PERUVIAN ECONOMIC ASSOCIATION

# Green Innovation in Natural Resource Industries: The case of Local Suppliers in the Peruvian Mining Industry

Ana Sofía Aron

Oswaldo Molina

Working Paper No. 145, May 2019

# Green Innovation in Natural Resource Industries: The case of Local Suppliers in the Peruvian Mining Industry[1]


**Ana Sofía Aron** **Oswaldo Molina**

**Universidad del Pacifico**



**A B S T R A C T**

Concerns about climate change are gaining more notoriety and exerting a pressure for more stringent environmental regulations in the mining sector. Thus, demand for sustainable methods of production has increased and created opportunities for Peruvian mining suppliers that offer green innovations (GI). In this paper, we follow the technological trajectories of a set of local firms who successfully undertook green innovations, in order to analyze the main factors which determined their development and integration into the mining value chain. Our study reveals that due to the novelty of the demand for GI, most local suppliers engaged in these activities are emergent ones. Moreover, they tend to follow different strategies which facilitate their entrance to the market: they establish relationships with strategic partners, specialize in niches that can hardly be covered by foreign multinational companies, and adapt their innovations to client's requirements. However, innovations by emergent suppliers remain limited due to multinational mining companies favoring incumbent suppliers with a positive trajectory in the market, financial constraints, and lack of communication and coordination channels within the sector. Thus, successful emergent suppliers depend highly on governmental financing, and linkages with research centers at universities.



***Keywords:*** *Green innovations; sustainable innovations; Natural Resource Industries; suppliers*



[1] Corresponding author: Oswaldo Molina, o.molinac@up.edu.pe. The authors gratefully acknowledge funding support by the Center for Mining and Sustainability Studies (CEMS) at Universidad del Pacifico. Jorge Aguayo, Gonzalo Torres, and Vanessa Trujillo have provided excellent assistance throughout the development of this research. All errors are ours.

## 1. Introduction

Climate change, environmental concerns, and resource limitations have become increasingly important in determining the conditions under which productive activities take place. Environmental regulations related to natural resource intensive activities have become more stringent over time. This regulation along with increasing societal pressure about activities that impact the local and global environment have created an important demand for sustainable methods of production. Against this background, suppliers of mining activities must adapt to the demand to be "greener." This demand is a window of opportunity for local suppliers who are willing to commit to the development of green innovation (GI) in products and processes that reduce energy and water consumption, environmental risk, pollution, and other negative impacts of productive activities.

Because mining is an important activity in many developing countries, an understanding of how local firms that offer GI can integrate into the more knowledge-intensive stages of global value chains is a valuable pursuit. The literature on global value chains argues that the internal and external factors that affect the innovation patterns in these chains impact the integration of the productive processes of local suppliers into them. Specifically, the literature has identified that along with these patterns, the introduction of local suppliers that offer GI to global value chains are determined by their production costs (Hottenrott & Peters, 2012) and their technological and knowledge capabilities (Walker, 2008) but also by market factors (Arundel & Kemp, 2009), the institutional and regulatory frameworks (Robert Mohr, 2008) and social pressures.

This study examines the empirical determinants of the GI in the natural resource industries (NRIs) of local suppliers in a developing economy. Specifically, we focus on the case of the Peruvian mining industry. Peru is a middle-income country with immense geological potential that has a predominant mining sector.[2] The study uses a sample of suppliers that have created GI for the mining industry. Specifically, we conduct semi-structured interviews with the selected firms, mining firms, and sector experts. The interviews are structured in order to identify the main local mining suppliers that have been able to create GI. We then use a demand-supply analysis to discover the main system and market structures that hinder or foster the development of these suppliers within the Peruvian mining sector.

Our fieldwork discloses that the adoption and creation of GI in the Peruvian mining sector remains limited. However, the increase in environmental regulation, the societal pressure to adopt greener practices in production, and the increase in the cost associated to environmental damage are generating new opportunities for local suppliers to introduce GI to the sector. Thus, we find that a small group of new firms have taken advantage of this context to introduce their innovations to the mining sector. Further, we find that these innovations have been sporadic and heterogeneous in their form and execution. The firms have followed different strategies to develop their innovations and to integrate them into the value chain. For example, they have established key relationships with actors related to mining companies in order to facilitate their entrance to the mining sector, they have adapted their innovations to clients' requirements and they have specialized in niches that can hardly be covered by foreign multinational companies

The role of the communities' acceptance is crucial for the sustainability of the mining industry: firms must acquire a social license for operating or are subject to barriers to their activities imposed by the communities (Nelsen, 2006). In this regard, social

[2] Currently, it ranks second worldwide in producing copper, silver, and zinc and ranks as the leading producer of gold, lead, and zinc in Latin America. Thus, Peru houses several of the world's most important mining projects (Ministerio de Energía y Minas, 2018a).

disruption may become linked with the lack of green innovation: if firms cross ecological thresholds, degradation in the social system can and often does follow (Olsson et al., 2017). Thus, conflicts between communities and mining firms can halt extractive operations thereby leading to a stop in green innovation.

Although the Peruvian mining industry has experienced huge transformations in the last few decades to increasingly become more innovative and specialized (Bartos, 2007), the sustainability of this industry and the efficient use of its resources remain crucial for the region. Therefore, understanding the role that local suppliers can play to foster more sustainable and environmentally friendly mining is important. This study contributes to three different strands of the literature on mining. First, it leads to the understanding of how local firms are successfully exploiting relationships with different actors that operate in the mining industry. Second, it adds new evidence on how the mining sector can foster the development and diffusion of local suppliers that offer GI through institutional mechanisms, policies, and other relevant mechanisms. Third, it contributes to the identification of the main market and system failures that hinder the development of local suppliers of GI in the mining sector.

The rest of the paper is organized as follows: Section 2 provides some empirical and theoretical backgrounds about GI drivers and challenges. Section 3 presents the background on Peruvian mining and the opportunities for development of GI by local suppliers. Section 4 explains the method used to gather data for the present investigation and the structure behind it. Section 5 provides the evidence collected through our fieldwork in order to explore how the dynamic of the mining sector and the context surrounding Peruvian mining suppliers influences the development of GI. Finally, Section 6 concludes.

## 2. Background: Green innovation and local suppliers.

The literature defines GI as the production, assimilation, or exploitation of a product, production process, service, management, or business method that is novel to an organization—either to its developer or adopter—that leads to a reduction in environmental risk, pollution, or other negative impacts from the use of resources (Kemp & Pearson, 2007). In order to be considered GI, an innovation does not need to be intentionally aimed at the mitigation of a negative environmental impact (Carrillo-Hermosilla et al., 2010).[3]

A first approach for understanding GI by local suppliers relies on the analysis of the factors that determine their potential to engage in knowledge-intensive activities. The literature identifies these factors as belonging to two groups: first, endogenous or internal factors that are preconditions and features found within firms that facilitate their involvement in a technological change or that allow them to achieve a technological upgrade (Morrison et al., 2008; Del Río, 2009). Second, the exogenous or external factors that derive from incentives provided by several actors that exert pressures to which firms respond (Del Río, 2009).

