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Innovation in an Unfavorable Context: Local Mining Suppliers in Peru

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Abstract

Traditionally the Peruvian mining sector has been unfavorable for innovation by local suppliers. 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 such a context. We identify and analyze the mechanisms that lead to innovative activities through the study of the experiences of a group of local suppliers. We pay special attention to the role of interaction between contractors and large mining companies in the framework of Global Value Chain theory, as well as to the way that suppliers take advantage of new opportunities in the sector. Evidence found shows that innovation by local suppliers in the Peruvian mining sector has a limited scope, characterized by three particular traits. First, local suppliers who manage to innovate are mainly incumbent firms whose experience in the market allows them to integrate into the high-tech stages of the production chain. Second, most of these firms maintain close relationships with important national or international companies in the mining industry, which direct innovation efforts through incentives and the transmission of knowledge. Third, the more important innovations seem to be concentrated in specific market niches, where there is less foreign competition because of their specificity to the Peruvian context.

Keywords: Mining, Peru, Innovation, Value Chain, Suppliers, Incumbent Firms

JEL Codes: O13, O32

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1. Introduction

During the last decades, Natural Resource Industries (NRIs) have experienced huge transformations, increasingly becoming more innovative and specialized. 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 potential for development (Marin et al., 2015). Regarding mining, Urzúa (2007) argues that the sector's model of production has shifted from the traditional "enclave" system to a highly disintegrated one, where key services along the production chain are being outsourced to independent firms. Considering that mining activity has a heavy weight in the economic activities of many developing countries, there is an increasing interest in the emergence of knowledge-intensive and diversified local suppliers in this industry (Marin & Stubrin, 2015).

In order to understand enterprise upgrading[1] in developing countries, attention needs to be paid not only to firm-specific actions but also to the environment in which they operate. Specifically, external factors like the governance pattern of the sector's Value Chain and industry-specific features of knowledge acquisition have an impact on the process of innovation (Giuliani et al., 2005). Therefore, a useful framework for the study of these aspects is the Global Value Chain approach, which focuses on how the relationships between actors influence the decisions along the stages of production (Humphrey & Schmitz, 2000). Additionally, the dynamics of these interactions are closely linked to the nature of knowledge required for participating in an industry (Pietrobelli & Rabellotti, 2011). These concepts need to be applied in order to understand how local mining firms achieve technological innovation.

The focus of this paper is precisely to understand how the mining industry can encourage upgrading among local companies through the inter-firm linkages that characterize the Mining Global Value Chains (MGVCs). In order to achieve this, we address the experience of Peru, a developing country that is highly dependent on mining activities. According to Giuliani et al., upgrading in large NRIs like mining is highly complex. In fact, outsourcing by large companies in this sector depends on the technological capacities of suppliers, as well as their access to external sources of knowledge (Giuliani et al., 2005). In the particular case of Peru, we find that innovation is indeed achieved by incumbent suppliers rather than by new and entrepreneurial firms. Thus, we focus on understanding the incentives and opportunities that the Peruvian context offers that have driven these firms to transform their operations in order to enter the higher value-added stages of the MGVC.

In order to address our research questions, we conducted field interviews with important mining companies and key informants of the sector, which allowed us to identify seven examples of local suppliers that have been successful in technological upgrading. In this paper, we base our analysis on information gathered through detailed interviews with each of these firms. As a result, our sample of innovative suppliers captures a wide range of services that mining firms contract locally. The study of these exceptional experiences allows us to provide evidence that can contribute to the literature regarding the relationship between NRIs in developing countries and innovation among local contractors.

Evidence found shows that, even in an environment with poor conditions for innovation, a small group of incumbent firms has seized the new opportunities for technological upgrading that the mining sector offers. However, their efforts have a limited scope and some particular characteristics. First, incumbents

[1] Following Humphrey & Schmitz (2002), the concept of upgrading is henceforth understood as adding value to products or services through innovation.

have the advantage of knowing the market because of their experience in the sector. Second, the entrance of local suppliers to the high value-added stages of the MGVC is usually supported by their relationships with larger transnational companies. Finally, the major and more important innovations seem to be concentrated in specific sectors where there is less foreign competition. We also identify that interaction between local suppliers and mining firms is essential in directing innovation efforts. While demands from mining companies are the main driver for innovation by local contractors, their preference for large international suppliers is the main reason why innovation in Peru is scarce.

This paper is relevant for several reasons. First, it analyzes how technological upgrading occurs in a specific context that can be related with other experiences in NRIs: the case of a developing country that offers poor conditions for innovation and scarce governmental support, despite recent economic growth. In fact, Peru only invested 0.12% of its GDP in R&D in 2015, well below the Latin American average (0.67%). Second, this paper explores a generally overlooked issue in the GVC literature, which is the distinction between incumbent firms and new ventures when analyzing linkage dynamics and their effect on enterprise upgrading. Finally, few studies have used a methodology of case studies to assess the influence of interactions along the GVC over innovation by local suppliers (see Marin & Stubrin, 2015, and Marin et al., 2015, for two examples). In that sense, we contribute by generating new qualitative information that helps understand the dynamics of this process and complement the findings of other quantitative studies.

This paper proceeds as follows. In Section 2, we briefly describe the current situation of the Peruvian mining context and present the new opportunities that may incentivize structural change and diversification in the mining industry. Section 3 then describes the methodology applied in this study. In Section 4, we address the experiences of the suppliers interviewed in order to understand their transformation. Specifically, we will first analyze how interaction between mining firms and suppliers affects innovation by local mining contractors. Second, we will explore the role of big mining firms in directing innovation efforts in the Peruvian sector. Then, we will identify the factors that allowed incumbent firms in our sample to achieve high-quality innovations. Finally, the restrictions for further development of these firms will be discussed. In Section 5, we will summarize the main results of our research and conclude.

2. New opportunities in the Peruvian mining context

Peru is well known for its mineral wealth, which makes it one of the world's biggest producers of base and precious metals. Mining has been one of its main economic activities since the 1950s, but factors such as nationalization policies, macroeconomic instability, and internal conflicts, limited private investment in the sector during most of the past century (Glave & Kuramoto, 2007). However, the economic reforms undertaken during the 1990s allowed the country to integrate into global markets and encouraged important capital flows (Bury, 2005). The General Mining Law (1992) was a vital step towards the establishment of a friendlier environment for investments in the sector, as it provided greater incentives and legal security. As a result, new projects were undertaken, and others were expanded and modernized (Glave & Kuramoto, 2007). This transformation led to a surge in mining activity, which strengthened and reinforced the sector's position as one of the country's main drivers for economic growth.

Nowadays, Peru ranks among the leading global producers of several different minerals (in 2014, the country was among the world's top 6 producers of copper, silver, zinc, lead, gold, tin, and molybdenum). Although the country's production volumes represent only a small percentage of the world's top producers[2], its diverse mineral supply has become one of its main competitive advantages against other countries in the region (see Annex 1).

