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Global Value Chains in the Peruvian Mining Sector

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Abstract[*]

Traditionally the Peruvian context has been unfavorable for innovation by local firms in the mining sector. However, some firms have managed to innovate despite these conditions in recent years. The aim of this paper is to understand the factors and incentives that foster or hinder innovation in the Peruvian mining industry. Through the study of the experiences of a group of local suppliers, the mechanisms that lead to innovative activities are identified and analyzed. Special attention is paid to the role of interaction between contractors and large mining companies in the framework of Global Value Chains, as well as to the innovative efforts of some local suppliers. Evidence shows that innovation by local suppliers in the Peruvian mining sector has a limited scope and some particular characteristics. First, local suppliers who manage to innovate are mainly incumbent firms whose experience in the market allowed them to integrate into the mining value chain. Second, most of these firms are usually supported by their relationships with larger national or international companies. Third, the more important innovations seem to be concentrated in specific sectors where there is less foreign competition because of their specificity to the Peruvian context.

JEL Codes: O13, O32
Keywords: incumbent firms, innovation, mining, Peru, suppliers, value chain

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Content

1. Introduction

During the last decades, Natural Resource (NR)-related sectors have experienced huge transformations, increasingly becoming more innovative and specialized. The mining sector is no exception, as the industry has shown a significant increase in productivity and innovation (Bartos, 2007). Specifically, new historical circumstances and recent changes in global markets, technology and institutions are opening new opportunities for the development of local suppliers and linkages with a high development potential in association with mining activities (Marin, Navas-Alemán, & Perez, 2015). Considering that mining activity has a heavy weight in the economic activities of most developing countries, there is an increasing interest in the relation between Natural Resource-related industries and the emergence of knowledge-intensive and diversified local suppliers (Marin, 2015; Stubrin, 2015).

Peru is considered one of the top ten richest mineral countries in the world and one of the world's biggest producers of base and precious metals. Mining has been historically a key sector for the development of its economy.[1] However, there is limited evidence of innovative local suppliers linked to the Peruvian mining industry (Kuramoto, 1999) and very few researchers have explored this topic in recent years. Therefore, it is worth asking if the favorable conditions of the last decades (i.e. substantial increase in investment, start of major mining operations, price boom) have helped local suppliers to fast forward innovation.

The aim of this research is precisely to understand, from the analysis of the Peruvian case, how the mining industry can encourage structural change and economic diversification through the inter-firm linkages that characterize the Mining Global Value Chains (MGVCs). This analysis is particularly interesting within a macroeconomic environment that does not foster innovation such as Peru. Indeed, Peru's spending on Research and Development (R&D) as a percentage of GDP was only 0.12% in 2015, which represents a third of what Chile spent and less than a quarter of Mexico's expenditure. Only recently, tax incentives for innovation were introduced in Peru.

Through the analysis of local firms and their interaction with different actors of the mining sector we expect to gather new evidence on how the mining sector in Peru fosters (or hinders) local learning and upgrading of established firms and the emergence and consolidation of new ventures. In order to address our research questions, we selected eight local mining suppliers that have succeeded in introducing innovative solutions and services to mining companies. The suppliers selected capture a wide range of services that mining firms contract locally, and represent interesting cases where suppliers have introduced valuable innovations.

Evidence found shows that, even in an environment with unfavorable conditions for innovation, technological upgrading is sometimes observed in the Peruvian mining sector. However, it has a limited scope and some particular characteristics. First, innovation seems to be concentrated exclusively in incumbent firms rather than in new ventures. Incumbents have the advantage of knowing the market and have a large experience working in the sector, although they only started innovating in recent years. Second, the entrance of local suppliers in the high value-added stages of the MGVC is usually supported by their relationships with larger foreign transnational companies or Peruvian holdings. Finally, the major and more important innovations (for example, those that can be classified as world class) seem to be concentrated in specific sectors where there is less foreign competition, such as explosives and machinery for specific geographical characteristics (i.e. narrow veins in underground mining).

This paper proceeds as follows. In the next section we provide a simple conceptual framework centered on the learning process and on knowledge spillovers in Mining Global Value Chains. Section 3 briefly describes the current situation of the Peruvian mining

[1] Its contribution to GDP between 1951 and 2014 has been 13.1% on average.

context, emphasizing its relevance to the country and the world. Section 4 discusses the new opportunities identified in the Peruvian sector that may foster structural change and diversification in the mining industry. Section 5 describes the methodology applied in this study. In section 6 we describe the capabilities of local suppliers analyzed. This section is divided in two sub-sections: first, innovations achieved by local suppliers are presented and then, the processes and mechanisms that led to them are described. In section 7 we discuss the characteristics of the market and of the organization of industry that have allowed or hindered the development of the innovations described in the previous section. Finally, section 8 summarizes the main results and policy implications.

2. Conceptual background

2.1. Literature on natural resource specialization and innovation opportunities

An extensive literature during the ‘50s and ‘60s argued that natural resource-rich countries (NRRCs) needed to encourage a structural change away from the exploitation of natural resources (Prebisch, 1950; Singer, 1950; Seers, 1969; Myrdal, 1957). Authors argued that due to the enclave nature of commodities production, countries would not benefit from the forward and backward linkages between the primary export sector and the rest of the economy. According to Singer (1950), low income economies would not be able to handle the technological complexity involved in the extraction and production of minerals. Instead, the country of origin of the mining company was the one that benefited from the technological spillovers from the mining activity. Besides from the enclave nature of mineral production, Singer and Prebisch (1950) argued that the development of synthetic substitutes for natural resources, the low income elasticity of natural resources and the low technological progress in the mineral process where significant demand and supply rigidities which would translate in a constant decline in the price of commodities. This analysis led these authors to the conclusion that countries should not specialize in natural resources.

However, the huge transformation that the mining industry has experienced during the last decade has contributed to reinforce the idea that it is possible for economies to grow and diversify through natural resource specialization. The changing global market and technological and economic conditions are creating a new context in which developing countries can take advantage of NRs. In recent years several authors have discussed and identified these transformations (Urzúa, 2007, 2011; Morris, Kaplinsky, & Kaplan, 2011; Marin, Navas-Alemán, & Perez, 2015). Authors acquaint that, in general, mining activity has become more knowledge-intensive and increasingly involved in technological improvements in the different stages of the mining process. Multinationals in NR sectors have changed their usual behavior of acting as enclave towards adopting a more decentralized way of operating, mainly because mining companies have strong incentives to increase the level of outsourcing and near-sourcing in their non-core activities (Morris, Kaplinsky, & Kaplan, 2011). Moreover, mining companies are increasingly re-directing their extraction activities to developing countries, where there are under-exploited resources and less labor and environmental restrictions. This has led to the emergence of specialized suppliers locally.

Due to this recent transformation, a wide literature has emerged trying to understand and explain the linkages and the learning and innovation processes in natural resources industries that can encourage structural change and economic diversification (Ville & Wicken, 2013; Marin & Stubrin, 2015; Marin, Navas-Alemán, & Perez, 2015). This literature challenges the view that NRRCs should encourage structural change away from natural resources, and argue that structural change and production diversification should be achieved by working with the resources that countries possess. Moreover, the literature has identified that in the current context and under the new structure of the mining sector, new opportunities are emerging for the development of local suppliers associated to mining activities.

Marin et al. (2015) identify a new window of opportunity for the development of NRRCs, which emerges from the following global conditions: first, there is an increasing demand for minerals while easy-extraction mines are dwindling. The combination of these factors encourages innovation to achieve profitable mineral extraction from less favorable locations or from lower quality mines. These efforts would encompass processes related to exploration, extraction and transportation technology. Second, the worldwide demand for less standardized products is expanding. As a result, the market's focus on aspects like conservation methods, certification, and distribution has increased. This generates new opportunities for suppliers to cater to the added difficulties of dealing with more complex production systems. Third, the specific needs and challenges faced by particular NR industries in a region require the development of local knowledge-intensive services. Furthermore, associations between potential suppliers of technical and scientific services allow the industry to specialize in local challenges. Fourth, the increasing decentralization of mining companies' innovation activities creates an opportunity for local suppliers to get involved in the more sophisticated stages of the value chain. Finally, the increasing environmental regulation and the shift of demand preferences towards environmentally friendly products are driving innovation in products and processes in the mining sector in order to comply with the new requirements (Marin, Navas-Alemán, & Perez, 2015).

Nevertheless, the management of NR in a country can still face issues like a deficient governance, institutional weakness and lack of capabilities of local firms. In a review of historical evidence in economies such as Australia, Sweden, Norway and the USA, Morris et al (2011) observed that the association between low levels of industrialization and high dependency on commodities was determined more by the absence of capabilities in commodity-dependent economies than by the inherent conflict between the simultaneous and synergistic expansion of both sectors. Thus, the extent of the linkages between the local economies and the mining companies strongly depend on the capabilities of the local firms and the general economic and political context, which calls for regulations that encourage innovation by resource-based companies (Marin & Stubrin, 2015).

2.2 Theoretical framework of global value chains

The opportunities described above present a new context for mining activity that favors the creation of new local suppliers. However, the organization of industry that prevails in the mining sector often follows the form of hierarchical value chains that may hinder or foster to the creation of new suppliers in the sector. In order to explore this crucial dimension in the mining industry we are guided by the GVC theoretical framework (Gereffi et al., 2005; Pietrobelli and Rabellotti, 2007 and 2011).

A value chain is a system that encompasses the full range of activities which are necessary for the conception, production, delivery to final costumers, and disposal after use of a product or service (Kaplinsky and Morris 2000). The organization of these activities between firms is known as its governance pattern (GP) and it dictates what is manufactured and what services are offered, who is in charge of the production process for each segment of the chain, the manner in which that production is carried out, the standards of quality required, and the place and time of production. Specifically, according to Gereffi et al., 2005, the governance of a chain depends on the following key factors: (i) Complexity of the information involved in the transactions, (ii) Possibility to codify that information, (iii) Competence of the suppliers along the value chain and (iv) Degree of explicit coordination and power asymmetry. The interaction of these key determinants results in five types of global value chain governance –market, modular, relational, captive and hierarchy- which range from high to low levels of explicit coordination and power asymmetry.

Market chains are dominant for standard products that can be easily specified and can be manufactured with minimal input from buyers, so the costs of switching to new partners are low for both parties. The key element in transactions between the lead firms and suppliers is price. In modular value chains suppliers typically make products to customer's specifications taking full responsibility for the results. This relationship is possible when the design of products is modular (components are designed independently and have standard interface that allow this modules to function as integrated). In a relational value chain, transactions are complex and not easily codified, relationships tend to be idiosyncratic, and it is difficult and time consuming to re-establish with new value chains partners (switching costs are high). As bargaining power of suppliers and buyers tends to be relatively equal in this kind of chains, relationships are mostly determined through reputation and commitment. In captive value chains, small suppliers are highly reliant on large buyers and are under strong control from lead firms because they generally lack competences. There is a high power asymmetry where suppliers are tied up to the lead firm. Finally, hierarchy governance is characterized by vertical integration, with suppliers often owned and always controlled by them. This is the form of governance that tends to prevail in mining value chains, with very large and strong (often multinational) lead firms operating in several countries, bearing the high costs of long and risky explorations and developing a network of reliable "first-tier" suppliers that provide essential intermediate inputs and services in several mines across the globe (Morris et al., 2011, ECA, 2011). What is the scope for learning, innovation and value creation that is open to local suppliers? Can the windows of opportunity described in the previous section be exploited in fact given this prevailing GVC governance? These questions will be addressed in the following sections.

3. Peruvian mining context

3.1. Relevance of Peruvian Mining in the World

Peru is well known for its mineral wealth, and is considered one of the top ten richest mineral countries in the world. Currently, Peru is the world's third largest producer of copper and zinc and it is also a major producer of gold and silver, among other minerals (see Tables 1 and 2).

Table 1: Mining production: Peru and the world 2014

	Peru	World	Unit	Share
Copper	1,400	18,700	Tmt	7.5%
Gold	150	2,860	Mt	5.2%
Molybdenum	18,100	266,000	Mt	6.8%
Silver	3,700	39	Tmt	14.2%
Lead	270	5,460	Tmt	4.9%
Zinc	1,300	13,300	Tmt	9.8%

Source: Ministerio de Energía y Minas.

