries with high and rapid development. The conclusion is that the strategy's success was based on the knowledge economy, human capital strengthening, innovation promotion and greater levels of investments in applied science.

In 2006, CNIC noted the need for generating innovation practices that transform static advantages into dynamics. Through a national study of the country that was developed by the Boston Consulting Group (BCG), the council revised the status of the Chilean economy and its performance, challenges and opportunities for competitiveness. Consequently, 11 economic sectors with greater growth potential were identified. These exercises also detected the main public-private coordination failures and gaps that prevent each potential cluster from achieving high competitiveness levels globally.

Each of the sectoral studies developed by the BCG considered interviews with industry players and experts worldwide and specialized publications related to the sectoral competitiveness and benchmarking with other countries. In addition to the centering of the sectoral analysis on key issues and challenges, i.e., in the mining of copper and its derivatives, the analysis includes the exploration, development, extraction, processing and sale of copper minerals. Similarly, the study considers the construction of the value chain, the types of activity developed in each productive stage, the required inputs and services, the associated technology, the regulations and related environmental requirements, and the development needs that were differentiated from the need to strengthen R&D and human capital. Thus, it was identified that along the entire value chain, the mining of copper is supported by an extensive cluster, which includes actors from the private sector, educational / academic institutions and the public sector (Boston Consulting Group, 2006; OECD, 2006; CNIC, 2008).

By the end of 2007, after the results of the national study from BCG, the Committee of Ministers for Innovation, which was chaired by the Ministry of Economy, commissioned CORFO to implement the National Cluster Program, beginning with the first 5 priority sectors: Aquaculture, Agri-food, Mining, Tourism and Global Services.

The governance structure of the National clusters considered public-private councils in each of the prioritized economic sectors. These councils' constitution was based on the triple helix model as a means of representing the entire value chain. This model is from large producers to their main service providers, plus representatives of the public sector and academia. These councils were chaired by the highest public authority in each sector, usually Ministers. Additionally, clusters have technical committees composed of specialists

who analyze the proposed alternatives and their viability, allowing public and private counselors to make informed decisions. Through a consensus method, Directors who represent the value chain sanctioned strategic agendas aimed at reducing coordination failures and increasing improvements in competitiveness. The strategic agendas were constituted by axes and strategic guidelines, in which short to long-term actions were structured. Each cluster had an Executive who performed management tasks to implement the strategy.

Due to its experience in supporting associative projects aimed at promoting the innovation and competitiveness of firms, CORFO was able to lead the implementation of the national cluster program. In fact, as shown in figure N°1, since the 1990s, CORFO has implemented at least four policy tools related to the scope of clusters, assuring policy neutrality among economic sectors and increasing the level of associativity within the value chain. Those instruments are the following programs: the development program, the suppliers' development program, the integrated territorial program and the consortium program.

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In this framework, the mining sector implemented a range of initiatives coordinated through a suited methodological agenda to define the strategy to reach more advanced and technical human capital, enhance the institutional capacity building and achieve major investments amounts in technology (Boston Consulting Group, 2007; CORFO, 2008;

2009). However, the regional approach has been almost non-existent until recently, where the Cluster Program and Alta Ley program have included few variables related to mining regions. Similarly, the scope to backward linkages is still under development.

3.2. World Class Mining Suppliers

The World Class Mining Suppliers Program was initially led by BHP-Billiton (2008) and jointly coordinated with CODELCO (2010). In 2012, Fundación Chile, which is a public-private foundation focused on technology transfer, provided technical support for the program implementation among suppliers of services to mining companies. The program aims to address several market failures that hinder the development of innovation in the industry, such as high transaction costs due to weak relationships between mining companies and service suppliers, inefficient risk sharing with negative results for SMEs, and unbalanced information availability among actors, amid other factors.

The program sought to achieve the two main goals, the development of 250 world-class suppliers for the resource industry by 2020 and fostering the technical and managerial upgrading of mining industry service suppliers to adequately respond to critical industry operations challenges. Thus, this initiative seeks to define areas such as energy efficiency and generation, new or upgraded mineral extraction techniques, and mining operational productivity methods.

The program strategy based on the collaboration between the mining company and its suppliers generates new industrial links through the provision of services to support mining operations, achieving a new perspective for social corporate responsibility activities (Barnett and Bell, 2011; Korinek, 2013). In its early years, BHP Billiton chose 5 of 140 drafted problems to incentivize the development of technological and innovative solutions

from suppliers to the challenges posed. The volume of investment in the program is approximately US\$70 million to develop suppliers' upgrading projects (BHP, 2013).

The program of world class suppliers is structured through a systematic process that considers the challenge identification, the selection process and portfolio management, and the commercial escalation of mining solutions developed by suppliers (Urzúa, 2012). Then, mining companies provided information about their drafted problems to selected suppliers, provided facilities for testing opportunities and acted as technical counterparts for solutions developed by suppliers and for the provision of external consultants to transfer new organizational and managerial skills to suppliers. In addition, to guarantee the transition of suppliers to a world-class stage, mining companies oversaw the conditions for scaling successful innovations, mainly those that achieved enhanced performance and/or positive effects on companies' operational processes. Thus, the whole range of deployed actions were focused on solving the aforementioned market failures.

During the process of intra- industry and inter-firm association, suppliers had the opportunity to learn and accumulate new innovative capabilities, since this can sequentially address an increasing number of problems. What remains important is that during this process, supplier firms can also access public funds or use R&D tax incentives, due to efforts to develop new market or enhanced applied solutions for the industry, either in manufacturing or engineering processes, where the provider retains the intellectual property of the product or service developed.

3.3. Alta Ley Program

The National Mining Program Alta Ley began in 2015 under the framework of the Strategic Program of Smart Specialization, which was run by CORFO. This program was designed

considering the previous designs and the learning derived from the experience of the National Cluster Program, the Regional Competitiveness Initiative of Regional Development Agencies and the World Class Mining Suppliers Program (CORFO, 2016). Then, working with different Chilean mining players, authorities, mining companies, suppliers, entrepreneurs and representatives of the academy, Alta Ley's objective is to achieve a double purpose. On the one hand, the purpose is to strengthen the Chilean mining industry to maintain and consolidate its leadership worldwide. On the other hand, the purpose is to promote an open innovation system that takes advantage of the current leadership of this industry. Thus, it is necessary to surpass industry challenges to develop human, institutional and entrepreneurial capacities.