### 2.1 Endogenous factors

The firms' abilities to innovate cannot be treated as an exogenous consequence of conditions external to them, but rather as an endogenous process that depends on their preexisting capabilities (Pietrobelli & Rabellotti, 2011). Based on this stream of literature, endogenous factors are the firms' capabilities to innovate; such as the knowledge, competencies, resources, and skills of the workforce.

[3] This study use the following definition of green innovation: some of our case studies were not originally planned to reduce environmental risk. Rather they intended to reduce the production costs of mining firms.

The knowledge and appropriate skills of the workforce of local suppliers are defining factors in a firm's capability to innovate. Hence, if firms intend to innovate, they must focus on the skills of their human capital. Green innovations are not an exception to this rule. Walker et al. (2008), Marin et al. (2015), and Kumar et al. (2017) all regard the lack of expertise of a workforce on sustainable production methods and environmental knowledge as one of the main barriers to the promotion and adoption of sustainable consumption and production initiatives.

Equally important, financial assets are a major driver for innovation since firms with financial resources find investing in activities with uncertain outcomes easier to do. However, regarding GI, the literature identifies access to finance as a common barrier to this particular type of innovation since it tends to carry higher technical and commercial risk (Aghion, Veugelers, & Serre, 2009).

Furthermore, the organizational structure also influences the level of innovation by a firm, which can deeply affect the nature and outcomes of their innovation efforts (Molina, 2018). In this regard, Argyes and Silverman (2004) consider that higher transaction costs between the different areas of firms increase the specificity of their innovations and reduce their technological complexity and impact.

### 2.2 Exogenous Factors

The exogenous factors that influence a firm's incentives to innovate and engage in knowledge intensive activities are embedded in organizational, economic, institutional, political, and social systems (OECD, 2018). The literature has identified five main factors that influence the innovation by local suppliers: markets, knowledge flows, networks, public policy, and society.

One main determinant of technological upgrading in developing countries is the structure of market relationships, specifically the nature of the relationships between actors in the global value chain (Humphrey & Schmitz, 2000). The general picture in developing countries described by the literature is one in which large multinational firms tend to define the rules of operation in the market by generating highly asymmetrical relationships along the value chain. These relationships represent the differences in capabilities between local and multinational firms. They can become an impediment to the involvement of local suppliers in the more promising sections of the value chain (Marin & Stubrin, 2015).

Institutional factors are also relevant in promoting or hindering GI by local suppliers. First, the regulatory framework under which mining firms operate can generate a demand for local suppliers to offer sustainable solutions that comply with the environmental regulation. There is a consensus in the literature on how environmental regulation is likely to increase and promote GI in the future through enforcement mechanisms and the use of policies based on incentives (Lee & Alm, 2004; Jaffe, Newell & Stavins, 2005; Mohr and Shrawantee, 2008). In this regard, if organizations want to ensure their legitimacy, survival and access to resources, they have to conform and consequently comply with regulations and rules (Lin, 2014; Lin and Sheu, 2012; Zhu et al., 2010, 2012; Al-Twajiry Abdulrahman et al., 2003). Second, public policy also plays an important role in the development of local suppliers by offering environmental subsides, since financial constraints tend to be a common barrier among green innovators (De Marchi, 2012) (Belin, Horbach, & Oltra, 2011) .

The societal aspect has gained importance in the last few years since it influences the public's acceptance of firms' operations. Large societal changes can drive system and business innovations, for instance when firms seek public acceptance through green innovations (OECD, 2018).

## 3. Peruvian Mining Context and Opportunities for Green Innovation

Peru is one of the countries in Latin America and the world that enjoys a long mining tradition. In terms of aggregate production, Peru is one of the main countries producing metals in the world, since 2016 Peru has maintained itself as the second largest producer of silver, copper, and zinc in the world. Peru represents 17%, 12%, and 11% respectively of the world production of those metals (See Annex1).

Mining in Peru is a vital component of economic growth, the importance of the mining sector at the local level becomes obvious when one sees that its contribution to domestic production has been 10% between 2016 and 2017 (See Annex 2). Likewise, mining exports represented an average of 59.65% of the total Peruvian exports during the same period (See Annex 3). The mining sector also has made an important contribution to jobs creation. For the year 2017, it generated 189,961 jobs that represented 3.8% of the jobs in the total formal sector. Additionally, indirect employment generated by the industry is estimated to be around 6.25 jobs per every direct job: 1 indirect employment, 3.25 consumer jobs, and 2 investment jobs (Dirección General de Minería, 2018).

At the local level, mining is also an important sector for the development of regional and local government. During 2017 total transfers to regional and local governments for the concept of mining canon transfer amounted to 6.32 billion dollars, this amount is significant income for the subnational governments. However, the lack of a strong institutional framework, experience, and of trained personnel to handle these large sums of money can be seen in the management carried out by the corresponding regional authorities on the subject (Bebbington & Buryb, 2009).

The accumulated investment by mining firms in Peruvian territory amounts to US$ 3,928 million in 2017, this amount represents an increase of 17.83% with respect to 2016 (Ministerio de Energía y Minas, 2018b). However, this amount is far from equaling the levels at the beginning of this decade.[4]

The main actors of the mining sector in Peru are the large and medium sized firms that handle most of the mining production: 99.9% of copper production, 79.5% of gold production, 99.3% of zinc production, 96,4% of silver production, and 98% of lead production (See Annex 4). Even more, production is also concentrated in a small number of mining firms, for example, in 2017 the five main mining firms handled 78%, 43%, and 62% of the national production of copper, gold, and zinc respectively. The high concentration of production in a small number of mining firms also explains why only 10 mining firms accumulated 63% of the total investment in 2017 (See Annex 5).

### 3.1. Regulatory Framework

During the last decade Peru has embarked on a process of regulation and institutional changes aimed at achieving adequate protection of environmental interests. This process has led to a significant increase in the number of environmental regulations (EY, 2014). Peru has gone from not having any kind of environmental regulation in the 1990s to turning down 20% of the proposed mining projects each year due to the lack of compliance with social and environmental obligations (Molina et.al, 2016).