Table 2: Peru's Ranking in World Mining Production 2014

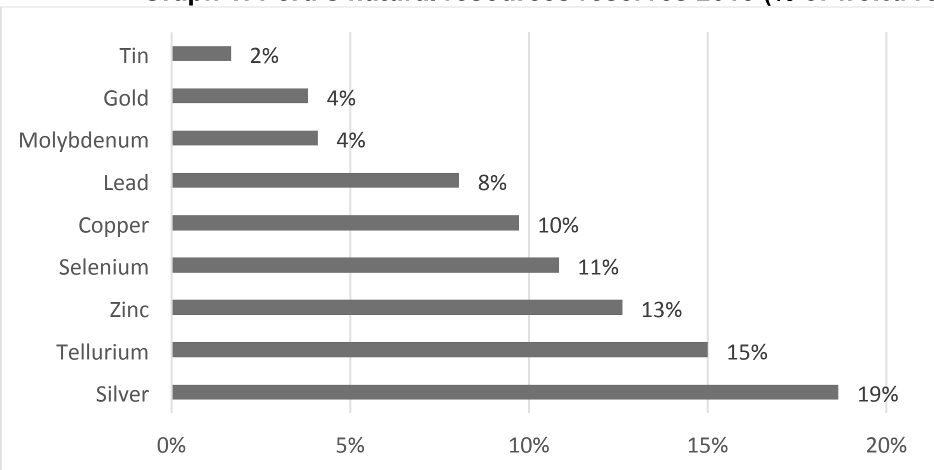
Product	Latin America	World
Zinc	1	3
Tin	1	3
Lead	1	4
Gold	1	6
Copper	2	3
Silver	2	3
Molybdenum	2	4
Selenium	2	9
Cadmium	2	8
Phosphoric Rock	2	12

Source: Ministerio de Energía y Minas.

Even though Peru occupies the first places in the production of different minerals, its production volumes are significantly lower than the leading countries'. Peru is the third largest producer of copper and the sixth largest producer of gold in the world, but its copper production only accounts for 23 percent of Chile's, and its gold production is only 35 percent China's (See Annex 4) (USGS, 2015).

Nevertheless, Peru is present in the top 5 global ranking of mineral production for several different products like copper, gold, silver, and zinc. Besides production, Peru also possesses a wide range of mineral deposits with potential in both volume and variety (See graph 1). This diverse supply has become a major competitive advantage of the country. However, Peru's share in global production is still lower than its share of global reserves for most of these minerals.

Graph 1: Peru's natural resources reserves 2015 (% of world reserves)



Source: (USGS, 2015).

3.2 Relevance of Mining for the Peruvian Economy

The importance of the mining sector for the Peruvian economy becomes obvious when one sees that its contribution to domestic production has been 12.35% on average between 2010 and 2014. Likewise, in 2014 mining exports totaled US$20.5 billion, more than 70% of traditional exports and 51.9% of total Peruvian exports. This implies an important increase of Peruvian mining exports since 2000, when they totaled only US$3,220 million (67% of traditional exports and 46% of total exports), which can be partially explained by the commodity prices boom. In the past few years however exports have been falling - -13.4% in 2014- due to the decreasing prices of minerals (graph 2).

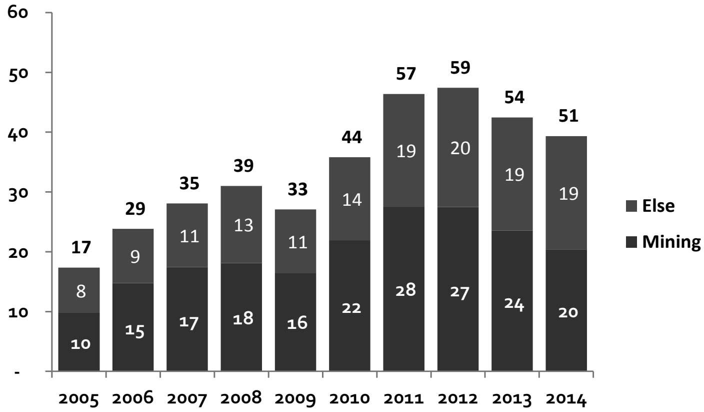
As mineral prices continue to fall, mining activity is slowing down. Over the last 5 years, investment has grown an average of 10%, but it fell 11% in 2014. Investments in plant and mining equipment especially fell 38% and 28% respectively (see Annex 5). Currently, US$ 63.92 billion are being invested in 51 mining projects. Eighteen of these projects (45% of the value) have their Environmental Impact Studies (EIS) approved (see Table 4 and Annex 6 and 7).

Table 3: Peru: Mining and total GDP (US$ of 2007)

	Mining GDP		GDP		Mining GDP/GDP
	US$ MM	Growth	US$ MM	Growth	
2010	17,857	1.27%	134,641	8.45%	13.26%
2011	17,973	0.65%	1443,328	6.45%	12.54%
2012	18,476	2.80%	151,857	5.95%	12.17%
2013	19,379	4.88%	160,642	5.77%	12.06%
2014	19,227	-0.78%	164,400	2.35%	11.70%

Source: BCRP, 2014.

Graph 2: Peru Exports in US$ billions



Source: Banco Central de Reserva del Perú, (2014).

Table 4: Amount of investment in ongoing projects		
Current Phase	US$ MM	%
Extension	9,280	15
EIS approved	28,867	45
EIS presented	701	1
Exploration	25,081	39
Total	***63,929***	

Source: MINEM, (2014).

The dominance of the mining industry in Peru's GDP makes this sector a major contributor to the state and regional government's budgets through the mining canon, mining royalties, concession fees, and the penalties for irregularities. Mining canon[2] is the most important source of income, as it represents 83% of mining transfers. The amounts provided are markedly varied since they depend on company sales and revenues, but they still represent a significant income for regional governments. Total transfers in 2014 amounted to US$ 1.26 billion, which represents 3% of the total government budget and 19% of the regional governments' budgets.

Additionally, direct employment generated by mining activities accounts for 1.2% of the economically active and employed population nationwide. The number of workers engaged directly in this activity has nearly doubled between 2005 and 2014, increasing from 98,703 to 195,361 (see Annex 8). The mining sector generates direct employment not only through the hiring of workers within mining companies, but also through their contractors. In fact, contractor companies account for 67.7% of total direct employment generated by the sector. It is also estimated that the indirect employment generated by the mining industry is around 1.8 million (MEM, 2014).

Although mining regions have benefited largely from significant monetary transfers and employment opportunities during the period of rising prices, this has not always led to an increase in individual welfare in these regions. It has been acknowledged that the limited institutional capacity of the sub-national authorities and their lack of human resources and

[2] According to Law 27506, the canon is the share of local and regional governments in the rents and revenues obtained by the State from natural resources. Mining canon represents 50% of net income tax to mining industries and is distributed between local and regional governments where the resources are extracted with the following distribution: Local Governments from the district (10%), local Governments from the province (25%), Local Governments from the departments (40%), Regional Government (20%), public universities of the region (5%). For more information about the canon distribution and usages consult "Ley de Canon" (Law No 27506)

experience have resulted in a poor management of these transfers (Aragon & Rud, 2013, OECD, 2015, Bebbington & Bury, 2009, GTZ, 2009).

4. New opportunities for structural change and diversification in the Peruvian mining industry

Despite the increasing participation of international enterprises since 1990, innovation efforts were scarce during the following decades among local firms (Glave & Kuramoto, 2007). Until a few years ago, large mining companies relied mostly on the expertise from outside Peru to solve technological problems and to obtain cutting-edge technology, and all technological services and new equipment and machinery were imported from abroad (OECD, 2011). As a result, the local mining suppliers' technological capabilities have not changed considerably in the past few years. Because they did not develop in the early stage of the mining industry of Peru, now the space for developing solutions to standard problems is mostly occupied. In the present section, we analyze the main changes in the global and Peruvian mining context and the possible opportunities for innovation that they provide.

4.1 Changes in the volume and requirements of demand

According to recent estimates, Peru is well endowed with resources to meet a growing global demand, since only a small percentage of Peru's mineral reserves are currently being exploited. While 14.6 percent of the territory is ear-marked for mining concessions, only 1.34 percent is currently being exploited for exploration and mining (MEM, 2014). However, an expansion would inevitably imply a shift to less competitive and costlier sites. This leads to four main challenges that mining companies in Peru will increasingly face:

i) Impurity of deposits

Due to the depletion of clean deposits and the increasing demand for minerals, "dirty mineral" deposits are becoming increasingly important natural resources. As the current methods of extraction of minerals with high content of arsenic are very pollutant, new strategies to extract these minerals are required. Furthermore, if mining companies continue to increase their production, the complexity of extraction for impure deposits will increase.

ii) Decreasing-grade ores

Ore grades of Peruvian gold and copper mines have decreased over time and will continue to do so. In general, projections of average copper grades from 2012 to 2025 estimate that Peruvian grades will decrease on average by 19% - in line with the world average, which is estimated to fall 21%- (McKinsey&Company, 2013).

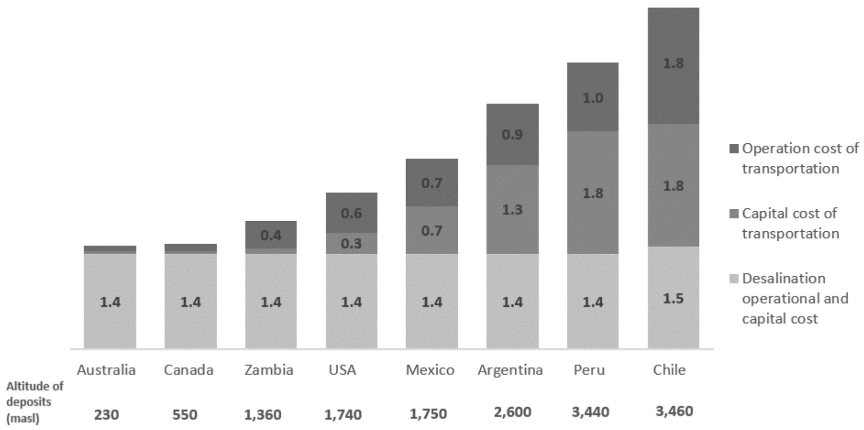
iii) Peruvian specific geographic characteristics

Due to some specific geographic characteristics of Peru's mines, machines and traditional methods tend to underperform. The highlands, a region that consists of the Andean mountain range and covers 31.8% of the territory, host most of Peru mineral deposits, where the existing mining equipment usually underperforms at such high altitudes. Narrow veins in underground mining are also a challenge for Peruvian mining production with traditional machinery.

iv) Management of water

Due to the scarcity of fresh water and conflicts with local communities, mines in southern Peru are increasingly using seawater, which needs to be transported to mines generally located at high altitudes (GWI, 2011). Due to the cost of capital and transportation from the coastline, the cost of seawater in Peru is considerably higher than in other mining countries (see Graph 3).

Graph 3: Cost of use of sea water (U$S/m3)



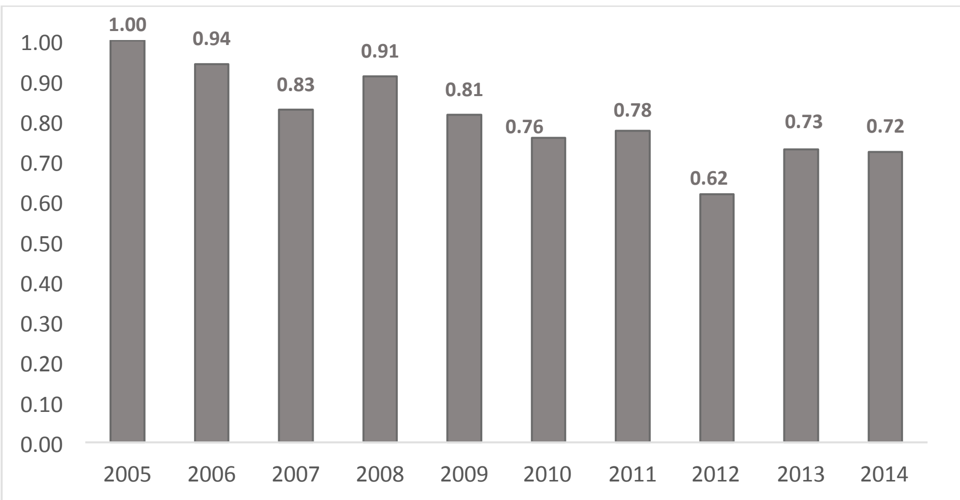
Source: Análisis McKinsey, Consejo Minero, CRU Group, Wood Mackenzie (2013).

