

Knowledge Intensive Mining Services in Chile

Challenges and Opportunities for Future Development

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Abstract

The mining industry in Chile is currently facing a set of challenges that need to be addressed to remain competitive in the global economy. These are related to a more efficient use of basic resources such as water and energy (due to increasing costs), better treatment of waste, the need to drill deeper to get to new deposits, lower ore grades, among other challenges. Given the tendency toward vertical disintegration and the high operational costs the industry is currently facing, innovative solutions addressing these challenges are not expected to be internally provided by the lead mining firms. This, consequently, opens up new opportunities for local suppliers. The question is if local suppliers have the capabilities required to exploit these opportunities. This study aims at understanding the factors and drivers that enable the development of local innovative suppliers to the Chilean mining industry that have the potential to positively impact lead mining companies' performance through the provision of upgraded and/or knowledge intensive services.

JEL Codes: O13, O2, O3, Q3

Keywords: Chile, development, innovation, mining

Introduction

Chilean mining industry is facing important challenges stressing the need of finding opportunities to keep the relative advanced position in global production. For this purpose to increase the total factor productivity is a key challenge. Moreover, sectoral discussions about efforts oriented to reinforce the industry global leading position are focused on the actual geological conditions of mines, due to the progressive lower ore grades; the accessibility to human capital, since skilled employees are needed and labor costs are rising; the shortage of key resources provision, since there are decreasing levels to access to water resources for mineral treatment processes coupled with the permanent conflict that the consumptive use of water have with local communities and producers; the need for energy provision alternatives, since energy costs are increasing; the major concern to strengthen the relationship between mining companies and local communities, due increasing environmental awareness; and last but not least the innovation as a way to achieve positive impacts on industry productivity, which is particularly relevant considering that current R&D and innovation investment in Chile is the lowest among OECD countries.

In this vein, the attention to providers of goods and services to the mining industry is seen as an opportunity to establish strategies for learning and knowledge accumulation oriented to the provision of contextualized technologies and innovations aimed at upgrading the Chilean mining competitiveness. Interventions to upgrade the technological capacity and the innovation performance of local suppliers are at the base of facilitating new industrial dynamics where providers can create new or enhanced knowledge intensive solutions that answer the Chilean mining industry major problems. In this regard, the progressive escalation and exports of new solutions produced by local suppliers will be to the extent to which those innovations succeed in responding to the industry major productivity issues.

Thus, providers to the mining industry are important actors to sustain the sectoral and regional development –where they are located or develop their service provision- but also they are one of the drivers to become a natural resources-based intensive knowledge economy. There are examples of countries that have overcome the resource curse effect and lead to path of sustained development and growth. For instance, comparing the mining industry between Australia and Chile one can notice how the local context of the economy, the abundance and quality of natural resources can shape the industrial development and the evolution of economic actors across the time. At the end, as stated by Urzua (2011) and Fundación Chile (2014), those countries have grown through different trajectories where one became a world leader in the provision of technology and related knowledge-based services, while the other grow into a world leader in production supported on a weak industrial fabric of related services or local development of solutions for a demanding economic activity.

Nowadays, Chilean mining sector accounts for more than 12% of the national GDP in 2013 and peaked at 21% in 2001. Complementarily, as projected mining investments in copper will lead direct investment for the period 2013-2017 -accounting for more than US\$

50 billion- including CODELCO, then new prospects for related services and labor demand are appearing in the local industry (COCHILCO, 2013). Indeed, mining companies are progressively focusing more on their core business by delegating what is not strategic to third parties, using outsourcing arrangements, which creates new business opportunities for suppliers. About, 60% of the operating cost in mining companies is related to the purchase of goods and services to providers (FCh, 2014). Then, technological capacities of local mining suppliers of services are crucial in determining the quality of supplies and services provided contributing to improve the productivity and competitiveness of the mining industry as a whole.

Due to the constraints that the mining industry is facing -like the progressive lower ore grades and shortages of water accessibility and energy provision- the sectoral investment on technology and innovation seems to have a double effect. On one side, providers will have more incentives to offer consistent services based on new knowledge, suited or enhanced technologies and innovative solutions aimed at improving the productivity, efficiency and quality of processes and products of the mining industry. On the other hand, the industry will be benefited by strengthening productive linkages across several stages of the value chain as the “mining multiplier effect” (Korinek, 2013), highlighting the progressive expansion of the sector and its effect in the Chilean economy. Then, as the industry is improving its performance and accomplishing its investments, there is more room for incubation, development and consolidation of better products and services buttressed on sophisticated providers.

This prospective viewpoint for improving the suppliers’ capabilities have led to major mining companies in Chile to run interventions. For instance, the World Class Suppliers Program, designed by BHP Billiton in Chile, and currently jointly implemented by BHP and Codelco, is one of the major examples of an effective outcome of a public-private partnership with clear goals and scope in supporting the transition of local suppliers upgrading. The program seeks that providers strengthen their ability to produce and export knowledge-intensive services and technologies to related economic sectors, both locally and globally. The goal is achieving 250 world-class suppliers by 2020.

Consequently, it is necessary to understand factors and drivers that define the innovative experience of providers to the mining industry in Chile, since these firms might have positive impacts on mining companies’ performance through the provision of upgraded and/or knowledge intensive services. Taking this into account, this note is structured in five sections. The first part is focused on the characterization of the suppliers to the mining industry in Chile. It aims at describing their internal composition, geographical distribution, contribution to labor and employment, among other features. The second part, will address key features of selected firms that support the case study analysis presented later. Part three describes the factors that enable or hinder innovation performance of providers to the mining industry, structured upon the information and experience of firms –cases of study- in providing solutions and faced the industry response to build bonding opportunities and linkages for better performance. The section four present a discussion

that contextualize the path of innovation development of Chilean suppliers considering the industrial organization and the institutional setting that provides the World Class Suppliers Program. The last section, presents concluding remarks regarded to main topics and learning derived from the analysis. Therefore, the above-mentioned sections are organized to address research questions such as:

- Which is the starting point and key characteristics of the suppliers of services within the mining industry in Chile?
- Is the local context a determinant for path development of the providers of services defining specific assets or limits to innovation?
- Is it vertical disintegration in natural resources sectors an opportunity for local innovation?
- Is it the industrial organization of the natural resources industries key determinant of innovation activity in firms?
- Are particular successful public policies targeted to foster innovation aligned with the industrial organization of the natural resources industries?
- Does the World Class Mining Suppliers Program bring effective support to innovation in mining in Chile?
- Are conceptual market failures effectively addressed by this program?
- What are other innovative paths followed by KIMS firms?
- What are major determinants and obstacles for innovation in KIMS in Chile?

Key characteristics of Chilean Mining suppliers of services

Mining industry, as one of the major sector in Chile, accounts for an important economic dynamic both locally and globally. Indeed, Chile represents one third of the global production of copper, mining industry account for 12% of the national GDP, and nearly 60% of the total exports of Chile are explained by mining, and about 50% of the mining suppliers sold more than US\$ 1 million, in 2012 (Salas, 2014; FCh, 2014). Nevertheless, this general picture of the sector does not represent the internal composition of the suppliers of services, as key agents of the mining industry growth. Suppliers' characterizations carried out in Chile highlight firms' differences considering aspects like their geographic distribution along the country, size –based on the number of employees– sales volume, export share, labor qualification, innovation capabilities of firms, among other variables (DICTUC, 2007; IPSOS, 2009; FCh, 2012; FCh, 2014).

Correspondingly, this document considers the definition of suppliers stated by Fundación Chile (FCh, 2014), where *“firms mining suppliers to all those productive units that sell goods and services to mining companies; including contractors, suppliers of goods and supplies, services and consulting suppliers -in topics like security, transport, travel, health, safety, etc”*. Thus, the review of key characteristics and issues related to Chilean mining suppliers of services is addressed upon this definition, that allow the comparison and evolution of suppliers since late 2000s up to date.

Since 2007, formal mining suppliers' characterization studies in Chile are based on a progressive and deepening understanding of firms, its geographical distribution and sectoral composition. The main structure of those studies is upon a probabilistic design, based on a stratified sampling according to firms' size and sector participation –along the range of services provided- that would represent the universe of suppliers to mining companies. Information is obtained from major databases with registry of mining suppliers, such as Achilles. Based on that information, suppliers characterization studies classify firms' size accordingly to its number of workers, where:

- Micro-enterprise: between 1 up to 9 employees.
- Small-sized firm: between 10 up to 49 employees
- Medium-sized firm: between 50 up to 199 employees
- Large firm: more than 200 employees.

Then, defined firms categories are consistent with those described on the SMEs Statute used in the Chilean legislation. This preliminary typology of firms is methodologically helpful in studies of characterization, since it facilitates the sampling design considering each size segment and the main differentiation of suppliers across defined standards. Those standards group several firm capabilities, like (1) enabling capabilities –organization management: planning, finance control, IT, etc.-; (2) management systems capabilities related to Health, Safety, Environment and Community (HSEC); (3) strategic management capabilities; (4) innovation capabilities; among other issues (FCh 2012, 2014).

Current characteristics of Chilean mining suppliers

The number of mining suppliers has been increasing from 3.443 firms in 2007 up to 5.998 firms in 2012 (FCh, 2012; 2014). Considering two periods, 2007-2009 and 2010-2012, the former accounts for a 35% of increase, while the latter explains a 29% of growth in the number of providers for the mining industry. Accordingly, the internal composition shows that medium-sized and large firms are increasingly relevant, with a participation of 27% and 34% of mining suppliers, in 2010 and 2012 respectively. On the other hand, micro-enterprises and small-sized firms group around 65% of mining suppliers.

Services provided by mining suppliers show that there are two major drivers for business – that explain about 30% of services supplied, each. Those are Equipment and Supplies – like building and structures, pumps and pipes, electrical equipment, software, among others-, and Services of Support –transport of personnel and travel, monitoring services, health and safety, legal and financial services, etc. Similarly, contractors provide about 25% of services like maintenance, catering, communication and telecommunication, IT services, among others. Lastly, engineering and consultancy, mostly related to knowledge intensive services -management and finance, mine planning, environment and personal services, etc- explain about 10% of business among suppliers (FCh, 2012; 2014).

Business development shows an increasing creation of SMEs due to the demand of mining companies. Indeed, current suppliers firms tend to be about 15 years old, on average. However, 20% of firms started their commercial activities 5 years ago and they

are micro-enterprises and small-sized firms, mainly. By contrast, 24% of suppliers run their business for more than 20 years, which are predominantly medium and large-sized firms. Thus, since 2010, sectoral growth of mining services shows a growing incorporation of smaller firms. Also, near the 50% of recently created firms (less than 5 years) develop their business providing services mainly to mining companies, so they show a narrow portfolio of services oriented to other sectors of activities.

In comparison, the development of the mining sector in Australia accounts for more than US\$ 71 billion in sales in the year 2012. Indeed, between 1990 and 2004, this sector explained about 5% of the Australian GDP surpassing the 8% by 2011. The mineral exports were US\$ 138 billion in 2009-10 explaining about the 50% of the total country's exports of goods and services. This Australian industrial dynamic is supported, mainly by the Mining, Equipment, Technology and Services sector (METS), which encompasses between 1.200 to 1.500 firms in Australia. A recent survey conducted to METS¹ sector shows that it is structured by small-sized firms (at least 40% of them have less than 10 employees and 7% of them have more than 300 workers). Firms' property is mainly Australian -84% of the total- while foreign providers represents 16% of firms. These providers take part in segments like equipment manufacture and supply –like electronic and heavy machinery for exploration- Specialist technology and related service supply – like technologies for exploration, mineral processing, mine communication, etc- and consulting services –like geological an geotechnical assessment, environmental management, among others. Australian METS employs more than 386.000 workers (Scott-Kemmis, 2011, 2013, 2014; Cutler, 2012; Satchwell, 2013; Austmine, 2013).

In Chile, the geographical distribution of mining suppliers shows high degree of concentration in the Metropolitan Region of Santiago, despite an apparent reduction in the number of firms between 2010 and 2012. Currently, 62% of mining suppliers are located in Santiago. While, 23% of firms are located in the mining regions (Tarapaca, Antofagasta and Atacama). Antofagasta, concentrates 12% of mining suppliers. In this vein, the advantage of closeness to services networks and supply chain coupled with the accessibility to skilled labor and land prices could be at the base of explanations of the number of suppliers located in Santiago by contrast of mining regions. In addition, comparing years of service provision and sales between suppliers established in mining regions and in non-mining regions –mainly Santiago- there are evident differences. The former shows that suppliers with headquarters in mining regions developed their business 10 years ago -on average- but those on non-mining regions did the same 19 years ago. The latter, shows that suppliers located in mining regions provide their services, on average, since 9 years ago, which is lower than the 13 years showed by suppliers established in non-mining regions.

Accordingly, sales is one of suppliers' characteristics which is difficult to keep track, because studies display different references, like rate of growth, sales in US dollars or sales in relation to the firm's size en Chile –defined in terms of volume of annual sales.

¹ This survey was developed between December 2012 and February 2013. Among the estimated number of METS it was responded by 860 firms. So, all number presented here are referred to this total.

Notwithstanding, between 2007 and 2012, at least 44% of mining suppliers sold less than US\$ 1 million annually. In this situation is classified Micro and Small-sized suppliers. In 2010, medium-sized (US\$ 1million and US\$ 4million of sales) and large firms (more than US\$ 4million of sales) participate with 21% and 35% of suppliers, respectively. Those numbers are interesting too when they are compared to the firms' distribution by size within the country, since Micro and Small-sized Chilean firms represents 96% of businesses, while the medium and large sized firms participate with 3% and 1%, respectively.

Mining suppliers' distribution by firms' size shows a relative compensated allocation within the extremes² –small and large sized firms–, where it seems that all firms have room to provide services for the mining industry. Indeed, in general terms, 87% of mining suppliers presented an increase in their sales, between 2010 and 2012. Complementary, the establishment of new entrants –since 2010– is a sign of sectoral dynamism and an evidence of growth opportunities within the industry; considering its current challenges and the projected investments for next years.

By contrast, the Australian case shows that 77% of METS are located in three states – Western Australia, Queensland and New South Wales– mainly close to major cities of the country. The distribution of METS among service segment explains the 33% of firms supplying equipment and machinery –with 38% of METS sales. Consulting services group the 33% of firms and the 16% of sales, while Technology and Applications is provided by 25% of firms and explain 23% of sales. However, 10% of METS delivers Contract Services accounting, which may imply that there are some large firms in this segment. According to the firm size, about 30% METS show sales below to US\$ 1million, but 24% have sales above US\$ 10 million per year. Statistics comparing the level of sales of 2006-07 and 2008-09 show the increase of sales of firms with more than US\$ 2million on average per year (Scott-Kemmis, 2011; 2013; 2014; Satchwell, 2013).

The demand for labor force of Chilean suppliers to the mining industry depicts an increase of direct employment reaching 1 million of direct jobs, which represents 13,3% of the occupied workforce of the country. Between, 2010 and 2012, there is a 43% of growth of the employment within the mining suppliers. Distinguishing by size –considering the number of employees–, large firms represent 81% of sectoral employment; medium-sized firms participate with 14% and small-sized and micro-enterprises represents 1% and 5%, respectively. Distribution by sector shows that 52% of workforce develops supporting services, 25% participate in contractors activities, 18% provide equipment and supplies, while the remaining 4% of labor force supply services in engineering and consulting. Those figures are consistent with the increase of labor evidenced by mining suppliers since 2009. In fact, 60% of firms seen the rise in the number of employees, especially in engineering and consulting. Thus, this is evidence of the relative importance that mining suppliers have for national economy.

² This fact contrast with the national distribution of firms where SMEs concentrate the majority of productive units in Chile.

Something interesting to bear in mind is the formal qualification of employees of mining suppliers firms, due to the growing importance of professionals versus technicians employed by firms. Indeed, professionals represents about the 20% of labor within mining suppliers, while technician saw a rapid rise in the number of direct jobs between 2010 and 2012, which resulted in the current 27% of occupations. Accounting for the level of professionalization of mining suppliers by size exhibits that micro and small-sized firms group the 42% and 35% of professionals, respectively, while large firms concentrates 16% of professionals. Consistently, major professionals allocation is in services related to engineering and consulting, while supporting activities attracted about 5% of employees with high levels of formal qualifications, between 2010 and 2012, showing a clear difference among services amid those more knowledge intensive and those less intensive in skilled labor.

This contrast in the demand for professionals along services provided by firms making evident the potential for suppliers' development and innovation. Even more evident, the number of professionals that work for suppliers are less –in number- than those that do so for the mining companies. Then, this situation imposes challenges to suppliers, so to reduce institutional and knowledge distances in their path of development.