The most important change to affect the environmental regulatory framework of the mining sector during the last decade has been the approval of the regulation of environmental liabilities of the mining activity in 2005.[5] This framework established a

[4] By 2013, total investment in Peruvian mining reached its maximum level of US$ 8,864 million.
[5] On December 9, 2005, the Constitutional Presidency of Peru signed the Supreme Decree Nº 059-2005-EM that approved the Regulation of Environmental Liabilities of Mining Activity.

precedent to delimit the procedures so that the firms responsible for environmental liabilities would assume the costs of environmental remediation. These costs include the design and implementation of different measures such as dismantling, demolition, physical, chemical, and hydrological stabilizations; treatment of acid mine drainage and leaching of metals; recovery or rehabilitation of land; and revegetation and rehabilitation of aquatic habitats (Supreme Decree Nº 059-2005-EM, 2005).

Further, the establishment of the Ministry of Environment in 2008 was an important step in order to promote and ensure a sustainable and ethical use of natural resources. This idea was reinforced by the creation of the National Service of Environmental Certification for Sustainable Investments (SENACE) in 2012 with the purpose of overseeing, among others, the mining sector by evaluating and authorizing the environmental impact assessment study (EIA) that ensures the sustainable use and conservation of natural resources as well as the environmental quality of mining projects by guaranteeing key aspects, such as a mine closure plan for large-scale investment projects. Furthermore, in recent years, Peru has enacted crucial legislation such as the new Environmental Protection Regulation in Mining and Metallurgical Activities in 2014, which states that operations in the mining sector must have identification, prevention, supervision, and correction systems of possible negative environmental impacts derived from their activities.

Nevertheless, the literature emphasizes that regulation only becomes effective when state actors and social forces put their power behind them. If there is an enforcement gap, then actors struggle to translate legal acts into new practices (Dargent, Orihuela, Paredes, & Ulfe, 2018). For example, previous studies identify that at a regional level, EIA are ineffective when they have a limited scope, inadequate administrative support, and no effective control mechanisms and public participation (Toto, Requena, &

Zamorano, 2010). Specifically, it has been found in some cases through studies of water, soil, and air quality in mining areas in Peru that contamination levels are higher than those allowed by regulations. (OECD/UN ECLAC, 2018).

Although environmental regulation in the Peruvian mining sector is similar to other mining countries which are characterized with a high regulation[6], there is the perception that regulation fails to ensure that firms choose the best environmental alternative to reduce the impact of their activities, but instead the minimum required to comply with regulation. This failure leads us to the hypothesis that environmental policy is still not a main driver of environmental innovation in the Peruvian mining sector.

### 3.2. Social pressures and environmental concerns

Peru is an important case of resource conflict, as it experiences alarming levels of protest surrounding the mining sector. Throughout the years, the government has made many attempts to resolve the conflicts, but these have generally been predominantly short-term solutions. Maybe the most important institutional change regarding this aspect was the approval of the Prior Consultation Law in 2011 that requires prior consultation with indigenous communities before any infrastructure or projects, especially mining and energy projects, are developed in their areas. [7] In this context, achieving a social license to operate is one of the most important challenges that the mining industry faces in Peru (Ernst & Young, 2017).

In the Peruvian mining sector, there is still a lot of work to do in order to align the interest of communities and mining firms. According to the Office of the Ombudsman,

---

[6] Baker McKenzie (2018) assessed local mining laws and regulations in over 30 important mining countries and established that for Peru the level of regulation of environmental protection is high.

[7] Law N° 29785-law of the right to prior consultation with indigenous or native peoples. This law was recognized by Convention 169 of the International Labor Organization (ILO) created the procedure of the right to prior consultation with indigenous or native peoples regarding legislative or administrative measures that directly affect them.

there were 199 active social conflicts in 2018 of which 83 are directly related to the mining sector (See Table 1) (Office of the Ombudsman, 2018).

Social conflicts happen to be the channel through which environmental and social risks affect business costs and decision-making. In the Peruvian case, social conflicts have led to the stoppage of three mining projects, which their projected investment would have been approximately US$ 2,800 million (see Annex 6) and would have been a substantial contribution in the aggregate mining production. The Ministry of Energy and Mines has estimated that the projected annual production of the three mining projects would be around 374,000 metric tons of copper, 680,000 ounces of gold, and 3,000 metric tons of molybdenum (Ministerio de Enegría y Minas, 2018a).

**Table 1**: Peru: social conflicts by type and by main competent authority, October 2018- (number of cases)

| | TOTAL | % | National Government | Regional Government | Local Government | Others |
|---|---|---|---|---|---|---|
| **TOTAL** | **199** | **100.0%** | **121** | **37** | **20** | **21** |
| Socio environmental | **123** | **61.8%** | 98 | 20 | 4 | 1 |
| Local Government affairs | **19** | **9.5%** | 0 | 1 | 15 | 3 |
| National Government affairs | **19** | **9.5%** | 19 | 0 | 0 | 0 |
| Communal | **9** | **4.5%** | 0 | 7 | 1 | 1 |
| Electoral | **8** | **4.0%** | 0 | 0 | 0 | 8 |
| Other Affairs | **7** | **3.5%** | 0 | 1 | 0 | 6 |
| Regional Government affairs | **7** | **3.5%** | 0 | 7 | 0 | 0 |
| Labor | **4** | **2.0%** | 2 | 1 | 0 | 1 |
| Territorial Demarcation | **3** | **1.5%** | 2 | 0 | 0 | 1 |
| Illegal Coca Cultivation | **0** | **0.0%** | 0 | 0 | 0 | 0 |

Source: (Office of the Ombudsman, 2018)

The environmental aspects of a mining project can be determined in the first stage of the development in which it must carry out the prior consultation with the communities. During this consultation, mining firms must demonstrate that the operations of the mine will have a reduced environmental impact or that the environmental impact will be remediated, so having a clear environmental strategy for the impacts generated by the mining activity may influence the decision of a community to accept the mining project's operations. For example, nowadays in Peru water has become a high point of discussion between communities and mining firms. The main demands of the communities revolve around how water is collected, recycled, and then how the firm gets rid of it.[8] In this context mining firms must have a clear strategy in terms of their actions in order to mitigate the possible negative effects of their operations.

Experts consider that a key driver in the adoption of GIs in mining firms is the role they play in contributing to overcoming social conflicts that are associated with the environment since the more socially and environmentally responsible a firm is perceived to be, the higher are the chances that the firm will not be associated with or involved in social conflicts. Although experts do not consider GI as a solution for possible social conflicts in developing countries like Peru, it is necessary to adopt technologies that reduce the environmental impact of mining activities. Thus, due to the geographical proximity of communities to mines, GI can affect their health or productive activities.

### 3.3. New market niches

The recent changes in regulation have generated market pressure on mining firms to adopt GI. Regarding regulation compliance, GI can be an option for mining firms in order to reduce the costs associated with the environmental sustainability of the project and to reduce the costs of remediation and mitigation as well as compensation for the environmental damage. On the other hand, the social pressures to adopt GI can

[8] Large mining projects such as Conga (in the Cajamarca region) have been paralyzed due to the community's conflict with the mining company for the use of water in the development of the mining project.

contribute to the reduction in the costs that are associated with the risk of social conflicts that could paralyze mining projects.