A clear example of the importance of the mining sector at the local level is the fact that its contribution to domestic production averaged 13.18% between 2005 and 2015. Likewise, mining exports represented an average of 58.15% of total Peruvian exports during the same period (see Annex 2). Regarding employment, mining and contractor companies generated more than 195 thousand jobs in 2015, which accounted for 1.15% of the economically active population. Additionally, indirect employment generated by the industry is estimated to be around 1.75 million (Ministerio de Energía y Minas, 2016).

The preponderance of the mining industry in Peru's GDP makes this sector a major fiscal contributor. Between 2006 and 2015, transfers to regional governments averaged 6.34% of the total government budget (Ministerio de Energía y Minas, 2016). Still, the limited institutional capacity of the sub-national authorities, who lack the human resources and experience, has resulted in a poor management of transfers (Aragon & Rud, 2013).

The increasing participation of international enterprises since the 1990s had little impact on innovation within the Peruvian mining industry, which remained stagnant. According to Kuramoto (2001), high technological development in the industry limited the possibilities of Peruvian suppliers to solve technological problems. As a result, this author noted that national producers failed to capture the demands from the most important mining companies during this period. In fact, until a few years ago, large mining companies relied mostly on the expertise from outside Peru to obtain cutting edge technology.

However, some studies argue that there is a new window of opportunity for NRI in developing countries. The demand for natural resources is increasing and new conditions and challenges have transformed the context for innovation in developing countries, allowing local firms to pursue an active participation in knowledge-intensive activities based on natural resources (Marin et al., 2015). In the present section, we analyze the main changes in the global and Peruvian mining context and the new opportunities for innovation that they provide.

a. 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 is currently being exploited[3]. However, considering that the best locations are the first to be taken, an expansion in mining activity would inevitably imply a shift to less competitive sites. This leads to three main challenges that mining companies in Peru will increasingly have to face:

i) Complexity of mineral deposits

Due to the depletion of clean deposits and the increasing demand for minerals, "dirty mineral" deposits are becoming increasingly important. Additionally, ore grades of Peruvian mines have reduced over time

[2] As an example, Peru's copper production only accounts for 23% of Chile's, the world's top producer (USGS, 2015).
[3] While mining concessions comprised 20.2 percent of national territory in 2013, only 1.23 percent was occupied by mining operations in the extraction or production phase (Grupo Propuesta Ciudadana, 2014).

and will continue to do so[4]. As the current methods of extraction of minerals are limited in this context, new strategies to extract these minerals are required.

ii) Peruvian specific geographic characteristics

Due to a number of specific geographic characteristics of Peru´s mines, common mining machinery and traditional mining methods are not as effective as they are in other countries. Most of Peru's mineral deposits are located in the rugged Andean highlands, which comprise 31.8% of the national territory. In fact, most of the mines are located at altitudes where common mining equipment usually underperforms. Narrow veins in underground mining are also a challenge for Peruvian mining production, since traditional machinery is unable to handle this type of settings.

iii) 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 sites generally located at high altitudes (GWI, 2011). The high costs of transportation from the coastline result in seawater being considerably more expensive in Peru than in other mining countries (Bitran, 2014).

Overall, 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. Standardized mining methods are not viable in these difficult conditions and large multinational suppliers are generally unable to provide solutions to the complicated Peruvian conditions. 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

b. Lower mineral prices

The increase in demand for metals and minerals in the early 2000s quickly translated into increased prices and mining profitability, encouraging the industry to expand production of certain major commodities by 50 percent or more, particularly over the last decade. As a result, worldwide mining operations are as much as 28 percent less productive today than a decade ago (Lala et al., 2015) and Peru's mining sector has been no exception. During 2005 and 2014, workforce productivity decreased 28% (Ministerio de Energía y Minas, 2015).

However, 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). So there is a growing interest across the industry in raising productivity by cutting costs incurred to produce mining output, or to increase output at no additional cost (Lala et al., 2015). This need for more efficiency creates a new window of opportunities to suppliers who offer innovative processes for the mining industry.

c. Social conflicts and environmental issues

Regarding the national context, social conflicts have been increasing in the mining sector[5] (Triscritti, 2013). This trend is motivated by local concerns about livelihood security, environmental degradation,

[4] In general, projections of average copper grades from 2012 to 2025 estimate that Peruvian grades will decrease on average by 19% -close to the world average, which is estimated to fall 21%- (McKinsey&Company, 2013).

and by the perception that well-being has not increased in proportion to the profits of mining companies (Bebbington & Bury, 2009). Although changes in legislation through the last decade have increased the participation of indigenous communities in decision-making, communities still consider that their rights are not properly secured. Therefore, in recent years the government acted to protect the environment and the interest of the communities. This political process has brought a significant increase in the number of environmental regulations in Peru[6] (EY, 2014).

In this context of adjustment to increasing social conflicts and environmental and social regulation, local suppliers can find new opportunities to offer innovative solutions to mining companies. Firms 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. As technological progress regarding environmental impact needs to be implemented at various stages of production, it involves all actors in the mining value chain.

3. Methodology

In order to report on recent innovation trends among suppliers in the Peruvian mining sector, we use a case study approach. Data for this paper was collected through semi-structured interviews to relevant actors of the mining sector: mining suppliers, mining firms and key informants (see Annex 3 and 4, and Table 3). Interviews to mining firms and key informants enabled us to identify the local firms that have succeeded in introducing innovative solutions and services to mining companies.

It was important to select for the interview those mining companies that could provide us with as complete a picture as possible. When selecting the sample, we took into consideration the following factors: (i) Amount of foreign/Peruvian capital, (ii) Length of time operating and (iii) Company size. In Annex 3, we give details of the mines selected for interviews, and some of their main characteristics[7]. The last three columns specify each firm's classification within the factors mentioned.

After the main suppliers were identified during the interviews with the mining firms, a group of eight companies was selected to be interviewed. Our selection criteria focused on suppliers that have brought innovative products to the market in order to address some of the emerging needs of the mining companies. Although our sample covers different stages of the mining value chain, we do not intend for it to be representative of the Peruvian mining sector.

As Table 3 summarizes, seven of the eight chosen firms were founded before the 90´s. In fact, UTEC was the only recently founded firm pointed out during the interviews. Information gathering also revealed that the most innovative suppliers focus on acquisition and exploration, mine planning and construction and mineral extraction. Thus, considering that a broad sample of mining companies and key informants was

[5] Due to social protests, important mining projects worth US$ 21.5 billion were delayed between 2010 and 2014 in Peru (Palomino et al., 2015).

[6] As a result, Peru has gone from not having any kind of environmental regulation in the 1990s to turning down 20% of the proposed mining projects every year due to their noncompliance with social and environmental obligations.

[7] Considering that different minerals will 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 required from technologies in the first stages of the mining value chain depends mostly on operational characteristics rather than type of mineral.

covered, we can infer that the innovation process in the Peruvian mining sector generally favors incumbent firms that operate in the first stages of the value chain.

Table 3: Peruvian mining suppliers selected*

Firm	Year of foundation	The firm is a….	Capital**	N° 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 and 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 refers to 2014 levels*
*** Approximately*
****The whole group has companies in Zambia, DR Congo, India, Mexico and Argentina. The global turnover of the group for 2014 was US$ 71.47*
Source: own elaboration with data from interviews

Listed below we provide a brief review of the local suppliers chosen for the study:

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 nine different countries.