All in all, the challenges imposed by the decrease of ore grades, impurities in deposits, geographic characteristics and water management open a window of opportunities to local suppliers. The application of standardized methods in these difficult conditions is not viable and large multinational suppliers generally do not provide solutions that are specific for the Peruvian context. In this regard, local suppliers can take advantage of their knowledge of local problems and technological difficulties to develop machinery and systems that will allow mining companies to improve their current methods and operate in locations that were previously inaccessible or economically unviable

4.2 Lower mineral prices

The surge in demand for metals and minerals in the early 2000s quickly translated into prices and increased mining profitability. Boosting production volumes became the industry's top priority. Over the past decade, the industry has succeeded in expanding production of certain major commodities by 50 percent or more, though at the expense of productivity levels. Worldwide mining operations are as much as 28 percent less productive today than a decade ago (Lala, Moyo, Rehbach, & Sellschop, 2015) and Peru's mining sector has been no exception. During 2005 and 2014, workforce productivity decreased 28% (See Graph 4).

Graph 4: Peru Mining Workforce productivity (Baseline 2005=1) (*)



(*) *Ratio of total mining production to total workforce in the mining sector.*
Source: (MEM, 2014).

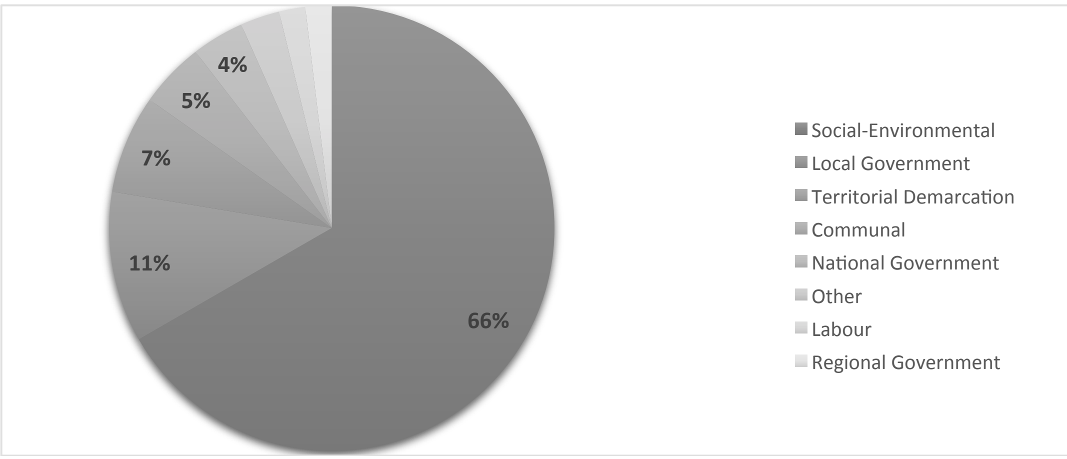
Moreover, during the last few years, the global mining industry has been facing lower mineral prices in a context of higher capital and energy costs, weak external environments, political instability, and social disputes (EY, 2014). Therefore, there is a growing interest across the industry in reversing the excesses of the 2000s. Miners are seeking to raise productivity by cutting costs or increasing output (Lala, Moyo, Rehbach, & Sellschop, 2015). This has been acknowledged by CEOs and investors (Lala, Moyo, Rehbach, & Sellschop, 2015).

The industry has entered an era characterized by a completely new set of challenges that require the adoption of new approaches and technologies, which creates a new window of opportunities to suppliers who offer innovative processes for the mining industry. As stated by the logistics manager of Antamina mining company, Enrique Alania, *"today is the moment to try new technologies, because if prices keep decreasing mining companies will be very affected (…) now we need to focus on trying to change the cost structure of the company (…) Opportunities for innovation would be higher in certain stages of the value chain where risks of testing new technologies are lower".*

4.3. Social conflicts and environmental issues

Regarding the national context, social conflicts have been increasing in the mining sector (Triscritti, 2013). Between 2012 and 2014 Peru registered 140 social or environmental conflicts associated to mining activity (See graph 5) (DP, 2015). The increase of social conflicts in Peru is motivated by local concerns about livelihood security, environmental degradation, and by the perception that well-being has not increased in proportion to the profits of mining companies (Bebbington & Bury, 2009). Due to social protests, important mining projects worth US$ 21.5 billion have been delayed between 2010 and 2014 (IPE, 2015).

Graph 5: Type of conflict 2012-2014

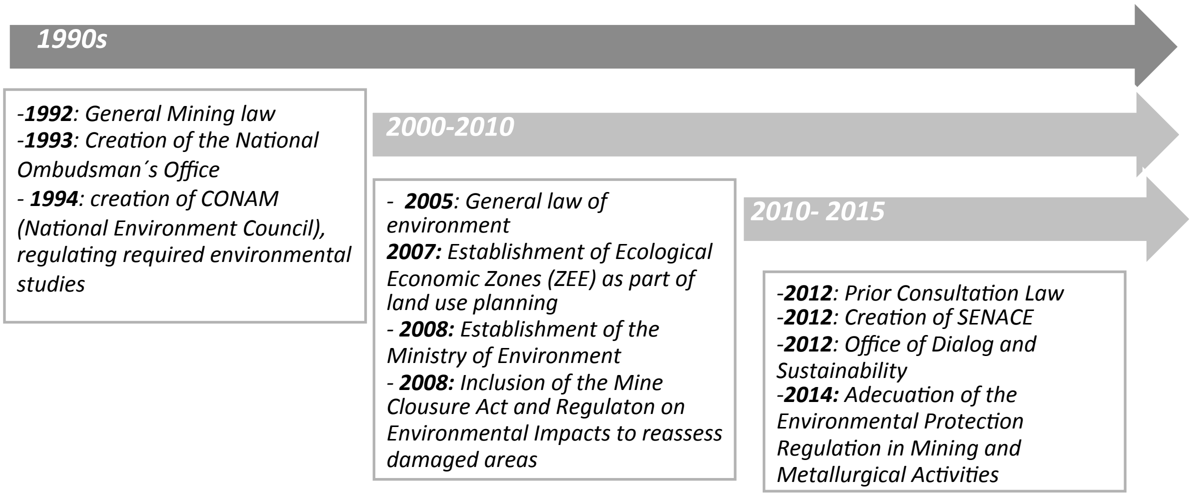


Source: Defensoría del Pueblo, (2015).

Although changes in legislation through the last decade have increased the participation of indigenous communities in decision-making (See Figure 1), communities still consider their rights are not properly secured. They argue that their participation in the Environmental Impact Assessment studies (EIAs) is weak and not well organized and that there is no proper involvement of the government. Therefore, in recent years the government has taken action in order to protect the environment and the interest of the communities. During the last years, there have been several changes and improvements affecting the mining sector. The most important changes affecting mining sector are the creation of the Ministry of

Environment in 2008[3], the approval of the "Prior Consultation Law" [4] and the creation of a new oversight institution known as SENACE[5] in 2012[6], and the enactment of the new Environmental Protection Regulation in Mining and Metallurgical Activities in 2014[7]. In addition to safeguarding the environment and natural resources of the country, the new regulation defines principles of good social management like sustainable development, local employment and economic development, among other areas that will be evaluated through the use of different indicators.

Figure 1: Major Changes Regarding Mining Regulation in Peru



Source: MINEM, SNMPE, McKinsey & Company (2013).

Regulation and institutional change are the most recent steps in a political process aimed to achieve an adequate protection of environmental and communities' interests. This has led to a significant increase in the amount of environmental regulations in Peru, which have established a number of environmental management standards as well as guidelines with respect to particulate emissions in the air, water quality, exploration, tailings, and water discharges, among other requirements (EY, 2014). Peru has gone from not having any kind of environmental regulation in the 90s to turning down 20% of the proposed mining projects every year due to the unfulfillment of the social and environmental obligations. Today, the government demands the execution of an EIA every 5 years during the operation of the mine, instead of only one at the beginning. It is also worth mentioning that, in 2013, Peru ranked 79th in the index of Stringency of Environmental Regulation made by the World Economic Forum (the higher the rank and index value, the more stringent the regulation). Its position relative to other countries in the region can be seen in Annex 10.

It is in this context of adjustment to increasing social conflicts and environmental and social regulation, that local suppliers can find new opportunities to offer innovative solutions to

[3] "The overarching mission of the Ministry is to promote environmental conservation to ensure a sustainable, responsible, rational and ethical use of natural resources, and the environment that sustains them." (Peruvian Legislative Decree N°1013, 14 May 2008)

[4] Prior Consultation Law requires prior consultation with indigenous communities before any infrastructure or projects, especially mining and energy projects, are developed in the area where they live.

[5] Is comprised of representatives from six ministries and is chaired by the Ministry of Environment.

[6] SENACE's principal function is to review and approve Environmental Impact Assessment study (EIAs), which incorporate technical, environmental, and social matters, and a draft mine closure plan for large-scale investment projects (KPMG, 2013).

[7] This framework was developed to replace the previous one, established in 1993 (International Centre for Trade and Sustainable Development, 2014). It states that production operations of the mining sector must have identification, prevention, supervision and correction systems of possible negative environmental impacts derived from their activities.

mining companies looking to fulfill the new requirements imposed on them by the government. Some examples are offered below. Companies that take advantage of these new opportunities and commit themselves to the development of unique knowledge assets oriented to reduce energy and water consumption and environmental damage would have an opportunity to enter the market. Technological progresses regarding environmental impact need to be implemented at various stages of mining activity and therefore this process of innovation involves all actors in the mining value chain.

In addition, the increase of social conflicts has created a space for innovation regarding internal and external organizational aspects of the companies, particularly developing direct relationships and joint work between mines and communities. An example of successful management of social projects is the creation of the Fondo Social La Granja (FSLG) by the Municipality of Querocoto and the mining company Rio Tinto, whose main objective is to improve nutrition, education, health, and labor conditions in the region. In its 4 years of existence, the FSLG has carried out more than 200 projects. Its success is attributed to the involvement of communities in the decision-making procedure for the allocation of funds.

5. Methodology

Data was collected through semi-structured interviews to relevant actors of the Peruvian mining sector: mining suppliers, mining firms and key informants (see annex 1). Interviews were conducted on the basis of a questionnaire aimed to collect both qualitative and quantitative information. The study also made large use of secondary data, which includes previous investigations and company reports and publications. In this regard, an important limitation to the study was the lack of previous research about value chains in the Peruvian mining sector. In the present section, we introduce the mining companies and suppliers involved in the study.

5.1 Suppliers

Interviews to mining firms and key informants enabled us to identify the local firms and new ventures which have succeeded in introducing innovative solutions and services to mining companies. Eight of them were selected for interviews (see Table 5).

Table 5: Peruvian mining suppliers selected*

Firm	Year of foundation	The firm is a….	Capital**	Employees	Turn over (USD million)	Stage in the value Chain
Bisa	1977	Subsidiary of mining company Buenaventura	68% foreign capital	350	35	Exploration/Planning and construction
Exsa	1956	Part of a group enterprises	National capital	800	220	Exploration/Planning construction/ Extraction
Ferreyros Corp	1922	Independent firm	35.79% foreign capital	3600	1902	Extraction
Resemin	1989	Independent firm	National capital	400	27.34 ***	Extraction
Tumi Raise Boring	1982	Independent firm	65% foreign capital	210	34	Extraction
Fima	1969	Independent firm	33.1% foreign capital	1250	85	Planning and construction
UTEC	2012	Private University	nonprofit	40	0.1	General Investigation
TECSUP	1984	Private Technical Institute	nonprofit	15	0.095	Metallurgical Investigation

** Data in this table refer to year 2014.*
*** Approximate figures.*
****The whole group includes companies in Zambia, DR Congo, India, Mexico and Argentina. The global turnover of the group was US$ 71.47 million in 2014.*

As Table 5 summarizes, 7 out of the 8 firms selected for the study where founded before the 90s. This selection can be explained by the fact that no recently founded firms besides UTEC were mentioned during the interviews. This likely reflects the slow creation of local new ventures in the Peruvian mining sector.

In this regard, on the basis of the interviews we selected a group of firms that, despite being established before the 1990s, have intensified their innovation activities in recent years. Interesting cases where suppliers have made valuable innovations and creations are shown. To this aim, we considered two main factors: Originality and innovation in solving mining problems, and presence in different stages of the value chain. We have tried to ensure that the sample of suppliers selected worked at different stages of the value chain in order to have a better understanding of the nature of the relationships. Thus, the study covers firms operating in mine planning and construction (Fima and Bisa, Exsa), mineral extraction (Tumi, Resemin, Exsa) and research institutions that work in several stages of the value chain (TECSUP, UTEC).

Suppliers analyzed in the study can be grouped in 4 different areas of specialization:

1. *Metal-mechanics/Engineering services*: The engineering services offered by local suppliers include the design and implementation of projects. These companies aim to provide comprehensive solutions to meet their clients' needs. This group includes FIMA and BISA.