In this context, new suppliers are generally in a better position to take advantage of the pull factors in this new market. This is due to incumbent businesses facing huge sunken costs and commitments to existing technologies that make things more difficult for them to respond quickly enough to changes (Rothaermel & Hill, 2003). Incumbent firms have important investment and knowledge that are associated to technologies and processes rooted in a different paradigm when energy and resources were abundant and cheap. On the other hand, new entrants can start from scratch, so they have flexibility to design and deliver solutions that already embody these imperatives and therefore can more easily face the changes in regulations.

There is a tension of course in which opportunities for local suppliers may not materialize. However, changes in the market have created space for new entrants to develop new cycles in many of the services required to mine in an efficient and environmentally sustainable way. Local suppliers can be in a privileged position to occupy this new space.

## 4. Methodology

We used a case study approach. Data was collected through semi-structured interviews with three groups of participants: mining suppliers of GI, mining firms, and industry experts. In Annex 7we provide details of all the participants that we interviewed for this study. Interviews were conducted on the basis of a questionnaire that collected both qualitative and quantitative information. The study also made large use of secondary data that included previous investigations and firms' reports and publications. In this regard, an important limitation to the study was the lack of previous research about GI in the Peruvian mining sector.

In order to identify the local suppliers that have succeeded in introducing GI to the mining sector, we started our fieldwork with interviews of representatives from mining firms and key experts on the sector. In order to capture the sample of suppliers with the most innovative products and services to be interviewed, we sought a representative perspective on the range of mining firms that operate in Peru. (See Annex 8 for a detailed characterization of the mining firms in our sample).

The information gathered during these interviews enabled us to select our final sample of GI suppliers for the second round of interviews. Specifically, we chose to focus on five suppliers that captured the range of local mining suppliers that have been able to achieve green technological upgrading in Peru.

It is important to highlight that although at the academic level there is no consensus on the ways to measure the impact of an innovation, for the purpose of this study we use as proxies for the degree of innovation, the novelty rate of the innovation, the number of patents acquired, and the participation of these firms in local and international markets. We conducted extensive interviews with at least one representative from each supplier to identify the factors that allowed them to achieve technological innovation. Additionally, we applied a detailed questionnaire to gather information about the firm's general characteristics related to the capacity and trajectory for innovation.

Table 2 summarizes the main characteristics of the firms in our sample of GI local suppliers in Peru.

**Table 2:** Suppliers

| Firm | Year of foundation | Problem addressed | Description of innovation | Degree of novelty |
|---|---|---|---|---|
| Qaira | 2015 | Air pollution | Adaptive drones that monitor and process information on environmental pollution. | New for the world |
| Exsa | 1956 | Air pollution | Quantex explosive technology that reduces the use of blasting fuel by up to 100%. | New for the world |
| Green Mining Nueva Minería | 2015 | Waste management | Green Mining process that manages to obtain metallic compounds by recycling the necessary inputs for the recovery of metals that gives a greater added value to the exportable mineral. | New for the world |
| Green Metallurgy | 2013 | Waste management | Technological kit that contributes to the process of decontamination of mining tailings to use in the manufacture of ecotechnological bricks. | New for the world |
| Dinamo | 2014 | Energy consumption | Mobile towers that use 100% solar energy to illuminate areas of difficult access for electrical wiring. | New for the market |

As Table 2 shows, our sample addresses different environmental challenges with their innovations, nevertheless we do not intend for it to be representative of the Peruvian mining sector. The innovations address different environmental externalities such as air pollution, energy consumption, and waste management. Also, these firms vary in size and in the number of years in the market. These variations provide the first insight into the local suppliers; their GIs are sporadic and heterogeneous in their form and execution.

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

- **QAIRA** is a Peruvian startup funded in 2015. It developed drones that are equipped with sensors to monitor contamination, such as toxic gases and dust. The drones process the information collected with their algorithms to create maps of contamination distribution. The drone is designed to operate in harsh geographical and climatological environments like mine sites. Currently, the startup works with air measurement projects for Antamina[9] and is conducting pilot tests for surveying and air measurement services with the mining company Yanacocha[10] and Gold Fields[11] both of which are among the 10 most important mining firms operating in Peru. The start-up is supported by StartupPeru and Seedstrarsworld, which are respectively national and international venture capital groups.

- **EXSA** is a Peruvian firm that started operations in 1956. It offers rock fragmentation and integrated blasting services using explosives and electrode welding. The firm developed Quantex that eliminates the brown smoke that occurs after blasting, which reduces the emissions of greenhouse gases (GHG) by 18%. Furthermore, this technology generates savings of up to 20% on the total cost of rock fragmentation for mining and open pit construction.
- **Dinamo Technologies** is a startup launched in 2014 that is dedicated to the development of projects and electrical maintenance for civil, maritime, and construction operations, By 2016, it had developed a mobile solar energy tower that could adjust its solar panel to any latitude in the world that made it adjustable to any geographical situation in the mining industry. This GI has since been improved and its use has escalated with the financial aid of the Peruvian public funding organization, CONCYTEC.
- **Green Metallurgy Technologies** is a startup that was launched in 2013 to develop a technology that allows them to decontaminate the mining tailings of gold, copper, silver, and other minerals. Using this technology, the firm offers the service of

[9] Minera Antamina S.A. is a polymetallic mining complex that contains one of the most important copper deposits in the world. The mine is located in the district of San Marcos that is in the Ancash Region of Peru. In the year 2017, it produced 400,000 metric tons of copper.
[10] The Yanacocha deposit is considered the largest gold mine in South America and the second largest in the world. It is located in Cajamarca, Peru. Yanacocha registered a production of 534,691 ounces of gold in 2017.
[11] Gold Fields is a South African transnational mining company that has a mining operation in Cajamarca, Peru. The mining company in question estimates an annual production of approximately 2 million ounces of gold.

processing mining tailing's compounds into bricks, tiles, sardines, and retaining walls. In the specific case of bricks, Green Metallurgy Technologies has managed to produce a low-cost and highly resistant brick in comparison to the average brick in the market.

- **Green Mining Nueva Minería** is a startup launched in 2015 that is financed by Innovate Peru's program StartupPeru in 2016. It has developed a green mining process to recover metals in a sustainable way, recycling the inputs needed for the procedure from the slag and hence generating and extracting value-added products for export while incurring minimal investment and environmental costs.