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

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 machinery in Peru, but also because it differentiates itself from the competition by offering complementary services such as in 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.

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 growing success when 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.

*Tumi Raise Boring***:** a contractor and manufacturer of raise boring machines[8] with over 40 years' experience in drilling and the provision of related services. They began to do important innovations in 2012, when they built a raise bore machine that significantly reduces operating costs and risks. The company exports its machines to 22 countries.

Fima: established in 1969 to provide engineering, manufacturing, and installation solutions to various production sectors. With regard to mining, Fima offers a wide range of products, with mining spools[9] standing out above thanks to its highly specialized design and manufacture.

In addition, the following universities and institutes have been included:

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 in mining.

*TECSUP***:** A private Technical Institute for Higher Education 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.

4. Findings and Discussion

Section 2 described the main opportunities for innovation that Peruvian mining suppliers have in the current context. In this section, we report on evidence collected through our fieldwork in order to assess the main questions raised in the introduction. Following the literature on technological upgrading, we recognize three different types of strategies that a firm can follow in order to achieve innovation within an industry (Morrison et al., 2008). These can be focused on the value of products (product upgrading) or the efficiency of production processes (process upgrading), as well as more complex strategies oriented to developing new functions in the sector's value chain (functional upgrading).

By definition, innovations must have a degree of novelty, which may be in one of the following groups: (i) new to the company, (ii) new to the market, and (iii) new to the world (OECD & Eurostat, 2005; 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 (Exsa, Tumi Raise Boring, Resemin), four an innovation to the local market (Ferreyros, UTEC, TECSUP, Fima), and one an innovation to the company (Bisa). Based on this classification, we intend to present examples of how upgrading occurs in a specific context like the Peruvian mining industry, while highlighting the role of value chain interactions in fostering or hindering this process.

[8] Raise borers are machines used to excavate a hole between two different levels of an underground mine without the use of explosives.

[9] 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.

The structure of this section is the following: first, we will describe how the governance pattern in the mining value chain affects innovation among local suppliers. Second, we present a discussion about the features that allow incumbent firms to achieve technological upgrading in the Peruvian mining sector. Finally, we will assess the nature and scope of innovation achieved in the Peruvian context. Throughout this analysis, we will identify the external opportunities seized by local firms to integrate themselves into the higher value-added stages of the MGVC.

4.1 Patterns of interaction in the MGVC

In the Peruvian mining sector, large multinational companies govern the value chain. In fact, 81% of total copper production in 2015 was carried out by five large firms (Antamina, Southern Copper Corporation, Cerro Verde, Antapaccay, and Chinalco). Although the production of gold and silver is shared among more companies, still a small number comprises more than the 50% of the total production. In 2015, seven large firms produced 55% of Peruvian gold (Yanacocha, Barrick Misquichilca, Consorcio Minero Horizonte, Buenaventura, Retamas, Gold Fields La Cima, and La Arena), while seven companies accounted for 57% of Peruvian silver (Buenaventura, Antamina, Ares, Volcan, Chungar, Cerro, and Chinalco) (Ministerio de Energía y Minas, 2016).

As is standard practice worldwide, large mining companies in Peru tend to outsource their general mining operations to mining contractors. Additionally, mining companies have strong incentives to increase the level of outsourcing in general, and near-sourcing in particular in their non-core activities, such as research, exploration, development, and technical assistance services (Morris, Kaplinsky, & Kaplan, 2011). This is also true in Peru, where mining contractors group approximately 68% of the labor force working in the Peruvian mining sector (Ministerio de Energía y Minas, 2016). By giving the contractors and suppliers the responsibility to update technologically, mining companies minimize their operational risks; their role in the process of innovation is rather to inform the potential suppliers of their needs and provide them with adequate tools to achieve the solutions required. After these have been successfully developed and tested, mining companies acquire the resulting products.

Despite mining companies' growing demand for innovation in Peru, we found that only a few local companies are hired to produce high-technology solutions. These findings are in line with a study of the mining cluster of Yanacocha conducted more than a decade ago, which identified that this important mining company limited its relationships with local suppliers to commercial partnerships due to their technological limitations (Kuramoto, 2000). According to our study, this trend generalizes to the Peruvian mining sector and has not changed substantially in recent years. Our sources indicated that mining companies mostly rely on international suppliers for long-term broad solutions, which avoids the costs of looking for functional partnerships with local firms and significantly reduces the risk of failure. The suppliers interviewed also stated that there is still a prejudice against local innovation, which makes it difficult for local suppliers to introduce their innovations. Since Peruvian firms are relatively new in the global market, they have yet to build a reputation for good quality in their products and services. As a result, most technological services and brand new equipment and machinery tend to be imported from abroad (OECD, 2011).

Another issue identified by local contractors is that mining companies are reluctant to apply new processes that have not been tested worldwide because they may not achieve the expected results. This situation arises because of the high costs that testing new systems or machinery may involve, which makes it very difficult for innovative suppliers, especially smaller ones, to have their inventions valued in

the market. Therefore, local innovation is constrained by the mining companies' demands, which establish that extensive, successful pre-testing be conducted in numerous mines with the technology developed by local suppliers before they use it. They also require that contractors meet high profile production standards in order to be eligible. All of this imposes high entry costs to companies offering alternatives to the standard suppliers in the MGVC.

Following Giuliani et al. (2005), who develop a classification of value chains based on their governance patterns[10], we have found that relationships between mining companies and local suppliers in Peru are mainly quasi-hierarchical, as local contractors typically have a lot more to gain from transactions. According to the authors, quasi-hierarchical chains are characterized by firms that are legally independent, but have to comply with the rules defined by the industry's leaders. In the extraction stages 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. Additionally, contracts tend to last only a few years, after which renovation could be subject to the result of open tenders or the administration's preferences. Although these companies have managed to innovate in the sector in which they specialize, they still compete in terms of price and reputation with other suppliers and permanently face the risk of their contracts not being renewed.

Among the suppliers that provide consulting services (Bisa, Fima, Ferreyros, UTEC, and TECSUP) we found that relationships tend to be more idiosyncratic, as it is difficult and time consuming for mining companies to establish ties with new value chain partners (once a research program or engineering service with a particular firm has started, "switching costs" are high). However, the relations between suppliers in this segment and mining companies remain relatively asymmetric: while the former depend economically on their businesses with mining firms, the latter usually have a wide variety of potential suppliers that they can turn to if something goes wrong. In these sectors of the MGVC, reputation and commitment are key determinants when mining companies choose the suppliers they will hire. Mining companies that decide to contract with local engineer companies (i.e. Bisa) do so because they can "(…) obtain high-quality engineering locally, with much more competitive pricing and a closer relationship for after sales services" (GBR, 2014).

Furthermore, an analysis of the communication channels between mining firms and contractors highlights the aforementioned governance patterns. According to Cousins et al. (2006), establishing tight inter-firm relationships between buyers and suppliers is a critical differentiator of high and low performers in global supply chains. Following the authors' classification, we have detected both formal and informal channels of communication.