Exports participation of mining suppliers shows increasing figures between 2007 and 2012. Indeed, 27% of firms experienced international business in 2007, while in 2012 there were 34% of suppliers with exporting capacity. Currently, 65% of foreign sales go to any link within the mining global value chain and the remaining 35% go to other industries round the globe. Although the participation of Chilean mining suppliers has been increasing, the level of exports is quite far from levels reached in developed countries. I.e. in Australia 75% of mining suppliers are exporters. Then, there is a great extent for business development of Chilean firms (FCh, 2012; 2014; Korinek, 2013).

Explanations related to the exports participation of local suppliers point an indirect relationship between the level of internal sales and the volume of international trade. Indeed, firms with a volume of domestic sales above their sectoral average are less eager to export than those with internal sales below the average. Also, international sales of exporter suppliers represents a marginal revenue of its total sales –between 1% and 10%- compared with sales that these firms perform within the domestic mining industry (FCh, 2012; 2014). Then, it might be related to the high level of development of the Chilean mining industry in last years, where many suppliers have increased their local business participation in response to the domestic demand of goods and services.

In Australia, METS are usually established by entrepreneurs from the mining industry or from firms that supply goods and services to the industry. Frequently, they are engineers or technicians of the industry, where at least 1 out of 3 has related industrial experience and about 20% of them come from related research organizations. Upon this profile, firms develop R&D activities as its main business orientation of services. In fact, *“in 2008-9 almost 75% of METS firms claimed to be carrying out some form of R&D and 15% were investing over \$1m per annum”* (Scott-Kemmis, 2011:50).

Among Australian service segments, the Technology and Applications doubled the amount of R&D investment of the Equipment and Machinery or the Consulting Services segments, with US\$ 530millions and US\$ 240millions or US\$ 200millions, respectively. With these figures, the segment of Technology constitutes one of the most dynamic service sector. Exports seem to be growing promptly since the 2000s. Indeed, some export estimations for the top 100 Australian METS firms surpassed \$ 6billion in 2010. Comparing service segments, Consulting Services show the highest level of export dynamics, whereas the Contract Services show the opposite situation. Equipment and Machinery accounted for the 40% of export share in 2008-9 –the highest among METS. Major markets for Australian mining services provision are Africa (16%), Indonesia (15%), and North America (15%) (Scott-Kemmis, 2011, 2013, 2014; Cutler, 2012; Satchwell, 2013; Austmine, 2013).

Patenting experience within the mining industry and its suppliers

Mining industry in Chile has been continually investing in patenting newly developed solutions. In fact, between 2000 and 2014, there are 2.069 patents documents locally presented by several actors involved along the value chain of the Chilean mining cluster. Interestingly, within the mining cluster the range of patents requirements from local residents reach the 34% of the total, which is high considering the annual average of requirements from local residents considering all sectors of the economy, defined in 10% of the total. Some figures that highlight this topic are³:

- Seven countries explain the 80% of patents documents. Those initiatives come from Chile, United States (USA), Australia, Finland, Germany, South Africa and Japan. In this context, Chile lead the local ranking of mining patents requirements, in a range of 31 countries. Between 2000 and 2010, Chile represents about 41,4%, Finland 11,5% and USA 10,8% of the total of presented documents related to the mining sector.
- Patents presented by solicitants can be classified in 15 thematic fields. The major fields are related to lixiviation, melting and blasting processes. While less required areas are subproduct, general and exploration. Figures show that both Electrometallurgy and Hidro-metallurgy explain more than a half of patent initiatives of Chilean firms, with 25% and 20% of presented documents, respectively.
- Patents initiatives, during this period, are concentrated in four thematic areas, like Hidro-Metallurgy (19%), Electrometallurgy (16%), Transport (11%) and Exploitation (11%). Between 2010 and 2014, the area of Transport has experienced the major growth of patent initiatives in Chile.
- Distinguishing by origin, the three main areas where local residents apply for patents are lixiviation, crushing and grinding, and melting. In its turn, non-resident solicitants apply patents for lixiviation, thunder and melting.

³ For further details related to methodology, thematic areas of classification and analysis please refer to INAPI (2010).

Accordingly to thematic analysis of INAPI (2010 and 2014), in Chile, major patents requirements are related to 13 out of 15 identified thematic fields. Those documents are regarded to extraction, crushing and grinding, flotation, lixiviation, extraction by solvents, melting, electrowining (EW), electrorefining (ER), ER/EW, subproduct, loading and transport, general field and environment. In this line, patents presented along the value chain and that represents 50% or more in each thematic field are related to general components, extraction by solvents, crushing and grinding, ER/EW, electrowinning and environment.

Related to this, distinguishing by solicitants, it is interesting to take into account the extent to which stakeholders take part in patenting process:

- From the perspective of firms, local firms lead the patent applications with 63,2% of the total, while particular applications explain the 30,3% and local universities represents the 6,5% of requirements, between 2000 and 2010.
- Complementary, foreign-owned firms also have an important participation in patents initiatives in specialized areas of the mining industry. Indeed, Outokumpu OYJ –from Finland- explain about 7,2% of applications, mainly focused on Pyrometallurgy, Concentrates, Electrometallurgy and Hidro-metallurgy; while, Orica Explosives Technology PTY Ltd –from Australia- represents 3% of patent applications focused on Thunder processes.
- The local mining company Codelco explain about 9,74% of patent applications in this period. Codelco, Outokumpu and Orica, represent about 20% of the total patent applications in Chilean mining industry during the analyzed period.
- Local mining companies that have conducted patents initiatives are Codelco –with 188 patent initiatives, where 32 are Codelco's own initiatives and 86 joint initiatives⁵-, New Thec Copper S.A. -with 13 documents-, Biosigma –with 12 documents- MI Robotics Solutions –with 11 documents. Mining companies that have presented less than 10 patent documents are HighService Ltd, Minera Los Pelambres, Cerro Colorado Mining Company, Barrick Chile Mining Company Ltd, and Minera Michilla.
- Patents related to local universities correspond to –hierarchically presented- University of Chile with eight documents, Technical University Federico Santa María and University of Concepción –both with 7 documents. In addition, University of Santiago, Catholic University of the North and Pontifical Catholic University of Chile take part of this group, with less than four presented patents.

Similarly, patents linked to the mining sector in Australia shows that between 1994 and 2011 there were 6.539 inventions filed –grouped in patent families. This is a sharp trend ranging from 97 application in 1994 to about 830 filings in 2011. Actors involved in this process have the METS sector as keystone with 75,5% of the total, while the operating miners and the public bodies represent the 13,2% and the 11,3% of patents applications

⁴ This figure considers both CODELCO's own patent application process and joint initiatives with the Institute for Innovation in Mining and Metallurgy.

⁵ These 86 joint initiatives distinguish 75 presented documents with the Institute for the Innovation in Mining and Metallurgy, 7 joint initiatives with local universities and 4 presented documents with related firms.

during the period, respectively. Regarded to the focus of the innovative effort, it seems that each actor play a specific role along the value chain. Indeed, the operating miners display efforts on new methods for processing ore, like refining and the production of iron and steel. In its turn, public bodies are focused on researching material's properties, its separation through evaporation and data processing. While, METS sector apply patents in dredging and soil shifting equipments, gearing systems, electric appliances, and so forth (Francis, 2015).

METS involved in patent related to key processes like dredging and soil shifting equipments are the Japanese firms Komatsu and Hitachi construction and machinery. Distinguishing the origin of patent applications Japan and Germany both comprise the 30% of the total, while Australian explain about the 8% of the filing documents. Among, main Australian applicants the Australian Government and CSIRO, Rio Tinto Alcan International and The University of Queensland explain the 78% of the country's patents of the mining industry. Considering the possible export of innovations⁶ United States, Canada, China, Japan and Europe are the main regions where METS aims to commercialize their innovations. In Latin America, Mexico and Brazil are the main markets for Australian innovations (Francis, 2015)

In sum, since the early 2000s, Chilean mining industry and its suppliers present figures of improvements in the number of local suppliers, the participation of SMEs within the service provision, the volume of sales both internally and externally the country, the participation of direct employment, the level of professionalization within suppliers, and the rise in patenting initiatives, ultimately. However, there is a sort of structural geographical concentration of mining suppliers in Santiago Metropolitan Area, rather in the so called mining regions, due essentially to better accessibility to skilled workers and closeness to related services along the mining value chain. This regional distribution of firms enlighten the growing and locational potential of service suppliers in Chile considering mining investments projections by 2020. This potential coupled with challenges that the industry is facing are two arguments to sustain suppliers' innovation upgrading interventions.

Innovation capabilities of suppliers of services in mining.

Providers of goods and services to the mining industry in Chile are recently introducing solutions and enhanced services to respond to mining companies requirements. Indeed, the path of development and innovation of local mining suppliers is understood considering the evolution in mining companies' ownership and the impulse within the industry when more and progressively complex services were demanded.

From an evolutionary perspective, one can distinguish that at early stage of development foreign owned corporations did not influence the innovation or technological catching-up among local suppliers of services. However, this situation was different since the 1970s,

⁶ It is estimated as the election of applicants for foreign prosecution, like "those countries in which the applicant seeks protection and (...) use this as an indication for the markets to which they are likely to export" (Francis, 2015)

due to the change of ownership of mining companies from foreign companies to national property. In Chile, this process is known as the nationalization of the mining sector, mainly for the copper exploitation. This transformation of the industrial picture suggested incentives and expectations for local suppliers in linking with the state-owned firm – CODELCO- that could be the cornerstone for knowledge accumulation processes in Chile. In this regard, CODELCO's vertical disintegration –during the 1980's- allowed to local suppliers take part in the provision of solutions related to engineering and productive issues allowing the development of its initial technological capabilities.

Notwithstanding the progress of local suppliers, they were not able to compete with foreign-owned firms. Actually, foreign providers from developed countries with technological capabilities based on their accumulated knowledge play against the competitiveness of local suppliers. Then, foreign providers achieve -to great extent- regular business relationships with mining companies. However, some changes are evidenced in Chile from these days where some interventions are aimed at improving local providers' innovation and development capabilities, like the Supplier Development Program (PDP from CORFO) and the World-Class Suppliers Program exclusive for mining sector currently run by BHP Billiton and CODELCO.

Topical characterizations of Chilean mining suppliers of services (FCh, 2012; 2014) showed that self-declared innovation initiatives are at higher rates of innovation than those of the mining industry and other industries performance within the country. In fact, as shown in table N°1, mining suppliers enhance their products and the organizational management of provided services, so to respond to increasing demands from mining corporations.

Table N°1

Innovation experiences in the national industry, mining industry and mining suppliers.

Type of Innovation	2012			2014		
	Firms	Mining sector	Mining Suppliers	Firms	Mining sector	Mining Suppliers
Products	9,0%	7,1%	50%	11,6%	11,7%	60%
Process	10,7%	23,2%	39%	15,6%	35,0%	41%
Organizational	10,5%	23,2%	36%	13,8%	26,7%	51%
Marketing	8,1%	5,4%	14%	10,0%	10,0%	31%

Source: Adapted from FCh (2012; 2014) and MINECON (2012; 2014)

As mentioned above, the rise in the number of professionals and technicians among providers accounts for the innovative potential of firms, as the mining industry can be a source of technological development where the learning process play a crucial role (Urzua, 2011). Therefore, upgrading processes are based on firms' internal sources for innovation, the existence of specialized consultants, competitors and locally based Universities. In a sum, despite the difficult environment to develop solutions and achieve regular business dynamics with mining corporations, mining suppliers show better performance related to innovation investment compared to the national and mining industry, more recently.

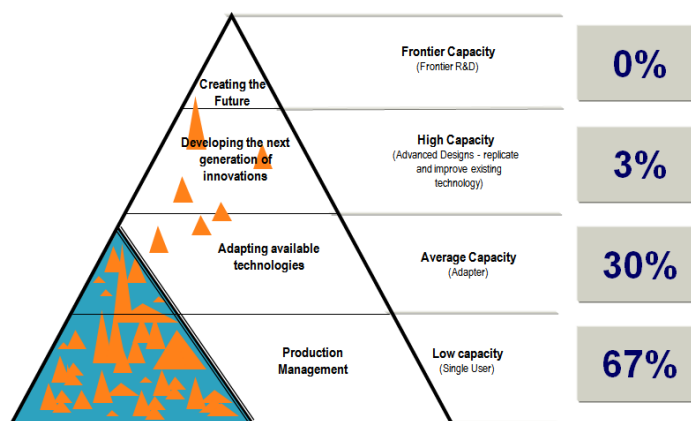
Typologies of mining suppliers' innovative capacity.

Since mid-2000s, there is an increasing interest to understand which are the main characteristics, sectoral dynamics and technological capabilities of Chilean providers to the mining industry. From that time, several studies defined strategies to explain major figures and facts of suppliers. In this vein, there are three ways to understand the innovation process among Chilean mining Suppliers. Those methodologies are the distinction of Technological capabilities of mining suppliers (Dictuc, 2007 and Innova, 2009); the Suppliers Segmentation, according to their innovative capacity (Fundación Chile, 2014); and the Knowledge Intensive Mining Suppliers –KIMS (Urzua, 2011) definition and distinction that take into account the local context of the industry and the national development.

a) Technological capabilities of mining suppliers:

Several studies regarded to the local development of the Chilean industry establish that the future of mining business requires a greater participation of technology and knowledge management to strengthen its competitive advantages (Cochilco, 2009a; 2009b; Salas, 2013; CSiro, 2014; FCh, 2014). However, local suppliers are not able to meet these challenges, especially in light of their limited learning and innovation capabilities (Urzua, 2007). Indeed, 97% of mining suppliers can be classified as average or low capacity in the use of technology. Thus, as depicted in the figure N°1, most local suppliers operate in a context of production management and adaptation of available technologies, without achieving benefits derived from the adaptation of available technologies.

Figure N°1. Innovative capabilities of mining suppliers in Chile



Source: InnovaChile, 2009

Consistently, only 3% of firms show advanced conditions that facilitate the development of innovation processes and/or the advanced design to improve existing technology.

Furthermore, there are no local suppliers whose activity is focused on expanding the knowledge frontier in mining, as seen in the figure below. In a sum, the vast majority of Chilean mining suppliers tend to be less capable to develop new knowledge or innovations in their business, so to have positive effects on the mining industry and its value chain.

These facts are related to the lack of conditions of local suppliers in create new knowledge, basically, because the weak knowledge accumulation in previous stages of the mining development and due to the high level of competitiveness of foreign suppliers, which have a negative effect in the accessibility to new business for local supplier.

Strengthening of innovative capabilities of local suppliers should enable them to develop skills aimed at reducing the existence of vulnerable conditions to the fluctuations in copper prices and local investment cycles. In fact, suppliers have the opportunity to leverage the significant investments made by the global mining industry in various projects, mainly in South America. In Chile, the projection of mining investments coupled with the significant presence of global mining companies in the country, could be translated as an advantage in situ for global demand for goods and services. Besides, as the industry is focusing on their core business, it relies on outsourcing mechanisms to delegate support processes. This industry trend becomes an important opportunity for local suppliers with technological capacities able to gain and offer outsourceable activities for mining companies.

b) **Suppliers segmentation**

This segmentation was defined to gain a better understanding of providers for the mining industry and their potential to develop innovations. The distinction of suppliers developed by Fundación Chile (FCh, 2014) was done upon five variables, such as the type of technological innovation developed in the year 2012 (product and/or process), the type of non-technological developed in the year 2012 (organizational and/ or marketing), the pro-innovation culture (measured on a scale from 1 to 5), the intra-firm existence of Policies and Practices to develop innovations, and Technological capacity (distinguishing between “with” or “without” capacity). When the model was run four group were identified:

- **Essential innovators:** In this category, innovation is part of the business essence of suppliers, so providers present the best internal condition to develop innovation. It represents to 25% of providers. Suppliers of this category show substantial technological capabilities to improve and/or develop technologies or equipment.
- **Experimental Innovators:** firms with technological capabilities to develop or adapt new technologies. Innovations are mainly focused on products and processes. It represents to 20% of providers.
- **Commercial Innovators:** firms that do not possess technological capabilities to develop new solutions and/or equipment. Innovation is mainly focused on marketing and/or Organizational management. It represents to 32% of providers.

- **Skeptical Innovators:** firms that do not have capabilities to develop technologies and/or equipment. Innovations are developed as a mean to keep a market presence. It represents to 23% of providers.

Accordingly, once segments are established, then measures of labor, sales and exports were developed. Table N°2 show the performance of providers.

Table N°2

Suppliers' segmentation according to their innovation capacity and performance distinction.