The mission of Alta Ley is to design and accompany the implementation of a strategy to improve the competitiveness of mining in the long term, strengthening local content and ensuring that the country has technological capabilities and advanced technical and professional human capital in addition to support of industrial growth.

Actors involved in the program recognize the need to take a long-term perspective for the development of copper mining in Chile. This perspective surpasses the rentier approach on the contribution of this sector, which is focused on maximizing the income that the country can obtain from it; this is fundamental to finance public policies. The diverse records indicate that the challenges that mining must confront to maintain and enhance its contribution to the country require a change of focus. This change of approach requires improving knowledge management and innovation initiatives as fundamental axes for the development of the sector.

The technological road map commands each initiative of the program, and it is the result of an unprecedented collaboration between the actors involved and of a profound logic of mutual benefit. The roadmap began with the identification of challenges and problems that the industry is currently confronting in the various stages of the mining value chain. Thus, "gravitating core challenges" and "core enablers" were identified. The former refers to the core and most important technological challenges of the mining process for the industry's evolution, such as mine operations and planning, ore concentration, hydrometallurgy, tailings, and smelting and refining. The latter refers to factors that condition the industry's capacity to develop, such as the human capital, the adoption of new information and communication technologies (Smart Mining), suppliers and innovation (Fundación Chile, 2015b).

The Chilean mining roadmap proposed by Alta Ley is based on processes, criteria and results applied in the experiences of various industries in Canadian, South African, European and American mining. As a reference, particular interest was focused on the systematized learning and knowledge of the roadmap developed by the Institute for Manufacturing at the University of Cambridge and on the identification of the technological challenges identified in the Copper Technology Roadmap of the Australian Minerals Industry Association (AMIRA) from 2004 and 2006 (Fundación Chile, 2015b).

The roadmap is considered a tool to take an active role in sectoral improvement through the coordination of R&D initiatives, between companies and suppliers, where the role of academia is essential. Thus, the construction of the road map had as its background the construction of the R&D&i agenda "Mining: A platform for the future for Chile", which resulted from the Public-Private Commission led in 2014 by the National Council of

Innovation for Development (CNID, 2014). The validation or elimination of the challenges of the industry, as well as the identification of new challenges, was made through interviews with leaders and experts of the national mining industry. Using this information, the gravitating core challenges and the core enablers were defined. After that, technical workshops were developed to elaborate the roadmap for each prioritized nucleus. The Technological Plan of the University of Cambridge (Phaal et al., 2001; Phaal et al., 2009) was used as a methodology to define challenges, solutions, and technologies and to map key initiatives.

Among the strategic priorities defined to implement the technological roadmap, the non-operational areas that are aimed at strengthening the value chain are identified as transversal factors, and they are linked to the following: (a) the development of knowledge and technology-intensive suppliers, which are associated with the open innovation program in the large-scale mining value chain; and (b) the strengthening of human capital according to the current and future requirements of the industry, which is associated with the Transfer Center project for technical training in the mining value chain.

There remain no visible results associated with the implementation of the program, except that the bidding processes and public calls for research that have been generated within the framework of its development. Since the creation of the program did not mean the creation of special instruments for the economic improvement of the mining industry, the managerial factor of the program has been crucial, since it focuses on seeking a strategic alignment between currently available policy instruments in CORFO and CONICYT.

3.4. The regional scope to mining competitiveness

When CORFO was mandated to implement the Cluster Program, it was already promoting the development of so-called "territorial clusters". At this point in time, both programs ran parallel from CORFO. The territorial clusters corresponded to the Regional Competitiveness Initiatives (PMCs) under the implementation of the Regional Development Agencies (2006-2012). Regional Agencies provided a framework for the design of PMCs in three regional relevant economic sectors according to each Regional Development Strategy (Pietrobelli and Maggi, 2005; BID, 2006; 2007; CORFO, 2007). The methodology of these regional initiatives was based on the cluster approach proposed by Porter (1990) to improve the territorial articulation and dynamism of the value chain in each of the three economic sectors prioritized in every region of Chile. In this context, the value chain approach provided room to consider the enhancement of backward and forward linkages during the design of PMCs. However, the emphasis of the program coordination was to strengthen the public-private governance scheme of each PMC and the identification of club goods as a way to incentivize trust among stakeholders.

An important effort between these two programs administered by CORFO was to align and coordinate the strategic actions defined by each, whose effect at the territorial level could be perceived in the short and medium term for PMCs and in the medium to long term for the National Cluster Program.

The articulation of the two programs advanced the solution of competitive gaps that were expressed at the territorial and institutional levels. PMCs sought to improve the competitiveness of economic sectors through the articulation of the regional value chain, while the National Cluster Program addressed gaps that require a national scope. Similarly,

each initiative contributed their capacities to solve the territorial or meso-regional problems.

In the quest for regional arguments that emphasize the importance of strengthening the competitiveness of mining suppliers, it is imperative to consider the trajectory and definitions derived from related Regional Governments –through their Regional Development Strategy- and the experience of programs that were designed from Regional Development Agencies.

Thus, the Regional Government of the major mining regions in Chile establishes the need to strengthen this industry at the local level. This finding is not new and is very obvious; however, what remains important is that the scope and the extent to which the industry improvement is conceived vary from one region to another. In addition, there are no illustrated mechanisms of collaboration and associativity to address a common challenge within this industry.

One may believe that this lack is appropriate since in hard commodities production linkages one size does not fit all (Morris et al., 2011; Bastida, 2014). However, without these associative mechanisms and minimum agreements, the task of internalizing the local benefits and boosting the local economy based on the meso-regional deployment of the mining industry will become difficult. In fact, the region of Tarapaca defines a strategic action to build the mining cluster and to thus coordinate public funds (Gore Tarapaca, 2011). In Antofagasta, regional actors aim to consolidate a Productive Mining, Industrial and Services Complex as a way to strengthen the trajectory that the region has experienced since the 1990s (Gore Antofagasta, 2009). For the Atacama region, the strategic emphasis established the priority of developing enabling conditions for regional economic

diversification beyond mining, such as roads, human capital, and the promotion of investments in small and medium mining (Gore Atacama, 2007).