Regarding formal channels of communication, we have identified two direct links through which suppliers regularly communicate with mining companies in the Peruvian mining industry. The first is 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. The second is during the monthly and annual established meetings that most mining companies typically organize with their main contractors to discuss their performance, possible improvements, and other related issues.

[10] These authors identify that governance patterns can be divided in three kinds: (i) networks, which imply a high degree of cooperation and equal power between firms, (ii) quasi-hierarchy, where a leader in the chain dominates the actions taken by other firms, and (iii) hierarchy, where external firms own contractors (Giuliani et al., 2005).

On the other hand, informal channels between mining companies and their current suppliers are continuous and direct. This is particularly important, since informal socialization processes have been found to be more important than formal communication in the creation of relational capital between contracting organizations, which in turn leads to better relationship outcomes (Cousins et al., 2006). In the case of Peru, our fieldwork revealed that some 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 mining project needs as they appear.

Ferreyros is a good example of this type of relationship, as it offers many post-sale services such as maintenance of equipment and monitoring of operations. These activities require the installation of a workshop in the mines, and Ferreyros provides the human assets for its functioning. Naturally, this relationship demands constant and direct communication between the contractor and its clients.

It is important to note that most communication channels are only available for suppliers that are currently working with the different mining companies. Aside from open tenders, there are no formal channels through which new suppliers can gain access to mining companies. Furthermore, mining companies do not have many incentives to create these formal channels for potential suppliers. Instead, suppliers are the ones who incur in the transaction costs that are needed to approach the mining companies and offer their products/services. Once again, this reflects a clear hierarchy between mining firms and suppliers, as the latter have much more to gain or lose from the relationship.

Because formal and informal channels are primarily determined by current relationships between mining companies and suppliers, emerging suppliers are at a big disadvantage. Herein lies the importance in generating communication channels in which new suppliers can be involved. Some firms have noticed this problem and have recently acted to tackle this situation. Antamina, for example, introduced a program to improve its formal channels of communication with potential suppliers. Through the transmission of its technical problems to potential suppliers, this firm has significantly reduced information asymmetry.

This type of efforts highlights the lack of organizations that can play a coordinative role between mining companies and suppliers in the Peruvian mining sector. Economic literature has shown that industrial clusters allow for efficient information flows that improve firm performance and foster technological upgrading (Giuliani et al., 2005). However, our fieldwork reveals that local mining suppliers in Peru operate mostly in an isolated environment where cooperation among firms is difficult. As Bamber et al. (2016) note, this lack of collaboration in the industry limits the potential to fully understand the needs of the sector and develop a medium to long-term sector strategy. Therefore, key actors could potentially intervene in these situations, thereby reducing transaction costs between local mining suppliers[11].

4.2 Integration of local suppliers in the higher value-added stages of the MGVC

Recent studies argue that the nature of the knowledge required in a specific industry has a direct influence on the development of the value chain governance patterns (Morrison et al., 2006). Regarding NRIs, Giuliani et al. (2005) state that the complexity of technology used in these sectors requires that suppliers already have a high degree of internal capabilities in order to be contracted. Additionally, relationships

[11] For example, the case of the Chilean government's initiative "Fundación Chile" shows the potential benefits of external intermediation in the sector. This initiative fosters innovation and technical capacities in different economic sectors through the development of firm networks and specific programs (Atienza et al., 2016).

with external sources like transnational corporations or research centers allow them to access codified knowledge that is necessary for upgrading.

Our findings mostly support these theoretical predictions. As mentioned in the introduction, our fieldwork revealed that there are some local suppliers with high technological capacity that have managed to compete with multinational companies in certain specialized niches. However, in the particular case of Peru, we did not find new ventures introducing innovations to the market. Instead, we identified a group of incumbent firms that became innovative at some point, changing from one category to another. From the interviews with our sample of suppliers, we have identified that the main factors that allow these firms to enter the higher value-added stages of the MGVC, which are: (i) partnerships with important actors in the market, (ii) identification of market niches, and (iii) internal restructuring efforts. We will now examine these mechanisms in detail:

i) Relationships with market players

Economic literature identifies alliances —bilateral agreements between firms— as essential engines for innovation activities in companies (Edquist, 2000; Becker & Peters, 2000; Teece, 1992; Schilling & Phelps, 2007). Among the innovative suppliers analyzed in this paper, we have found that many firms maintain close relationships with multinational companies governing the MGVC. While 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), others were established by mining companies from the beginning. The latter are often created 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). Regardless, the entry of these companies into the innovation sectors of the MGVC 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 originally created by Buenaventura as a technical support company for their own mines. However, in 2003, Fluor —a global engineering construction company involved in providing EPCM services in the mining project Yanacocha- decided to work together with Peruvian professionals in order to reduce costs. This led to the decision to work jointly with Bisa, which was the firm's first time offering a service to a mine outside the Buenaventura group[12]. The joint work with the multinational allowed Bisa to improve its capabilities significantly as a company, since the project it was involved in 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 achieve process upgrading, which enabled it to gain a major presence in the value chain. As a result, the company currently provides consulting services to many mining companies in Peru and other countries[13].

Another example of a firm that has benefited from an alliance with a big player in the MGVC is Ferreyros, the official Caterpillar distributor in the country since 1942. Maintaining a close relationship with this important partner for such a long time has enabled Ferreyros to achieve high levels of internal capacity. This has led to a variety of internationally recognized innovations regarding efficiency,

[12] 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%).

[13] Graña y Montero Ingeniería (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, which represented a cultural shift for the firm that helped it internationalize (GBR, 2014).

technology, and communications, among other areas. As a result, Ferreyros constantly achieves process upgrading, which allows it to provide its clients with better service. Both these experiences show that the learning curve for local companies can be enriched by joint projects with large EPCM players. 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 of process upgrading.

ii) Identification of market niches

Some of the companies in our sample 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 in the market acts as a proxy for incremental capabilities accumulation, as it allowed these firms to gain valuable experience in market dynamics and its main actors' demands. Within this group, the key factor that allowed for technological upgrading was the identification of a niche in the market that offered an opportunity for a strong positioning in the MGVC. According to Cooper et al. (1986), a recommended strategy for small firms to enter industries with well-established competitors is to seek the protection of a market niche, where specific market characteristics limit big players' interest to participate. Among the firms analyzed, Resemin and Tumi (suppliers of machinery for underground mining), as well as Exsa (production of explosives) match these characteristics.

Resemin is a good example of how experience helped develop the skills and contacts needed to identify an opportunity for innovation and start making technological efforts. The company was founded in 1989 as a supplier of spare parts for drilling machines. However, its experience in the sector allowed it to identify a gap in the market of jumbos for underground mining —higher productivity machinery was needed— and take advantage of it. In 2001, a request by the firm Glencore led this company to produce its first drilling rig (jumbo), which was successful thanks to its knowledge of the complexity of Peruvian mines. Additionally, its geographic proximity allowed Resemin to test its products in the setting where they were intended to work, which gave the firm an important advantage against its international competitors. This achievement meant an increase in productivity for many mining companies in Peru and other countries, as it is the smallest jumbo in the market and significantly reduces drilling time. It also allows for mechanization in tunnels, which has important implications for the safety of operators (who no longer need to be involved physically in the drilling process). Today, Resemin has an important global presence, with a 2.5% share of the world market and approximately 60% share of the local Peruvian market for drilling machines.