Typology	Technological Innovation	Non-Technological Innovation	Pro-Innovation Culture	Policies and Practices	Suppliers (%)	Exporters (%)	Sales (% of rising)	Labor (% of rising)
Essential	100%	100%	4,2	3,7	25%	50%	95%	65%
Experimental	71%	12%	4,0	3,2	20%	20%	82%	68%
Commercial	47%	100%	3,5	3,3	32%	32%	94%	66%
Skeptical	53%	0%	3,6	3,1	23%	23%	82%	40%

Source: Adapted from Fundacion Chile (2014)

In relative terms, providers that exports show significant levels of productive development rather than those that did not sold abroad. This is particularly important considering variables like policies and practices to develop innovation, and networks and knowledge management. Something interesting is the two-way effect due to the link between innovation and exports. In this regard, innovation could induce firms to be better equipped to export, but it is also true that greater levels of economic integration at global level may strengthen the innovative capacity of firms, since they can access to new knowledge not available within the internal market (FCh, 2014).

- **Essential innovators:** developed innovation in the four types of innovation (Product, Process, Organizational and Marketing). In addition, they have developed the best intra-firm conditions to support and develop innovations. This kind of innovators show the highest rates of exports, sales and labor; as a direct effect of firm's setting to generate new or enhanced solutions.
- **Experimental Innovators:** they develop innovations focused on Products and Processes, but they have weak experience innovating on marketing and organizational improvements. This segment of innovators show the lowest rate of export, but they have an interesting share of sales and labor.
- **Commercial Innovators:** innovations developed converge to marketing and organizational issues. With very low rates of technological innovations, this segment show low rates of increasing in exports and labor, but an interesting economic performance of sales.
- **Skeptical Innovators:** this category show the lowest level of innovation development. The few innovations implemented scoped to Products and Processes, but this kind of suppliers have no experience developing solutions in marketing and organizational aspects. They present low levels of exports and labor, but high levels of sales.

c) **Knowledge Intensive Mining Suppliers –KIMS.**

This segmentation is referred to the group of providers which services are strongly based on their knowledge. Usually, these providers have a path of sectoral development that allowed them to accumulate related knowledge and experiences developing suited answers to the industry requirements and challenges. Knowledge Intensive Mining Suppliers (KIMS) may be broadly classified into two main categories distinguishing services related to mining industry processes (Urzúa, 2012). As shown in table N°3, there are several examples of Products and Services offered by providers, where KIMS are related mainly to engineering and consultancy services.

Table N°3

Stylized services provided by Mining Suppliers

Services provided	Categories of Suppliers and Examples of Product and Services			
	Knowledge-intensive services (KIMS) Consultants	Specialized Services Contractors	Capital Goods and Equipment Suppliers	Consumable Inputs Suppliers
Services and goods mainly for investments projects	<ul style="list-style-type: none"> - Exploration services - Investment project management - Engineering services such as mine planning, process design, and metallurgy engineering - Mine closure, reclamation and remediation design 	<ul style="list-style-type: none"> - Development and construction services - Tunneling services - Shaft sinking - Drilling services - Sampling services 	<ul style="list-style-type: none"> - Heavy machinery and equipment such as: mills, crushers, and smelting equipment 	
Services and goods mainly for ongoing operation	<ul style="list-style-type: none"> - Mine automation and optimization - Blasting engineering - Equipment design and adapting - Equipment maintenance and repairing - Geological testing - Metallurgical analysis 	<ul style="list-style-type: none"> - Drilling services - Shaft sinking - Laboratory Services - Mineral handling contractors - Education and training - Mineral processing - Environment monitoring - Tailing dam operating 	<ul style="list-style-type: none"> - Light machinery and equipment - Replacements - Drilling equipment - Conveyors - Ventilation equipment - Excavators - Electronic equipment - Engines and generators - Trucks 	<ul style="list-style-type: none"> - Explosives and blasting accessories - Chemical products - Abrasives - Acids - Drill bits - Tires

Source: Urzúa (2012)

Chilean providers to the mining industry have a distinctive path of development of their technological and innovation capabilities. Historical reviews of the process of related knowledge accumulation enlighten key drivers that have allowed their service development. Particularly interesting is taking to account the extent to what the high ore grades, the lack of a consistent mineral exploitation of the local industry and the ownership of mines implied for the accumulation of local capacities in providers to develop more

context-suited solutions for local mining. In this vein, table N°4 resume central ideas in comparing the evolution of capacities of KIMS sector worldwide and the process experienced by local suppliers.

Table N°4

The emergence and consolidation of Knowledge Intensive Mining Suppliers (KIMS) in Chile

Period	International KIMS Sector	National Mining Industry	Chilean KIMS experience
Gestation (around 1940s – 1970s)	Local mining production expansion, with high growth rates. KIMS vertically integrated within mining companies.	Industry dominated by copper with few international mining companies. There are not incentives to strengthen technological capabilities.	Local mining companies with low levels of technological capabilities. Limited KIMS incubation
Emergence and Development (Mid-1970 – early-1990s)	KIMS vertically integrated increasingly within suppliers Vertical disintegration favored the development of KIMS	Chilean Industry nationalization and production focused on copper achieving an output of 20% of the world production.	Vertical disintegration of mining companies facilitated the development of a reduced number of KIMS.
Internationalization (late 1980s – early 2000s)	Mining Companies and suppliers with capacity of international operations	Non-local mining developed internationalization process	Few Chilean KIMS with possibilities to take part in international projects and operations.
Consolidation (late 1990s and continuing)	Technological capabilities spread worldwide	Local Industry achieve about 35% of world copper production	KIMS experts participate at international level. Acquisition experiences in Chile. Local KIMS have to compete with 1 st tier international KIMS in accessing to business, learning and innovation opportunities

Source: Adapted from Urzúa (2011)

Then, the starting point of providers development in Chile was the nationalization of the industry coupled with the industrial vertical disintegration experienced in the '80s. However, this process of local providers' capabilities upgrading started various decades behind compared to those experienced by the KIMS sector in developed countries, like Australia.

Cases of suppliers' innovation in the Chilean mining industry

Case studies presented here analyze different firms, from those that has a long trajectory of more than 40 years of participation in its economic activity, like ENAEX, Bailac and Neptuno Pumps; to those who are recently defining their approach to provide their improved services and solutions, after years of R&D investments, like INGMAT and MSMIN. Indeed, the five cases presented here will help in realizing differences between patterns of innovation performance, among mining suppliers of services. In general, at least two groups of suppliers can be defined, like those with a long technological and industrial trajectory -which usually take part in advanced group of providers that have capabilities to innovate- and those newly established providers for the industry that face hard difficulties to develop intra-industry linkages with mining companies. Thus, patterns determine ways in which firms socialize their enhanced services ranging from very technical solutions -based on applied knowledge- to more integral service provision oriented to develop regular linkages with mining companies.

In all cases, technology and accumulated knowledge management has been crucial components in developing new products or processes, coupled with non-technological experiences. This is because bonding mechanisms of the local industrial environment is structured fundamentally upon transactional schemes rather intra-industry relational dynamics which –in its turn- could sustain mutual development and collaboration among mining companies and its suppliers.

In this local scenario, it seems relevant to contrast similarities and differences between the current industrial organization of the mining industry and those contributions and milestones of change identified by providers, through the implementation of the World-Class Suppliers Program run by BHP Billiton and CODELCO in Chile.

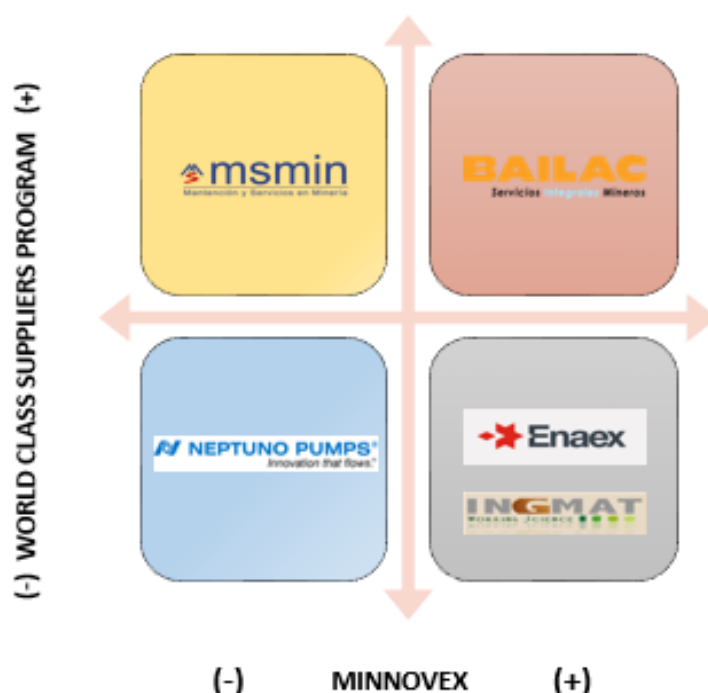
Firms selected for cases are those suppliers that have developed innovative experiences in areas related to mining requirements in Chile. Then, the selection was organized in a sort of double-axis that combine providers' affiliation to mining associations⁷ and their participation in the World-Class Suppliers Program, as shown in the figure N°2.

All firms studied self-recognize themselves as innovative units, and there are evidences of that experience, like products and services developed and industrial awards. Nonetheless, the innovative intensity is different in each firm, despite the common starting principle: the continuous improvement. For instance, the innovation path developed by Neptuno Pumps, Bailac and ENAEX is very distant from the experience developed by firms that have recently established their business and industrial linkages, like INGMAT and MSMIN. However, the experience of MSMIN highlight the importance of related knowledge and its topical proximity, since the firm is formally new established (less than five years), but the accumulated knowledge of founders is essential in the way that services are developed

⁷ In this case study we refer to MINNOVEX, which is a Chilean Association of almost 30 firms for Innovation and Export of Products, and/or Knowledge Intensive Services for Mining and Industries.

and provided to mining companies. In any case, key factors that promote or hinder innovations dynamics are quite similar, like the difficult industrial environment to develop stable intra-industry linkages between mining companies and suppliers, the weak access to specialized human capital that is evident in facilities located in the north of Chile, the administrative burden associated to available public tools that foster innovations, the suppliers ability to institutionalize new knowledge and its management in developing solutions for mining needs. Those aspects are synthesized in the comparative analysis of firms' innovation performance presented later in this document.

Figure N°2. Cases selection: Suppliers associability (MINNOVEX) and development (World Class Suppliers Program)



Summarizing, cases studied shed light about the intensity of the innovative activity that providers in the mining sector develop in one of the major economic sector of a developing economy such as Chile. Revised experiences rely on the exploitation of competitive assets strengthened by firms. In most of cases, innovative activity is predominantly financed internally, but where collaborations with local mining companies are identified as one of a key role to promote and enlarge the number of firms involved and the degree of quality of improved and costumed services provided. Then, alternatives like the World-Class Suppliers Program contribute to the reduction of transactional costs in accessing to sources of information and to key partners in designing and developing suited innovations that improve efficiency and quality of processes within the Chilean mining industry.

Neptuno Pumps – *innovation that flows.*

Neptuno Pumps was established in 1972 as an early provider of pumping services to the fishing industry in the Region of Tarapaca, in the north of Chile. After the Chilean economic downturn in early 80's, the firm decides to change its strategy to the provision of services and engineering –manufacture- to the resurgent mining sector in the north of Chile. This, new direction was rooted on the firm's technological trajectory and the related knowledge achieved in providing products, services and solutions on centrifugal pumping systems to the fishing industry. Then, new developments took part in a path of progressive improvements applied to the design and manufacture of pumps, so to respond to the increasing needs of the mining industry on energy efficiency and carbon dioxide emissions reduction. Among services provided by the firm, it is possible to find experiences linked to the provision of customized pumps –Neptuno Pumps has its own facilities to manufacture pumps and its components. Currently, pumps system customization may include analysis of piping system design and/or the hydraulically balance of pumps systems and its thrust forces. Those studies allow to the firm developing solutions that maximize the pump's system balance and its pumping performance. In addition, and more related to pumps design, the analysis of pumps working conditions -like environment or the quality of liquid to be pumped- are some of the parameters in the selection process of pumps -type- and its material components to achieve better system performance.

In this context, Neptuno Pumps pioneered technological solutions unknown to the local environment until then. For instance, in the mid-90s, they digitized models and projects in Autocad and practiced the tri-dimensional printing at industrial level, which constituted one of the first experiences in Latin America. In addition, the firm developed a software of fluid dynamics and effort simulation and the capacity of computerized vacuum casting machining. The progress of applied solutions provided by the firm redounded on the numerous distinctions that it has awarded locally and internationally; from the Pumping Industry, Engineers Associations, Mining Suppliers Industry, among others. Currently, firm's R&D expenditure represents a range of 5 to 10% of the annual sales.

The progressive improvement of services provided by the firm are founded on its long trajectory of applied research and the close relationship that it has been able to cultivate with mining companies. Currently, Neptuno Pumps has 130 employees, where 20 of them –mainly civil engineers from different disciplines; like mechanics, aerospace, materials, among others- take part of the R&D department of the firm. This department play a key role in the development and supply of custom engineering solutions to mining companies aimed at generating improvements that reduce the energy consumption during pumping processes, the optimization of customers' practices and ultimately the improvement of pumping capacity of clients' facilities. Those technical advances are attractive for companies due to the evident and shortest return periods for their projects. This capacity enabled to the firm to develop projects with big mining companies operating in Chile, like Collahuasi, Escondida, and Los Pelambres. Complementary, foreign business are settled providing services in Peru, Mexico, Bolivia and Argentina coupled with exploration or early negotiation projects in Russia, Kazajistan and US.

BOX N°1. Re-powering water reclaim systems with effective energy consumptions and CO2 emissions reductions.

This solution was the result of an engineering consulting that Neptuno Pumps delivered to Minera Los Pelambres Mining Company in 2011. In this process the mining company carried several studies to develop improvements in its reclaim water system. After three different alternatives, the cost-benefit analysis determined that just one was the most suitable solution in helping the company to increase pumping capacity and advancing in energy efficiency, at the same time.

The existing reclaim water pumping system comprised two fixed pumping stations that were built with a total capacity of 950 liters per second. This facility in Minera Los Pelambres responded to previous maximization requirements, but in 2011 the mining company wanted to reach new levels of recycled water. In this scenario, each station contained six vertical turbine pumps. The study determined that stations were functioning below their efficiency point, with a 69% of operating performance coupled with progressive equipment damage and high operational costs due to the elevated level of energy consumption. This situation had a potential improvement scenario where the infrastructure could get up to 1100 liters per second –almost a 16% of improvement potential. Capital using technical progress. Expanding yields of existing capacity.

Three potential solutions were assessed.

- Modifying the piping and improve the system to the Best Efficiency Point flow. This alternative was discharged due to its economic cost and the volume of civil works involved.
- Re-engineering existing pumps recycling its components to reduce costs. This alternative was discharge due to the associated interruption of pumps operation in the entire system. In addition, this alternative required structural modifications, components replacement and an important volume of civil work.
- Selected alternative. Installation of new pumps –designed and manufactured by Neptuno Pumps- that could achieve the desired Efficiency Point flow and increasing the efficiency in the use of energy with slight intervention to the existing stations system.

The solution implemented.

Neptuno Pumps run a computational fluid dynamics (CFD) analysis coupled with a Failure Effect Analysis (FEA) upon which suggested a vertical turbine pump with technical specifications appropriate to the goal required by Los Pelambres. This solution involved a custom engineering and custom fabrication aimed at reaching a level of 80% at its Best Efficiency Point. The solution was designed and engineered after defining the necessary components, the appropriate materials to resist wet conditions and the hydraulic thrust –including pump's mechanisms (impeller and shaft)- so to assure the best hydraulic balance for the adequate work of the pump.

Outcomes of the innovation.

- Improvements in the use of resources and in the operation of the pump contrasted with the second alternative assessed.
- Reduction of existing equipment in pumping stations by 33% and releasing space for related equipment.
- New pumps system reached a Best Efficiency Point at a capacity of 1194 liters per second, which was 99% of flow increase above the expected.
- The achieved efficiency levels allow the re-use of previous pumps motors, and then requiring less number of pumps motors than initially considered.
- The operation of the strengthened pumps system supplied increases in the pumping capacity by 9%, a drop in energy consumed, which meant a total savings of US\$ 1,197,460 per year in electrical expenditures.

Neptuno Pumps has developed experiences of innovations in areas like the energy efficient pumping solutions, engineering solutions for pumping systems –consultancy, design and project management-, spare parts manufacturing and pumps' reparation and updating. Neptuno Pumps operates –by their own resources- advanced 3D digitalization and high precision inverse engineering technology for the manufacture of pumps' components and pieces, from any brand. This firm is equipped with prototype technology (rapid prototyping) for the manufacture of pieces and components - directly from 3D CAD models- for final use. All the above features are mentioned to emphasize the capability accumulation of Neptuno Pumps in speeding up the conceptual design process and the development of high precision and faster manufacturing of complex models.