Furthermore, in 2008, the regional governments of Tarapaca and Antofagasta decided to prioritize the strengthening of mining suppliers, as a means of adding regional value to the sector's performance in the region. To make this decision, the Regional Government considered the results of the studies that supported the National Cluster Policy, as well as the regional productive economic diagnosis that underpinned the formulation and regional validation of the Regional Agenda for Productive Development in 2007.

The scope to enhance the backward linkages of these PMCs that were oriented to suppliers in the regional mining industry are found in the definitions of strategic guidelines, such as:

- *“The systematization of work related to preventive-corrective maintenance, incorporating technologies, automation mechanisms and integrated systems of monitoring with online measurement that allow to anticipate the failures of the equipment or machinery” (ARDP Tarapaca, 2009)*
- *“To reinforce the specific technical knowledge of regional suppliers, necessary to develop new competences to provide integrated services solutions in the medium and long term” ...”to strengthen and consolidate the production linkages, providing support in different productive phases of the firm and its projects” (ARDP Antofagasta, 2010).*

Unfortunately, the abrupt closure of the global program of the regional agencies, as well as the short period that PMCs had to implement their initiatives, make it difficult to determine whether the strategic guidelines achieved expected results.

Chile has experienced several public-private programs focused on improving the competitiveness of the mining industry, as shown in table N°2, which synthesizes the main findings of this section considering the regional perspective to policy tools, the strengthening of backward and forward linkages within the industry and the evidence of results or impact assessment initiatives.

INSERT <Table N°2>

One development that is somewhat distressing is that the regional perspective is not a relevant factor, since the mining industry is conceived as a homogeneous activity that operates in homogeneous spaces. This conception is crucial, since some challenges are typical of the industrial dynamics, but some are geographically imposed by the location of mining sites.

Second, the approach to backward and forward linkages is broad. Although the concern for the improvement of knowledge-intensive suppliers is defined as relevant, the designed guidelines are not very specific. Thus, it is worth the experience of the World Class Suppliers Program, which is the prelude to the work proposed by the Alta Ley Program. Finally, none of the reviewed programs contemplate the development of formal evaluation of results and impacts. This makes it more difficult to determine whether those initiatives generate the expected improvements in the industry.

4. Suppliers challenges and opportunities for development.

The development of Chilean mining in the last 20 years has led to the creation of a large number of national suppliers of services, consumables (spare parts) and, to a lesser extent,

capital goods (technology intensive). However, for both consumable supplies and capital goods, foreign suppliers predominate in the market.

The evolution of the global mining industry and the moment of its development in Chile are at the base of the different paths that distinguish the industry in Chile from developments that are appreciated worldwide such as those in Australia, Canada, and South Africa. Consequently, global suppliers gain strong competitive advantages through inputs, economies of scale, and consolidation of their market presence in local mining services.

Thus, strengthening the capacity of mining suppliers in Chile is not only necessary but imperative since the Chilean projection of mining investments coupled with a significant presence of global mining companies in the country offers local suppliers the opportunity to fulfill the global demand for goods and services in situ. In fact, suppliers have the opportunity to leverage significant investments made by the global mining industry in various projects, mainly in South America. A means for this purpose is the actual mobilization of backward and forward linkages that are primarily expressed at the regional level, as a local incentive for mining suppliers. Thus, the acquired innovative capacities of local suppliers will enable them to develop skills to absorb the fluctuations in copper prices and local investment cycles.

As discussed above, a major trend within the industry is that mining companies are more and more focused on their core business and on solving their technical challenges. The direct effect of this corporate decision is a reliance on outsourcing mechanisms to delegate support processes. This industry trend becomes an important opportunity for local suppliers due to their focus on services, consultancy and engineering, which are necessary outsourceable activities for big companies.

From a global perspective, the technological trajectory of the mining companies in resource-rich countries -now labelled developed- demanded that suppliers of goods and services adapt quickly in response to increasing challenges linked to operations (Scott-Kemmis, 2011, 2013; Urzúa, 2011; Morris et al, 2011). The backward and horizontal linkages enjoyed by mining suppliers from countries such as Australia or Canada helped them achieve competencies to provide innovative and flexible services to meet their customers' demands. In contrast, several researchers (Aroca, 2001; Urzúa, 2011; Bravo-Ortega and Muñoz, 2015; Fundación Chile, 2016b) show that in the particular case of Chile, although the country enjoys comparative advantages in the mining industry, the consolidation of KIMS has not been an easy process. For instance, in the 1970s, the process of outsourcing of non-core activities of the mining industry began, which accelerated the development of specialized suppliers in Australia; however, in Chile, local mining companies had low levels of technological capabilities, and mining suppliers' intensive knowledge (KIMS) had limited possibilities for incubation. In the 1980s and 1990s, the international expansion process of large mining companies occurred, and vertical disintegration favored KIMS development; however, in Chile, this process facilitated the technological development of a reduced number of suppliers. This situation caused leading mining companies, primarily foreign-owned, to rely on suppliers from their countries of origin to supply their operations abroad, helping to promote the international expansion of the traditional suppliers of global mineral companies. Therefore, these companies allow minimal space for the development of alternative local suppliers.

Nonetheless, after the 1990s, as technological capacities spread worldwide and due to the last boom of commodity prices, Chilean KIMS exploited their opportunities to participate

in international projects. Consequently, local mining suppliers began to compete with 1st tier international KIMS in accessing local businesses and innovation opportunities. This story is what is behind the case studies of mining suppliers. However, a question may arise related to the moment in time that these opportunities with local mining operations appear. The vertical disintegration process in Chile was an important opportunity for suppliers; however, today, new opportunities occur given the increasing demand of copper from China and the outsourcing of services from mining companies, that requires rapid service responses in which short geographical distance could be an asset.

Therefore, considering the mining regions and their local firms, their suppliers and workers enable the understanding of the relevance of locality in the design of initiatives targeting the strengthening local economic development processes. This aspect is weak in the revised instruments, which leads to weakness in the treatment of backward and forward linkages, knowledge spillovers, labor mobility, which is nearly absent, and business sustainability.