This example shows how Resemin managed to enter the MGVC as a supplier that provided a solution for a previously unattended demand from mining companies. Specifically, this opportunity was related to a specific geographic characteristic of Peruvian mines: the higher complexity of underground mining. The experience of Tumi Raise Boring was similar, as this firm also took advantage of the specific needs of Peruvian mines for narrow veins. These two cases also reveal the importance of mining companies in determining innovation efforts, as will be discussed later in this section.

Exsa, on the other hand, is an example of a firm taking advantage of a different type of niche. The company was founded in 1954, and until 2010 specialized in the production of standard explosives. However, the company identified the need to add some value to their products and services in order to differentiate itself from other companies and obtain a better positioning in the market, as it operated in a

sector highly dependent on external factors (economic cycles). Therefore, near 2012, it decided to offer different solutions for rock fragmentation and succeeded in developing the Quantex technology, which was new to the world. This achievement, which generates savings of up to 20% on the total cost of rock fragmentation and significantly reduces environmental impacts, is currently used by 40% of the local market. Although its participation in the international market is reduced due to the limitations to the trade of explosives, the company is planning to introduce a subsidiary in Colombia and Chile to address this problem. As this example highlights, the identification of a need in the market that cannot be met by the more experienced multinational suppliers (in this case, the fact that international trade of explosives faces strict restrictions) can potentially lead to a significant innovation that allows for functional upgrading.

These firms' time in the market before innovating 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 make contact with the mining companies and sell their machines and services. Still, what allowed Resemin, Tumi, and Exsa to introduce innovations that were new to the world was their ability to identify and take advantage of a gap in the mining industry. While Resemin and Tumi developed a solution for problems that were specific of Peru's geography, Exsa identified an issue that needed to be solved by a locally based firm due to international regulation. In all cases, their efforts allowed these firms to achieve functional upgrading, by switching to a higher value-added stage of the value chain and contracting with the main mining companies that govern it.

iii) Internal restructuring efforts

According to Argyres and Silverman (2004), centralizing research within a firm reduces transaction costs associated with R&D coordination between units, thus generating innovations that have a broader impact. In our fieldwork, we found that some of the companies analyzed have conducted organizational restructuring to support internal innovation processes over the years. In general, we find two types of reforms: cultural and structural.

Regarding cultural reforms, most of the firms in our sample 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. Firms must now have a customer-oriented vision that allows them to gather the information required to focus their innovations on the needs of their clients. As for structural reforms, they argue that the new innovation-governed context has led companies to make changes in their organizational structure by creating or restructuring management offices in order to give R&D a formal and visible place in their companies.

Exsa is a clear example of a company that has conducted both organizational restructuring processes aimed to support the company's innovation processes. Regarding structural changes, in 2013, they created the office of Innovation Management in order to focus the company's innovative activities in one area. Regarding cultural changes, the company 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: (i) urgency to reduce costs and (ii) environmental concerns. Once they had gathered this information, they designated a special team to work in the development of an explosive that could meet their clients' needs (from which they developed the already described Quantex technology). Additionally, in order to align the company's innovation objectives with those of their clients they held

periodical meetings with their clients to discuss the main issues regarding innovation in the Peruvian mining context.

Overall, the examples reviewed in this subsection confirm the theoretical predictions made by Giuliani et al. (2005) about the nature of knowledge in NRIs like mining. As technology in this industry is highly complex and usually codified, local suppliers need advanced internal capabilities and reliable access to external sources of knowledge in order to achieve innovation. Accordingly, we found that firms are more likely to achieve technological upgrading when they foster R&D through their organizational structure and collaborate with more advanced companies that benefit them through spillovers. Additionally, our fieldwork allowed us to identify that firms with more experience in the local market have the advantage of knowing its actors and their needs better, which allows them to seize the opportunities for upgrading in their environment.

4.3 Nature and scope of technological upgrading among local suppliers

After having reviewed how the structure of the market and a firm's own characteristics contribute to innovation by local mining suppliers, we will now assess the main features of these firms' technological efforts. As mentioned, we have found that although upgrading has occurred among a group of incumbent firms, it is limited in scope. In this subsection, we will first discuss the role of mining companies governing the value chain as the main drivers for innovation efforts. Then, we will present the main constraints to upgrading that our fieldwork allowed us to identify.

4.3.1 The role of mining companies as drivers of innovation

The dominant position that mining companies hold in the MGVC results in innovations that are mainly driven by these firms' needs and demands, instead of by local firms' own initiative. This situation is marked in the Peruvian case, especially since suppliers are smaller and less autonomous. As Pietrobelli and Rabellotti (2011) note, integration in the Global Value Chain can enhance local innovation in developing countries through different mechanisms. Following these authors' framework, we have found that requirements from big mining companies influence the direction of all innovation efforts by Peruvian suppliers directly or indirectly.

One way that GVC leaders can affect enterprise upgrading in the local context is by pressuring suppliers to achieve international standards (Pietrobelli & Rabellotti, 2011). A case in point is the experience of Tumi Raise Boring. The company was founded in 1982 and during several years, it specialized in the production of standardized raise boring machines. 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 requested machine —currently in the process of being patented— and introduced it into the market in 2012. This allowed the firm to expand its markets and integrate into higher value-added stages of the MGVC (functional upgrading). As illustrated by this experience, mining companies offer the most important incentives for local suppliers to innovate and their needs are the main motivation for the direction of the efforts taken. This example also highlights how specific geographic characteristics in Peru pose unique opportunities for technological upgrading by local suppliers.

A different dynamic can be observed in the case of the universities and research centers covered in the sample (UTEC and TECSUP), which were created specifically to outsource the more complex research activities aimed at finding solutions to the mining companies' technological requirements. The rapid

growth of the mining sector driven by the increase in investment flows in the early 1990s brought a significant increase in demand for skilled labor and R&D services for mining operations. However, this demand was not covered at the local level because there was a lack of education and research centers in the market. Given the shortage and deficiency in the sector, local mining companies decided to solve the problem by supporting the creation of education and research centers, first creating TECSUP and more recently UTEC. This case illustrates the second mechanism identified by Pietrobelli and Rabellotti (2011), who state that innovation can be facilitated by the direct involvement of international firms in order to compensate for the local suppliers' limited capabilities in a specific area.

An example of these efforts is the case of TECSUP, which is currently addressing the problems related to deposits containing high levels of arsenic. Because of its specific nature, this problem demands a solution by a local agent. Additionally, it shows how lower quality mineral deposits and the introduction of new environmental regulations can open important opportunities for local firms to innovate. Researchers at TECSUP have already developed a new technology to address this issue, but it is still too expensive for mining companies to adopt. Therefore, further investigation is required to find a more feasible solution (Corcuera, 2015). Another example of the influence of mining companies on innovation can be found in the relationship between the mining company MILPO and UTEC. In this case, the mining company proposed to provide funds to the university so that it could develop a research program for the mining of narrow veins. Although both projects need further development to have a real impact on the mining industry, these are clear examples of how company needs are the main drivers of supplier innovations.