## 5. Findings and discussion

In this section, we report the evidence collected through our interviews in order to explore how the dynamic of the mining sector and the context surrounding Peruvian mining suppliers influences the development of GI. We divide our analysis as follows: First, we report on the governance patterns and inter-firm linkages that characterize the Peruvian mining sector in order to identify if they favor or limit the emergence and consolidation of local suppliers. Second, we study the firm's technological capabilities and innovation systems to understand the learning processes and knowledge transmission mechanisms among local suppliers. And third, we analyze the institutional and regulatory factors surrounding GI in local suppliers.

Although we divide our analysis into three separate components, they are not isolated determinants but rather are part of an endogenous process in which outcomes of local suppliers are constantly being shaped through their interactions.

### 5.1. Innovation capabilities

#### 5.1.1. Human capital resources

As discussed in subsection 2.1, the skills and abilities of a firm's workforce are a critical component in its capability to innovate. The interviews we conducted showed, in concordance with the literature, that given the highly specialized nature of GI in the mining sector, the common denominator in firms' decision to innovate was their academic background and the previous experience of either the founders or the employees in the mining sector.

Regarding the academic background, we find that most of the workforce of the five suppliers considered in this study has a strong academic background in the area of their innovations. For example, Qaira was co-founded by engineers with specific training in mechatronics, aeronautics, and electronics, respectively. In fact, their innovation originated as a thesis for a bachelor's degree. Even today, four years after Qaira's foundation, the firm still maintains its knowledge intensive origins: two out of three of their employees—aside from the co-founders—are mechatronics engineers. In the case of Green Mining Nueva Mineria, its founder is a metallurgical engineer and the five other employees of the firm hold PhDs in areas such as chemistry and environmental sciences; and master's in engineering processes, mining engineering, and environmental sciences. Their expertise has led them to a process to extract common metals (e.g., copper, zinc, molybdenum, lead, etc.) and precious metals (silver and gold) from sulfide minerals. Similarly, Green Metallurgy's co-founders hold a master's degree in metallurgic extractions and a bachelor's degree in metallurgical engineering. Their training in those subjects allowed them to invent several new technologies aimed at alleviating environmental liabilities by transforming mining tailings into inputs used for manufacturing ecological bricks. Lastly, Dinamo's three co-founders all have a bachelor's in engineering.

Just as important as the academic background of the workforce of the local suppliers, we find that previous experience in the mining sector was also a common denominator that determined their ability to conceive their innovations. For example, Dinamo's co-founders all worked in mining or petroleum firms when they came up with the idea for the solar towers. Specifically, they realized their employers had to rent costly illumination towers—most of them fueled with diesel—for exploration activities. While there were solar towers used by mining firms in other countries, they could not be adapted to the climatic conditions in Peru.[12] Thus, they came up with the idea of designing solar towers that could satisfy this unmet need in the local market. Along the same line, Exsa's years of experience in the mining sector helped it identify that local mining firms could benefit from a more efficient technology for rock fragmentation than the one available at the moment and that foreign alternatives were not available due to strict international regulations on the trade of explosives. This regulation led it to conceive Quantex as a direct solution to both issues: it generated savings of up to 20% of the total cost of rock fragmentation for mining and open pit constructions and was a pioneer in the local market.

Another case of inspiration that stemmed from experience in the mining sector was that of Green Mining Nueva Mineria: its founder and major shareholder had over 35 years of experience working with small and medium sized mining firms when he decided to start this firm in 2015. Specifically, the decrease in the prices of minerals that had occurred in the previous years led him to realize that mining firms could benefit from

[12] Most models at the time were designed for countries in the Northern Hemisphere where sun rays impact differently. This impact meant that the inclination of those solar towers was ad-hoc for a latitude different than the one needed for countries in the Southern Hemisphere.

commercializing pure metals such as lead, silver, copper, and zinc instead of sulfide minerals, which only contained a small proportion of those metals and thus became unprofitable with low international prices. Thus, he conceived the possibility of inventing a process that could extract metals from sulfide minerals and founded Green Mining Nueva Mineria in order to serve this purpose.

After the analyses we can conclude that firms generating green innovations require a highly specialized human capital work force, this due to the knowledge intensive nature of innovations. As explained before, Peru faces a context in with low levels of innovation and a scarce workforce with specialized knowledge. The lack of workforce with the capacities necessaires to develop and implement innovations could explain why we do not find many local suppliers offering this kind of innovations.

### 5.1.2 Research and Development efforts

As regarded by Hojnik and Ruzzier (2016), R&D efforts done by the local suppliers were another internal factor that was decisive for the success of their innovations. We find that the specific efforts carried out by each supplier vary; however, all of them were important for transforming the status of the innovations from an idea to a concrete possibility.

One way through which local suppliers engaged in R&D efforts was in collaboration with local universities. As asserted by Pietrobelli and Rabellotti (2011), working together with academia can be favorable for new suppliers since they can provide the public the goods required for technological innovations to occur at the firm level. For example, Qaira used facilities from a Peruvian university in order to carry out tests of their air drones. It also recruited some university students as interns to help it with the process. Similarly, Green Mining Nueva Mineria undertook several experiments to test its process of extracting metals from sulfide minerals. Specifically, its employees used laboratories from the chemistry faculties from Peruvian universities[13] to improve its technology and to be able to extract a higher percentage of metals from those sulfide minerals. Its research led it to achieve average recoveries of 99.1% for lead and 96.1% for silver. Dinamo incubated itself at the Center for Innovation and Entrepreneurial Development at a Peruvian university in order to receive advice on its business plan and to have access to the university's facilities for doing research. Thus, it worked closely with the university to improve its initial prototype of the solar towers.

An interesting finding, and in which the local suppliers of this sample differ form those studied in (Molina, 2018), is that since this innovations require a highly specialize knowledge, they tend to work hand in hand with universities. However, the fact that the academic ecosystem in Peru is not very developed can be considered as an obstacle for the generation of GI.

Another way in which suppliers undertook R&D efforts to consolidate their innovations was through changes in their organizational structure. These changes were mainly the case for incumbent suppliers. Exsa, as the oldest firm out of all the interviewees, did not establish itself as an innovative entrepreneurship but rather conducted an organizational restructuring process in order to prioritize its novel R&D intentions. Thus, in 2013, the firm created the office of Innovation Management that centralized all of its technological efforts. In our interview, we learned that this centralization allowed for the building of common R&D goals at the company level, thereby reducing transaction costs between different areas of the firm (Argyes and Silverman, 2004) and leading to a significant increase in R&D investment in the following years. As a part of the activities done by

[13] The National University of San Marcos (UNMSM) and the National University of Engineering (UNI)

their new office, Exsa institutionalized a series of business breakfast meetings with mining firms' employees in which they discussed the potential benefits of Exsa's upcoming Quantex innovation. Exsa also visited different innovation labs at other mining firms on the continent and at universities: it went to Codelco, in Chile, and to the PUCP and UTEC.