The mining industry has had a considerable impact in the regions where it is located (the regions of Tarapaca, Antofagasta and Atacama represent 72% of mining concessions), contributing to the development of regional economies, the generation of direct and indirect jobs and improvements in the quality of life. However, there is still an opportunity to enhance regional development. For instance, 63% of mining suppliers are based in the metropolitan region of Santiago mainly due to the difficulty of establishing operations in the mining regions because of the low availability of skilled labor force and infrastructure.

In the same token, related to results derived from policies that promote the cluster approach, there are some concerns about the effectiveness of vertical linkages between MNC and local mining suppliers in achieving greater levels of innovation, the

strengthening of local suppliers' absorptive capacity and the fluency of knowledge spillover along the value chain (Atienza et al., 2016). As mentioned above, a strong industrial fabric at local level can be achieved if directed policies are implemented. Thus, it is important for policy makers to take into account learning, results and recommendations from previous policies when new local economic development initiatives are designed and budgeted. Since, in each mining region, Chile has the opportunity to further develop the mining industry and strengthen the formation of linkages, develop industry suppliers, improve regulatory aspects, enhance applied R&D, invest in gaining greater knowledge of the territorial mining potential and foster associativity among mining companies, suppliers, local government, academia and NGOs.

5. Mining Services Suppliers' innovative experience

The firms selected for cases are those suppliers that have developed innovative experiences in areas related to mining requirements in Chile. Among cases of study we will focus on those learnings from regionally-based mining suppliers. All firms studied self-recognize themselves as innovative units, and there is evidence of that experience, such as products and services developed and industrial awards. Nonetheless, the innovative intensity is different in each firm, despite the common starting principle: continuous improvement. Moreover, not all firms have experienced the initiatives related to public-private programs to strengthen the mining industry.

The technological path and industrial atmosphere shown by firms is an essential factor that determines their approach to develop innovations and a solutions-oriented perspective. This strength may be at the center of firms' abilities to cope with weak industrial environments

were fierce rivalry and feeble social capital is dominant. The suppliers' trajectories within the industry determine their accumulation of formal linkages and informal contacts with mining companies. The outcome of this path is evidenced by different levels of knowledge acquisition and by its management, which is displayed when firms need to respond to mining companies' requirements. Indeed, Bailac, established in 1950 in Chile, and Neptuno Pumps, founded in 1972, elucidate their relative advantages, since they stated that until the early 1990s, the mining industry was more accessible and was less averse to risk. Thus, suppliers within the industry achieved experiences and contacts that have delineated their skill development and their relative accessibility to companies' managers.

Conversely, Bailac states that the establishment of INACAP, a private technical University, in Iquique made it possible to locally hire technicians in certain areas such as ICT or machinery maintenance processes. Previously, all the staff originated mainly from Santiago. However, developing innovations in the North of Chile that obviate the nearly mandatory consideration of the Metropolitan Area of Santiago is not an easy task.

Thus, local mining suppliers that strengthen their capacity in knowledge management are better equipped to find and exploit new sources of knowledge. This strength is more visible in those suppliers that have accessed external experiences, due to joint projects, membership in international associations, foreign investments, and their participation in technical fairs or conventions. This mechanism, external exposure, spills over the related knowledge that suppliers translate into their local experiences of innovation in services and products provided to mining companies in Chile. Indeed, Neptuno Pumps is a member of the Hydraulic Institute in Great Britain; Bailac developed foreign experience through business facilities in Argentina, Brazil and the US. Similarly, INGMAT, in developing

electronic circuits, created an alliance with a French company that had the infrastructure and the specific knowledge they needed for the innovation.

Among the factors that suppliers identified as limiting the achievement of greater levels of technological solutions are the shortage of a local skilled labor force, the high level of risk aversion of companies and the weak bonding scheme among firms. A direct result of this situation is the unbalanced negotiation power between mining suppliers and companies. Thus, mining companies promote highly transactional schemes, and small-sized suppliers find it difficult to invest in new solutions or new technologies. However, there is important growth potential for local demand from mining companies. Indeed, the current demand for foreign products and services is not aligned with the movement of fostering and exploiting local solutions that are developed by domestic suppliers.

Although mining suppliers have noticed an increase in the local demand for solutions and services, they have a critical perception about intra-industry linkages and the business dynamics in progress. This perception is because suppliers observe a rentier approach to trade and interaction from mining companies. This issue could be related to the level of involvement that local suppliers must assume once they achieve a contract of services, along with the absence of intra-industry policies for local buying targeting boosting the domestic industry. Consequently, the regional scenario is more like a business scheme with a commercial rather than an industrial development centered in collaboration and competition. Thus, local suppliers encounter a strong rivalry framework, where competing firms override instances of cooperation between them.

Furthermore, it appears to be a lack of policy tools to encourage joint initiatives that links mining companies and suppliers. Indeed, the largest (and state-owned) mining company in

Chile, CODELCO, is very passive regarding generating joint projects with local suppliers. However, the company has several collaborative projects with foreign companies. Thus, local suppliers find it difficult or have no incentives to increase their internal strengthening to upgrade them to world-class suppliers. Therefore, small-size suppliers assume all the risk associated with the deployment of an innovation project.

As a contra factual, mining suppliers that experienced the World-Class Suppliers program positively evaluated it. Local firms state that this Program is an instance of change in the approach of how mining companies promote intra-industry linkages. In the providers' words, this initiative is translated into a collaborative strategy that improves the suppliers' environment to develop suitable answers to challenges raised by companies. This experience could be defined as that incentive to expand the technological frontier for suppliers who encountered an adverse industrial environment. Therefore, suppliers feel eager to apply their knowledge in finding the appropriate solutions to address mining companies' difficulties in their operational processes. Indeed, suppliers that have participated in the program, such as Bailac and MSMIN, emphasize that initiatives and activities regarding the program help in creating or strengthening intra-industry linkages throughout the value chain. This finding is because mining companies, such as BHP Billiton and CODELCO, lead changes that reduce the level of uncertainty of risks associated with the implementation of new solutions and technologies required by the industry.