Fima: established in 1969 to provide engineering, manufacturing, and installation solutions as well as starting up, maintaining, and supplying spare parts to various production sectors. With regard to mining, Fima offers a wide range of products, with mining spools[8] standing out thanks to its highly specialized design and manufacture.

Bisa: has been in the Peruvian market for more than 3 decades providing consultancy, engineering, project management, and construction services for the mining, infrastructure, and industry sectors. In recent years, the company has undertaken many operational improvements that allow it to efficiently provide various services to customers from 9 different countries.

2. *Manufacturers of mining machines:* This sector encompasses various types of capital goods. The most important are different types of drills, excavators, loaders, and components and spare parts for different machines, to name a few. Companies in this category, such as Tumi and Resemin, design and manufacture their own drilling machines. Ferreyros import the machines and they provide a wide range of maintenance and monitoring services.

Tumi Raise Boring: a contractor and manufacturer of raise boring machines[9] with over 40 years' experience in drilling and the provision of related services. They began to introduce important innovations in 2012, when they built the largest raise bore machine in Latin America. The company exports its machines to 22 countries.

Resemin: founded in 1989, it specializes in the design and manufacture of jumbo drilling equipment for underground mining and civil works tunnels. The company experienced a growing success since it began to implement considerable innovations in their machines in 2007, which helped it become the world's fourth largest producer of jumbos for underground mining in 2013.

Ferreyros corp: specializes in the import, sale, and rental of capital goods of different brands, the most important of which is Caterpillar, with which it has been working since 1942. Ferreyros is not only interesting because it is the leader in buying and selling

[8] A spool is a cylindrical device on which cable is wound. Its size, design and material vary depending on the mining firm's specific needs.
[9] Raise borers are machines used to excavate a hole between two different levels of an underground mine without the use of explosives.

machinery in Peru, but also because it differentiates itself from the competition by offering complementary services such as real time monitoring services. It has also been a pioneer in improving services offered to its clients, since it has been the first Caterpillar distributor worldwide to have an electrical control room for bulldozers

3. *Explosives*: Explosives are key in mining and the high demand for them has boosted their production locally. EXSA become a strong competitor in Latin America.

Exsa: offers rock fragmentation services and integrated blasting service using explosives and electrode welding in mining and manufacturing. This company, which started operations in Lurin in 1956, currently has three industrial plants in Peru, and has holdings in Panama, Colombia, and Brazil. Recently they have succeeded in developing the Quantex technology that reduces significantly the total cost of rock fragmentation in mining.

4. *Consulting (Mining educational and research institutions)*: Educational institutions specializing in fields related to mining that conduct studies on metallurgy, hydrometallurgy, robots for mining operations, and the mechanical preparation of minerals (ore dressing), among others.

UTEC: The University of Engineering and Technology (UTEC, its Spanish acronym) is the new undertaking of a group of mining companies —in which Hochschild stands out— to train people in carriers required by mining and related to engineering and innovation. In addition to providing highly trained personnel to mining companies, UTEC is dedicated to providing specialized research for mining.

TECSUP: It was founded in 1984 by a group of mining companies, including Hochschild. Since its establishment, it has been dedicated to training young people in careers related to the implementation of technology in the operation and maintenance of industrial activities. Additionally, it provides consulting, research, and application of technology services to the private sector.

5.2 Mining companies

The following section describes the key characteristics of the selected mining companies leading the value chains focusing on those characteristics that we expect may affect inter-firm relationships (Table 6).

Amount of foreign/Peruvian capital: We began by considering beforehand that the background of mining company shareholders could influence how they recruited their suppliers. As a result, we have included companies with different percentages of foreign/Peruvian shareholders. Therefore, we included:

- Mining companies owned 100% by foreign capital, such as Southern Copper Corporation (Grupo Mexico).
- Mining companies whose shares are divided equally between domestic and foreign capital, such as Yanacocha (43.7% Buenaventura and 51.35% Newmont)
- Mining companies whose capital is mainly domestic, such as El Brocal (Buenaventura).

Length of time operating: We selected mining companies at different operational stages and companies that had been operating for different lengths of time because we expect this variable to influence the type of providers they contract and the kind of relationships they develop (i.e., companies that have recently selected their main suppliers vs. companies that have been working with a group of suppliers for some years).

- Mining companies in the pre-extraction process, such as AngloAmerican. These have recently begun negotiations with local suppliers.

- Mining companies operating for an intermediate length of time, such as Yanacocha, that has been operating for 21 years. These companies have invested heavily in capital goods and have a lasting relationship with local suppliers.
- Older mining companies operating for a long time, such as Milpo, whose first mining operations began in 1949 in El Porvenir, and Southern Copper Corporation, whose mining operations in Toquepala began in 1960. These companies began large-scale mining in Peru, and as a result, the origin and development of the mining supplier industry are closely linked to them.

Company size: We chose mining companies that generated different levels of income in order to show how size can determine relationships with suppliers. Therefore, we have:

- Very large companies, such as Antamina and Southern Copper Corporation, which have annual incomes of US$2.5 and US$2.48 billion, respectively.
- Large companies, such as Yanacocha, which generate annual incomes in the order of US$1.2 billion.
- Medium-sized mining companies, such as El Brocal and Milpo, which have annual gross sales of US$223 and US$104 million annually, respectively.

Table 6: Mining Companies

Mining Company	Products	Region	% of mining GDP*	Income* US$ M.	Company Size	Foreign capital	Length of operation
Antamina	Copper, Silver, Lead, Molybdenum	Ancash	16.8	2,504	Very large	100% (foreign)	1996 (intermediate length of time)
Souther Copper Corporation	Copper, Molybdenum	Moquegua	13.8	2,482	Very large	100% (foreign)	1960 (long time)
Yanacocha	Gold, Silver	Cajamarca	4.1	1,210	Large	51.34% (equally divided)	21 years (intermediate length of time)
El Brocal	Silver Sulfide, Lead, Zinc, Copper	Pasco	1.9	223	Medium sized	0% (domestic)	1956 (long time)
AngloAmerican	Copper	Moquegua	-	Project in development (US$ 5000 - 6000 million CAPEX)	Very large	100% (foreign)	Pre extraction (short time)
Milpo	Zinc, Lead, Copper	Junin	6	104	Medium sized	60% (foreign)	1949 (long time)

**Data refers to 2014 levels.*
Source: MINEM, 2014.

Considering that different minerals require different technologies and production functions it may seem contradictory to study mines treating different varieties of minerals. However, it is important to note that the degree of specificity of the technologies will depend on the stage of the mining process. The suppliers considered in this study operate in the first stages (tiers) of the mining value chain: acquisition and exploration, mine planning and construction and mineral extraction.[10] In these stages technologies do not tend to be so specific for each type of mineral, contrary to the last stage of the MVC - processing the minerals-, where there is a wide range of technologies that are adapted to each kind of mineral.

[10] It is important to clarify that this was not a requirement for the selection of suppliers for the present study. The selection resulted from interviews to mining companies and important actors of the sector and it turned out that the most innovative suppliers worked in the first stage of the value chain.

6. Local firms, new ventures, and capabilities

Levels of innovation in Peru are still relatively low compared to global and regional levels.[11] Particularly in the mining sector, Peru has been relatively unable to diversify in upstream and downstream industries. According to literature on the topic, this is partly due to factors like the lack of incentives from the public sector for the business sector to invest, the lack of favorable framework conditions for innovation, the scarcity of qualified human resources, and relative prices (OECD, 2011). Although levels of innovation in Peru are still low in general, our research has found that some areas of the Peruvian mining sector represent promising exceptions. Specifically, from interviews to mining companies and key informants, we found five technical areas in which local suppliers have made or are making efforts to innovate and generate new technologies: engineering, metal-mechanics, manufacture of mining machines, explosives, and consulting.

This section aims to analyze the capabilities of the local suppliers included in the study and to describe the innovations they have introduced to the market. This section is divided in two subsections. We first describe the innovations that local suppliers have introduced to the market as a materialization of their efforts. Then, in the second section, we shed light on the internal process that the suppliers followed to innovate, acquire new capabilities and develop new technologies.

6.1. Results of Efforts to Innovate Products and Processes

It is very complex to determine the degree of innovativeness in a company[12], and even more so to measure the economic and social outcomes of investments in R&D. Considering these difficulties we will focus on proxies such as the degree of novelty of innovations, the number of patents acquired, and company participation in local and international markets.

By definition, innovations must have a degree of novelty and be either: (i) new to the company, or (ii) new to the market, or (iii) new to the world (OECD & Eurostat, 2005). Of the eight companies included in this analysis, we found that three companies have managed to introduce an innovation to the world (Exsam, Tumi Raise Boring, Resemin), four an innovation to the local market (Ferreyros, UTEC, TECSUP, Fima), and one an innovation to the company (Bisa).

Exsa, a company specialized in rock fragmentation, succeeded in developing the Quantex technology. Their innovation, which is patented in Peru and the United States (USPTO), represents a substantial progress in the market of rock fragmentation. The technology generates savings of up to 20% on the total cost of rock fragmentation for mining and open pit construction.[13] Furthermore, it has managed to address an important emerging need of mining companies: environmental impact reduction. Quantex offers environmental benefits as this technology eliminates the brown smoke that occurs after blasting, reducing emissions of greenhouse gases (GHG) by 18%. Currently around 40% of the local market is using the product, which was introduced in mid-2014. The technology has been adopted by important mining companies like Southern Peru Copper in Toquepala and Cuajone mines, Newmont in the Yanacocha mine, and HudBay in Constancia and La arena. Although the presence of the product in the international market is reduced due to the limitations to the trade of explosives, the company is planning to introduce a productive subsidiary in Colombia and Chile to address this. The Quantex technology came as a result of the efforts of the company to innovate described in the previous section, and involved an investment of approximately US1 M.

[11] Peru has been investing in R&D only 0.12% of GDP, compared to 0.67% in LAC and 1.1% in Brazil. Advanced countries spend more than 2% of GDP.
[12] The Oslo Manual defines innovation as the implementation of new or significant improvements in products, services, or processes, a new method of marketing, management, labor organization, or external relations.
[13] The reduced cost is associated to the fact that the system does not use porous ammonium nitrate, with significant savings for customers in both purchasing prices and operating costs.

Peru counts about 150 operations nationwide in underground mining. This has led to several local firms to offer their locally-manufactured machines, among them: Tumi, a raise boring specialist and Resemin, a producer of underground jumbos. Resemin and Tumi Raise Boring manufacture a wide range of drilling machines that compete with multinational companies, (i.e. Resemin competes with Sandvik and Atlas Copco). These companies have managed to acquire and incorporate technological knowledge through their extensive experience in underground mining, interaction with multinational companies, and a “learning by doing” process (this will be addressed in the following section). This allowed them to harness changes in science and technology to solve present and future challenges of Peruvian mining: narrow veins and high altitude mining (See Box 1.1).

In addition, although TECSUP has not managed to introduce an innovation that is new to the world, their efforts to solve the problems related to deposits containing high content of arsenic are now in this direction. During this year, TECSUP was awarded the National Award in the category of Mining Environmental Management in the 2015 Mining Convention Perumin for their research: "Implementation of pressure leaching in stabilizing arsenic in arsenopyrite minerals containing gold".[14] Their investigation presents a new method for the processing of gold with high content of arsenic. The process proposed uses the application of pressure leaching in order to stabilize minerals containing arsenic, which allows the control of the pollutant element in the process of extraction of gold, thus reducing the negative impacts on the environment (Corcuera, 2015). However, as Professor Juan Corcuera explained, this method is still too expensive for mining companies. Further investigation in this area is required in order to reach a solution that is feasible in terms of cost.

Besides the introduction of innovations that are new to the world, literature identifies other measures to recognize the innovative components of a firm. The patent stock of a company has been widely used in the literature as a proxy of a company’s accumulated knowledge and levels of innovation (Ahuja & Katila, 2001; Zoltan, Anselin, & Varga, 2002; George, 2005; Fosfuri & Tribó, 2008). The present study found that some companies have managed to obtain patents, both in the national and international market. These are: Exsa (two international patents and nine national), Resemin (four national patents) and Tumi Raise Boring (in the process of obtaining one national patent). Regarding the rest of the firms, considering that they have not introduced innovations that are new to the world they have not had the need to use patents.

However, the number of patents does not contemplate minor or incremental innovations in a firm that despite not deserving a patent has an important innovative component. For example, Ferreyros has been a pioneer in improving services offered to its clients, since it has been the first Caterpillar distributor worldwide to have an electrical control room for bulldozers (opened in 2014) exclusively designed for training in Cat’s heavy-duty bulldozers, strategic in mining production.