It's interesting to note that the only company that had to go through an organizational change in order to develop their innovation was Exsa, since this is the only company of our sample which was an incumbent firm. As noted in the literature, is harder for incumbent firms to innovate and in order to do those they usually tend to undertake organizational changes.

### 5.2 Governance Patterns in the mining sector

In this subsection we analyze the governance patterns in the Peruvian mining sector.

#### 5.2.1 Entrance to the mining sector

As discussed in section 3, the Peruvian mining sector is characterized by a small number of mining firms that handle most of the production. Thus, multinational firms govern the value chain process in the Peruvian mining sector. In this context, innovation patterns among local suppliers tend to be highly dependent on external incentives posed by the most important players in the market (Gereffi, Humphrey, & Strugeon, 2005). This market structure is more favorable for incumbent suppliers than emerging ones since large multinational firms may tend to have the privilege of very well known, standardized, modular solutions because they can simplify contracts and reduce transaction costs. They may also prefer to rely on very well-known suppliers to deliver solutions to their problems to reduce uncertainty as well as problems and costs (Molina, 2018).

Most local suppliers in our sample had no experience commercializing GI products previous to their innovations and, besides Exsa, they did not have any experience commercializing their products with the mining sector. Our interviews showed that emerging suppliers were at a disadvantage since reputation and experience in the mining sector were key factors in local suppliers engaging in a commercial relationship with mining suppliers. Moreover, generating this commercial relationship was hard for suppliers since they had no formal channels through which they could offer their products so they had to use indirect linkages to engage with the mining sector. Thus, the linkages they had with the stakeholders in the mining sector (e.g., private investors, professional network, and contact with mining firms) were vital for the insertion of their products into the market. We find that almost all the suppliers in the sample establish contact with mining firms through indirect contact that is a common method among emerging suppliers that need intermediators such as business partners in order to contact mining firms, as regarded by Nair and Ndbuidsi (2011).

In the case of Qaira, the entrance of an investment partner with over 30 years of experience working in a private firm that had several clients within the mining, energy, petroleum, and gas sectors was a determinant for its insertion into the mining sector. Through him, Qaira was able to establish a business relationship with Antamina[14], which was one of the biggest mining firms in Peru. At first, the mining firm purchased Qaira's air drones; however, over the years their business relationship has grown and now Antamina also purchases their data processing, equipment maintenance, and software assistance services. Qaira's successful partnership with Antamina has given it

[14] Minera Antamina S.A. is a polymetallic mining complex that contains one of the most important copper deposits in the world.

reputable credentials and helps it initiate business relationships with other mining firms such as Yanacocha and Gold Fields.

In the case of Dinamo, the professional networks of their co-founders' were determinants to establish business relationships with firms within the mining sector. In this regard, it were able to contact Rock Drill, which was a firm that specialized in diamond perforations that had ties within the mining sector; and Redrilsa, which was a firm that also specialized in diamond perforations, through professional networks of the co-founders. These two firms were interested in producing and commercializing solar towers to mining firms they were already working with; however, they lacked the knowledge to do so. Thus, Dinamo became their supplier of solar towers and established indirect links with the final clients: the mining firms.

Similarly, Green Mining Nueva Mineria is going to test their innovative technology of gold extraction project from sulfide minerals this year with a mining firm. This business relationship was established thanks to the fact that both firms share the same owner. In this regard, Green Mining Nueva Mineria, up to this moment, has exclusively oriented itself to doing research aimed at perfecting their innovative technology until it is ready to be applied in practice.

Lastly, the case of Green Metallurgy differs from the common strategy taken by local suppliers since instead of using indirect relationships to enter the mining sector they have used a strategy of signaling. Green Metallurgy has been able to register the intellectual property of eight GIs, all of which revolved around their process of using mining tailings as inputs for manufacturing ecological bricks, and thus decontaminating the environment. The firm was determined to acquire these patents because it is a small enterprise, and there was no assurance that they were going to be able to make their innovations "profitable". This supplier is currently under negotiations with three mining firms[15] in order to establish a business relationship based on their manufacturing technology for ecological bricks; however, at the time of this study the firm had not been able to establish a commercial relationship.

While new suppliers' suppliers had to use intermediaries in order to get to mining firms (i.e., private investors or a professional network), others were able to go directly to them. This is the case for Exsa; however, it is important to note that the trajectory of Exsa differs significantly from those of the other firms in the sample, since before generating their GI the firm already had worked in the mining sector and had several years of experience. At the time of the Quantex innovation, Exsa was already a business partner of Southern Peru, which is the most prominent copper mining firm in the country. This linkage was useful as Southern allowed Exsa to test their prototype of Quantex at their ongoing projects. The success of Quantex as a blasting technology gave them the credentials necessary to start commercializing their product to other firms in the sector such as Yanacocha, Antapaccay, Marcobre, Shahuindo, and Chinalco.

Besides reputation and past experience working in the sector, in the particular case of GI products and services we find another important barrier associated to the introduction of GI to the Peruvian mining sector. Our study shows that most mining firms are willing to acquire GI products and services when they do not incur an additional cost to the firm's operations. This is one of the barriers that Green Metallurgy currently faces since their products and services are not substitutes for current inputs to the productive processes of mining firms, but additional ones. Thus, there are no circumstances under which a cost reduction scenario, by mining firms, is feasible. On the contrary, purchasing these products and services, while contributing to decrease

[15] Minera Recuperada, Buenaventura, and Nexa

contamination, requires an additional investment with an uncertain profitability: the benefits of these purchases rely, for example, on the demand for ecological bricks.

Additionally, an important pattern which facilitated the entrance to the market of Exsa and Dinamo is that these firms focused on a niche market which could not be covered so easily by multinational companies. Because of their previous experience within the mining sector, these firms recognize the opportunity to innovate and to seize it at the right moment. In the case of Dinamo because solar panels available in other markets could not be adapted to the climatic conditions in Peru, so the company specialized in a specific model of solar panels. In the case of Exsa, since explosives have legal restrictions on imports there is an important market barrier for international companies,

In general, we find that emerging local firms are highly dependent on indirect relationships in order to be able to enter the mining value chain, since multinational firms tend to privilege well know suppliers. In the case of GI, we see that firms end up being highly dependent on external incentives posed by mining companies. Specifically, we find that GI products/services will have an easier entrance to the market only if they do not imply and additional cost to the current process of mining companies.

### 5.3 Institutional and Regulatory Framework

Peruvian government has not yet established national programs that encourage mining firms to acquire services or products from local suppliers that come from innovative and green processes. Nevertheless, there are measures public entities have established to encourage the creation and development of innovative and green enterprises. They are mainly public funds that provide financial resources to firms aiming to develop innovative products and services. Our interviews disclose that government support was a determining factor that provided local suppliers with the necessary funds to make their innovations viable. Four of the local suppliers considered in this study had access to these funds, which were crucial for the development of their GI.