Beyond the experience of the suppliers analyzed in this study, we have also identified some mining companies that specifically aim to build relationships based on the pursuit of innovation with their suppliers. Some mining companies seek to train locals so that they can form their own businesses and provide products and services to the mines directly. In addition, mines invest in improving local suppliers so that they comply with formal requirements and provide the quality service needed in the operation. However, these efforts seem to be oriented to solving the social tensions that may harm the mining companies' operations. As pointed out in section 2, the mining industry in Peru is currently characterized by growing social conflicts that complicate mining investment. This has led mining firms to adopt a diverse set of strategies to deal with this issue. In some cases, this involves providing technological support to local suppliers.

An example of how relationships between mining companies and their suppliers are driving value creation locally is the Anglo American mining company's "Emerge and Progress" program, which trains entrepreneurs in setting up and running businesses. The Yanacocha mining company also promotes the development of nearby communities through the hiring of local operators whenever it is possible. These experiences add to the previously mentioned program "The Development of Suppliers of Excellence", through which Antamina seeks to encourage the search for creative solutions to practical problems the company faces. However, since these efforts are usually aimed at reducing social conflict and supporting communities living around the mines, the support given to suppliers is seldom in complex sectors that involve higher technical and scientific requirements.

4.3.2 Restrictions to innovation by local incumbent firms

Although the examples of enterprise upgrading described allow some local firms to enter the more innovative stages of the MGVC, the scope of their technological undertakings is still limited. Compared to other international suppliers, local firms do not have the capabilities to participate in the most advanced

innovation sectors of the MGVC. Since only a few firms are investing in more sophisticated products and processes, the opportunities for knowledge spillovers among other local suppliers in the industry remain scarce (Bamber et al., 2016).

In this sense, our evidence partially supports the argument made by Humphrey and Schmitz (2000) regarding quasi-hierarchical governance patterns. According to the authors, participation in this type of value chains offers very favorable conditions for process and product upgrading, but hinders functional upgrading (which implies acquiring new and superior functions in the value chain). While Exsa, Resemin and Tumi are examples of firms that took advantage of a niche in the market in order to achieve functional change, most suppliers in our sample oriented their efforts towards product or process upgrading. The interviews conducted allowed us to identify the main reasons behind this situation in Peru. These are (i) an unfavorable overall context, (ii) low internal capacity, (iii) lack of incentives from firm alliances, and (iv) low degree of educational and research centers involvement.

First, the overall context in Peru is not favorable for innovation by local firms. In 2015, investment in R&D accounted for only 0.12% of GDP, while in similar countries like Mexico and Argentina the same indicator was above 0.5% (OECD, 2015). Consequently, Peru ranks 71st in the world and 9th in Latin America in the Global Innovation Index (2015), while Chile (the country's main mining competitor in the region) ranks 36th and 2nd respectively (Dutta et al., 2015). Further complicating matters is the fact that during the last decades, Peruvian Higher Education has seen a significant decrease in quality in spite of a growing supply (Lavado et al., 2014). In fact, our fieldwork revealed that many firms in the mining sector sense a gap in the labor market, which often does not satisfy their human capital demands.

Moreover, in the current context where investment in mining is shrinking due to the fall in mineral prices, the risk of investing in innovation becomes even greater. Innovation involves both a significant capital investment and a risk for the company, especially considering that technologies change rapidly. Accordingly, some of the suppliers interviewed indicated that uncertainty and low return expectations were important barriers to technological upgrading. In short, Peru's relatively unfavorable conditions and the complicated situation that the mining industry is currently going through pose significant constraints on local suppliers' technological efforts.

Second, incumbent firms' low technological capacity is another factor that limits these firms' impact on innovation. This is partly because most local suppliers started to grow as a result of the increase in mining investments during the 1990s, and have not yet had the time to reach the highest point on their learning curves. However, a lack of external incentives has also slowed this process. According to most economic literature, fiscal incentives have a stimulating effect on innovation efforts (measured as R&D spending) within different industries and countries (Hall & Van Reenen, 2000). Until 2015 in Peru, there were no tax incentives for businesses to quantify their R&D costs explicitly. The recent approval of tax reductions for companies that conduct innovation projects through their R&D departments or through national technological services suppliers automatically creates incentives for companies to keep track of these expenses. Still, a comprehensive survey of the evidence showed that this effect can be very heterogeneous among firms, sometimes even generating perverse incentives (Hall & Van Reenen, 2000). It remains to be seen if these policies will have the desired impact on local firms' technological efforts.

Because of the lack of incentives for technological upgrading, the companies included in our study are not yet at the forefront of innovation. In an environment of rapid technological change, high levels of internal R&D and linkages with the science base are required for firms to achieve technological upgrading (Tidd,

2001). Peruvian suppliers do not allocate budgets for the acquisition of intellectual property[14], partially because they have yet to acquire the necessary skills to manage it. In the firms analyzed, the high level of technology required and the complexity of the development of new technologies are major hurdles for the development of high-impact innovations. Companies are still at initial levels of innovation, and therefore few have the systems or platforms and workforces to handle the constant flow of information that comes from innovations. It is important to note that despite the efforts that the firms interviewed were making to improve their technology and knowledge, most of them did not have a fully developed R&D department or an accounting system that quantified their R&D expenditures. Therefore, they had to make special efforts to provide us with this information.

Third, the alliances and agreements that local suppliers maintain with bigger firms of the sector may hinder the incentives to make efforts in this area. Sometimes, contractors that have strategic relationships with other multinational companies, despite having a high degree of technological knowledge, have less incentives to exploit them than those firms that do not maintain those relationships. This may happen because they are used to internalizing the solutions provided by their partners instead of generating their own. Additionally, these firms' operations mostly respond to their partners' demands, and in many cases multinational companies do not need their local contractors to invest in research as more advanced facilities already cover their needs (Lydall, 2009). All of this is a direct consequence of the hierarchical relationships that some local suppliers maintain with their more important partners.

Of the firms analyzed, both Fima and Ferreyros have shown a high level of technological knowledge because of their extensive experience in the market and a close relationship with a key player in the global mining chain (Metso and Caterpillar, respectively). However, their alliances with multinational companies also explain to some extent why Fima and Ferreyros do not feel the need to introduce major technological innovations specific to the sector, since the more experienced companies cover this. This is not due to a local supplier lacking capacity, but rather lacking the incentives to engage in functional upgrading[15]. Still, both firms have managed to use their experience to achieve certain levels of incremental innovation in their mining products and services. 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.

Fourth, the low degree of involvement of educational and research centers constitutes another restriction for technological upgrading. Innovation is a complex process that requires acquisition and assimilation of knowledge, so it is essential that firms combine their internal efforts with those of other more specialized institutions. In general, economic literature on external R&D argues that the relationship between academic agents and firms motivates innovation and cross-boundary learning through the generation of human capital, funding of research programs that specifically focus on resolving mining problems, and

[14] The literature shows that businesses with large intellectual property portfolios 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).