[14] See Corcuera, (2015)

BOX 1.1 Tumi Raise Boring and Resemin

Peru is recognized as one of the main underground mining countries worldwide, so over the last years it has developed extensive expertise in this field. Resemin and Tumi Raise Boring are Peruvian companies founded in 1989 and 1998, respectively, serving the drilling industry in underground mining. The extensive experience of both companies providing replacements for machinery and drilling services allowed them to gain the knowledge and skills needed to venture into the development and innovation of machinery years later.

Originally Resemin was founded as a supplier of replacement parts for drilling machines, but in 2001 they decided to begin the design and production of drilling jumbos. Later, in 2007 they produced their first full equipped jumbo with self-propelled diesel engine. In terms of innovation, this represents a turning point for the company, which nowadays produces 6 different product lines. One of the main achievements of the company has been the creation of the *"Muki"* Jumbo which is now patented in the United States. The Muki is a micro-jumbo of 1.05m width created to face narrow veins and to withstand the extreme environments of underground mining: high temperatures, lack of water, excessive corrosion, humidity and high altitude. Although largest mining suppliers have developed drilling jumbos to operate in these veins, they have faced limitations to run in sections of 1.8m width or less; however it has never been the top priority of these suppliers to solve this problem. Narrow veins are an important niche market that Resemin took advantage of when they introduced the Muki, the smallest jumbo on the market. Its creation has also meant an increase of productivity for the mining companies, as it can drill a 2.4 hole in 40 seconds, unlike traditional methods which take seven minutes. The Muki also allows the mechanization in tunnels, which has important implications in the safety of the operators who do not need to be involved physically. Resemin has an important global presence, with a 2.5% share of the world market and approximately 60% share of the local market. It also exports its machinery to more of 12 countries, such as Bolivia, Chile, India, Canada, and South Africa

Likewise, Tumi Raise Boring is a global company specialized in the Raise Bore Industry, its raise boring product line offers 7 different types of machines. During several years they specialized in the production of somehow standardized raise boring machines, however in 2010 the request of a mining company for a raise boring machine that could work in narrow veins induce the company to innovate in this area. Two years later, in 2012, they introduced to the market the SBM 400 SR a raise boring machine for narrow veins, which is currently in the process of being patented.

The machine has a built-in conveyor that allows it to reach the workstation at a speed of 4.8 kilometers per hour on a flat surface. It also has 12 hydraulic pistons that serve as an anchor, this makes unnecessary the construction of concrete slabs usually used to anchor this type of equipment, resulting in significant savings in time and cost to the mining company. It also has an integrated system with hands-free functions, which reduce the risk of operating accidents. Given the high level of mechanization of vertical vents that it provides for narrow vein mines, its services are key in accelerating mining productions in large mining projects. The high level of innovation and specialization of the firm has enabled them to enter the international market, Tumi Raise Boring has a 4% share of the international market of raise boring, and a 35% of the local market. It exports to various markets, such as Mexico, Chile, Australia, and Canada.

Finally, a company's national and international market participation is also a good proxy of its technological capabilities. In this regard, some of the companies included in this study have managed to capture both national and international markets thanks to their innovations (see table 9). Their expansion into foreign markets has often occurred also by establishing productive and commercial subsidiaries. Resemin, for instance, has productive branches in America, Africa, and Asia, and commercial subsidiaries in America, Africa, and Oceania. Most companies have also managed to obtain a large share of the local market, which shows that their technological capabilities are at the level of multinational companies established in Peru.

Table 9: Companies General Information 2014 *

	BISA	EXSA	FERREYROS	RESEMIN	TUMI	FIMA
Turn over (USD M)	35	220	1902	27.34**	34	85***
Local market share (of main mining product/service)	-	50%	54%	60%	40%	70%
Export Turnover (USD M)	1.5	15.4	-	-	19	8
Export market share****	-	-	-	2.50%	4%	-
Main export markets	Brasil, Argentina, Ecuador y Guatemala	Chile, Ecuador, Panamá, EEUU	-	Chile, México, Argentina, Bolivia, Zambia	Mexico, Chile, Australia, Brasil	USA, Canada, Mexico, Chile, Bolivia -
Productive Subsidiaries	Argentina (Cerrada en el 2014)	Se espera en Chile y Colombia	None	Mexico, Argentina, Congo, Zambia, India	Mexico, India, Australia	None
Commercial Subsidiaries	None	Chile y Colombia	Guatemala, El Salvador y Belice	Canada, Nicaragua, Brazil, Bolivia, Chile, South Africa	None	Panama, Bolivia,Ecuador , Chile

Source: Interviews to suppliers.
*UTEC and TECSUP are not included because due to their line of business education services represent a high percentage of their activities.
** The whole group counts with companies in Zambia, DR Congo, India, Mexico and Argentina. The global turnover of the group for 2014 was US$ 71.47.
*** From which 50 million are attributed to operation in the mining sector.
**** Approximately. Source: stated by manager interviewed.

6.2. Efforts to Innovate Products and Processes

Following the literature, our research uses spending in R&D - an influential variable in determining a firm's ability to innovate (Dosi, 1988; Freeman & Soete, 1997; Shefer & Frenkel, 2005) -, workforce skills, innovation agreements with institutions, and cultural and structural changes in the organization as proxies for the efforts of the firms to innovate.

Concerning the companies' workforce capabilities, we found that on average 3.3% of the workforce of the selected companies work in R&D. Firms that have managed to introduce patents and develop new technologies, such as Resemin, Tumi Raise Boring, and Exsa, also have a higher percentage of workers in R&D (between 4% and 10%). Previous experience in the sector and practical knowledge are a priority in a company's recruitment decisions, even over a candidate's degree.

In general, we found that companies included in the study spend most of their R&D budget on the acquisition of machinery, equipment, and hardware, followed by internal R&D and incorporating software, while virtually nothing is spent on the acquisition of intellectual property or franchises. This appears to indicate that firms are not yet at the forefront of innovation, given that the management of intellectual property requires companies to have specific technical knowledge to manage it properly.[15] Companies do not allocate budgets for the acquisition of intellectual property partially because they have yet to acquire the necessary skills to manage it. According to the firms analyzed, the high-level technology required and the complexity of the development of new technologies are major hurdles for the development of innovations. Although some technological upgrading is in fact being achieved in these firms, they appear to be still at the preliminary stages of innovation.

Additionally, some firms mentioned that their technological strategies do not require them to spend resources in licensing (especially given the high costs that this implies). Ferreyros and Fima, for example, base their work on representing high-technology mining equipment

[15] The literature shows that businesses with large portfolios of intellectual property are the first to adopt innovations. Companies with large intellectual property portfolios are typically more efficient managers of their knowledge, and therefore, have a higher degree of intellectual capacity, enabling them to create greater benefits from the knowledge acquired (Harison & Koski, 2010).

that is developed abroad. Therefore they do not require the know-how to innovate at this level of the value chain, but rather to provide technical assistance to local mining companies using these products. Another reason for the low levels of spending in licensing may be that its high costs induce local suppliers to seek different strategies in order to develop innovative products. According to Kuramoto (2000), some mining suppliers in the Peruvian market prefer methods like process imitation and informal interaction with clients in order to achieve technological innovation.

It is also important to note that firms interviewed were making internal efforts to improve their technology and knowledge, although most of the companies did not have an accounting system to quantify them exactly. In general, this can be attributed to two factors. First, to the fact that most of the R&D departments of the companies studied are in early stages of development and their technological efforts do not take the form of R&D or they cannot measure them. And second, because until this year there were no tax incentives for businesses to quantify these costs. Nevertheless, the recent approval of law N°30309[16] "Law of promotion of scientific investigation, technological development and technological innovation", which reduces taxes to companies conducting their innovation projects through their R&D departments or through national technology service suppliers, automatically creates incentives for companies to keep track of these expenses. It remains to be seen whether this norm will have the desired results.

We have also found that over the years, companies have conducted organizational restructuring to support internal innovation processes. In general, we observed two types of reforms: cultural and structural. Concerning cultural reforms, various firms agree that in the current environment, where innovation and the application of technology by firms determine their survival in the market, the pressure for change in the organizational culture is increasing. Moreover firms must have a customer orientation vision that allows them to gather the information required to focus their innovations on the needs of their clients. Furthermore this new context has led companies to make changes in their organizational structure by creating new management offices or restructuring these.

Exsa is a clear example of a company that has conducted both organizational restructuring processes aimed to support the company's innovation processes. In 2013 they created the office of Innovation Management and they institutionalized a new client-oriented process in order to have a more direct channel of communication with their clients and gather information about their needs. For instance, they conducted interviews with the CEOs of several mining companies, which allowed them to identify their main needs, namely the urgency to reduce costs and their environmental concerns. Once they had gathered this information, they designated a special team to develop an explosive that could address these needs that resulted in the "Quantex technology" (see next section). Additionally, in order to align the company's innovation objectives with those of their clients, they held periodically "Innovative Breakfasts" where they invited their mining clients to discuss the importance of innovation with the ambassador of *Singularity University*.

Innovation is a complex process that requires the acquisition and assimilation of knowledge, so it is essential that firms combine their internal efforts with those of other firms and research centers through technology alliances (Edquist, 2000; Becker & Peters, 2000; Teece, 1992). Two firms analyzed maintain some form of alliance with another firm (Fima and Ferreyros) and two companies (i.e. Tumi and Exsa) had strategic collaboration agreements with research centers. Section 7 analyzes these interactions to a deeper extent.

[16] Law N°30309 approved in May 2015. See: http://www.leyes.congreso.gob.pe/Documentos/Leyes/30309.pdf

7. Interaction in the global mining value chain

In the previous section, we shed light on efforts to innovate and innovation performance of the companies analyzed. The purpose of this section is to understand how inter-firm linkages that characterize value chains promote or limit the innovations in these firms and the emergence and consolidation of local businesses.

7.1. General governance pattern of the mining value chains

The GVC literature identifies 5 archetypical governance patterns: market, modular, relational, captive and hierarchy (Gereffi et al. 2005). In the case of the Peruvian mining sector, large multinational companies govern the value chain. 79% of total copper production can be accounted to four large firms (Antamina, Southern Peru Copper Corporation, Cerro Verde and Antapaccay). Although the production of gold and silver is shared among more companies, a small number still comprises more than 50% of the total production. Six large firms produce 56% of Peruvian gold (Yanacocha, Barrick Misquichilca, Madre de Dios, Consorcio Minero Horizonte, Buenaventura and La Arena) and six large firms account for 54% of Peruvian silver (Buenaventura, Antamina, Ares, Volcan, Shungar and Milpo) (MEM, 2014).

As is standard practice worldwide, large mining companies in Peru tend to outsource their general mining operations to mining contractors. Additionally, mining companies outsource various specialized services for each stage of production such as research, exploration, development, and technical assistance services, to contractors and other supplies. Thus, mining contractors group approximately 75% of the labor force working in Peruvian mining sector (MEM, 2014). By leaving the contractors and suppliers with the responsibility to update technologically, mining companies minimize their operational risks. Their role in the process of innovation is only to inform the potential suppliers of their needs rather than to provide them with adequate tools to achieve the solutions required. Only after these have been successfully developed and tested the required solutions mining companies acquire the products or services.

Relationships between mining companies and suppliers are mainly based on hierarchy, with a remarkable asymmetry as suppliers typically have a lot more to gain from transactions. In the extraction stage of the MGVC, we found that suppliers like Resemin, Tumi and Exsa must typically follow the specifications of the mining companies and take full responsibility for the performance of their products and services, and they still compete by price and reputation with other suppliers. In the case of Exsa, for example, the contracts for blasting services tend to last one or two years and the renovation of the contract depends on the results of an open tender. As for manufacturers of drilling machines for underground mining (Resemin, Tumi), contracts tend to last 1-2 years and their renovation of usually depends on the administration of the mining company. As these companies explained, if the administration of a mining company changes, they would tend to hire a contractor they already know.

Among the rest of suppliers (Bisa, Fima, UTEC and TECSUP) we found that relationships tend to be more idiosyncratic, as it is difficult and time consuming to re-establish new relationships with new value chain partners: once a mining company starts a research program or engineering service with a particular firm, “switching costs” are high. However, the power of suppliers and mining companies remains relatively asymmetric: while the former depend economically on their businesses with mining firms’, the latter usually have a wide variety of potential suppliers from which to choose. In these sectors of the MGVC, reputation and commitment are key determinants of the selection of which suppliers to hire. According to Morris et al (2011), mining companies have increasing incentives for near-sourcing in their non-core activities, due to factors such as the specificity of their demands, the need for constant communication with their suppliers, and the lower costs. This opens interesting opportunities for Peruvian companies, and mining companies that decide to contract local engineering companies (i.e. Bisa) declared that they can "(…) obtain high-quality engineering locally, with much more competitive pricing and a closer relationship for after sales services" (GBR, 2014).