Among key experiences deployed by the provider, one can find the “re-powering water reclaim systems with effective energy consumptions and CO2 emissions reductions”. This solution was developed for the mining industry in Chile and achieved five –national and international- innovations awards, like the Technical Innovation of the Year –Projects, Pumps Industry Awards 2013 and 2015 (UK)-, the Prize Ramon Salas Edwards (2013) from the Institute of Engineers in Chile, The Sustainability Awards in Mining (2014) from the Racyclapolis Foundation, The National Innovation Awards (2014) Avonni. In addition, in the Energy Awards 2014 (UK), Neptuno Pumps is finalist in the category of water efficient project of the year.

With all those background in mind, what makes interesting of this firm is to understand its approach to innovation inspired by a mixture of mutual co-operation, commitment and technology development in service provision. Some results of this attitude for innovating are expressed in their services, the internal integration of processes –design, manufacturing, services-, the continuous R&D unit solutions development and improvement based on human capital development. Similar learnings derived from empirical studies applied to electronics (Rosenberg and Steinmueller, 1980). Also, the key role of human capital (Crespi and Zuñiga, 2012) and the conceptualization of institutions to strength the economic performance and, ultimately, the innovative effort run by actors through different economic policy settings (Nelson, 2005; Katz, 2000) are helpful in understanding the firm's flexibility to adapt its services to different industrial environments worldwide. As a result, Neptuno Pumps looks to socialize its innovations and solutions developed through specialized bodies, which has yield in the multiple distinctions awarded in recent years.

ENAEX

ENAEX S.A. is a supplier of explosives and related services for mining companies. It was established in 1920 developing a wide experience in the market providing its products and services, directly or via third parties, in a broad portfolio of contracts with major open pit and underground mining firms operating in Chile, Argentina and Peru. In recent years, ENAEX has increased its business projection both locally and international, so it provides products in about 40 countries, where Bolivia, Ecuador, Australia, New Zealand, Japan and Indonesia have acquiring important relevance.

Firm's business model is based on an integrated service delivery with high standards of efficiency and safety, which provides a crucial value added to customers. Services provided include activities such as the transport of explosives components to the mining operations site - and its management within it - including its storage. Before detonation, ENAEX provides rock profile studies, screening, drilling, and control the access to the detonation and storage areas. All those activities are the base for the in-site manufacturing mix of the explosive and the blasting process, among others.

ENAEX has plants installed within the client's site with all the necessary equipment to perform its services. This territorial deployment respond to the strategic value of the firm in sustaining the growth process that it has developed jointly with its customers, so it implies the provision of high value added in services to the mining industry. In addition, the firm is permanently striving to establish world-class standards in key issues for the mining industry, like safety, reliability, and innovative services.

Employees are considered at a center of importance, since people play a key role within firm's development and provision of services to clients. Currently, ENAEX employs over 1.300 highly experienced workers, committed with challenges posed by the mining business. Consequently, the firm runs several initiatives to keep standards of qualification, motivation and integral development of its employees. In fact, initiatives consider permanent training, fair compensations, benefit structure focused on permanent improvement of work and family life quality, among others.

The innovative experience of ENAEX is related to productivity improvement, service innovation and safety issues. Indeed, through innovation, ENAEX aims to generate (1) productivity improvement in the capacity to manage and transport raw materials during loading operations, (2) service innovation in processes oriented to the reduction of costs and damages during operations, and (3) safety management of chemicals and explosives through safe equipment, which is an advantage for customers compared with available alternatives. For instance, related to Milodon –an explosive factory-mounted on a truck- in loading 10.000 tons of explosives the number of involved trucks is reduced by 30%, approximately, which has a positive effect for mining operations. Similarly, the use of Intellidrill help in reducing the overall costs and improves the outcomes of rock fragmentation.

ENAEX has plants of mining explosives in Chile, mainly in mines that outsource the service of rock blasting. In some cases, the firm handles the entire process providing engineering services, people, machinery and technical assistance -from the design of operations to the blast of rocks. Additionally, in mines that have staff and expertise for the blasting process, ENAEX contributes to the provision of initiation mechanisms and explosives. Technical support is provided, mainly on those mining sites located near communities. In some cases, the company has provided the installation of monitoring stations to ensure a certain level of vibration, noise and dust associated with the blasting process.

In 2010, the firm experienced a formal reorganization, where areas like Chemical and Services were redesigned and made independent. This restructuring and organizational design meant changes at the level of managements. Consequently, the area of innovation has had to re-set formally, in this new intra-firm scenario.

Currently, a R&D team develops applied research to improve processes and quality control. This group consists of 34 people. R&D unit comprises two engineers, four chemicals –focused on research–, two technicians and assistants who follow the instructions of those with tertiary education. The head of this group is a chemical engineer who receives requirements from the area of operations, mostly. Therefore, the role of the head of R&D Management seeks to relieve a projects portfolio and initiatives that invigorate innovative capacity within the firm.

BOX N°2. INTELLIBLAST®. In-Mine loading system

This innovation consists of a software development in accordance with a set of input data, such as compression, fracture frequency, among others, which determines the type of rock fragmentation to develop.

INTELLIDRILL: It is a mix of software and hardware used in the drilling process for adding explosives. The application measures a number of parameters related to the strength and characteristics of rock used later for the optimal fragmentation through the blasting process. This application reduces overall costs and improves the outcomes of rock fragmentation. For the execution of this process, drilling sensors are used in the capture of rocks composition and strength data, which is transformed into electrical signals related to the rotational speed of the drill, power consumption, etc. Lately, those signals are translated into a characterization of the rock quality that helps the design of the blasting and eases the fragmentation.

The design of the blasting process is transmitted to the truck factory –Milodon® (the world's largest truck for mixing and loading of explosives)–, which has a GPS device mounted on the arm allowing detecting the location of the perforation, the type and volume of explosives to charge in each point. Through this system, it is possible to develop customized designs of blasting processes according to the field data obtained.

The whole process is supported by the communication system "INTELLIBLAST"® with satellite support, a global pioneer in achieving efficiencies by ensuring the location, proper mixing and dosing with simultaneous transmission of data and process traceability.

Additionally, the QED® software, one of the most advanced in the world (developed by Austin Powder, ASP Blastronics and Earth Technologies, and licensed by ENAEX), is used to design, analyze and simulate rock fragmentation to optimize the location of the necessary explosive charges.

This solution is not being exploited currently because it is relatively expensive to operate, due to the integration of several processes and the equipment development required to implement this technology within mining operations. However, it generates a more appropriate use of inputs to the fragmentation of the rock, which optimizes the result and the benefit associated with the effectiveness and productivity of the blast.

This case study will highlight issues related to motivations, limitations, effort and success of ENAEX in developing innovations in a sector characterized by low levels of R&D investments and innovation in a context of a mature industry. From

an evolutionary perspective, the analysis is focused on understanding how the firm has developed its internal capacity to carry out R&D activities and what kind of learnings are necessary to formalize with the aim of orientating initiatives to strengthen the industry through the value chain. In this context, arguments related to the firm's organization to conduct R&D processes and to sustain its technological path (Nelson, 2000), and the scope of how the skilled labor involved in innovation contribute to the Total Factor Productivity (Helpman, 2004; Crespi and Zuñiga, 2012) are at the base of analysis of this case considering its long trajectory within the mining industry.

INGMAT – Working Science

INGMAT was established in 2008, as an academic start-up of a mathematical engineer professor at the Catholic University of Chile. The issue was to develop a place where transform basic knowledge to industry oriented applied knowledge. Then, the background of the firm's staff is about research project funded fundamentally by public funds from CORFO⁸ and CONICYT⁹. It is a small-sized firm, with six permanent workers. The number of employees may fluctuate depending on the number and complexity of projects they develop.

The approach of innovations that INGMAT develop is quite different from cases like Neptuno Pumps and Bailac. This firm aimed at transforming knowledge accumulated in previous or current research projects into applied solutions that could fill in industry needs. Contrasted to other suppliers, this firm has not a specific focus on mining. Indeed, one of their major innovation is SIPROL a wave prediction system to be used in port's activities, in its early stage.

The link with the mining industry is rather new, but INGMAT has developed a couple of prototypes as solutions that could help in the exploration and operational stages. One of these solutions is a prototype to analyze the mineral law by identifying debris composition during the exploration stage. This technological development is mounted in the drill of mineral exploration and use electroscopic analysis techniques, where sensors and detectors determine the mineral content of the substrate. This solution allows in understanding the quality of mineral banks deposits, so to make decisions related to the programming of the mineral exploitation. It is expected that the use of this solution will support decisions about the volume of explosives used or to develop a more efficient operation of the ore.

Another technics is the application of radar technology to detect solid materials in a dump truck. Usually, this material is not possible to grind generating interruptions in mining

⁸ CORFO is the Economic Development Agency of Chile. Hierarchically, it is located as a service within the Ministry of Economy structure.

⁹ CONICYT is the National Commission for Research, Science and Technology. Hierarchically, it is located as a service within the Ministry of Education structure.

operations with the consequent economic losses. This technological innovation is an extension of the knowledge obtained in a research project developed in 2006, in designing a prototype to detect the location of landmines in northern Chile supported by radar technology. The analysis of materials occurs between the truck and the primary grinder. The expected result is the creation of a 3D image of the materials transported by the truck, so to determine whether a solid material must be extracted. The organization of this improvement considers the location of the radar on a porch through which trucks move, so facilitating the analysis of its contents. The idea is that in the future this solution could automate the process and incorporates other improvements, such as a robotic arm to extract the solid material.

Those solutions are not commercialized yet. This is because, INGMAT has found difficult to achieve contracts with mining companies or to get involved in industrial initiatives, like the World-Class Supplier Program. Some of the reasons is due to the absence of HSEC¹⁰ certification. On the other hand, as they are member of MINNOVEX, since recently, some expectative of collaboration and coordination to develop collaborative solutions between several suppliers are in mind of INGMAT.

This case study shed light about the difficult experience of newly established suppliers within the mining industrial fabric. Interestingly though, INGMAT meets specialized human capital and the technical expertise to carry out developments that can contribute to mining productive improvement from what is called the “demand-pull” or “ market-oriented” innovation (Nelson, 2005; Mowery and Rosenberg, 1979), linking firms’ needs, invention and solutions socialization (Nelson, 2000). However, the INGMAT’s particular understanding of the R&D process, focused on an academic routine, imposes difficulties of coordination between research outcomes and the need for short-term solutions in the mining industry.

Bailac – Integral Solutions for the Big Mining

Bailac is a firm that provides solutions for mining companies in tire-related services, like maintenance and management for Off-The-Road (OTR) tires. It was established in 1925 in Argentina and started its operations in Chile by 1952. Since that time, Bailac has specialized its services provision to mining and construction companies in areas like savings and costs reduction, through tire retread and reparation. The Global Tire Management -throughout the tire life cycle- is the approach behind the strategy implementing by the firm. A broad view of services provided by the provider are the OTR-Tire savings consultancies that determine proactive and predictive maintenance processes; the OTR Tire repairs and retreats –with several plants in Chile, Argentina and US; the real time tire pressure and temperature monitoring, based on the integration of management software, technologies and equipment allowing tires’ checking process without human intervention within mining operations. Currently, the firm comprises about 500 employees and has facilities and operations in Chile, Argentina, Brazil and US. All

¹⁰ HSEC: Health, Safety, Environment and Community

those countries group about 20 mining companies as customers. Services provided in Chile cover almost the range of big mining companies along the country.

From an evolutionary perspective, Bailac has achieved great levels of knowledge management within the mining industry, upon which the firm has increased in the number of plants and facilities with similar infrastructure and standard procedures to provide a global tire management service. However, more relevant, the firm has evolved to a level where it is capable to customize its technological solutions to contextualized requirements of the industry accordingly to its location. Indeed, business models and firm's organization is not replicated in all the countries but rather they are adapted to the context of operations. Then, firm's services improvement and organization is supported by the R&D department located in Iquique city –in the north of Chile. This unit is mainly focused on proposing services and equipment enlargements, like those introduced to the software PASCUAL for tire's control and management, the Active Tire's Monitoring Unit (UMAN), and the Global Tire Service (GTS). Particularly, in Chile, Bailac is the unique firm that offers the whole range of tire management services in the same facility, from monitoring to retreat and reparation. This integral perspective of the service means that Bailac generates economies of scale in service provision, which is the base for its attractiveness within the mining industry and its share of 80% of the domestic market.

In Chile the long interaction between Bailac and mining companies, since 1950's, has created strong business and strategic ties that contextualize specific techniques task provided in each operation site. This has meant that the firm is organized and offers a wide-range of integral services related to its core business. In fact, the firm has a territorial perspective to cover the country, where Bailac-Thor provides solutions from Arica and Parinacota to Antofagasta regions in Chile –where mining activity is highly located- Bailac San provides services from Chañaral to Punta Arenas region. Those bodies are coordinated with other branches like Bailac Recamin focused on repairs and retreads of OTR-tires in Chile, Bailac Incamin which provides inputs for assembly and disassembly of giant tires, Dust A-Side for dust control in mining roads, and Bailac Capacita which is constituted as a Technical Organism for Qualification. Services and solutions developed and provided by the firm are supported in a mix of technological adaptations and internal developments. For instance, at the beginning of firm's operations in Chile there was neither related infrastructure nor experiences or applied knowledge to the mining industry. Then, for challenges that are more complex the firm adapts foreign technology, as a first stage –like UMAN- but after that, it develops its own solutions, like internal-tire sensor for UMAN-GTS.

This progressive knowledge accumulation implied that this provider achieved greater room for business development within mining industry, rather than foreign suppliers. Indeed, early operations of BHP Billiton in Chile hired tire service management with OTRACO—an Australian firm- but the quality, the variety and the closeness of services provided by Bailac meant that it gained a more regular linkage with the mining company. Similarly, services contracted with Michelin implied that any requirement or maintenance services

must be delivered from France. Thus, locational externalities play in favor to the local supplier strengthening its advantages in respect of its foreign competitors.

BOX N°3. PASCUAL – specialized software for tire's control and management

In the first quarter of the XX century, Off-The-Road (OTR) tires measured one meter as a diameter and hold a load of 2.500 kilos. This scenario has changed nowadays, where OTR-tires measure more than four meters diameter and hold 100.000 kilos of load each. Thus, mining providers must meet stringent demands of mining companies.

Bearing this in mind, in 1994, Bailac developed a first version a Tire Control System based on a local management software that kept track of the use and lifespan of tires. Initially, this information –tire pressure and temperature- was collected on-site and registered in a suited application. This, first version of the software had two main drawbacks. Firstly, each time that data was collected mining trucks was stopped until the registry was completed. Secondly, as the data collection was made manually the risk of accident of operations on-site was too high. Thus, Bailac searched to improve both the system of data collection and the wireless transmission and registration of tires data.

In 2006, Bailac developed a new version of PASCUAL as a software for managing the lifecycle of OTR, rims and chains through a webservice that inform about tyre performance and waste. It is called the consolidation of one of the major solutions developed by Bailac to help in tires fleet administration for mining operations. The OTR tires history is registered since first mounted until the end of its use or final removal.

It is an expert support tool for the Control and Management, Tire Savings & Components. The software keeps a complete control of information throughout the life of tires, rims and chains. It also, facilitates information about the current state of tires via internet access, that allow to increase by 100% control, effectiveness and speed in decision-making.

The software delivers reports with information related to OTR tire proactive and predictive maintenance activities necessary to maximize the use of tires. Key software features are:

- Control of interventions to tires, hoops and chains.
- Checking information of remnant rubber, pressure and temperature.
- Sending and receiving processes for tire, rings and chains reparation.
- Control of usability of any component.
- Damage control of tire.
- Reports and graphs delivering.

Key reports delivered are related to an OTR tire life-maintenance card; an on-the-job tire operation that provides data of level of use; the tire operational condition describing three stages, as known normal, observation or critical levels of operation; the discharged components within a defined period; a components stock of available tires in the mine operation; installed tires and its level of use; retired tires within a defined period; and repaired components a traceability of the tire repair process, its characteristics (preventive or corrective), and results obtained.

Technically this software runs amiably on the web. Therefore, information regarded to OTR tire can be checked from any navigator connected to internet in servers lodged in BAILAC datacenters. Upgrading of the software made it available an easy navigation in English, Spanish and Portuguese.

The implementation of the whole preventive tire management system based on data registered on Pascual allow to mining companies in evaluate the level of usage and reparation of tires extending its lifespan up-to 40% more work on mine operations.

Bailac took part in the first version of the world-class suppliers program implemented by BHP Billiton due on its service dynamics, its quality performance and due to the firm's regular implementation of continuous improvement principles¹¹. Particularly, the improvement service provided to the mining company was an updated OTR-tires predictive maintenance system based on the Global Tire Management approach. This innovation was aimed at maximizing the use and reparation of tires at Cerro Colorado. The result of this initiative implied an important extension of tires utilization in BHP Billiton operations.