The revision of international successful experiences of local economic development linked to commodities activities shed light about the extent to which policies are targeted towards sectors that had comparative advantages and potential regional industry development. In Chile, the analysis of policy tools tells us that there is room to improve the relationship

between the declared forward and backward linkages in policy tools and the local incentives to embed the economic activity at regional level. However, as the regional approach is nearly absent it makes difficult to visualize direct effects from public-private policies on local firms' performance. It seems that the majority of local firms' achievements are due to particular efforts with a timid government support for the improvement of suppliers' quality in processes and services and required certifications, as a starting point.

6. Policy Implications

Global change in the mining industry, such as the increasing demand in China and India of hard commodities such as copper and the trend of large companies to outsource non-core services, poses interesting business and development opportunities for mining suppliers. Those better equipped in knowledge and technology will be able to achieve greater benefits. However, experience states that the technological development of resource-intensive industries or the competitive improvement of their suppliers does not occur naturally or spontaneously. Therefore, initiatives must be generated to guide and lead the processes of local change in adjustment to global trends and demands. These initiatives can originate from different actors, as we have observed in the review of the various programs implemented in Chile. This finding is not an exclusively public faculty; however, the government plays a preponderant role in guaranteeing that procedures, actions and results are aligned to Chilean culture and regulations. Ultimately, successful experiences and the policies implemented must be based on mutual trust and close interactions among local stakeholders.

In Chile, the mining industry has been a decisive engine of the Chilean economic growth and a platform for technological innovation. Therefore, it is relevant to develop the innovative capabilities of local suppliers due to the potential impact that they may have in the regional economy. Indeed, the experiences discussed above elucidate the possibility of mining suppliers in mobilizing R&D investment in related areas and subsectors, coupled with a rising trend of exports of services worldwide. These facts are not trivial since they may drive great levels of local labor demand sustained in the industrial clusters that organize the natural resource industry.

As the mining industry has failed to develop linkages along the value chain due to incomplete local value chains or the persistent transactional rather than collaborative schemes of businesses that mining companies run, the mining picture has been framed as an enclave activity. This issue has important implications for the industrial organization, the innovative efforts of firms, labor commuting, the income spillover around the mining region and, ultimately, the performance of the regional economy. Then, a proposal to enhance backward and forward linkages appears to be useful.

Mining supplier's development initiatives in Chile have achieved results that do not talk with the main challenges and technological demands from the industry. The big picture that the paper shows is consistent with the effects derived from horizontal and neutral policies implemented to solve sectoral needs (Bravo-Ortega and Eterovic, 2015), where after the implementation of policy tools, there persist unsolved competitiveness gaps, with little local integration of firms and a policy resistance effect from local actors.

Thus, the mining industry in Chile has undergone several public-private programs focused on improving the competitiveness of the mining industry. Although backward and forward

linkages are noted as a key orientation for program implementation, it is disappointing that strategic guidelines are excessively broad and designed from a public rather than a private perspective that identifies opportunities for those linkages. However, newly designed programs considered the constitution of public-private teams of work and public-private governance schemes. Undoubtedly, this contribution advances the strengthening of trust among the local actors, which in its turn may incentivize a deeper consideration of linkages.

Another concern with implemented programs regards the regional perspective and knowledge-intensive mining suppliers' development. Most of the National Mining Programs, which curiously address an industry that has regional expression and local impact, disregard the regional perspective. This is because the mining industry is conceived as a homogeneous activity that operates in homogeneous spaces; however, its challenges are not homogeneous. Additionally, although knowledge-intensive suppliers are defined as relevant, the designed guidelines are not very concrete. In sum, it is difficult to explain that publicly financed programs do not achieve local results or that the volume of business of suppliers does not increase until we consider these two factors. Otherwise, local mining suppliers will continue to show weak linkages, thin labor markets and limited knowledge spillovers along the value chain.

From the backward and forward linkages' perspective, business collaboration may trigger productivity improvement among mining suppliers, since the close and smooth relation with mining companies will provide support to develop new or improved solutions suited to specific challenges. In this frame, public bodies, governments and agencies, must agree on the rules of the game and the policy instruments needed to achieve positive results.

Finally, public programs focused on mining suppliers' development have evolved. However, these programs need to consider the regional context of firms. For instance, in Santiago, mining suppliers of service are located in an environment with a wide spectrum of technological possibilities due to the existence of major Universities, central offices of Development Agencies, and managerial departments of large mining companies operating in Chile. However, due to the extent of economic sectors operating in Santiago, any knowledge gained by mining suppliers of services located there tend to be minimized and thus do not spillover to the remainder of the value chain. In contrast, the possible short distances among mining suppliers, mining companies and regional universities appears to have the potential to invigorate the local economy through the mining industry. However, it is necessary to state that this is one part of the story. The other part is related to infrastructure, levels of investments both local and foreign, local labor and the institutional setting. As these topics become more articulated and suited to the local needs, we should expect that the industry becomes a cluster. This process takes time and huge efforts and above all requires a collection of assertive directions where a policy framework could make it possible to design and align policy tools and private actions to enhance the local economic development process.