7.2. Entry into the MGVC

The local suppliers that gained entry into the higher value-added stages of the MGVC achieved it with an intense process of innovation. From the interviews with our sample of suppliers, we have identified that the main factors that allow these firms to enter the MGVC are: i) partnerships with important actors in the market, and ii) experience and time in the market. Both factors raise their prestige through mechanisms that we are now going to explain in detail:

Relationships with market players

Among the innovative suppliers analyzed in this paper, we have found that many firms maintain close relationships with multinational companies governing the MGVC. Some local contractors began to collaborate with major foreign companies at some point (for instance, local firm Fima becoming a licensed contract manufacturer for Metso), while others were established by mining companies from the beginning to fill a void in the market and reduce their operating costs by outsourcing certain activities (for instance, the creation of UTEC and TECSUP by a group of mining companies, Box 1.3).Regardless of the mechanisms, the integration of most of these companies into the technological stages of mining production was facilitated by their relationships with well-known companies.

Bisa, a company founded in 1977 and dedicated to engineering, design, and project management consulting services, is a good example since it encompasses both mechanisms. The company was created by Buenaventura economic group as a technical support for their own mines. However, in 2003, Fluor —a global engineering construction company providing EPCM services in the mining project Yanacocha-, decided to work together with Peruvian professionals, in order to reduce costs. Finally, they decided to work jointly with Bisa. For Bisa this was their first time offering a service to a mine outside Buenaventura group.[17] The joint work with the multinational allowed Bisa significantly improves its capabilities as a company, since the project required the synergy of various components of the company that had previously been isolated. The know-how Flour transmitted to Bisa during the time they worked together allowed the latter to increase its capabilities and gain a major presence in the national mining value chain. This experience shows that the learning curve for local companies can be enriched by joint projects with large EPCM players[18]. In these cases, collaboration with important international companies allowed for a significant transmission of knowledge that improved the local suppliers' internal capabilities, which in turn led to important product or process upgrading. Although the mining companies' demands determined the direction of the innovation efforts, these firms provided the required support for local suppliers to achieve successful technological upgrading.

Length of time

On the other hand, there are companies that started out as small suppliers of goods and simple services with low added value, only to become medium- and large-scale suppliers generating innovation by adapting technology to customer needs. In this regard, time allowed incremental knowledge accumulation. Within this group are Resemin and Tumi Raise Boring, suppliers of machinery for underground mining. These companies found it more difficult to enter the GMVC than others, but three factors determined their consolidation

[17] Yanacocha at that time was a joint venture between the North American company Newmont Mining Corporation (51.35%) who operated the mine, the national mining group Buenaventura (43.65%) and the International Finance Corp. (5%)

[18] Graña y Montero Ingenieria (GMI), a firm specialized in engineering work, was involved in a similar experience In 2000 the company worked together with Fluor in several jobs at Yanacocha, and this represented a cultural shift for the firm and helped the firm to internationalize (GBR, 2014).

as important high-tech suppliers. First, the quality of their work. Second, their flexibility to design products to customer specification, unlike larger suppliers who already had standardized processes and products. Third, their knowledge of the local market actors, which allowed them to identify opportunities in the market.

Resemin was founded in 1989 as a supplier of spare parts for drilling machines and produced their first jumbo in 2001. Similarly, Tumi started as a contractor in Peru in 1996, and later in 2001 started to build its own raise boring. The time in the market between the foundations of these companies and the production of their first machine allowed them to know the local market actors and their needs. Since they were already known in the market, it was easier for them to contact the mining companies and sell their machines and services.

However, as stated by suppliers, in the local mining market there is much resistance to the application of new processes that have not been tested worldwide. This is because of the high costs that testing a new system or machinery that may not achieve the expected results may involve. This makes it very difficult for innovative suppliers, especially smaller ones, to have their inventions valued in the market. The governance of the national mining industry hinders local innovation, as extensive, successful pre-testing should be conducted in numerous mines with the technology developed by local suppliers before they use it. This scheme imposes high entry costs and risks to companies offering systems or alternatives to the current standards. An additional factor mentioned by suppliers is that there still exists a prejudice towards local innovation. Mining companies rely more on the products and services offered by foreign multinational companies, which makes it difficult for local suppliers to break through the lack of confidence and introduce their innovations.

7.3. Communication channels

Both formal and informal channels of communication occur between mining companies and their suppliers.

Regarding the former, we have identified two direct links through which suppliers regularly communicate with mining companies. First, the times when mining companies invite suppliers to open tenders. Technological knowledge is required to be able to apply for these contracts and firms finally choose the applicant with the best price to efficiency ratio. In this regard, communication is just for transactional means. Second, most mining companies typically organize monthly and annual meetings with their main contractors to discuss about their performance, possible improvements and other related issues.

On the other hand, informal channels between mining companies and their current suppliers are continuous and direct. Suppliers have a large number of workers stationed at the mines who conduct daily, monthly, and annual meetings with their clients. This proximity is crucial to coordinate extractive activities and to communicate the needs of the mining firms as soon as they are detected. This allows suppliers to customize services and respond to the mining project needs as they appear. These channels are created to solve short run problems that may appear in the process. They do not intend to establish long run solutions beyond the period of the contract between mining firm and supplier that would improve efficiency within the mine.

It is important to note that there are very few formal channels for mining companies to transmit their needs to their suppliers, and most importantly formal channels are only available for suppliers currently working with the mining company. Potential newcomers are at a clear disadvantage, because there is no formal channel through which they could access the mining companies, and the burden of proving their capability is all on their shoulders. Even more, mining companies do not have many incentives to create these formal channels for potential suppliers, as the prospective profits are so large to attract a variety of potential suppliers, and the risk of possible failures of new solutions discourages mining companies from experimenting with new suppliers.

Due to the lack of formal channels of communication, some mining companies have created their own mechanisms to transmit their concerns to suppliers. For example, Antamina introduced in 2013 the program “Developing Suppliers of Excellence for the Mining Industry” through which it conveys its technical problems to the mining suppliers (Box 1.2). Through this program Antamina has improved the formal channels of communication between potential new suppliers and mining companies, reducing the inherent information asymmetry. However, the companies stress that the main goal of this kind of programs is to improve the social environment between the community and the firm, rather than find innovative solutions to the main problems of the latter.

Nevertheless, the relevance of these programs lies in the fact that there are few organizations in the Peruvian mining sector that can play a coordination role between the mining companies and their suppliers. Suppliers, on the other hand, are also making efforts to improve these channels. A clear example is the previously mentioned case of Exsa, that holds interviews with the CEOs mining companies and institutionalized the “innovative breakfasts”.

7.4 Incentives to innovate and cooperation agreements

The present section analyzes, from both the internal and external perspectives, the incentives that the Peruvian mining sector creates for innovation and technological development, through the relationships between the different actors in the value chain. As mentioned before, in the particular case of Peru we did not find new ventures introducing innovations to the market. However, we found incumbent firms, like Tumi, Resemin and Exsa, which became innovative at some point. In this section we will address what induced these firms to make a technological leap and what hindered innovation in other firms.

BOX 1.2: Antamina´s program "Developing Suppliers of Excellence for the Mining Industry"

In 2012 the mining company Antamina introduced the program "Developing Suppliers of Excellence for the Mining Industry", aimed to develop suppliers capable of providing innovative services and solutions to the mining industry. The program strategy consists of identifying and solving High Value Challenges (HVC) in the mining operation, entailing existing operational problems, inefficiencies or anomalies that have not been solved. Spaces are created to co-design solutions between Antamina and the supplier where suppliers play a fundamental role in finding a new solution. Although there are references of similar programs in Chile and Australia, the strategy presented by Antamina presents new approaches. For example, in 2014 they have managed to introduce the academia into the program, proposing a space of collaboration between clients, suppliers and universities. Antamina also lets their suppliers use their mine as a laboratory to try their new solutions, a practice that has not been so widespread in other countries.

Overall the program is structured as follows. At first, the company defines the operational challenges it faces from interviews with the employees of different areas. Then, after defining which of the problems are aligned with the strategic needs of, the customer and the supplier they establish the HVCs. The program is then launched through an event where the HVCs are presented to the potentially interested suppliers and universities. By involving the latter the company generates a space for suppliers to establish alliances with them to design a solution. In this respect, the program presents a model of supplier-universities cooperation that facilitates access to technical research support- laboratories, infrastructure, human resources and research capacities- and management support. Finally, after testing all the received proposals the company selects the solutions which offer the greatest economic benefit and that have the more innovative components.

Since the program's foundation, the company has developed three different portfolios (one per year since 2013), with a total of 29 HVC projects involving 150 suppliers and 10 Peruvian leading universities. In general, within the 21 challenges of the portfolios belonging to the first two years of the program, it has implemented 7 projects with 4 projects in pilot phase, through which the program has generated savings of half a million dollars to the company. If all the approved solutions achieve to be replicated on an industrial scale it is projected after five years a potential saving of up to US $ 10M dollars for the company. Antamina benefits by reducing its operational costs.

Among the most representative solutions generated through the program is the case of the company RENOVA, which in 2013 managed to extend the life of OTR tires by 40%. This company also achieved a good response in their pursuit of generating alliances between the academia and the suppliers. During 2014 and 2015 it managed to involve 6 and 10 universities, respectively, with 25 alliances for the development of solutions. As a representative example, a strategic alliance was made during 2015 between the company Cargo Transport and three universities in order to make the transport of fuel more efficient. Specifically the Pontificia Universidad Católica del Peru gave the technical support designing a research professor to the project, the Universidad Peruana Cayetano Heredia validated the security and health of the drivers and the Universidad Peruana de Ciencias Aplicadas designed the commercial model.

Internal factors

The idea of increasing economic gains is one of the main internal incentives that drive innovation by local suppliers. As James Valenzuela, owner and CEO of Resemin explained, the company began operations in 1989 when the Peruvian economic context that discriminated against imports due to the difficulty of getting foreign currency. This created an advantage for his company, a specialized supplier of spare parts, in the local market. Once the Peruvian economy opened and major foreign competitors began to enter the market, he realized that he needed to start developing his own drilling machines –Jumbos- in order to stay in the market as a strong competitor. So in 1994 he outsourced the production of a jumbo to an American company. He did not have any specific client, still he identified that there was a gap in the market of jumbos for underground mining. However, the jumbo had a very bad performance and the company almost went broke. In order to recover part of the investment, he was forced to improve the machine himself.

During this period, he learned to a broader and more specific extent about the mechanics of underground mining jumbos. Therefore, after this experience Resemin became a specialized supplier of spare parts and maintenance of drilling jumbos. Later in 2001 and with much more experience, he ventured back into manufacturing of a jumbo. As in 1994, he identified another market opportunity: as an active actor in the jumbo market he acknowledged that Glencore acquired seven jumbos for their mine Yaliyacu Casapalca in Ticlio. He knew that those Jumbos had very low productivity, so he decided to speak directly with Glencore and made a deal with them: Resemin would manufacture a Jumbo for Glencore and after three months of trials Glencore agreed to purchase or rent it. Resemin succeeded with its first jumbo. Five months later, they sold six additional machines for another Glencore-owned mine in Zambia that had a similar structure as the one in Peru. Resemin later established a company in Zambia to operate the machines and turned into an important mining contractor.

Exsa was founded in 1954 and until 2010 it specialized in the production of explosives. However, the company realized that it had to add some value to their products and services in order to differentiate from other companies in a sector highly dependent on the business cycles. Therefore, since 2012 they decided to offer services and solutions for rock fragmentation.

Due to their extended experience in the market, local suppliers analyzed have significant technological knowledge in the market and the capabilities to acquire and assimilate external knowledge. However, the alliances that these companies maintain with other firms of the sector may sometimes hinder the incentives to make further efforts in this area. Sometimes, suppliers that have strategic relationships with other multinational suppliers get key technologies transferred by multinational companies, and whilst this represents an advantage, it also reduces the incentive to generate further innovation. Additionally, they mostly respond to their partners' demands, and the scope for additional innovation in new areas is reduced. Among the firms analyzed:

1. Fima and Metso: Fima is a licensed contract manufacturer for Metso.
2. Ferreyros and Caterpillar: Ferreyros is the official distributor of caterpillar in Peru, El Salvador, Guatemala and Belice.