[15] For example, Fima has made major contributions to technological innovation in other sectors, such as fishing, where it is not closely linked to a multinational firm that transfers knowledge and skills to it. The firm has become the leading producer of equipment for the processing of fish flour, and it sells its products to many Peruvian and international fisheries. Unlike the situation in its mining activities, technological upgrading in the fishing sector drove the firm to protect its innovations with patents.

collaboration between company personnel and university researchers to develop new products and services (Becker & Peters, 2000). Moreover, universities and research centers face different incentives than other key industry actors, which makes them less likely to appropriate knowledge created in R&D alliances (Bercovitz & Feldman, 2007).

However, we have found that in Peru, research centers and universities play a limited role in fostering innovation in the mining sector when compared to other countries of the region. Although one third of the firms analyzed have worked together at some point with universities to develop new products, this process is not continuous and some local suppliers have managed to maintain innovation processes within the company, not requiring support from research centers. Among the suppliers analyzed, we found two main reasons why some firms 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, links between firms and educational or research centers are weak, which limits the potential for technological collaboration between them. Nevertheless, this group believes 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).

5. Concluding remarks

In this paper, we studied the extent to which local suppliers are taking advantage of the opportunities that have arisen in the Peruvian mining sector. Through the analysis of eight local firms and their interaction with different actors of the industry, we gathered new evidence on the factors than foster or hinder local learning and upgrading by established firms. We also intended to increase the understanding of how the inter-firm linkages that characterize global value chains operate in the mining industry in Peru, and how they influence innovation efforts by local suppliers.

Our fieldwork revealed that innovation by local suppliers in Peru is limited, since important international firms undertake most mining outsourcing activities. When mining investments increased during the 90s, very few local firms had the required knowledge to meet the new competitor's technological demands. However, after more than two decades, some of them are reaching a point in their learning curve where they have enough capabilities to contract with big actors in the global mining sector. Consequently, a group of local incumbent firms has managed to achieve technological upgrading and integrate into international markets in recent years. These companies have taken advantage of both their experience in the market and their alliances with global leaders to innovate in their products and services.

All the same, despite the emergence of local firms with enough technological capacity to innovate, their efforts are still limited in scope. In fact, they are mostly focused on particular market niches, where specific factors restrict the entry of international competitors. This is the case of Tumi and Resemin, which took advantage of the complicated geographic characteristics of Peruvian mines, and Exsa, which benefitted from international trade regulations. Among the factors that make it difficult for Peruvian firms to achieve significant innovation are the lack of incentives from international partners and the low degree of cooperation with educational and research centers.

The current situation in the mining industry poses some additional challenges for Peruvian suppliers seeking technological upgrading, since international prices are falling and mining investment faces grater uncertainty. Furthermore, low investment in R&D and poor-quality education in Peru limit local

suppliers' internal capabilities, making it more difficult for them to achieve significant innovations. Nevertheless, this new context also offers some opportunities for local suppliers. Stricter environmental and social regulations require innovative solutions, while the need for higher productivity in more complex geographical settings is increasing. Some of the local suppliers that we have studied are already taking advantage of these changes, but we believe that there is potential for further technological upgrading by incumbent or emerging firms in such a setting.

6. References

Aragon, F., & Rud, J. P. (2013). *Natural resources and local commmunities: Evidence from a peruvian gold mine.* American Economic Journal: Economic Policy.

Argyres, N., & Silverman, B. (2004). R&D, Organization Structure, and the Development of Corporate Technological Knowledge. *Strategic Management Journal, 25*, 929-958.

Atienza, M., Aroca, P., Stimson, R., & Stough, R. (2016). Are vertical linkages promoting the creation of a mining cluster in Chile? An analysis of the SMEs' practices along the supply chain. *Environment and Planning C: Government and Policy*, *34*, 171–187.

Bamber, P., Fernandez-Stark, K., & Gereffi, G. (2016). *Peru in the Mining Equipment Global Value Chain: Opportunities for Upgrading.* Duke CGGC.

Bebbington, A., & Bury, J. (2009). *Institutional challenges for mining and sustainability in Peru.* B. L. Turner II, Arizona State University, Tempe, AZ.

Becker, W., & Peters, J. (2000). University knowledge and innovation activities. *P., Nooteboom, B. (Eds.) Technology and Knowledge: From the Firm to Innovation Systems*, 80–117.

Bercovitz, J. E., & Feldman, M. P. (2007). Fishing Upstream: Firm Innovation Strategy and University Research Alliances. *Research Policy, 36*(7), 930-948.

Bitran, E. (2014). *Minería Virtuosa. Desafíos de productividad y sustentabilidad como una oportunidad de desarrollo tecnológico para Chile.* CORFO. Berlin: Foro Chileno-Alemán de Minería y Recursos Naturales Minerales.

Bury, J. (2005). Mining mountains: neoliberalism, land tenure, livelihoods, and the new Peruvian mining industry in Cajamarca. *Environment and Planning, 37*, 221-239.

Cooper, A. C., Willard, G. E., & Woo, C. Y. (1986). Strategies of high-performing new and small firms: A re-examination of the Niche concept. *Journal of Business Venturing, 1*(3), 247-260.

Corcuera, J. (2015). *Aplicación de la Lixiviación a presión a minerales arsenopiríticos que contienen oro para estabilizar el arsénico.* Lima: TECSUP.

Cousins, P. D., Handfield, R. B., Lawson, B., & Petersen, K. J. (2006). Creating supply chain relational capital: The impact of formal and informal socialization processes. *Journal of Operations Management, 24*(6), 851-863.

Edquist, C. (2000). *Systems of innovation growth, competitivenes and employment.* London : E. Elgar.

EY. (2014). *Peru´s mining & metals investment guide 2014/2015.* Lima: EY and Ministry of Foregin Affairs Peru.

GBR. (2014, August). Peru´s mining industry: Gearing up for new wave of investment. 103-104.

Giuliani, E., Pietrobelli, C., & Rabellotti, R. (2005). Upgrading in Global Value Chains: Lessons from Latin American Clusters. *World Development, 33*(4), 549-573.

Glave, M., & Kuramoto, J. (2007). La minería peruana: lo que sabemos y lo que aún nos falta por saber. In *Investigación, políticas y desarrollo en el Perú* (pp. 135-181). Lima: GRADE.

GWI. (2011). *Water for Mining: Opportunities in scarcity and environmental regulation.* Global Water Intelligence.

Hall, B., & Van Reenen, J. (2000). How effective are fiscal incentives for R&D? A review of the evidence. *Research Policy, 29*, 449-469.

Harison, E., & Koski, H. (2010). Applying open innovation in business stategies: Evidence from Finnish firms. *Research Policy, 39*, 351-359.

Humphrey, J., & Schmitz, H. (2000). *Governance and upgrading: linking industrial cluster and global value chain research.* Brighton: Institute of Development Studies.

Humphrey, J., & Schmitz, H. (2002). How Does Insertion in Global Value Chains Affect Upgrading in Industrial Clusters? *Regional Studies, 36*(9), 1017-1027.