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References

- Aduanas (2016) Estadísticas de exportaciones chilenas. (online)
<http://www.aduana.cl/estadisticas-2016-tablas-excel/aduana/2017-06-06/092346.html>
(Accesed 30 may 2017)
- ARDP Tarapaca (2009) D-TekTarpro, Proveedores de la Minería de la Región de Tarapaca. Programa de Mejoramiento de la Competitividad (PMC). Iquique: Agencia Regional de Desarrollo Productivo Region de Tarapaca.
- ARDP Antofagasta (2010) Antofagasta Mining Suppliers. Programa de Mejoramiento de la Competitividad (PMC). Antofagasta: Agencia Regional de Desarrollo Productivo Region de Antofagasta.
- Arias, M., Atienza, M. and Cademartori, J. (2014) "Large mining enterprises and regional development in Chile: between the enclave and cluster". *J Econ Geogr* 14 (1): 73-95
- Aroca, P. (2001) "Impacts and development in local economies based on mining: the case of the Chilean II region." *Resources Policy* 27.2. pp.119-134.
- Aroca, P. (2002) "Impacto de la minería en la II Región." In: Meller, P. (ed.) *Dilemas y debates en torno al cobre. Santiago: Dolmen/Centro de Economía Aplicada.*
- Aroca, P., & Atienza, M. (2011) "Economic implications of long distance commuting in the Chilean mining industry". *Resources Policy*, 36(3), 196-203.
- Atienza, M., Aroca, P., Stimson, R., & Stough, R. (2016) Are vertical linkages promoting the creation of a mining cluster in Chile? An analysis of the SMEs' practices along the supply chain. *Environment and Planning C: Government and Policy*, 34(1), 171-187.
- Atienza, M., Lufin, M., Soto, J., & Cortés, Y. (2015) ¿Es la Región de Antofagasta un caso exitoso de desarrollo local basado en la minería. op. cit, 97-117. En: *Sistemas, Coaliciones, Actores y Desarrollo Económico Territorial en Regiones Mineras. Innovación Territorial Aplicada. Universidad Católica del Norte, Antofagasta, Chile.*
- Auty, R. (2006) "Mining Enclave to Economic Catalyst: Large Mineral Projects in Developing Countries". *The Brown Journal of World Affairs*, 13(1), 135-145.
- Banco Central (2015) Base de datos estadísticos. Cuentas Nacionales (online)
<http://si3.bcentral.cl/Siete/secure/cuadros/home.aspx> (Accesed 30 may 2017)
- Barnett, A., & Bell, M. (2011) Is BHP Billiton's Cluster-Programme in Chile relevant for Africa's mining industry. *Policy Practice Brief*, 7, 1-8.
- Bastida, A. E. (2014) "From extractive to transformative industries: paths for linkages and diversification for resource-driven development". *Mineral Economics*, 27(2-3), 73-87.
- BHP Billiton (2013) World-Class Supplier Programme in Chile (Cluster Program). Document based on the application of the Programme to the Community Award – Category Supply Chain.

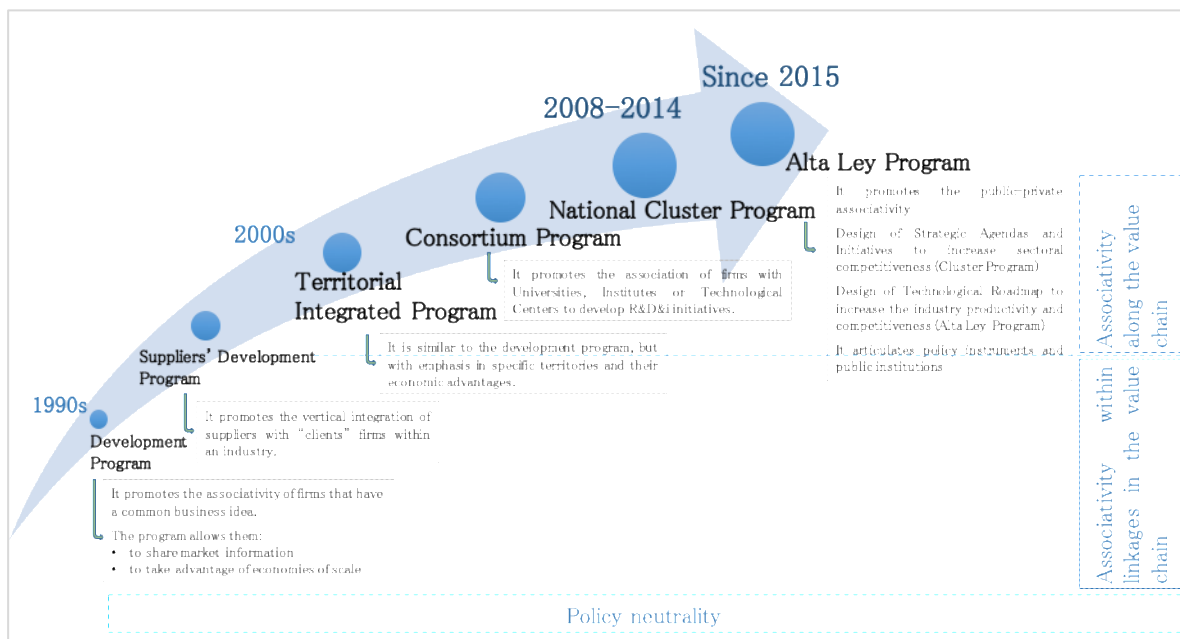
- BID (2006) “Programa de Agencias Regionales de Desarrollo Productivo”. Documento Conceptual de Proyecto, Santiago, Chile.
- BID (2007) “Programa de Agencias Regionales de Desarrollo Productivo”. Contrato de Préstamo No. 1829/OC-CH, Santiago, Chile.
- Boston Consulting Group (2006) “Priorización de clusters e identificación de plataformas transversales”, en Estudios de Competitividad en Clusters de la Economía Chilena para el Consejo Nacional de Innovación (CNIC), Santiago, Chile.
- Boston Consulting Group (2007) “Estudio Sectorial para la Minería”, en Estudios de Competitividad en Clusters de la Economía Chilena para el Consejo Nacional de Innovación (CNIC), Santiago, Chile.
- Bravo-Ortega, C., & De Gregorio, J. (2007) “The relative richness of the poor? Natural resources, Human Capital, and Economic Growth”. In: Lederman, D. & Maloney, W.F. (eds.) *Natural resources: Neither Curse nor Destiny*. Washington, D.C.: Stanford University Press and The World Bank, 71-103.
- Bravo-Ortega, C., & Eterovic, N. (2015) *A Historical Perspective of a Hundred Years of Industrialization. From Vertical to Horizontal Policies in Chile*. Serie de documentos de trabajo, No. wp399, Universidad de Chile.
- Bravo-Ortega, C. & Muñoz, L. (2015) “Knowledge Intensive Mining Services in Chile”. Working paper IDB-DP-418. Inter-American Development Bank. DOI: 10.18235/0000187.
- Capello, R. (2009) “Spatial spillovers and regional growth: a cognitive approach”. *European Planning Studies*, 17(5), 639-658.
- Camagni, R. (2009) “Territorial capital and regional development”. In: Capello, R., & Nijkamp, P. (eds) *Handbook of regional growth and development theories*. Cheltenham: Edward Elgard, 118-132.
- CNIC (2008) *Hacia un Estrategia Nacional de Innovación para la Competitividad*. Volumen I y II. Consejo Nacional de Innovación para la Competitividad (CNIC), Santiago, Chile.
- CNID (2014) *Minería: una plataforma de futuro para Chile*. Informe final comisión Minería y Desarrollo de Chile. Sanitago: Consejo Nacional de Innovación para el Desarrollo (CNID).
- COCHILCO (2016a) *Proyección de la producción de cobre en Chile 2016 - 2017*. COCHILCO. Santiago.
<https://www.cochilco.cl/Mercado%20de%20Metales/2016%2011%2023%20Proyección%20de%20producción%20esperada%20de%20cobre%202016%20-%202027%20Vfinal.pdf>
 (Accesed 19 may 2017)
- COCHILCO (2016b) *Propiedad minera en Chile: estado y medidas de perfeccionamiento*. Comisión Chilena del Cobre. Santiago, Chile