Both companies, -Fima and Ferreyros- have demonstrated to have a high level of technological knowledge as a result of their extensive experience in the market and their close relationship with key players in the GMVC. However, even though both firms achieved good levels of incremental innovation in their mining products and services[19], they do not feel the need to introduce major technological innovations since they source innovation from the more experienced companies (Metso/Caterpillar). In other words, local suppliers lack necessity. To strengthen this hypothesis, Fima has made major contributions to technological innovation in the fisheries sector, where it is not closely linked to a multinational firm that transfers knowledge and skills to it, rather than in its core business.

Drivers from the Demand

In addition to the internal incentives that suppliers may (not) have to innovate, mining companies are also a driving force behind innovation among suppliers. Their demand for innovative solutions influences the directions of suppliers' innovation. For example Tumi Raise Boring, founded in 1982, specialized in the production of somehow standardized raise boring machines during several years. However, in 2010 Hochschild mining company requested Tumi to design a raise boring machine for slot raises that could work in narrow veins. After signing a contract with the mining company and following their specifications, Tumi developed the SBM 400 SR and introduced it to the market in 2012 with its own efforts, enjoying the advantage of a secured demand. SBM 400 SR is currently in the process of being patented.

Beyond the experience of the suppliers analyzed, we have also identified some mining companies that have attempted to go from a purely transactional and economic relationship to a relationship nurturing innovation. Some mining companies seek to train people in the

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[19] Fima, for example, took advantage of its experience and technological knowledge to become a specialist in the manufacture of mining Spools, thus achieving important product upgrading. Ferreyros, on the other hand, developed a loader laboratory with a pioneering infrastructure that is unique among Caterpillar dealers worldwide. This important innovation allowed the firm to upgrade its processes in order to provide better service to its clients.

vicinity so that they can form their own businesses and provide the mining companies with products and services. In addition, mines invest in improving local suppliers so that they comply with formal requirements and provide the quality services needed in the operation.

An example of how relationships between mining companies and their suppliers are driving value creation locally is the "Emerge and Progress" program of the Anglo American mining company, which trains entrepreneurs in the formation and administration of businesses in order to create thriving businesses. This program is not limited to future suppliers of the company, since 45% of the resulting companies do not do business with Anglo American. The Yanacocha mining company also promotes the development of nearby communities through the hiring of local operators whenever it is possible. In addition, as mentioned previously, Antamina has implemented "The Development of Suppliers of Excellence" Program (See Box 1.2). However, these actions are usually more oriented to reduce social conflict and to support communities living around the mine than to support suppliers in more technically sophisticated sectors.

7.5. In addition, the current context of shrinking mining investments due to the fall in mineral prices is further raising the risk of innovation. The fear of failure discourages innovation in firms in a sector where technologies change rapidly. The role of research centers and universities

Innovation is a complex and systemic process that requires the integration of firms' internal efforts with those of other more specialized institutions. In general, the relationship between these agents and suppliers motivate innovation and learning through the following:

i. Alliances in the generation of human capital: Educational centers and universities provide engineers and skilled personnel to suppliers and mines.
ii. Funding research programs that specifically focus on resolving mining problems: A clear example of the aforementioned cooperation is the relationship between the mining company MILPO and UTEC, where the mining company proposed to provide funds to the institute so that it could develop a research program for the mining of narrow veins.
iii. Collaboration between company personnel with university researchers to develop new products. (i.e. Tumi and UTEC)

However, we have found Peruvian research centers and universities play a limited role in fostering innovation in the mining sector when compared to other mining countries. As mentioned previously, (ii) and (iii) are not yet widespread practices in the mining sector. Although some of the analyzed firms have worked together at some point with universities to develop new products, this process is not continuous and local suppliers have maintain innovation efforts within the companies' borders.

We found four main reasons why most suppliers have not demanded the support of research centers. First, partnerships with international firms provide them with the necessary innovations for the development of knowledge. Second, there is a group of companies that has been able to manage simple innovations in-house without the need to collaborate with other research institutions. Third, the main research centers that focus on the mining sector are still in an early development stage, which means that the may not have the capabilities or the structural organization required to work with firms on complex innovation projects. And finally, some firms are still very reserved about the information and technologies they possess. Nevertheless, the studied group of firms is realizing that in the medium term they will need to create partnerships with research centers to increase the level of product and process innovation (i.e., Resemin). On the other hand, sometimes mining companies have demonstrated a very different attitude and a great interest in involving research centers and universities in the innovation process, not just through the creation of programs (i.e. Antamina's suppliers program) but also funding the creation of universities and research centers (See Box 1.3).

BOX 1.3: UTEC and TECSUP

The relationship between higher education and research institutions and the mining sector in Peru is interesting. The rapid growth of the mining sector driven by the increase in investment flows around the 70s brought about a significant increase in demand for skilled labor and R&D services for mining operations. However, this demand was not fulfilled locally because there was a lack of education and research centers in the country. Thus local mining companies decided to solve the problem by directly supporting the creation of education and research centers.

In 1982, mining entrepreneur Luis Hochschild Plaut, together with a group of Peruvian industrialists, decided to create The High Technology Centre (TECSUP, its acronym in Spanish). The professional careers that TECSUP offered —such as mining operation and chemical and metallurgic processes, for instance— sought to make up for the shortcomings of high level study centers that provided mid-level quality technological training. Approximately 175 national companies donated more than US$ 18 million for its creation (Buitelaar 2001). TECSUP currently has three campuses in different departments of Peru (Lima, Arequipa, and Trujillo).

Thirty years later, in spite of the improvements in mid-level skilled workers availability, mining companies must still contend with a shortage of skilled labor in mining —engineers, chemical engineers, and chemists, to name a few—, and an absence of specialized research centers. Given these shortcomings, the University of Engineering and Technology (UTEC), which inaugurated its official campus in 2014, was created. Once again, the Hoschchild Mining Group promoted this initiative. The financing came from various actors of the Peruvian economy, including several groups involved in the mining sector: Hochschild Mining, Buenaventura, Southern Copper Corporation, and Ferreyros, among others. So far, approximately US$ 100 M. has been invested in the university, which promises to be highly beneficial for local development of technology also thanks to its collaboration with Harvard and MIT. UTEC aims to become one of the most modern research centers in Latin America in the field of engineering and technology.

8. Concluding remarks and policy implications

This paper studied the extent to which local suppliers of the Peruvian mining sector are taking advantage of the opportunities that have been opened in the mining sector. Through the analysis of eight local firms and their interaction with different actors in the sector, we gathered new evidence on the processes of learning and innovation in the mining sector in Peru and its relationship with inter-firm linkages within MGVC.

One of the main findings of the study is that the establishment of local new ventures is slow in the Peruvian mining sector. No new major local venture introducing innovations to the market was identified. Instead, they recognized that incumbent firms - mostly founded before the 90's-, are carrying out the bulk of innovations in the sector. Among the incumbent firms it is the mining companies that invest most in R&D and innovation, whilst many suppliers tend to rely on external sources of innovation.

However, the current situation of the sector still implies a great potential for the development of local suppliers that largely remains to be developed. In recent years it has been noted how multinationals in NR sectors have changed their usual behavior of acting as enclave towards adopting a more decentralized way of operating (Marin & Stubrin; Marin, Navas-Alemán, & Perez, 2015). Mining companies have strong incentives to increase the level of outsourcing in general, and near-sourcing in particular in their non-core activities (Morris, Kaplinsky, & Kaplan, Commodities and Linkages: Industrialisation in Sub Saharan Africa, 2011). In the Peruvian mining sector, the policy of most multinational companies is to outsource most of their activities. Thus in principle this provides a substantial opportunity for alliances between mining companies, existing and potential suppliers, national governments and supporting institutions.

The empirical analysis revealed that some of the suppliers analyzed are already exploiting these opportunities. The increasing demand for natural resources can trigger several opportunities for local suppliers, as with the continuing exploitation of mining deposits, the demand for complex local solutions will also increase, together with the demand for skilled and knowledge-intensive services. For example Resemin and Tumi Raise Boring provide locally-specific solutions to local technological challenges by producing drilling machines for narrow veins and TECSUP by exploring extraction methods for minerals with a high arsenic content. Likewise, the increase of social conflicts and environmental and social regulation are also creating new opportunities for suppliers who offer innovative solutions to reduce environmental harm or fulfill the new requirements imposed by the government. For example Exsa is addressing this problem by introducing a technology of rock fragmentation that reduces emissions of greenhouse gases. Still, many of these emerging needs still remain to be addressed and new efforts, investments, and institutional solutions are required.

Most importantly, for this potential to crystallize companies need to increase their technological capabilities. The study appears to indicate that local firms are not yet fully committed to innovation. One major hurdle for the development of innovations is the complexity of the technologies required. Few companies have the organization and personnel to handle these challenges. The system in which local suppliers are embedded is not supporting them adequately and firms tend to rely only on their internal efforts.

The study also found that the entrance of local suppliers was determined mainly by two factors (i) their relationships with other major market players and (ii) the experience in the market. This represents a genuine barrier for the development of new ventures, especially smaller ones, which usually are not related to major players. The problem lies in that there is a generalized lack of confidence in the capabilities of local suppliers to provide specialized services in the sector. This scheme imposes high entry costs on local companies that have to prove the efficiency of their products/services through successful pre-testing and extensive experience to gain the trust and be considered potential suppliers by mining companies. In this regard, the lack of formal communication channels among mining firms and suppliers hinders the entry of new suppliers. The already established formal channels are mainly available for suppliers that are already working with a mining company and this signals a set up against the entry of new suppliers. In efforts to fill this gap, some mining companies of the sector have developed programs that allow them to communicate their emerging needs to potential suppliers. Antamina, for example, has introduced the program "Developing Suppliers of Excellence for the Mining Industry", which aims to develop suppliers capable of providing innovative services and solutions to the mining industry.

The increasing success of Antamina's program encourages the idea of strengthening this kind of programs to diminish some of the barriers that new and small suppliers face, and strongly encourage partnership between universities and the industry. However, such initiatives should go hand in hand with additional efforts and policies to incentivize innovation among firms and to strengthen the sector's innovation system.[20] However, the involvement of the government in this regard is still very limited in Peru, in contrast to the the Chilean experience. In Chile, initiatives like CORFO and Fundación Chile[21] provide funding and assessment for innovation among small local suppliers. On the other hand, the only example of governmental support in Peru is a small fund called "Innóvate Peru", but this does not distinguish between big or small firms. Therefore, public policies should be focused on providing technological assessment to small suppliers, which usually face important capability restrictions. Additionally, specialized credit could help these firms access the funding required to develop technological innovations that could lead to more efficiency in the local mining value chain.

Finally, there is a need for stronger institutional channels to link the different firms in the sector. In Chile, mining suppliers are organized in an association ("Asociación de Proveedores Industriales de la Minería"), while in Peru they usually operate in isolation. This lack of institutions also results in limited access to reliable and comprehensive information about the sector, which makes it very hard to assess its main strengths and limitations. Formal cooperation could help local firms benefit from other's knowledge, leading to more efficient cluster economies that make it easier for them to develop technological innovations.

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[20] In Peru the most recent step forward was the enactment of the "law of promotion of scientific investigation, technological development and technological innovation" in May 2015, which gives tax incentives to companies conducting their innovation projects through their R&D departments or national technology service suppliers.

[21] A private non-profit organization that fosters innovation in partner with the State of Chile and BHP-Billiton-Minera Escondida. Fundación Chile develops local and international networks, delivering high impact solutions in areas such as sustainability, human capital development, education, aquaculture, entrepreneurship, and foods.