Among distinctions, in the last decade, Bailac has different acknowledgements from the National Association of Safety (ACHS) and mining companies (Anglo American, CODELCO, Disputada, Los Pelambres, Candelaria and Ojos del Salado), due to its performance in topics like risk prevention, safety, quality, environmental issues, and health. Furthermore, international tires companies (Bridgestone and Michelin) distinguished to Bailac in areas like quality performance and cooperation in the organization of thematic meeting.

As a case study of innovation in mining supplier, Bailac is interesting in understanding its approach to innovation inspired by a practical and instrumental interpretation of mining companies services demanded. Then, the challenge has been how to develop and maintain the internal integration of services provided, so to custom solutions to operational need of mining sites. From this perspective, this case help in understanding the coordination between a market-oriented innovation (Nelson, 2005; Mowery and Rosenberg, 1979) and in-house R&D facilities with dedicated human capital to improve solutions as a source of dynamic capacity (Nelson, 2000; Helpman, 2004; Crespia and Zuñiga, 2012). Thus, the R&D department -currently established in the north of Chile- has the perspective of contributing to strengthen more local dynamics of knowledge improvement and enabling initial opportunities for local production of innovations. The goal is to contribute in the reduction of the high dependence of mining regions to the metropolitan area of Santiago.

MSMIN – Maintenance and Services in Mining.

The firm started its service provision in 2011, as an instance to provide engineering services and maintenance in mining-related processes and environmental consulting. Its founders have an interesting career in the mining sector with an average of 25 years of experience on several aspects related to the industry, whether in mining departments of companies or as providers of services. This service provider is small-sized firm with nine professionals. Five of them are engineers from areas like industry, mechanical engineering, chemical and electrical engineering. In addition, there are two junior professionals and two administrative support professionals. The firm's strategy for service development is focused on developing services improvements in areas that match both the mining companies' challenges and MSMIN expertise. Thus, alliance strategies are

¹¹ Bailac's quality management system is certified with ISO norms 9001 and 14001 and the Occupational Health and Safety Management through OSHAS.

implemented and the hiring strategy aims to contract workers, for limited time according to projects' needs in specific periods. Usually, workers are hired for their business partners, who –in the end- develop and operate solutions in mining operations.

The management of the company take into account the cluster project -World Class Suppliers Program- as a window of opportunity consistent with their business vision of developing service provision to the mining industry. This is because the project where MSMIN was involved conjugated areas like maintenance for related-mining processes, operations, and environmental and chemical dust-control. Thus, the firm has defined two distinctive areas of service provision that are complementary in their integration to develop improved solutions. These areas of service development of MSMIN are:

1. Area of innovation projects which is mainly related to the cluster projects. In the firm's experience, their contribution to the World Class Suppliers Program is relate to the dust control due to the improvement of crushing and screening equipment, and also the provision of conditioned chemicals.
2. Area of service for the support and improvement of mining operation. Particularly, this area has been the one that allow the financial stability of the firm. MSMIN focuses on finding business opportunities, and the development of technical and financial proposals. Additionally, as a supplier negotiate conditions with mining companies to develop and implement projects to its final stage.

This supplier has supported its strategy in accessing to the mining business on the development of services that meet two minimum conditions, like the feasibility of previous agreements with related providers and the assurance of possibilities to develop solutions within the mining environment. At an early stage of firm's progress, the focus was on the development of mining and engineering projects that fit in the concept of MSMIN. Under this context, this firm finds an incentive to seek and promote alliances with international partners that were interested in taking part at the local mining market.

According to this supplier of services, its technical capacity in several areas aimed at improving mining companies' processes and operations is the base of MISMIN competitiveness. For instance, in addition to providing improved solutions in the technical field, this firm provide services in areas like safety, health, environment, staffing, training of staff about mining operation and entry to the mine, etc. This diversity is due to the starting point of MSMIN, which at the beginning was below the financial stability-compared with other competitors. Thus, as the number, the scope and the complexity of achieved projects has been increasing the firm has had the opportunity to get involved on more interesting technical challenges. In the short term, they expect to consolidate this path based on technical differentiation in providing innovative and quality services for mining companies.

The general scheme of firm's innovation process is structured upon key questions to guide each development phase of their solutions development. For instance, having awareness of the mining companies' improvement needs or requirement, key questions formalize where do they find such a solution?, where are the three or four essential parts that allow to structure an innovative proposal where all stakeholders win?, do they (MSMIN) have the

technical capacity to develop the project or need to outsource any stage?, which is the economic dimension and project development time? In this context, MSMIN develops a strategy of alliances and partnership with related suppliers ensuring an adequate coordination between design and implementation of solutions. As a leading firm, they assume an important part of business risks in proposing innovations to mining companies.

BOX N°4 – World Class Supplier experience in dust control within mining operations

Dust control in mining is a socio-occupational necessity rather than a mere technical solution. To MSMIN has been important to find a solution to this issue and keep compatible with the operations and maintenance of mining operations. The solution developed by this supplier is one that best fits -within the alternatives available on the market- to the requirements of the mining company operations in situ.

The problem of the mining company was the heavy dust or particulate matter (PM) in comminution processes. This amount of dust affects the health of workers, the operating equipment and the reduction of visibility hindering the crushing process. So, new technologies that provide real solution to this problem was required by the mining company in order to include the CODELCO's Division El Teniente in the National Plan for the Elimination of Silicosis (2009-2030)

The solution developed by MSMIN focused on the challenge presented by the Division of El Teniente – CODELCO- about the "High level of dust within the crushing plant and the mine surface". In this context, the provider identified sources of emission of particulate matter coupled with the assessment of design, operation and maintenance condition. The solution provided a new design for dust control in which processes of engineering, installation, operation, maintenance and provision of chemical inputs were considered. This project was validated by CODELCO for its implementation at the mine site and its operation.

The project development involved several stages. Specific studies and related research topics essential for the development stage took six months. At this stage, MSMIN outsourced specialist services to get a deep and contextual understanding of the topic to be solve, i.e. outsourced services were linked to ventilation specialist and mechanical engineering, conveyor belts, components and its maintenance, etc. Additional six months implied the deployment of pilot test and the solution upgrading to its final delivery. During this phase, MSMIN sought to strategic partners, so to enable them to develop a comprehensive and robust solution. Partners and stakeholder involved were selected according to their expertise, so to guarantee usability and durability to innovation. Some providers considered are SANDVIK, FINNING, CIMM T&S, among others. Finally, the contract considered 36 months for assembly processes, commissioning, operation and maintenance of the introduced innovation.

R&D Process

The research process involved working with specialized professionals –external to MSMIN- for 2 months. Both to investigate the reasons why the current dust control systems do not give the expected results, and to investigate innovative solution alternatives. During this period, specialized professionals analyzed the (1) Design of current conditions of crushing process, (2) the Operation and maintenance practices, (3) the Design and condition of conveyor belts and accessories, (4) the Design and condition of dust control systems per sector, (5) the Industrial Hygiene, (6) the Occupational Health, (7) the Ventilation conditions, and (8) the Chemical-metallurgic lab to assess effects of the solution.

The development process -three months- was aimed at working on the design and manufacture of a pilot equipment, with robust characteristics, that allows developing industrial tests on-site. In addition, during this time MSMIN designed and manufactured those chemicals to encapsulate the dust that give the expected results.

Innovation developed

The innovation was a prototype equipment and chemical product with measurable results through free crystalline silica measurements. The solution outcome accounted a reduction of 68% of the effects of breathable silica on workers, derived from the operation of crushing.

An external firm hired by CODELCO audited results of the improved solution to reduce the volume of dust emitted during the process of crushing ore. This outcome is an important credential for MSMIN, since it allow them to develop more projects related to this experience within CODELCO.

Currently, the dust control equipment is being installed in five crushing plants at Division El Teniente. While, MSMIN is in the process of generating a commercial network to continue installing their new chemical to encapsulate the dust originated in comminution processes. This innovation was financed by MSMIN own resources and with an important contribution from the agreement with CODELCO.

This case innovation is interesting to know, because it lets to recognize the path along with the knowledge accumulation of the mining industry acquired by founders has provided to a relatively new firm -of less than 5 years old- skills to provide regular services to mining companies in a successful, fair and innovative way. In addition, it is interesting the scope to innovate in a way of proposing and providing services to mining companies founded primarily in association with key stakeholders with related experience, skills and expertise to deploy quality services at an attractive price for the sector. Then, this provider aims to institutionalize its innovative effort displayed with a pragmatic scope in developing a business proposal based on what companies need (Nelson, 2000; 2005). A striking statement from the firm is its poor knowledge of public policy that fosters innovation development, currently existing in Chile. However, this aspect has not meant a delay or an obvious obstacle for MSMIN to keep innovating in the services it provides.

Internal factors related to KIMS innovation performance

Factors that facilitate innovations

The technological path showed by firms is an essential factor that determines their attitude to develop innovations and suited-solutions delivered. This trajectory -within the industry- determines their accumulation of formal linkages and informal contacts with mining companies. The outcome of this path is evidenced on different levels of suppliers' knowledge acquisition, accumulation and management, which is displayed when they need to respond to mining companies requirements. This asset may be at the center of firms' abilities to cope with weak industrial environments where the fierce rivalry and feeble social capital is dominant.

Experiences show that firms with decades of development within the industry enable them to achieve better results in signing contracts and provide services in a more regular way rather than those with few years or recently established as a service provider. Indeed, Enaex – instituted in 1920-, Bailac –established in 1950 in Chile- and Neptuno Pumps – founded in 1972- give an impression about firms' trajectory that their relative advantages,

mainly when they stated that until early 90's the mining industry was a bit more accessible and with less averse to risk. In fact, in their opinion, at that time local industry was constituted by people restless and prone to develop tests of materials and equipment aimed at generating improvements in mining. Thus, suppliers that operate within the industry since these days achieved experiences and contacts that have delineated their skills development and the relative accessibility to companies' managers, until today. Complementarily, this experience allowed them to develop a sense of brand, which is exploited in their competition with international suppliers. This marketing strategy is also combined with concepts of *continuous improvement* and the *permanent need of being up-to-date* so to offer appropriate and modern solutions to companies.

Supported on this approach of continuously investigating about related technological advances on services and products, firms deploy self-reinforcing improvement strategies of their services. Upon those plans, suppliers make progresses to overcome the declared transactional bond rather relational linkages between mining companies and providers. In this vein, Neptuno Pumps has developed innovation by their own resources, with little support of public tools. In fact, the project manager noticed that most of the public measures are focused on start-up or computing, but there few incentives to foster greater levels of engineering or local manufacture at industrial scale. The evidenced scope of the public measures has implied delays on innovation outcomes, compared to what is evidenced in other locations on the globe. For instance, *"in Finland there are public incentives for firms that hire specialized human capital or manageable tax incentives schemes related to innovation activities. These kind of things are hard to find in Chile, something that is even more inadequate considering the geographical position of mining regions in Chile"* (Neptuno Pumps).

Similarly, Bailac highlights that develop innovations in the North of Chile obviating the almost mandatory consideration of the Metropolitan Area of Santiago is not an easy step. Until recently, five years ago, a private technical University –INACAP- facility was built in Iquique. Nowadays, it is possible to hire technician in some areas like ICT or machinery maintenance processes. INACAP established in Iquique in a period when several regional actors were discussing the fundamentals and gaps that support the design of a regional innovation strategy for Region of Tarapaca. This regional process was financed by the Vice-Ministry of Regional Development (SUBDERE) and conducted by the Regional Government.

In this scenario, several universities –mainly private- implemented undergraduates programs related to mining responding to the expected investment of the industry during 2010-2015 and the requirement of human capital with related skills. For instance, the regional branch of Universidad Santo Tomas implemented engineering in mining and INACAP related to technical qualifications. Before this local qualification of human capital, all the staff hired by Bailac came mainly from Santiago. *"Currently, we are able to develop our own solutions, because people working on innovation is permanently viewing what is happening in other places, so the use of internet is intensive. Today the world is flat and this has produced a radical change in the regional environment...Nowadays, Santiago is*

reference of movements, things that are taking place there, but the local capacity of research is fundamental" (Bailac).

In line to this, the exploration of alternative areas within mining companies -different to the operation department- such as the innovation department, may help in learning about industry requirements to improve the exploitation and sustainability of the resource, from a medium to long run. For example, ENAEX has found in areas of innovation of BHP Billiton, Xstrata and Antofagasta Minerals Group, important sources and opportunities to improve service delivery, like effective blast, monitoring noise decibels, etc. Thus, informal networks-whether professionals or known people in mining companies- allow finding opportunities for services innovation. Such links can overcome, to some extent, the structural organization silos in Chilean mining companies, with little functional integration of its different business areas. For example, the development of INTELLIBLAST® system, for the design and implementation of rock fragmentation occurred thanks to the collaboration of ENAEX with two mining companies, Codelco and Antofagasta Minerals.

The need to strengthen intra-industry linkages is a fundamental issue in the development of national engineering equipment and control systems or safety features. Then, some firms –like ENAEX- are involved in creating opportunities for the development of local suppliers, to produce external economies derived from acquired knowledge. Thus, when there has been weakness or lack of access to information, ENAEX does his best to bring in foreign consultants to facilitate specific knowledge transfer processes according to requirements of innovations under development.

Afterwards, the development of local capacity in knowledge management enables local firms to find and access to new sources of knowledge based on the external experience developed through foreign business and the connection to global pipelines. Both mechanisms spillover related knowledge that suppliers translate into their local experiences of service innovation and product delivering to mining companies in Chile. The big argument behind this investment of local suppliers is that *"from all perspective local products and services are cheaper than foreign-manufactured, but this issue implies that one must invest time in updating knowledge, creating new knowledge and applying new knowledge to processes and products within the industry"* (Neptuno Pumps).

The provision of an improved solution is an opportunity to create both value for the supplier in its service provision and strategic alliance to increase the scope of innovation. Indeed, business strategy deployed by MSMIN seeks to strengthen partnerships with related providers of mining as a way to present services that are more comprehensive and involve actors with experience and capability to ensure the quality of supplies and services provided. For example, in the Integral Service Crushing implemented in Mina Ministro Hales –Codelco- MSMIN developed the project engineering, coupled with Sandvik as a supplier of crushing equipment, Finning as a Canadian supplier of machinery, CIMM T&S facilitated chemical capabilities, Maquiarios provided conveyors, among others. The strategy was to develop an institutional back up that make the proposal more attractive, where firms were defined as pre-selected providers. As the offer was accepted then all the

stakeholders have a space to sell their inputs. This proposal was successful in generating savings in administrative processes involved in the acquisition of products and equipment.

These kinds of firms that are continuously developing innovation have regular and multiple experiences of global exposition. Indeed, Neptuno Pumps is member of the Hydraulic Institute in Great Britain; Bailac developed foreign experience through business facilities in Argentina, Brazil and US; ENAEX takes part in associations of scientists or specialist engineers, like the Explosive Experts Engineers International Association, and SAFEX International; similarly INGMAT in developing electronic circuits to its innovation created an alliance with a French company that have the infrastructure and the specific knowledge they needed for the innovation; MSMIN in its strategic partnership scheme delivered new solutions jointly with foreign providers of equipment. However, ways of global linkages are different –through University or business- what they have in common is the perspective acquired by firms, since they define new approaches to processes and innovation itself, like a permanent consideration of being updated and applying continuous improvement in developing solutions.

Factors that inhibit innovations

The shortage of skilled human capital is one of the main factors that inhibits or delays the innovative performance of suppliers of services to the mining industry. Indeed, firms that develop innovations have assumed internally some measures to absorb the costs of this restrictive situation. For instance, Neptuno Pumps deployed an internal qualification program where recently hired engineers –most of them just graduated from the Universidad de Concepcion- are trained in applied sciences and technology managed by the firm. The option for engineers from Universidad de Concepcion is due to the basal knowledge required by the firm, since the undergraduate program at this university enables workers in absorbing applied knowledge related to the fluid dynamics, which is an asset. Particularly, firm's training program for workers takes about one year long considering two stages. Firstly, it focuses on support activities based on ICTs, since the firm has developed its own fluid simulation software. Secondly, and complementary to the previous, new workers are trained in technical aspects related to pumps design, as a way to enhance the link between engineering and creativity, so to achieve greater levels of quality in manufacture processes of products and services.

The fierce local rivalry and competition is identified as a common aspect that poses restrictions to increase the extent of innovations from the providers. There are two key factors emphasized by firms, like the number of suppliers versus the range of possible projects and the actual capabilities of providers linked to their size and qualification.