Specifically, Qaira used public funding from the National Council of Science, Technology and Innovation (CONCYTEC), the Association for the Conservation of the Amazonic Basic (ACCA), the National Service of Capacitation for the Construction Industry (SENCICO), and the United States Agency for International Development (USAID). They also won a grant from the startup competition organized by the Ministry of Production to finance their innovations. Similarly, both Green Mining Nueva Mineria and Green Metallurgy received financing from Innovate Peru, which is a public fund from the Ministry of Production that finances entrepreneurships. The former used it for the research they did at the chemistry laboratories at UNI, whereas the latter used it to implement their technology in the mining tailings of “Cerro El Toro”, a highly contaminated mountain in La Libertad. Lastly, Dinamo received a grant from CONCYTEC to develop their prototype for solar towers.

In addition, Ministry of Production manages the tool "*Clínica Empresarial*" that is part of the platform of support for the entrepreneur "*Tu Empresa*". This platform aims to strengthen micro and small enterprises by providing advice on five components: formalization, business management, digitalization, productive development, and access to financing (UTP, 2018). the Clínica Empresarial tool was incorporated into the activities of the First Business Convention Moquegua in 2018 that was managed by the Ministry of Production and Anglo American. This convention held business meetings between contractors of the Quellaveco mine and local suppliers. (Anglo American, 2018).

As explained in section 2.1 financial constrains tend to be a mayor barrier in order for innovative firms to expend their markets. This is also the case of the suppliers studied in this sample – with the exception of Exsa. This explains why government financing has been crucial for their development and growth. These local companies would not have been able to develop their initial ideas without government funding.

## 6. Concluding Remarks

In this study, we examine the experience of local suppliers that offer GI in the Peruvian mining sector. Specifically, we focus on the analysis of the technological trajectories of five local firms. This is an interesting case to analyze because of the changes in the Peruvian mining sector in the last decade are generating opportunities for the development of local suppliers with GI. In this research we identify three main opportunities. First, recent changes in regulation and those in institutions trying to protect the environment are creating opportunities for local suppliers that offer technological alternatives for mining firms. Second, increasing social pressures from environmental concerns are also a key driver for the adoption of GI in mining firms. Third, changes in the market demand for GI are creating opportunities and new niches for local suppliers who offer services in an efficient and environmentally sustainable way to mining.

An important first finding is related to the internal factor that leads these suppliers to their innovations. There are mainly three factor which are related to the development of GI in local suppliers; their knowledge capabilities, their organizational structure and their financial capacity. First, all of the firms in this sample had teams with intensive academic training in engineering that was vital for the conception of their business ideas. From this we conclude that firms generating green innovations need a workforce with a highly specialized knowledge. Since Peru faces a context in which this kind of knowledge is limited, this could explain why we do not find many local suppliers offering this kind of innovations. Second, firms hey have to be prepared organizationally to develop their innovations. Incumbent firms had to go through organizational changes in order to be able to innovate. Finally, financial constrains tend to be a mayor barrier in order for innovative firms to expend their markets. In these regards, we find that the government plays a fundamental role for startups by providing them with public contestable funds so that they can scale up their innovations. Two thirds of the firms interviewed in this research have received financing at some point from the state for the development of their innovations.

Regarding external factors we find that emerging local firms are highly dependent on indirect relationships in order to be able to enter the mining value chain, since multinational firms tend to privilege well know suppliers. Large-scale mining mostly has high levels of foreign investment, so they tend to stick to international standards and requirements that often cannot be met by innovation at the local level. Under this context, local firms have found that they can enter the mining value chain more easily through strategic partners. For example, Dinamo found that entering the sector through third parties that outsourced their work was more convenient. Also, in the case of GI, we see that firms end up being highly dependent on external incentives posed by mining companies. Specifically, we find that GI products/services will have an easier entrance to the market only if they do not imply and additional cost to the current process of mining companies.

Their experiences provide evidence that GI may be achieved by local suppliers in Peru and adopted by large scale mining firms. However, the firms in our sample are very new to knowledge-intensive activities, so the scope of their innovations remains limited. These suppliers have yet to reach the most advanced stages of their learning curves in which the potential for positive spillovers into the economy is even larger. As we mentioned at the beginning of this study, a growing focus is being placed on the role of the local institutional setting as a determinant of innovation among local firms. In this regard, our interviews have shown that support from the academic sector remains crucial for the entrance of local suppliers into the sector.

On the other hand, it is important that the public sector's interventions encourage the construction of an ecosystem conducive to the research and development of technologies. This construction could be done through articulation and integration of public and private sector entities. Finally, Peru needs to reinforce its interventions aimed at redirecting consumption and production patterns toward goods and services aligned with sustainable development to create demand for green innovation.

**References**


Arundel, A., & Kemp, R. (2009). *Measuring eco-innovation.* Maastricht: United Nations University.

Bartos, P. (2007). Is mining a high-tech industry?: Investigations into innovation and productivity advance. *Resources Policy,* 149-158.

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

Bebbington, A., & Buryb, J. (2009). Institutional challenges for mining and sustainability in Peru. *Proceedings of the National Academy of Sciences 106(41),* 17296–17301.

Berrone et. al, P. (2013). Necessity as the mother of 'green' inventions: Institutional pressures and environmental innovations. *Strategic Management Journal 34(8),* 891–909.

Berrone et.al, P. (2013). Necessity as the mother of "green" inventions: Institutional pressures and environmental innovations . *Strategic Management Journal 34(8),* 891-909.

Canepa, A., & Stoneman, P. (2008). Financial constraints to innovation in the UK: evidence from CIS2 and CIS3. *Oxford Economic Papers 60(4),* 711–730.

Carrillo-Hermosilla et.al, J. (2010). Diversity of eco-innovations: Reflections from selected case studies. *Journal of Cleaner Production 18,* 1073e1083.

Casas, C. (2017). *Conflictos mineros y acuerdos comunitarios: Identificación de mecanismos y retroalimentación.* Universidad del Pacífico. Lima: Centro de Investigación de la Universidad del Pacífico.

Castellares, R., & Fouché, M. (2017). *The Determinants of Social Conflicts in Mining Production Areas.* Peruvian Economic Association.

CCSI, UNDP, UN & WEF. (2016). *Mapping mining to the sustainable development goals: An Atlas.*

Cecere et.al, G. (2018). Financial constraints and public funding of eco-innovation: empirical evidence from European SMEs. *Small Business Economics*.

Cohen, W., & Levinthal, D. (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. *Administrative Science Quarterly 35(1),* 128-152.