- Consejo Minero (2016) Minería en números. (online) Consejo Minero. Santiago. https://issuu.com/consejominero/docs/libro_miner__a_en_n__meros (Accessed 19 may 2017)
- CORFO (2007) “Contenidos de Planes de Mejoramiento de Competitividad”. Documento de gestión operativa del Programa Agencias Regionales de Desarrollo Productivo, Santiago, Chile.
- CORFO (2008) “Diseño de Programas y Agenda Estratégica del Cluster Minero”. Programa Nacional de Clusters, Santiago, Chile.
- CORFO (2009) “Levantamiento de Requerimientos desde los Programas de Mejoramiento de la Competitividad de las Agencias Regionales de Desarrollo Productivo al Programa Nacional de Cluster”, Serie Regional N°1, Programa Nacional de Clusters, Santiago, Chile.
- CORFO (2016) “Información Complementaria Programas Estratégicos de Especialización Inteligente”, Santiago, Chile.
- Crescenzi, R., & Rodríguez- Pose, A. (2012) “An ‘integrated’ framework for the comparative analysis of the territorial innovation dynamics of developed and emerging countries”. *Journal of Economic Surveys*, 26(3), 517-533.
- Fessehaie, J., & Morris, M. (2013) “Value chain dynamics of Chinese copper mining in Zambia: enclave or linkage development?”. *The European Journal of Development Research*, 25(4), 537-556.
- Figueiredo, P. N., & Piana, J. (2016) “When “one thing (almost) leads to another”: A micro-level exploration of learning linkages in Brazil's mining industry”. *Resources Policy*, 49, 405-414.
- Fundación Chile (2016a) *Estudio de Caracterización Proveedores de la Minería Chilena 2016*. Fundación Chile. Santiago, Chile.
- Fundación Chile (2016b) *Desde el Cobre a la Innovación. Roadmap Tecnológico 2015-2035*. Fundación Chile. Santiago, Chile.
- Gore Antofagasta (2009) *Estrategia Regional de Desarrollo 2009-2020. Participa, Imagina, Construye*. Gobierno Regional de Antofagasta. Chile.
- Gore Atacama (2007) *Estrategia Regional de Desarrollo de Atacama 2007-2017*. Gobierno Regional de Atacama. Chile.
- Gore Tarapaca (2011) *Estrategia Regional de Desarrollo de Tarapacá 2011-2020*. Gobierno Regional de Tarapaca - PNUD. Chile.
- Hirschman, A. O. (1981) *Essays in trespassing: Economics to politics and beyond*. Cambridge University Press. London, UK.
- Humphreys, M., Sachs, J. D., & Stiglitz, J. E. (2007) “What is the problem with natural resource wealth? Escaping the resource curse”. In: Humphreys, M., Sachs, J. D., & Stiglitz, J. E. (eds.) *Escaping the resource curse*. New York: Columbia University.

- INE (2016) Estadísticas de la Situación en la Fuerza de Trabajo: Niveles y Tasas (online) <http://www.ine.cl/estadisticas/laborales/ene?categoria=Situación%20de%20Fuerza%20de%20Trabajo> (Accesed 30 may 2017)
- Korinek, J. (2013) “Mineral resource trade in Chile: contribution to Development and Policy Implications”. OECD Trade Policy Papers, No. 145. OECD Publishing.
- Lagos, G., & Blanco, E. (2010) “Mining and development in the region of Antofagasta”. *Resources Policy*, 35(4), 265-275.
- Lederman, D., & Maloney, W. F. (2007) “Trade Structure and Growth”. In: Lederman, D. & Maloney, W.F. (eds.) *Natural resources: Neither Curse nor Destiny*. Washington, D.C.: Stanford University Press and The World Bank, 15-39.
- Manzano, O. and Rigobon, R. (2007) “Resource Curse or Debt Overhang”. In: Lederman, D. & Maloney, W.F. (eds.) *Natural resources: Neither Curse nor Destiny*. Washington, D.C.: Stanford University Press and The World Bank, 41-70.
- Morris, M., Kaplinsky, R., & Kaplan, D. (2012) “One thing leads to another”—Commodities, linkages and industrial development. *Resources Policy*, 37(4), 408-416.
- Phaal, R., Farrukh, C. J., & Probert, D. R. (2001) “Characterisation of technology roadmaps: purpose and format”. In *Management of Engineering and Technology, 2001. PICMET'01*. Portland International Conference on (pp. 367-374). IEEE.
- Phaal, R., & Probert, D. (2009) *Technology roadmapping: facilitating collaborative research strategy*. University of Cambridge.
- Phelps, N. A. (2008) “Cluster or capture? Manufacturing foreign direct investment, external economies and agglomeration”. *Regional Studies*, 42(4), 457-473.
- Phelps, N. A., Atienza, M., & Arias, M. (2015) “Encore for the enclave: the changing nature of the industry enclave with illustrations from the mining industry in Chile”. *Economic Geography*, 91(2), 119-146.
- Pietrobelli and Maggi (2005) “Recomendaciones metodológicas para la elaboración de Planes de Mejoramiento de la Competitividad en Arranjos Productivos Locais (APL)”, Agorá 2000 for the Inter-American Development Bank, Washington, D.C.
- Porter, M. (1990) *The Competitive Advantage of Nations*. Free Press, New York.
- Prebisch, R. (1950) “*The Economic Development of Latin America and Its Principal Problems*”. Economic Bulletin for Latin America 7, NY: United Nations.
- Rivera, N., & Aroca, P. (2014) “Escalas de producción en economías mineras: El caso de Chile en su dimensión regional”. *EURE (Santiago)*, 40(121), 247-270.
- Rodríguez-Clare, A. (1996) “Multinationals, Linkages, and Economic Development.” *The American Economic Review*, vol. 86, no. 4, pp. 852–873.
- Sachs, J.D. and Warner, A.M. (1997) “Natural Resource Abundance and Economic Growth” in Meier G. & Rauch, J. (eds.) *Leading Issues in Economic Development*. Oxford: Oxford University Press.