The number of providers to the industry contrasted with the number of mining operations in the North of Chile implies that there is small room of business opportunities for all firms. Furthermore, local suppliers that can accomplish agreements with mining companies must respond in time, quality and safety as contracted, otherwise the potential of losing future chances are too high. Indeed, those that can achieve wide perspectives and regular

contracts are distinctive firms, and usually with high levels of technological capacities and limited or negligible domestic competitors. For this kind of suppliers, competition strategy is oriented to international providers of services and products, i.e. pumps, tires, explosives, among others.

Cases of suppliers of services for the mining industry have a privileged situation within the Chilean market. In the case of explosives, ENAEX competes with ORICA –from Australia– but the former covers the major part of the demand of mining companies in Chile. In OTR-tires management, Bailac covers the 80% of services provision in Chile, while there are competitors from Australia, France and Canada, like OTRACO, Michelin and Kal-Tire. Similarly, Neptuno Pumps is competing with suppliers from US and Germany, which have operations in Chile, like Flowserve, KSB and Sulzer.

In this domestic dynamic, mining companies regularly play a crucial role in a competition scheme tilted to foreign companies. Usually, those companies have long time of knowledge accumulation, good performance in the stock market and capacity to guarantee solutions. *“These advantages constitute the marketing portfolio that such companies offer to mining managers. Then, one direction –for local suppliers– is investing in technology, in knowledge, so to be at the forefront of solutions”* (Neptuno Pumps).

Another factor that hinder the innovative effort of providers to the mining industry is the high level of risk aversion of companies and the weak bonding scheme among firms characterized by transactional business schemes rather than relational patterns. The former depicts permanent requests of cost reduction from the mining company to the local supplier aimed at achieving good services at low costs, while the latter explains dynamics were mining companies take into account all the costs involved in developing services provided; like the costs of inputs, labor, technology accessibility and its implementation, regulations, among others. In transactional schemes, small-sized suppliers find it difficult to invest in new solutions or new technologies, since the amount of profit from services is too small. *“One of our main difficulties selling to mining companies is that we have no real capacity for scaling up our solutions ... our strength is in generating prototypes and as we have no access to mining infrastructure to develop tests, so we prefer to collaborate and others escalate solutions”* (INGMAT). Therefore, many suppliers to the mining industry absorb this reduction of earnings, with the conviction that in the long run they will achieve the expected return to investment.

Consequently, the local demand of mining companies has an important growth potential. Indeed, the current demand for foreign products and services are not aligned in fostering and exploiting local solutions developed by domestic suppliers, despite that it is possible to find local competences related to manufacture and services. In addition, local providers are able to offer quick, cheap and suited answers, value added in services delivered and accessibility, but changes in operational and acquisitions processes are needed at the mining companies tier. Usually, local suppliers argue that the lack of regular contracts of services with mining companies or the prejudice about the responsiveness and quality of local suppliers play against environmental –industrial– incentives of innovative dynamics involvement of firms.

Nature and organization of innovation activities

Providers with more experience in developing innovations to the mining industry invested in a R&D department. The investment in R&D is consistent with the approach to business of firms aimed at developing continuous improvement routines and the scope of worldwide competitive products and services provision.

Then, the profile of people that take part in R&D departments are diverse, but with a strong component of engineers. In fact, Neptuno Pumps' R&D department is about 20 engineers of several areas, with focus on mechanics; the department of R&D of Bailac comprised 12 professionals, with four engineers –IT and Electronics- and technician of related areas; ENAEX engage 34 professionals in R&D initiatives, with a combination of engineers, chemicals, technicians and assistants; the case of INGMAT and MSMIN, firms are formed by few engineers, which are fully engaged to R&D activities.

Some attributes that characterize the R&D departments' dynamics to develop innovation in suppliers to the mining industry are that professionals are constantly reviewing industry upgrading –congress, fairs- clients' requirements and new developments from competitors, a close relationship and interaction among members of the departments, group consolidation and internal confidence that allow processes of delegation and on-the-job training and upgrading. Among cases, ENAEX and Neptuno Pumps have developed experiences in patenting and diffusion. Particularly, Neptuno Pumps has elaborated several papers where innovations are explained and contextualized, mainly through specialized journals, like world pumps.

In addition, with the view of strengthening innovation processes and their management it requires other skills complementary to engineering within the firm. For example, ENAEX has seen that sociologists and professionals from related areas have capabilities and more holistic approaches to processes and its consequences. Therefore, the company has been developing talent retention strategies, especially those who have soft skills, such as teamwork and flexibility, among others.

Firms stated that create and keep its R&D department is an asset, which has enabled the consolidation of internal learning practices upon the applied knowledge behind solutions developed. Then, some firms have standardized the information and data related to innovations, with a defined structure that facilitate the induction of employees through multimedia resources. The scope of this product is aimed at balancing the retention of employees, and reducing those costs associated to employees that leave the firm.

The knowledge formalization seems to be an important process due to the industrial environment where firms provide their services to the mining companies. Indeed, initiatives are carried out so to tackle arguments about the *“high dependence of innovation processes in specific professionals within firms rather than an institutionalized mechanism of the firm”*. Through the time, this issue appears to be more difficult, since the relationship with customers –mining companies- is less direct due to the transactional scheme of doing business. Thus, the combination of a proactive R&D department and clear mechanisms to

formalize learning processes of innovation are fundamental issues of suppliers that exploit a close relation with companies providing integral services like the study of processes, the re-design of processes, the increase of the energy efficiency of processes and the emissions reduction associated to processes.

Institutional factors related to innovation performance

In Chile, providers to the mining industry affirm that business relationships are a bit outdated and developed through rigid structures, in contrast to what is seen worldwide in fields where suppliers develop their services. Similarly, firms with experience in foreign market argue that -by contrast to Chile- abroad is easy to get engaged and keep in touch with customers or even related competitors through fluid relations.

In this context, public support is not in the range of key initiatives undertaken by providers, since their main approach is to achieve regular services and linkages with mining companies. Indeed, suppliers more experienced in developing innovations are not fully aware of available public tools for boosting innovations. For some of them the support of public programs has been important but not fundamental in the introduction of innovations within the firm. They recognize that CORFO play an important role, but they usually prefer to finance innovations by their own resources or with credits. The argument behind is due to the administrative process of applying to public funds, where firms have to hire to an external consultant for the application process and during the project management. Otherwise, they have to relocate employees to develop this task, which diverts resources to areas unrelated to innovations itself. Some difficulties faced by firms are related to the effective support obtained from public officials in orientations, and management and development of innovations. *“Because the administrative demand is so high that when the executive is not 100% sure of something, then may not take decisions, delaying the project management”* (INGMAT).

Similar arguments are related to the application to the tax incentive for intra-firm R&D development, since they find that the process is not easy to carry out in demonstrating those expenses related to innovation activities. Complementary to this, a broad perception is that the Chilean environment is still lacking procedures and incentives that facilitate effective incorporation of researchers. Thus, the model introduced in U.S is seems as a good example, where researchers participate in a proportion of profits derived from successful introduction of innovation in firms.

Notwithstanding, firms like ENAEX evaluates the structure and approach of public instruments available in the mining area as well oriented. This is because firms at backward linkages are constantly looking for improvements in the provision of services to the mining companies, as a way to differentiate themselves from competitors and in the search for a more efficient exploitation of the resource. In this context, the access to public sources of funding can make a significant difference for SMEs in terms of their participation in the industry. This is particularly relevant when the amount of finance correspond to marginal figures compared to profits of big mining companies.

A domestic factor is related to the university-industry linkages. Most of the cases declared that there are no formal links with the local university –within the region where the firm is located-, since it does not offer human capital formation related to the fields of development of local providers. This issue is even more critically assessed when firms highlight the lack of knowledge production and its diffusion within the local industry, at regional level, with the purpose of improving firms' performance. Then, suppliers of services that are developing new solutions for the industry finds linkages with universities located in different regions of Chile that are distant from their mining operations and business –mainly in engineering- like Universidad Federico Santa Maria (Region of Valparaiso), Universidad de Concepcion (Region of Biobio), Universidad de Chile (Region of Santiago). This issue implies that providers have to weave their own network with universities –according to their needs- outside their location because of the weakness of the regional environment to support innovation processes. Then providers find that innovation performance could be more dynamic if local universities invests in human capital qualification and research initiatives –in a collaborative manner- to get more and enriched knowledge, mainly in related areas of suppliers' development.

Consequently, local suppliers argue that it is necessary to strengthen the performance of local universities in fields related to the industry development, like human resource qualification, basic and applied research. In a more close relation, the industry might provide experiences, questions and cases to local universities, so to favor the development of contextualized initiatives aimed at increasing the performance of mining companies and its suppliers. However, despite the existence of several public instruments like the Regional Strategy of Development and the Regional Innovation Strategy, those documents are not translated into effective initiatives from the academia, so to improve the innovation opportunity for local firms. Then, more advanced suppliers argue that there is a lack of a strategic plan to strengthen the industry –manufacture- at national or local levels.

On the other hand, providers that reached international of local networking with industry associations worth them as concrete instances to develop innovations. However, from a more regionally point of view, some supplier consider that there are amendments to develop, since they state that associations are captured by the demand to develop more regular contracts between mining companies and suppliers, and their specifications of quality and safety. In addition, the centralization of associations' management in Santiago is an issue that may discourage the effective participation of regional suppliers located in the North of Chile. As a contrasting initiative, MINNOVEX is implementing a new framework for mining suppliers aimed at promoting the collective development of solutions for specific companies' requirements. The idea is to develop a broad view of the problem and take advantage of suppliers' specific skills achieving integrated solution for companies. This new way of working is just starting, so it is expected to see results soon.

As a way to overcome the early stage of institutional development for innovation and knowledge accessibility related to the mining industry, more advanced suppliers attend to fairs, industrial and related conferences or take part in foreign associations that develop standard or innovative experiences. For instance, Neptuno Pumps take part of the

Hydraulic Institute, which brings together leading pumps manufacturers and designers worldwide. This instance is focused on developing standards and regulations related to pumps and pumping stations design. In this context, Neptune Pumps takes part of the commissions that create and revise these regulations, while ENAEX attends to SAFEX International, a voluntary association of explosives manufacturers aimed at reducing the harmful effect of explosives; so they access to first-hand information that allows them in sustaining improvement processes.

Patenting experience

In general, intellectual property protection is an issue with little development among mining suppliers. Patenting experiences have not been fully developed because this is not an area related to the core business of suppliers. However, there is coincidence in the need of protecting now solutions and innovations implemented. Then, some firms have mentioned that they implemented protection techniques like secrecy clauses in contracts or keeping the control and management of processes associated to the service provision. For instance, some firms that have developed their own software host and manage the tool on its own servers.

Currently, Neptuno Pumps and INGMAT have explored ways to protect their developments, through patenting experiences. Indeed, they consider that patenting is positive to keep and achieve those benefit derived from the investment period of R&D and Innovation. In this vein, firms absorb a new process of knowledge accumulation, related to patenting processes and its redaction, but usually are advised by a staff of specialist lawyers, that most of the time are located in Santiago.

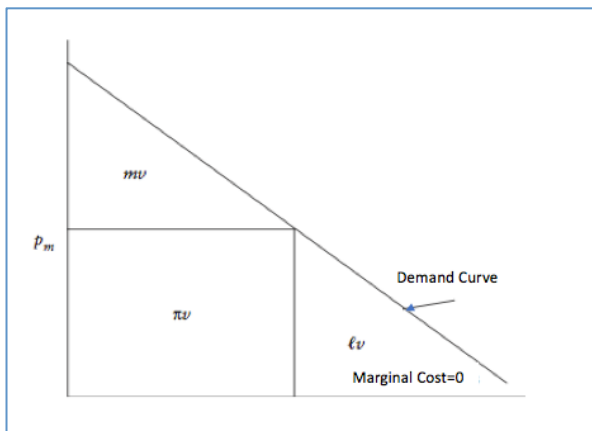
In its turn, ENAEX considers that patenting is a positive externality of the firm's developments, but it is not considered as a goal in itself. Indeed, patenting is considered a double-edge sword. While on the one hand the protection of innovations generated by the company is considered an advance, on the other hand the firm considers that putting information in the public domain will reveals an important part of the strategy that they are implementing leaving it unprotected against competition in a broader sense. Additionally, the firm makes use of industrial secret as a mechanism to prevent copying of key elements of their core business. In this regard, it establishes confidentiality agreements with suppliers, workers, students' internships and thesis. This was set up because recent ENAEX developments have been copied at least twice in a recognizable way. One of these occurred when a supplier tried to transfer the knowledge associated with an industrial model of an explosive device to the competition, a situation that was stopped on time.

Industrial organization and innovation in KIMS

The relationship between returns to scale and industrial organization may describe several productive scenarios among end producers and providers. By distinguishing among constant returns, internal increasing returns and external increasing returns to scale for both final producers and suppliers, it is then possible to classify industries according to nine categories shown below in Table 5. For each category, it is possible to identify the main characteristics in terms of profits and R&D incentives. From the analysis of profitability and industry configuration, it is possible to identify the appropriate set of development policies to boost innovation.

As Scotchmer (2004) summarizes, monopolistic power, sometimes granted by intellectual property, provides incentives to invest in R&D. Let us consider Figure 3. In this figure the marginal cost of producing a given good, named A, is zero. However, there is an R&D cost associated with the creation of good A. Thus, the efficient competitive price, zero, will not cover the costs incurred in developing A, and therefore the market will not provide the good. Intellectual property, or some sort of monopolistic power, solves the problem of generating the revenue to cover the development cost of good A.

Figure 3



Source: Adapted from Scotchmer (2004)

In the same manner that intellectual property generates monopolistic power that allows firms to fund R&D, economies of scale are key determinants for the existence of such profits. The notion of returns to scale describes the behavior of the rate of change in the level of firms' production — output — with respect to the rate of change in the inputs — factors of production — in the long run. Thus, returns to scale may be increasing, constant or decreasing according to what occurs with the output when inputs increase to a certain proportion. For instance, when the proportion of inputs increases to a level "t", then increasing returns are described when the increase in output is greater than "t", constant returns when the output increase is equal to "t" and decreasing returns when the rate of change in output is less than "t". In particular, increasing returns to scale imply decreasing marginal costs and average costs, which often give a cost advantage to firms that allows them to charge monopolistic prices or to charge a lower price than competitors, thereby

generating a stream of profits that allows them to fund R&D activities. On the other hand, constant returns to scale imply the coexistence of many firms whose competition erodes profits until they are null, thus preventing firms from investing in R&D. Notwithstanding this, improving productivity is a key challenge for governments around the world and a goal that often cannot depend on whether firms are able to self-finance R&D activities. Thus, there are often public programs in sectors that show constant returns to scale and no profits, but are all these programs likely to be successful? We believe that often the answer is no, which we will discuss in the paragraphs below.

Among industries showing increasing returns, it is useful to distinguish whether they are internal or external to the firm. The former are related to those shown as a consequence of significant fixed costs, which could sometimes be related to in-house actions that are developed by firms, such as continuous technological upgrading and R&D activities, and that coexist with constant marginal costs or significantly low marginal costs. On the other hand, external economies of scale differentiate those actions or interventions that occur in the environment surrounding the firm or industry, such as associativity, agglomerations, economies of urbanization. While internal increasing returns to scale could sustain profits under imperfect competition, external economies of scale are often found at the level of the industry in which it is possible to find perfect competition among firms with zero profits or with profits when firms act as price takers on global markets and have a cost advantage over other producers.

Table 5 depicts a proposed matrix that classifies industries according to the returns to scale shown by final producers and providers. Each cell shows industries that belong to each possible configuration, characteristics of the industry, whether final producers and providers have profits and hence whether they have the resources to conduct R&D activities. It should be noted that industries often move across cells in Table 1 based on their size and maturity stage in a given country. The discussion on the Chilean mining industry addresses how the industry has transitioned across different cells in Table 5 over its development in the last three decades.

By focusing on increasing returns to scale, we stress the notion that R&D initiatives run by firms can only be sustained in a context of increasing profits derived from improved processes and products, generating in this manner a virtuous circle. The presence of internal economies of scale should not be confused with lower innovation costs, which occurs neither in pharmaceutical nor capital intensive natural resources sectors. Indeed, the Chilean mining case described in Bravo-Ortega et al (2015)) shows that developing new solutions in the mining sector requires more expensive and modern technology and that similarly skilled labor has become costlier over time. However, resources invested in R&D initiatives, skilled employees and equipment have often been rewarded with greater revenues, thereby making it possible to keep the re-investment in new technological solutions.