Kuramoto, J. (2000). *Las aglomeraciones productivas alrededor de la minería: el caso de la Minera Yanacocha S.A.* Santiago de Chile: CEPAL - Serie Desarrollo productivo.

Kuramoto, J. (2001). Las aglomeraciones mineras en el Perú. In R. M. Buitelaar, *Aglomeraciones mineras y desarrollo local en América Latina* (pp. 139-158). México D.F.: CEPAL.

Lala, A., Moyo, M., Rehbach, S., & Sellschop, R. (2015). *Productivity in mining operations: Reversing the downward trend.* McKinsey&Company. Retrieved from http://www.mckinsey.com/insights

Lydall, M. (2009). Backward linkage development in the South African PGM industry: A case study. *Resources Policy, 34*(3), 112-120.

Marin, A., & Stubrin, L. (2015). *Innovation in natural resources: New opportunities and new challenges. The case of the Argentinian seed industry.*

Marin, A., Navas-Alemán, L., & Perez, C. (2015). *Natural resource industries as a plataform for the development of knowledge intensive industries.* Tijdschrift voor Economische en Sociale Geografie Vol. 106, No. 2, pp. 154–168.

McKinsey&Company. (2013). *An assessment of the competitiveness and health of Peru´s mining industry.*

Ministerio de Energía y Minas. (2015). *Anuario minero 2014.* Lima: Ministerio de Energía y Minas. Retrieved from www.minem.gob.pe

Ministerio de Energía y Minas. (2016). *Anuario Minero 2015.* Lima. Retrieved from www.minem.gob.pe

Morris, M., Kaplinsky, R., & Kaplan, D. (2011). *Commodities and Linkages: Industrialisation in Sub Saharan Africa.* The Open University.

Morrison, A., Pietrobelli, C., & Rabellotti, R. (2008). Global Value Chains and Technological Capabilities: A Framework to Study Learning and Innovation in Developing Countries. *Oxford Development Studies, 36*(1), 39-58.

OECD & Eurostat. (2005). *Oslo Manual: Guidelines for collecting and interpreting innovation data* (3rd ed.). Paris: OECD Publishing.

OECD. (2011). *OECD Reviews of Innovation Policy: Peru.* OECD Publishing.

OECD. (2015). *Gross domestic spending on R&D (indicator).* Retrieved from (Accessed on 4 December 2015): doi: 10.1787/d8b068b4

Palomino, M., Pérez, P., Castillo, P., & Ortiz, P. (2015). *El costo económico de la no ejecución de los proyectos mineros por conflictos sociales y/o trabas burocráticas.* Lima: Instituto Peruano de Economía.

Pietrobelli, C., & Rabellotti, R. (2011). Global Value Chains Meet Innovation Systems: Are There Learning Opportunities for Developing Countries? *World Development, 39*(7), 1261-1269.

Schilling, M., & Phelps, C. (2007). *Interfirm collaboration networks: the impact of large-scale network structure on firm innovation.*

Teece, D. (1992, June). Competition, cooperation, and innovation: Organizational arrangements for regimes of rapid technological progress. *Journal of Economic Behavior & Organization, 18*(1), 1-25.

Tidd, J. (2001). *Innovation management in context: environment, organization and performance.* Brighton, UK: IJMR.

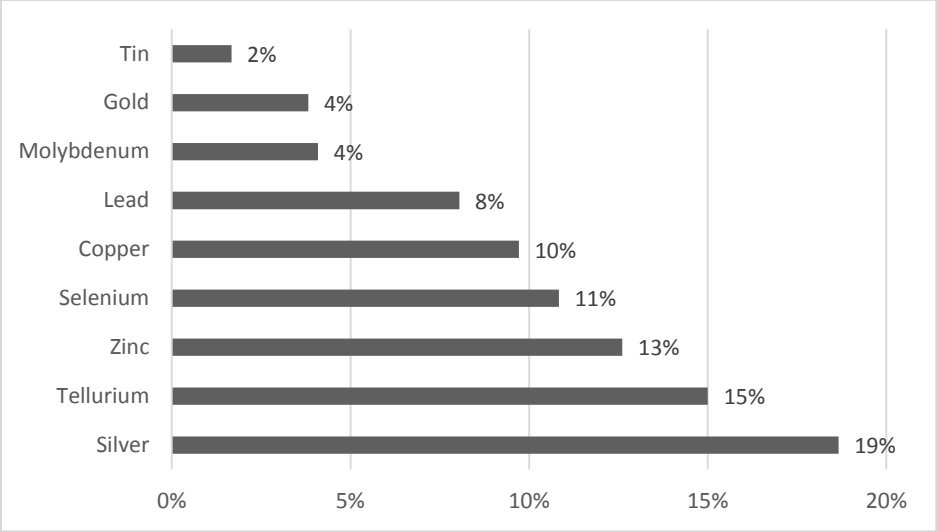
Triscritti, F. (2013). Mining, development and corporate–community conflicts in Peru. *Community Development Journal, 48*(3), 427-450.

Urzúa, O. (2007). *Emergence and Development of Knowledge-intensive Mining Services (KIMS).* UNCTAD: Brighton: University of Sussex, mimeo. .

USGS. (2015). *Mineral commodity summmaries 2015.* U.S. Department of the Interior & U.S. Geolgical Survey.

7. Appendix

Annex 1: Peru´s natural resources reserves 2015 (% of world reserves)



Source: (USGS, 2015)

Annex 2: Mining production and exports (2005-2015)

Year	Mining GDP US$ MM	Total GDP US$ MM	Mining GDP / GDP	Mining Exports US$ MM	Total Exports US$ MM	Mining Exports / Total Exports
2005	13,102	83,022	**15.78%**	2,967	5,263	**56.37%**
2006	13,473	90,091	**14.96%**	4,506	7,287	**61.83%**
2007	14,662	102,138	**14.36%**	5,572	8,976	**62.07%**
2008	16,928	119,086	**14.21%**	6,178	10,587	**58.35%**
2009	16,637	117,138	**14.20%**	5,443	8,994	**60.51%**
2010	17,920	135,117	**13.26%**	7,676	12,651	**60.67%**
2011	18,561	148,019	**12.54%**	10,009	16,864	**59.35%**
2012	19,876	163,361	**12.17%**	10,404	17,959	**57.93%**
2013	20,383	169,081	**12.06%**	8,811	15,874	**55.50%**
2014	19,209	164,579	**11.67%**	7,234	13,920	**51.97%**
2015	18,688	151,294	**12.35%**	5,905	10,732	**55.02%**

Source: MEM and BCRP (2016)

Annex 3: Mining Companies in the sample

Mining Company	Products	Region	% of mining GDP*	Income* (US$ MM)	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)**
Southern 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$ 5,000 -6,000 MM CAPEX)	**Very large**	**100% (foreign)**	**Pre extraction (short time)**
Milpo	Zinc, Lead, Copper	Junín	6	104	**Medium sized**	**60% (foreign)**	**1949 (long time)**

* Data refers to 2014 levels

Source: MINEM (2014)

Annex 4: Industry experts interviewed

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