- Sachs, J.D. and Warner, A.M. (2001) “Natural Resource Abundance and Economic Growth” in Meier G. & Rauch, J. (eds.) *Leading Issues in Economic Development*. Oxford: Oxford University Press.
- Scott-Kemmis, D. (2011) *Australian Story—The Formation of Australian Mining Technology Services and Equipment Suppliers*. A pilot study for the United States Studies Centre, University of Sydney. Sydney: the University of Sydney.
- Scott-Kemmis, D. (2013) How about those METS. *Leveraging Australia’s mining equipment, technology and services sector*. Minerals Council of Australia, Canberra.
- Sernageomin (2015) *Anuario de la Minería de Chile 2015*. Servicio Nacional de Geología y Minería. Santiago, Chile
- Singer, H. W. (1950) “The distribution of gains between investing and borrowing countries”. *The American Economic Review*, 40(2), 473-485.
- Storper, M. (1997) *The regional world: territorial development in a global economy*. Guilford Press.
- Urzúa, O. (2011) The emergence and development of knowledge intensive mining service suppliers in the late 20th century. 2013 (Doctoral dissertation—University of Sussex, United Kingdom)
- Urzúa, O. (2012) Emergence and development of knowledge-intensive mining services (KIMS) (No. 41). TUT Ragnar Nurkse School of Innovation and Governance.
- Ville, S., & Wicken, O. (2012) “The dynamics of resource-based economic development: evidence from Australia and Norway”. *Industrial and Corporate Change*, 22(5), 1341-1371.

Figure N°1. CORFO's associative programs



Source: Authors' elaboration based on strategic design of programs

Table N°1. Figures of the mining industry in Chilean regions

Region of Chile	Mining concessions (2015; % exploitations country)	Copper Production (2015; % of production)	Mining Exports (2016; % of copper exports)	Mining GDP (2015; % of regional GDP)	Mining Suppliers (2016; %)	Mining labor (Q4-2016)
Arica y Parinacota	1,9%	0,1%	0,0%	3,2%	0%	3.448
Tarapacá	12,6%	9,9%	8,7%	31,7%	1%	17.145
Antofagasta	36,9%	53,3%	61,7%	48,5%	13%	45.139
Atacama	22,8%	7,7%	3,6%	30,4%	2%	19.454
Coquimbo	10,2%	8,7%	8,9%	24,1%	2%	31.572
Valparaíso	3,9%	5,1%	17,1%	7,9%	8%	22.255
Metropolitana de Santiago	4,0%	6,9%	0,0%	1,7%	63%	19.328
Lib. Gral. Bernardo O'Higgins	1,9%	8,4%	0,0%	18,9%	6%	18.213
Maule	1,5%	0,0%	0,0%	1,9%	1%	1.764
Biobío	1,4%	0,0%	0,0%	0,0%	3%	10.304
La Araucanía	0,5%	0,0%	0,0%	0,0%	0%	1.531
Los Ríos	0,5%	0,0%	0,0%	0,0%	0%	231
Los Lagos	0,8%	0,0%	0,0%	0,0%	0%	796
Aysén del Gral C. Ibáñez del Campo	0,4%	0,0%	0,0%	1,6%	0%	1.167
Magallanes y de la Antártica Chilena	0,6%	0,0%	0,0%	4,7%	0%	3.721
Total	100%	100%	43,2%	8,8%	100%	196.069

Source: Sernageomin (2015), COCHILCO (2016b), INE (2016), Aduanas (2016), Fundación Chile (2016); Banco Central (2015)

Table N°2. Synthesis of the main elements in programs for the improvement of the competitive capacities of Miner Suppliers in Chile

Program	Period	Regional Approach	Production linkages observance (Hirschman, 1981)	Formal Impact Assessment
National Mining Cluster Program (CORFO)	2008 – 2014	No	Broad consideration, since this instance promoted initiatives to improve suppliers' capabilities in the supply of inputs for the mining industry.	No
World Class Mining Suppliers Program	2008 - 2014	No	The Program generates new links between selected mining suppliers and the Company through the provision of solutions that address its major challenges. This collaboration is formalized through a preferential commercialization agreement.	No
Alta Ley Program	Since 2015	No	This program inherited mechanisms and processes from the former World Class Mining Suppliers Program. The technological roadmap considers the development of knowledge intensive mining suppliers. Thus, coordination with CORFO and CONICYT targets improving the coordination of instruments to promote innovation and research initiatives related to the mining sector. In addition, the program considers generating public infrastructure to pilot innovation projects of mining suppliers.	No*
Regional Development Strategy in Mining Regions (strategy in force) - Tarapaca - Antofagasta - Atacama	2011-2020 2007-2017 2007-2017	Yes Yes No	Broad consideration, since strategies target coordinating public agencies that deliver policy tools for economic development and innovation of local firms. It appears as a referential framework for regional public bodies rather than for a private-public coordination for local firm development.	No Yes** No
PMC Mining Suppliers Region of Tarapaca	2010 – 2013	Yes	Broad consideration, since PMC D-TekTarpro targets coordinating public agencies that deliver policy tools for economic development and innovation of local suppliers.	No

PMC Mining Suppliers Region of Antofagasta	2010 – 2013	Yes	One of the proposed guidelines of the program was related to the strengthening of production linkages, primarily backward linkages. However, the scope of this action was oriented to provide support to local firms in their project's development.	No
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Source: Authors' elaboration based on strategic design of programs

* The program is in early stage of deployment.

** Instead, the assessment of results of the strategic guidelines of the previous strategy (2001-2007) is conducted, observing the amount of regional resources allocated from the National Fund for Regional Development (FNDR).