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9. Appendix

Annex 1: Interviews to relevant actor of the mining sector

Annex 1.1 - Mining suppliers

Name of the firm	Name Respondent	Position Respondent
Resemin	James Valenzuela	Owner/Director
Tumi Raise Boaring	Marc Blattner Carlos Dellepiane	Owner/Director Sub General manager
TECSUP	Guillermo Escobedo Aspajo	General Manager
Bisa	Juan Manuel Velez Piedra	Superintendente de Ingenieria
Fima	Ernesto Velit Suarez	General Manager
Ferreyros	Jose Miguel Salazar	Corporate Manager
UTEC	Ignacio Montero Dasso	Director de Innovación Empresarial
Exsa	Gustavo Gomez Sanchez Tommy Muhvic Pintar	General Manager Marketing General Manager

Annex 1.2 – Mining firms

Name	Name Respondent	Position
Southern Copper Corp.	Raul Jacob	Finance Manager
AngloAmerican	Luis Marchese Eduardo Rubio	General Manager External Affairs Manager
El Brocal	Raul Ponce de Leon	Logistics Manager
Milpo	Henry Aragon	Operation Manager
Antamina	Enrique Alania	Logistics manager
Yanacocha	Ricardo Sáenz	General Chief of suppliers and local staff

Annex 1.3 - Key informants/Industry expert

Name	Group	Position
Aldo Brigneti	Mining company	Senior Environmental Manager – Michiquillay Project at AngloAmerican
Carlos Casas	Academia	Executive Director of CEMS
Juana Kuramoto	Academia	Associate Researcher at GRADE and Director of Plans and Programs at CONCYTEC
Ricardo Labo	Mining company	Former principal Advisor for Latin American Global External Affairs at Rio Tinto
Wilfredo Vivanco Walter Sanchez	Governamental entities	Director of Mining promotion/ assistant director of mining promotion
Angel Murillo	National Society of Mining, Oil and Energy (SNMPE)	Assistant director of the mining sector
Penny Bamber	Academia	CGGC, Duke University

Annex 2: Destination of Peru Mining exports

Country	Products	US$ MM
China	Copper, Gold, Lead, Zinc, Iron, Molybdenum	5,753
Suiza	Gold, Zinc, Silver	2,623
Estados Unidos	Copper, Gold, Lead, Zinc, Iron, Silver, Molybdenum	1,302
Canada	Copper, Gold, Lead, Zinc, Silver	2,191
Japón	Copper, Lead, Zinc	1,017
Corea del Sur	Copper, Gold, Lead, Zinc, Iron, Molybdenum	968
Brasil	Copper, Lead, Zinc, Silver	695
Italia	Copper, Gold, Lead, Zinc	392
Alemania	Copper, Lead, Zinc.	579
Chile	Copper, Lead, Zinc, Iron, Silver, Molybdenum	312

Fuente: Ministerio de Energía y Minas.
Elaboración Propia.

Annex 3: Export of the Main Mining Products 2014 (US$ Millions)

Product	2014
Copper	8,807
Gold	6,742
Lead	1,515
Zinc	1,504
Iron	647
Tin	478
Molybdenum	360
Silver	331
Other	25.8
Gran total	**20,410**

Source: Ministerio de Energía y Minas. Own Elaboration.

Annex 4: Main countries producers of minerals 2014

Annex 4,1- Copper (Tmt)

Country	2013	2014	Reserves
Chile	5780	5800	209000
China	1600	1620	30000
Peru	1380	1400	68000
United States	1250	1370	35000
Congo	970	1100	20000
Australia	990	1000	93000

Source: USGS, (2015).

Annex 4.2- Gold (mt)

Country	2013	2014	Reserves
China	430	450	1900
Australia	265	270	9800
Russia	230	245	5000
United States	230	211	3000
Canada	124	160	2000
Peru	151	150	2100

Source: USGS, (2015)

Annex 4.3 - Silver (Tmt)

Country	2013	2014	Reserves
Mexico	4860	4700	37000
China	4100	4200	43000
Peru	3670	3700	98900
Australia	1840	1900	85000
Russia	1720	1700	NA
Bolivia	1290	1300	22000

Source: USGS, (2015).

Annex 4.4 - Zinc (Tmt)

Country	2013	2014	Reserves
China	5000	5000	43000
Australia	1520	1500	62000
Peru	1350	1300	29000
United States	784	820	10000
India	793	700	11000
Mexico	643	700	16000

Source: USGS, (2015).

Annex 4.5 - Molybdenum (mt)

Country	2013	2014	Reserves
China	101000	100000	4300
United States	60700	65500	2700
Chile	38700	39000	1800
Peru	18100	18100	450
Mexico	12100	11000	130
Canada	7620	9500	260

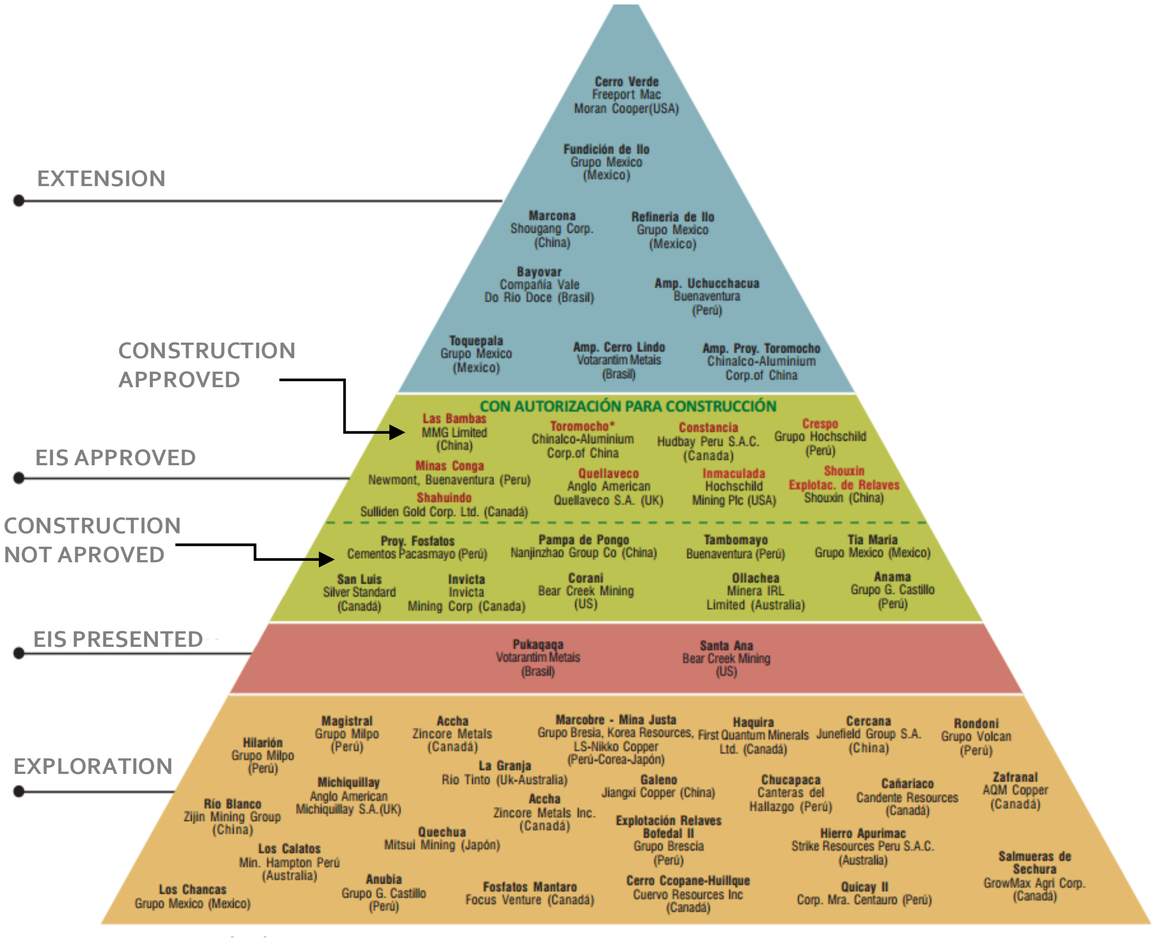
Source: USGS, (2015).

Annex 5: Investments in the mining industry

Year	Plant Eqpt	Mining Eqpt	Exploration	Extraction	Infrastructure	Preparation	Else	Total	Total Growth
2006	64	124	102	341	641	65	273	1610	
2007	64	126	137	338	337	50	198	1249	-22%
2008	141	177	168	440	321	132	329	1708	37%
2009	320	500	394	531	376	196	505	2822	65%
2010	416	518	616	738	828	510	444	4069	44%
2011	1125	776	865	870	1407	788	1412	7243	78%
2012	1140	525	905	1005	1797	639	2492	8503	17%
2013	1404	779	774	1072	1710	351	3629	9719	14%
2014	874	558	622	942	1362	297	3989	8643	-11%

Source: MIN.

Annex 6: Mining projects by current phase



Annex 7: *Future Main Mining Projects*

N°	Project	Firm	Location	Investment (US$ Millions)	Estado actual	Starting Date	Metales	Annual Production Capacity	Lifespan (years)
1	Amp. Shougang	Shougang Hierro Perú	Ica	1,000	Under Construction	2016	Iron	2 millions tons	n.d.
2	Las Bambas	MMG	Apurímac	7,000	Under Construction	2016	Copper, Molybdenum	400 million copper tons, 5 million molybdenum tons	20
3	Amp. Cerro Verde	Cerro Verde	Arequipa	4,600	Under Construction	2016	Copper	272 million copper tons	n.d.
4	Inmaculada	Hochschild Mining	Ayacucho	420	Under Construction	2015	Silver	6,6 million silver ounces	7
5	Ollachea	Minera IRL	Puno	220	EIS aproved / Looking for financing	2016	Gold	112 million gold ounces	9
6	Bayóvar	Fosfatos del Pacífico	Piura	500	EIS aproved	2018	Phosphate	2,5 million phosphate tons	n.d.
7	Tía María	Southern Copper Corp	Arequipa	1,400	EIS aproved	2017	Copper	120million copper tons	18
8	Amp. Toquepala	Southern Copper Corp	Tacna	1,253	EIS aproved	2017	Copper, Molybdenum	120 million copper tons, 3,1 million molybdenum tons	35
9	Tambomayo	Buenaventura	Arequipa	250	EIS aproved	2017	Gold, Silver	200-300 million gold ounces, 1,2 million silver ounces	5
10	Mina Justa	Minsur	Ica	744	EIS aproved / Under review	2020	Copper, Silver, Gold	110 million copper tons	10

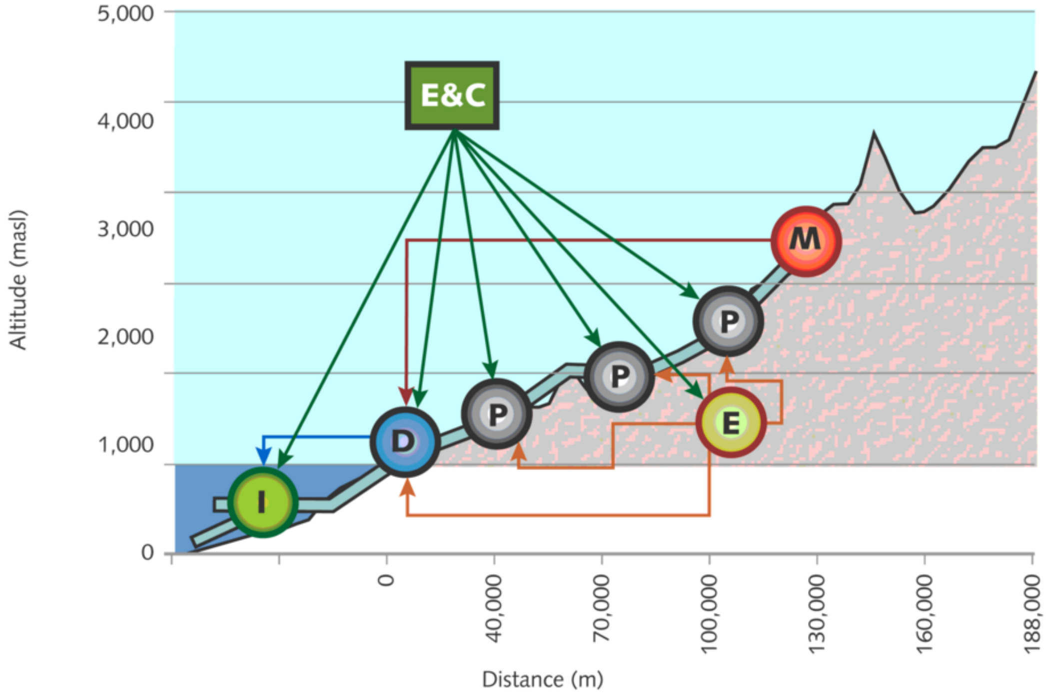
Sources: MINEM, Superintendencia del Mercado de Valores, Memorias Empresariales.

Annex 8: Employment generated by the mining industry (in thousands), 2006 – 2014

Year	Exploration	Company	Total
2006	68	41	108
2007	80	55	135
2008	66	61	127
2009	67	59	126
2010	98	68	166
2011	112	61	173
2012	139	68	208
2013	140	68	208
2014	132	63	195

Sources: MINEM.

Annex 9: *Transportation process of desalinated water*



KEY
M: Mine water requirement
D: Desalination plant
E: Environment and community
I: Intake Infrastructure
P: Pipeline and pumping system
E: Energy Supply

Source & Elaboration: WWI, 2015

Annex 10: Stringency of environmental regulation

Country	Rank	Index Value (mean: 4.1)
Brazil	49	4.1
Chile	51	4.5
Peru	79	3.7
Bolivia	90	3.6
Colombia	92	3.5
Venezuela	99	3.3

Source: World Economic Forum, (2013).