Table 5

Returns to Scale, Industry Organization and Availability of Funds to Carry Out R&D

		Final Producer		
		Constant Returns to Scale	Internal Increasing Returns to Scale	External Increasing Returns to Scale
Provider	Constant Returns to Scale	Textil 1 (iUSA*) Apparel 1 (i Bangladesh*) Fashion 1 Agriculture 1 Ancestral Medicine Food** Fishing** Characteristics Firms Non-Vertically Integrated Many Small Producers Final Producer: No R&D; Zero Profits Provider: No R&D; Zero Profits	Mining 1 Cars 1 (iUSA*) Planes 1 Machinery** Electronics** Characteristics Firms Vertically Integrated Final Producer: Does R&D; Monopolistic Profits Provider: No R&D; Zero Profits	Salmon 1 Characteristics Firms Vertically Integrated Few Large Producers Final Producer: No R&D; Zero Profits Provider: No R&D; Zero Profits
	Internal Increasing Returns to Scale	Agriculture 2 (i.e., USA*) Fishing** Sawmill products** Characteristics Firms Non-Vertically Integrated Many Small Producers Few Large Providers Final Producer: No R&D; Zero Profits Provider: Does R&D; Monopolistic Profits	Salmon 3 Mining 3 Cars 3 Planes 3 MNC Pharma Labs Oil Refining (iUSA*) Iron Steel ** Electronics** Characteristics Firms Non-Vertically Integrated Few Large Producers Final Producer: Does R&D; Monopolistic Profits Provider: R&D; Monopolistic Profits	Forestry 2 (iCanada*) Salmon 2 (iNorway*, Chile*) Software 2 (India*) Characteristics Firms Vertically Integrated Few Large Producers Final Producer: No R&D; Zero Profits Provider: Does R&D; Monopolistic Profits
	External Increasing Returns to Scale	Apparel 2 Fashion 2 Characteristics Firms Non-Vertically Integrated Many Small producers Final Producer: No R&D; Zero Profits Provider: No R&D; Zero Profits	Mining 2 (iSteel, India*; Copper, Chile; Aluminum, Norway*) Cars 2 (Japan*) Planes 2 Fashion 3 Pharmaceuticals 2 (i.e., India*) Iron Steel ** Electronics** Characteristics Firms Non-Vertically Integrated Few Large Producers Many Small Local Providers Final Producer: Does R&D; Monopolistic Profits Provider: No R&D; Zero Profits	 Characteristics Final Producer: No R&D; Zero Profits Provider: No R&D; Zero Profits

Source: Author's contribution. * Information on economies of scale taken from Sánchez and Tamayo (2015) and**Antweiler and Trefler (2002)

From an endogenous growth perspective, economic actors internalize technology as a factor of production, and then investments are linked to the achievement of increasing returns and monopolistic rents. Investments conducted by economic agents result in new knowledge that is formalized within firms through routines and blueprints or is tacit and embodied in workers. However, these investments are often out of reach for many firms. From this perspective, public policy interventions may help in fostering innovation in industries that are less favored but have economic potential in terms of productivity growth and/or significant labor demand in contexts usually described by constant returns to scale.

Regarding constant returns to scale, final producers and providers describe environments with many small-sized producers at early stages of productive development that often do not have profits. Thus, firms do not invest in R&D initiatives due to lack of funds coupled with small scale of production and distance to acquire the appropriate knowledge to innovate (Cohen and Levinthal (1990), Malerba and Orsenigo (1997), Boschma (2005), Balland et al (2014)), so industrial dynamics are characterized by many non-vertically integrated firms.

Table 6 shows different sets of policy alternatives depending on whether firms do earn profits greater than zero and are able to fund R&D depending on the economies of scale on final producers and providers. The policies prescribed in this Table rely on the assumption that firms conduct R&D by themselves only under the presence of profits, which generally exist under internal economies of scale and imperfect competition. Under the presence of constant returns to scale, we presume perfect competition and hence the absence of profits and lack of funds for financing R&D activities. Finally, under the presence of external economies of scale and perfect competition, we also assume zero profits for firms in a closed economy or non-tradable goods production. However, under external economies of scale and for firms that are global price takers, we presume that it is possible to obtain a cost advantage (remember average costs are decreasing under this industry configuration) by enlarging industry size and hence obtaining profits at a later stage, thereby sustaining R&D activities.

The design and delivery of public policies in consideration of returns to scale will consistently help in differentiating those industries that benefit from a better position due to monopolistic profits and allow them to undertake and finance innovation processes with their own resources; this is in contrast to those that evolve in a framework of zero profits. As described above, industries with constant returns to scale have no resources to undertake or even finance R&D activities, so several policy issues can be distinguished to facilitate knowledge transfer processes, finance innovation and invigorate the institutional aspect of firm development. Therefore, appropriate policies in this case are linked to the development of public research institutes that place their innovations in the public domain, public technology transfer offices, and subsidies for highly skilled human capital development. R&D subsidies and R&D tax credits will not be successful policies under these circumstances and neither will patent subsidies, as there will not be a demand for such instruments given that firms lack the funds for cofounding R&D activities. The exception would be subsidies being granted for the full amount of R&D and tax credits granted by a larger amount than expenditures.

Along these lines, policies differ depending on whether economies of scale are internal or external. Thus, to reinforce internal returns to scale, public policies to boost innovation are intended to facilitate a surge in profits, as public procurement and norms of origin, which in turn could provide internal funds to develop R&D. By the same token, R&D subsidies and tax credits could increase total expenditures on R&D in the industries, which could be justified by positive externalities to the rest of the industry or economy. Similarly, under external economies of scale and perfect competition, intervention might develop public facilities to enable knowledge accessibility, such as public research institutes, technical transfer offices, and human capital development. On the other hand, interventions aimed at strengthening benefits derived from external increasing returns will focus on producing a densification of the localized industrial fabric, primarily through cluster policies and consortia. These interventions aim to enlarge the size of the local industry and therefore enable the benefits of a larger scale and lower average costs to be reaped. By the same token, public procurement and norms of origin would serve the same purpose. Institutional settings, such as consortia and cluster policies, are meaningful when firms face geographical conditions of external increasing returns. These are starting points for vertical disintegration, with few large final producers and many small providers enabling the agglomeration of firms, the establishment of industrial clusters and networks for innovation.

Table 6

Industry Organization, Returns to Scale and Policy Prescriptions

		Final Producer		
		Constant Returns to Scale	Internal Increasing Returns to Scale	External Increasing Returns to Scale
Provider	Constant Returns to Scale	Textil 1 (i.e., USA*) Apparel 1 (i.e., Bangladesh*) Fashion 1 Agriculture 1 Ancestral Medicine Food** Fishing** Policy Public Research Institutes Technical Transfer Offices Human Capital Development Final Producer: No R&D; Zero Profits Provider: No R&D; Zero Profits	Mining 1 Cars 1 (i.e., USA*) Planes 1 Iron Steel ** Electronics** Policy Public Research Institutes Technical Transfer Offices Patent Incentives Public Procurement and norms of origin R&D subsidies and tax credits Final Producer: R&D; Monopolistic Profits Provider: No R&D; Zero Profits	Salmon 1 Policy Public Research Institutes Technical Transfer Offices Consortia Cluster Policies Public Procurement and norms of origin Final Producer: No R&D; Zero Profits Provider: No R&D; Zero Profits
	Internal Increasing Returns to Scale	Agriculture 2 (i.e., USA*) Policy Public Research Institutes Technical Transfer Offices Patent Incentives Final Producer: No R&D; Zero Profits Provider: R&D; Monopolistic Profits	Salmon 3 Mining 3 Cars 3 Planes 3 MNC Pharma Labs Oil Refining (i.e., USA*) Iron Steel ** Electronics** Policy Environment and energy efficiency Public Procurement and norms of origin R&D subsidies and tax credits Final Producer: R&D; Monopolistic Profits Provider: R&D; Monopolistic Profits	Forestry 2 (i.e., Canada*) Salmon 2 (i.e., Norway*, Chile*) Software 2 (i.e., India*) Policy Public Research Institutes Consortia and Cluster Policies R&D Subsidies Public Procurement and norms of origin Final Producer: No R&D; Zero Profits Provider: R&D; Monopolistic Profits
	External Increasing Returns to Scale	Apparel 2 Fashion 2 Fishing** Sawmill products** Policy Public Research Institutes Technical Transfer Offices R&D Subsidies Human Capital Development Final Producer: No R&D; Zero Profits Provider: No R&D; Zero Profits	Mining 2 (i.e., Steel, India*; Copper, Chile; Aluminum, Norway*) Cars 2 (i.e., Japan*) Planes 2 Fashion 3 Pharmaceuticals 2 (i.e., India*) Iron Steel ** Electronics** Policy Public Research Institute Technical Transfer Offices Cluster Policies Consortia R&D subsidies and tax credits Patent Incentives Public procurement and norms of origin Final Producer: R&D; Monopolistic Profits Provider: No R&D; Zero Profits	 Policy Consortia Cluster Policies Public procurement and norms of origin Final Producer: No R&D; Zero Profits Provider: No R&D; Zero Profits

Source: Author's contribution. * Information on economies of scale taken from Sánchez and Tamayo (2015) and **Antweiler and Treffer (2002)

Industrial organization and KIBS in mining in Chile

The mining industry in Chile shows significant internal increasing returns to scale at the final producers level. This allows mining companies, to continually upgrade machinery, processes of mine exploitation, exploration and so on. In this vein, providers show different degrees of returns to scale, which directly translate to their capability to invest in R&D activities. In our view, the mix of returns to scale in producers and suppliers has strong impact on industry organization and its development prospects. For instance, early stages of mining industry –defined this stage as gestation of KIMS (Urzúa, 2011) - providers are unable to perform R&D activities to improve their service provision. Despite of that, there are vertical integration processes between firms enabling limited KIMS incubation, but industry relations are asymmetrical where mining companies have strong bargaining power. Currently, linked to the innovative capability of mining suppliers in Chile –as mentioned above in this document- providers with constant returns to scales operate in conditions of low technological capabilities and low innovation.

But there might be also external increasing returns for some providers' activities. However, these economies of scale and localization for providers are not necessarily translated into improvements of their technological capabilities or to differentiate its provision of new solutions to the mining industry. This local environment has led to the emergence of weak industrial fabric, where prevails the called “transactional relationship” between mining companies and providers.

The best arrangement in the mining sector occurs when both final producers and providers achieve profits due to different degrees of increasing returns to scale. Accordingly, providers are able to develop innovation processes or even to improve the existing technology. Urzúa (2011) called this stage as consolidation where KIMS compete with foreign and well-known providers based on their accumulated knowledge management. At this point, firms are benefited by processes of vertical disintegration attending to social division of labor within the industry development. Thus, providers develop skills to adapt their services in responding to industrial requirements. In the end, there are few large producers and few providers with the level of technological capability and trajectory to achieve greater levels of business consolidation and service provision. Some of the cases of suppliers analyzed here, fit well into this pattern, since firms are regularly investing in internal assets and capabilities to increase their level of innovation and productivity (ENAEX; BAILAC).

From the public policy perspective, public tools should be tailored according to the industry configuration and the level of development that firms actually have within an industry. For instance, in the case of Chilean mining more advanced providers—those with skills to provide world class suited services- argue that public instruments to finance innovation are too broad, not necessarily adjusted to their needs and too bureaucratic in both the application phase and during the project development. Complementarily, all firms argue there is a lack of qualified human capital in the industry.

Regarded to cases of study, providers agree that developing R&D initiatives to provide a suited and improved service is expensive for individual firms and many can not afford this

type of investment. In this sense, costs are usually related to skilled employees, physical assets and IT infrastructure. Among them, human capital is the most costly issue, since in regions different to Santiago it is not easy to find, experienced workers in R&D activities are difficult to find and usually –new hired workers- require training instances related to fields of firms development, like engineering, programing, IT, specific service issues, etc.

The investment in human capital is highly important as a differentiation factor for R&D performance, because local suppliers recognize that China has a huge advantage to provide cheap manufactured or electronic goods. Though, local suppliers have developed strategies to provide improved services grounded on its geographical proximity to mining companies –contrasted to international providers, their ability to provide innovated services is substantiated on their accumulated knowledge about the industry requirement and needs, their ability to adapt services responding to mining companies, and ultimately, their capacity to afford the costs implied R&D.

In this sense, the World Class Suppliers Program (WCS) is highly appreciated, because local suppliers find a place to interact to mining companies, its actual needs, and where there are public funds that help to finance innovations.

Differently to the current situation, in early 80's mining industry was more prone to take risks related to new solutions development. Firms noticed that the change from a close relationship with managers of mining companies has evolved into forms that reinforce and stabilizes the institutional distance between companies and its suppliers. Thus, providers that have strengthened their business opportunities with mining companies rely on linkages of long time development based on mutual knowledge and trust.

This situation has been slowly changing within the WCS Pogram, where two mining companies –BHP Billiton and CODELCO- are creating conditions and opportunities for more advanced suppliers. Thus, suppliers that fill in the company's requirements will find incentives to keep innovative effort and conditions to strengthen their intra-industry linkages through improved services provision.

Therefore, one might describe that early 80's was an historical moment of the Chilean mining industry, since providers at that time benefited from opportunities to develop solutions in a sector that needed to increase its rate of mining production and investment levels. That contextual situation of the industry was used by a number of mining suppliers to strengthen their innovation advantages in specific services, like OTR-tire provision and its management, pumps services and explosives-related services. This opportunity was the chance to interact with mining companies at a time when it was feasible to implement improvements without institutional filters, as seen today that make it difficult for new firms the accessibility to conditions and information for the proposal of solutions that could positively affect the industry performance. As a result, nowadays, it is hard to find collaborative and mutual initiatives within the industry.

Thereafter, as the local industry is too rigid to promote innovations development along the complete range of stakeholders within the mining industry, the remaining question is how

do domestic suppliers get involved and reach benefits from the provision of improved services? All the firms presented in this document stated that the design and development of new solutions are demand-driven. Hence, once providers get access to information related to mining companies' needs and productive challenges, they locate and concentrate their resources in researching and developing solutions based on their own knowledge and capabilities. For instance, pumping improvements attend to the cost-effective solution linked to energy efficiency and CO2 emissions reduction. Similarly, tires management schemes attend to tire saving solutions. Prototypes and models applied to the mineral production and dust control respond to the tasks of facilitating the mining continuous operation.

From this perspective, providers have a critical perception about intra-industry linkages and the business dynamics in progress in Chile. About causes, they distinguish a rentier perspective applied to trade and interactions established between mining companies and their suppliers. This issue could be related to the involvement that local suppliers have to assume once the firm is established, coupled with the absence of intra-industry policies of local content, as a way to encourage the development of domestic industry. Consequently, the result of this complex scenario is materialized in a business environment centered in a commercial approach rather than industrial development. Then, firms interact within a strong rivalry framework, where competing firms override instances of cooperation between them.

Regarding to joint initiatives among mining companies and suppliers, it seems to be a lack of or a weak government policy at this respect. In particular, it is interesting to note that CODELCO, the largest (and state-owned) mining company in Chile, has a number of joint ventures with foreign companies, but has not generated any regular link or association with local firms. This deficiency has increased the difficulty of internal strengthening of local companies, in order to upgrade them into world-class suppliers.

Furthermore, achieving competitive skills in the local industry and being an alternative compared with international suppliers is a very demanding task for domestic providers. Indeed, successful local suppliers developed ongoing and regular linkages with mining companies, which go beyond the transactional scheme of service and/or product provision. Subsequently, innovation prone suppliers –in a non-transactional linkage- gain a deep understanding of problems that mining companies faces in their processes. In this situation, innovations offered do generate business benefits for both mining companies and providers. Therefore, what first should be tackled is the initial barrier of the transaction and operational link between firms. Additionally, risk aversion and stiffness in the way of doing business by the mining companies do not facilitate the development of solutions that require infrastructure for testing innovations.

World Class Suppliers Program

The World Class Mining Suppliers Program started by BHP Billiton in 2008. Later on, Codelco –the state owned copper company- joined the program in 2010. More recently, in

2012, Fundación Chile, a public-private foundation that works on technology transfer, joined to the program in assessing its impact among providers, in designing a methodology for suppliers development and running a sectoral suppliers characterizations on a regular basis. In this path, there is interest for new mining companies' partnerships and possible enhancements of the initiative.

In Chile, the program is structured upon two main objectives as follow:

- To develop 250 Chilean-based resource industry suppliers into 'world-class' global resource industry suppliers by 2020.
- To foster the technical and managerial upgrading of providers to the mining industry, so they develop innovative solutions to address challenges identified as critical by the Company's operations.

Thus, in its core the program addresses several market failures that hinder the development of innovation in the industry. Those issues are related to high transaction costs that could result in poor matching between mining companies and solutions delivered by suppliers, the inefficient risk sharing that could be an excessive burden for SMEs in the process of providing upgraded services and supplies, the asymmetries of information that could hinder the characterization of the problems and the leverage of services provided, the indivisibility of fixed assets and the presence of economies of scale that do not allow to have pilot plants for suppliers, and lastly, the lack of knowledge externalities and knowledge diffusion that limit the spread of solutions within the industry.

The program seems to be highly beneficial in its win-win strategy. Indeed, the institutional strengthening derived after the Program implementation is one of the aspects highlighted in this revision. This is because the Program generates new links between local providers of the industry and the company, through the provision of services for supporting the mining operations, achieving a new perspective for social corporate responsibility activities (Barnett and Bell, 2011; Korinek, 2013). Then, there are a quadruple win situation, where mining companies win new solutions with positive effect on their operations, suppliers win a regular market access for their upgraded services, the industry wins new development dynamics and the provision of new services upon further upgrading processes that will be developed, and Government wins a sustained production of the mining industry.

The Program rely on projects that involve solutions for the mining company addressing its major challenges. In this context, issues that are entailed for providers are related to the maintenance of equipment and plants, the human resources management, the provision of solutions that increases efficiency and generation of energy, the display of methods aimed at increasing the operational productivity of mining process, the securing of procedures of health, safety and environmental considerations required by the industry and the implementation of technics that upgrade the extraction of minerals efficiency.

Consequently, the program implementation is based on the collaboration between the mining company and its suppliers, so to generate new solutions to problems previously and carefully drafted by the mining companies. On the very beginning, BHP Billiton drafted

140 problems, but chose to address just 5 of them considering productivity improvements and long term commitments of suppliers. The main challenge of the program is how to articulate the collaborations between agents and how to develop a regular link upon the built social capital between the involved actors. After the problems has been drafted by the mining company, headhunters search for possible supplier firms that could solve some of the problems and fulfill the Health, Security, Environment and Community (HSEC) and commercial principles of BHP Billiton.

The volume of investment of the Program is about US\$ 70 million to develop suppliers' upgrading projects (BHP, 2013). In this context, mining companies deploy a process of re-modelling the standard local procurement process in the way that they create open opportunities for providers in encouraging the proposal of innovative answers to the industry challenges. BHP Billiton and Codelco provide to suppliers information about the drafted problems, act as technical counter parts of the provided solution and provide external consultants to bring into suppliers new skill in managerial and organizational aspects that ensure the world-class transition of local firms. In addition, mining companies provide facilities for testing opportunities and provided solutions undertaking the scaling up of the innovation, if they are successful in achieving enhanced performance and/or positive effects on the operational process of the company. Thus, the whole range of actions deployed solve markets failures mentioned above, such as asymmetries of information, the inefficient risk sharing, the asset indivisibility and allows to suppliers in enjoying the benefits of economies of scale derived from innovations.

The mining company and the supplier -previously of getting involved in the Program- sign a collaboration and preferential commercialization agreement. Along the process of intra-industry and inter-firm association, suppliers have the chance of learning and accumulate new innovative capabilities, since it can handle sequentially an increasing number of problems. What reminds important is that during this process supplier firms can also access to public funds or use R&D tax incentives, due to the effort for developing new to the 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. Once the innovation proved to be applicable and successful for industry requirement it can be scaled-up, which implies the possible commercialization of the solution with other companies and its internationalization.

Some examples of innovations developed under the program are:

- Reduction of electricity consumption per tone of copper produced by 2% in a electro-winning plant.
- Design of a plant that can generate electricity from mining tailings.
- Project that increases oxide recovery at a leach pad by 2%.
- Increase of the life usage of shovels cables by 40%.
- Increase the period between maintenances of engines and transmission systems of large mining trucks.

Some challenges that the World-Class Suppliers Program face point to managerial, commercial and industrial aspects, such as increasing the number and exports of products on the market derived from the mining industry, the strengthening of suitable skills of providers on managerial and commercial aspects, the enlargement of social capital within the industry expressed in the number of mining companies partnerships, the implementation of business accelerator and the rise of disruptive rather incremental innovations. Complementarily, from an industrial perspective learning about this partnership experience, the way it is implemented, the role of each actor, the formal commitment of involved firms in gaining mutual benefit impose the question about identify those key transferable factors to other industries also based on weak value chain dynamics. In its turn, the deep understanding of this program and the industrial evolution that gave it room will shed light about how and, eventually, what kind of learning aspects spillover to related and unrelated industries.

The Program is positively valued by firms as an instance of change in the approach of how mining companies promote intra-industry linkages. In words of providers, this initiative is translated into a collaborative strategy that improves the suppliers' environment to develop suited answers to challenges raised by companies. Ultimately, this program is an incentive for providers to expand their learning frontiers in applying their knowledge in finding the right solutions to tackle mining companies' difficulties of their operational process.

Thus, the program contributes in building an industrial environment different to the current transactional scheme within the mining industry. Indeed, suppliers that have took part in the program –like Bailac and MSMIN- emphasize that initiatives and activities regarded to the program help in creating or strengthening intra-industry linkages throughout the value chain. This is because mining companies –like BHP Billiton and Codelco- lead changes that reduce the level of uncertainty of risks associated to the implementation of new solutions and technologies required by the industry.

One of the aspects that is highly valued by mining suppliers is the close and collaborative work that it is possible to accomplish within the program. Then, providers see that transaction costs are reduced significantly when they gain access to information regarded to requirements and tasks that mining companies need to solve. Thus, suppliers are encouraged to develop innovative solutions in a frame of joint collaboration with the company. This process empowers to suppliers, which implies increases in firms' confidence, its reputation and the re-view of strategic areas of businesses beyond the routine performance of doing things.

For instance, Bailac, the domestic supplier of Off-The-Road (OTR) tire-related services participates in the world class supplier program, with BHP Billiton, providing intelligence for tire management and maintenance, in attention to tire savings and extending its useful life. Then, the interactive process between Bailac and BHP Billiton to develop a solution resulted in a predictive maintenance system to maximize the use and reparation of tires at Cerro Colorado. Accordingly to BHP Billiton, by the year 2011, the implementation of this innovation implied the extension of about 40% of tires usability within the company

operations. Thereafter, Bailac supplied regular services for tire maintenance assuring steady linkages with mining companies in Chile.

Similarly, MSMIN took part in the program within the Codelco framework in providing a solution to reduce the amount of dust due to the crushing process within the mine. Thus, the supplier developed a suited solution to the operational routine and the mine design of Division of El Teniente. The innovation involved a partnership scheme of MSMIN with suppliers of equipment and supplies, like Sanvik, Finning, and others. As the solution was successful in dust control, MSMIN is starting the industrial production of the solution bearing in mind the consolidation of this innovation and its commercialization to other mining plants and companies.

Current version of the program run by BHP-Billiton and CODELCO has a positive expectative from suppliers, similar to the first version implemented in 2008. However, those suppliers with more back-office competences and with less presence in mine operations tend to disregard some formal topics during the application process. For instance, INGMAT, despite its internal capabilities and the qualification of its human capital has not being accepted by the program because they do not possess safety certifications requested by mining companies. Undoubtedly, from supplier's perspective, this lack of credentials is seems as an unnecessary filter that makes the access more difficult to innovation opportunities. On the other hand, there are suppliers that consider that the program has introduced positive changes in the scope and in the amount of funds available, so there is a sense that those improvements were proposed to make things effectively happen.

BOX N°4. GTS –GLOBAL TIRE SAVER

In mining operations loading and transportation processes represent major cost items, reaching about 50% of the total cost of a mining operation. This, figure reaches 60% even in the case of ancient sites, where the pit has large dimensions and the distance to facilities may have several kilometers.

Therefore, tires involve the third input into the mine charge, followed by explosives and fuel. The latter, have restricted savings opportunities, but proper tires maintenance constitute a great chance for savings (over a million dollars/year).

In this context, Bailac firstly developed an active tire's monitoring unit, called UMAN, and further improvements allow them to develop GTS. GTS consists in a wireless tire's monitoring system based on an innovative technology that electronically monitor real time tire pressure and temperature, while it is moving.

In mine operations, issues like fuel, maintenance processes and tires are usually the largest expense. Therefore, it is crucial to have accessibility to precise information for achieving an optimal tire performance and ensure its maximization. The GTS system works on any OTR tire independent the brand, its type and size.

R&D processes that support this solution is local –Iquique (in the North of Chile)- allowing the development of local sensors for tires coupled with wireless transmission equipment available in the market. This innovative effort was developed in the context of the WCS Program and partially financed by CORFO allowing the product development in design, programing and electronic interface (code and equipment).

Benefits of the internal or new versions of the tool, with temperature measuring sensors inside the tire describe:

- A productivity improvement: since it reduces the number of equipment detentions for checking procedures.
- Tire's performance increase: it allows taking appropriate measures to prevent
 - ✓ Uneven wear on the boulder band
 - ✓ Cuts on the boulder band due to overpressure
 - ✓ Mechanical separation due to low pressure
 - ✓ On the sidewall cuts due to low pressure
 - ✓ Heating due to low pressure or dual contact
- Fuel saving
- Safety: Real-time monitoring of tire pressure and temperature, avoiding exposure of people within the operation

How does it work?

GTS is organized through wireless communication between internal sensors to the tire, a UMAN Box and the Service of Information Monitoring. The latter, could be remote located and based on web services. Among the utilities that this system provides are tire's management reports, tire's pressures corrections and a leakage indicator.

Sensors located both in the valve –for pressure measurement- and inside the tire sense the information about tire pressure and temperature every 5 minutes, and send a wireless signal to the receiver. Through the UMAN BOX this data is stored and transmitted to an alarm panel which is located in the operator's cab, so the driver knows the status of each tire permanently. This panel interprets alarms related to temperature and for high and low pressure, according to desired parameters. This data is also stored in the Service of Information. Monitoring that allow the remote tire monitoring system that is able to check tires information every 5 minutes.

In Chile, this innovation has been developed in mine operations like El Soldado, Los Colorados, Mantoverde, Codelco El Teniente, Codelco Mina Sur, Codelco Gaby, Codelco Ministro Hales, SGSCM - Sierra Gorda project.

Further developments are focused on the integration between PASCUAL and GTS, so to secure tires' information online. Currently, about 60% of trucks in mining operations are monitored using this wireless platform, so there is a potential opportunity to increase new mining operations and trucks for tire management services. This solution has not been delivered to Brazil and US yet, because of cost to implement and the experienced developed in those markets.

In addition, suppliers understand industrial changes –within the program and in the way that mining companies are working with providers- as a natural evolution of a more mature industry. Similarly, the progressive consideration of CSR schemes has resulted in favorable –while recent- changes in business conditions. In fact, over the past three years, there are improvements related to labor regulations, subcontracting and community relations linked to mining operations. This also means that providers should consider these aspects in their provision of value added services to companies. This aspect is reinforced by the implementation of the World Class Suppliers Program, since the improvement of solutions have greater impacts than the exclusive product development.

Conclusions

The importance of developing innovative capabilities of local suppliers in Chile is significant due to the impact that it may have in the local economy. Indeed, by observing the experience of Australian METS sector where firms are able to mobilize the R&D investment in related areas and subsectors, coupled with a rising trend of exports of services worldwide and great levels of local labor sustained on industrial clusters that organize the natural resource sector.

In Chile, the growing knowledge of suppliers in the last 5 years has made possible to identify its internal segmentation, business scope, geographical distribution, participation in sales and employment, and so on. Nevertheless, the participation of suppliers in R&D activities remains low affecting actual capabilities to achieve significant productivity improvements in the industry.

Despite this, the analysis of service innovation in Chile (Álvarez et al, 2012; 2013) shown that this sector in Chile has slowly initiated the path of innovation. However, structural conditions of local mining suppliers make it difficult for them to change their trajectory to a faster path where innovation is the key factor of economic development. Indeed, about 65% of local providers are micro and small sized firms, which have implications on their scales of service production, the number of professionals involved in daily tasks versus R&D activities, the limited or scarce possibility to invest in R&D and so on. Complementary to this, a great amount of local suppliers -67% of them- have low capacity to develop technological solution, which in turn limits their ability to perceive better returns for services provided. Despite of this adverse scenario, it is possible to find positive experiences where more advanced suppliers are able to adapt their service portfolio to mining companies requirements combining technological capabilities in upgraded or new solutions

developed. Those experiences were helpful in finding answers to the questions that drove this research.

The first finding, is related to the vertical disintegration is an opportunity for local innovation in service related to natural resources sectors. Indeed, our case studies agreed that mining sector and its relative geographical concentration is an opportunity for service provision and business development for local providers. The drawback is related to the persistent *transactional scheme* rather *collaborative schemes* of business run by mining companies that have important implications for the industrial organization and the innovative effort of firms. Something seems to be slowly changing after the stimulus of cluster policies and the World Class Suppliers Program. Early stages of sectoral development, mining companies achieved increasing returns to scale while most of suppliers might show constant returns to scale. This stage has been called gestation (Urzúa, 2011) since it refers to the incubation of suppliers of goods and services. In Australia, this process took part in the first part of twenty century while in Chile it occurred after the second half of the century. This mismatch has affected the level of knowledge accumulation of KIMS and imposed high challenges in technological catching-up for local suppliers. Thus, vertical disintegration has allowed to local suppliers accessing to real industry challenges to develop suited solutions, which after trial and development gave room for future contracts and increasing returns, if the innovation is successful.

A second finding is related to the differentiated effects of public policies to boost innovative experiences of Chilean firms, and particularly within the mining suppliers of services. There are several public policies that foster innovation aligned with the industrial organization in Chile, some of them are tax incentives for in-house R&D activities, suppliers' development, R&D incentives. However, the degree of alignment to natural resources is still weak. In words of mining suppliers in our case studies, available public tools are too broad in scope and not suited to strengthen actual needs of mining suppliers, like the acquisition of fix assets, the availability of facilities to test innovations and the accessibility to technical support. On the other hand, the administrative procedure of public tools is an important disincentive for innovator, since they feel that conducting a R&D activity funded with public funds implies to divert –limited- resources to this task. As a result, local suppliers opt to fund innovation by their own resources.

The third learning is regarded to the beneficial experience of the World Class Mining Suppliers Program run by BHP Billiton, and recently in joint initiative with Codelco. Suppliers –some in our cases studies- that experienced the World Class Suppliers Program (WCS) highlight that this initiative helped them in reducing existing transaction cost with the mining company. Then, WCS enable the collaborative and joint development of solutions in operational tasks linked to core processes of companies, like mineral grinding, dust management, tyre management, among others. Similarly, within this framework, suppliers were able to access to related operational information of the mine, which allowed them to develop contextual solutions rather standard development. Then, the risk of solutions development is minimized, as both company and provided share part

of the innovation involvement –mine provides facilities and suppliers assume part of cost related to solutions.

The fourth finding is that advanced and experienced suppliers are innovation prone actors with regular processes for searching opportunities to deliver enhanced technological solutions suited to mining companies requirements. However, this is the attitude of few mining providers and a huge gap is evidenced along other suppliers' development. In this context, one of the main aspects is that local innovators find a niche where to provide their services in a competitive manner. For example, all of them are aware of the low cost of manufacturing in China, then their scope is to provide maintenance management, recycling equipment, among others. This is because mining companies require this kind of services and international suppliers usually are not able to compete with the local offer.

Cases of study are helpful in highlighting those drivers and obstacles behind the innovation performance showed by mining providers. In this way, with the risk of overgeneralizing, firms providers to the mining industry emphasized five factors that promote innovative effort within the sector. Those factors are related to the governance and direction of innovation initiatives within the firm, the technological path that describe the business trajectory of providers, the continuous improvement approach displayed by firms, the human capital enhancement initiatives within firms, the formal and informal linkages developed between mining suppliers and mining companies and the opportunities to reduce transaction costs among agents involved in developing innovations.

On the other hand, considerations identified as impediments to strengthen the innovative capacity of firms are linked to the need for skilled workers with related competences within the industry, the local business environment characterized by weak industrial fabric and fierce rivalry, the level of risk aversion of mining companies, the weak university-industry linkage at regional level, the actual competences of mining suppliers and its possibilities to compete with foreign providers to the industry, and the need for differentiated public policies suited to firms' size and stage of development

Experiences of collaboration between mining companies and suppliers are incentives for the latter in getting engaged to their productivity improvement supported by developing new or improved solutions. In general, local suppliers recognize that mining companies require a close platform of high standard services at competitive prices. In this period of mining critical scenario to development –weak availability to water, the reduction of ore grades, the fluctuation of copper prices- coupled with challenges imposed by geographical locations of mines, innovation initiatives developed by suppliers could help in improve sectoral efficiency and the incidence that this activity has for the Chilean economy.

Finally, our short diversion into the implications on the impact of different degrees of economies of scale puts forth a caution note on the design of industrial policies due to the fact that it is unlikely that one-size fits-all policies will work in this case, as has been widely preconized in the implementation of horizontal development policies in Chile during the last decades.

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