CONCYTEC. (2016). *I Censo Nacional de Investigación y Desarrollo a Centros de Investigación 2016.* Lima: Consejo Nacional de Ciencia, Tecnología e Innovación Tecnológica (CONCYTEC).

CONCYTEC. (2017). *I Censo Nacional de Investigación y Desarrollo a Centros de Investigación 2016.* Lima: CONCYTEC.

Constitutional Presidency of Peru. (2005, December 09). Supreme Decree Nº 059-2005-EM. Lima, Peru.

Davis, R., & Franks, D. (2011). *The costs of conflict with local communities in the extractive industry.* Santiago: First International Seminar on Social Responsability Mining.

Dirección General de Minería. (2018). *Reporte Anual de la Dirección General de Minería 2017.* Lima: Ministerio de Energía y Minas.

Elisabetta Magnani, A. T. (2012). Green R&D, technology spillovers, and market uncertainty: An empirical investigation. *Land Economics 88(4)*, 685-709.

Ernst & Young. (2017). *Peru's mining and metals investment guide 2017/2018.* Lima : EY.

Espinoza, L. F. (2017). *Diseño de un sistema de iluminación LED alimentado por paneles solares aplicado a minería de cielo abierto.* Lima: PUCP.

Franks et.al, D. (2014). Conflict translates environmental and social risk into business costs. *PNAS 111 (21),* 7576-7581.

Gereffi, G., Humphrey, J., & Strugeon, T. (2005). The governance of global value chains. *Rev. Int. Political Econ., 12*(1), 78 - 104.

Gestión . (2015, Febrero 25). *Gestión.pe.* Retrieved from https://gestion.pe/economia/ey-cuatro-proyectos-mineros-peru-duplicaran-inversion-cobre-2016-152137

Hojnik, J., & Ruzzier, M. (2016). Drivers of and barriers to eco-innovation: a case study. *International Journal of Sustainable Economy*, 273-294.

Hottenrott, H., & Peters, B. (2012). Innovative Capability and Financing Constraints for Innovation: More Money, More Innovation? *Review of Economics and Statistics 4(94)*, 1126-1142.

Inthavongsa, I., & Drebenstedt, C. (2015). *Cost Estimation for Open Pit Mines: Tackling Cost Uncertainties.* Conference Paper.

Jaffe, A., Newell, R., & Stavins, R. (2005). A Tale of Two Market Failures: Technology and Environmental Policy. *Ecological Economics*, 64-74.

Jinzhou, W. (2011). Discussion on the Relationship between Green Technological Innovation and System Innovation. *Energy Procedia 5*, 2352–2357.

Jonek-Kowalska, I. (2017). *"Environmental Costs of Mining Production in the Perspective of the Mine Lifecycle".* Conference Paper.

Kapoor, S., & Oksnes, L. (2011). *Funding the green new deal: Building a green financial system.* Green European Foundation.

Kemp, R., & Pearson, P. (2007). *Final report MEI project about measuring ecoinnovation.* Maastricht: UNU-MERIT.

Kossoff et.al, D. (2014). Mine tailings dams: Characteristics, failure, environmental impacts, and remediation. *Applied Geochemistry 51*, 229–245.

KPMG. (2014). *Valuing social investment in mining.* KPMG Global Mining Institute.

Kumar et.al, M. (2017). Prioritizing the barriers to achieve sustainable consumption and production trends in supply chains using fuzzy Analytical Hierarchy Process. *Journal of Cleaner Production 151*, 509-525.

Labó, R. (2017). *Reforma de los Fideicomisos Sociales e Implementación del Fondo Social La Granja.*

Lee, A., & Alm, J. (2004). The clean air act ammendments and firm investment in pollution abatement equipement. *Land Economics* , 43-47.

Magnani, E., & Tubb, A. (2012). Green R&D, Technology Spillovers, and Market Uncertainty: An Empirical Investigation. *Land Economics*, 685-709.

Matus et al., K. (2012). Green chemistry and green engineering in China: drivers, policies and barriers to innovation. *Journal of Cleaner Production 32*, 193-203.

McCarthy et al., D. (2014). A First Nations-led social innovation: a moose, a gold mining company, and a policy window. *Ecology and Society 19(4).*

Minisiterio de la Producción. (2018). *Hoja de ruta tecnológica: Negocios vinculados a minería.* Lima.

Ministerio de Enegría y Minas. (2018a). *Perú: Cartera de Proyectos de Construcción de Mina 2018.* Lima: Ministerio de Enegría y Minas.

Ministerio de Energía y Minas. (2018b). *Anuario Minero 2017.* Lima: Ministerio de Energía y Minas.

Mohr, R., & Shrawantee, S. (2008). *Distribution of the environmental costos and benefits, additional distorsions and the Porter Hypothesis.* Land Economics.

Molina et.al, O. (2016). *Global Value Chains in the Peruvian Mining Sector.* IDB.

Molina, O. (2018). Innovation in an unfavorable context: Local mining suppliers in Peru. *Resources Policy 58(C)*, 34-48.

Nelsen, J. (2006). Social license to operate. *International Journal of Mining, Reclamation and Environment 20(3)*, 161-162.

Nurmi, P. (2017). Green Mining - A Holistic Concept for Sustainable and Acceptable Mineral Production. *Annals of Geophysics* , 60-67.

OECD. (2005). *Oslo Manual: Guidelines for collecting data and interpreting innovation data.* OECD Publishing.

OECD. (2015). *Multi-dimensional Review of Peru: Volume 1. Initial Assessment.* Paris: OECD Development Pathways, OECD Publishing.

Office of the Ombudsman. (2018). *Reporte Mensual de Conflictos Sociales N.° 176.* Lima.

Olsson et al., P. (2017). The concept of the Anthropocene as a game-changer a new context for social innovation and transformations to sustainability. *Ecology and Society 22 (2).*

Robert Mohr, S. S. (2008). Distribution of Environmental Costs and Benefits, Additional Distortions, and the Porter Hypothesis. *Land Economics (84)*, 689-700.

Runhaar et.al, H. (2008). Environmental Leaders: Making a Difference. A Typology of Environmental Leaders and Recommendations for a Differentiated Policy Approach. *Business Strategy and the Environment 17*, 160–178.

Samimi Namin et.al, F. (2011). Environmental impact assessment of mining activities: A new approach for mining methods selection. *Gospodarka Surowcami Mineralnymi 27(2)*, 113-143.

Savignac, F. (2008). Impact of financial constraints on innovation: What can be learned from direct measure. *Economics of Innovation and New Technology 17(6)*, 553-569.

Schiederig, T., Tietze, F., & Herstatt, C. (2012). Green innovation in technology and innovation management - an exploratory literature review. *R&D Management, 42*, 2.

The Lock Gate. (2016). *Mine Rehabilitation and Closure Cost: A Hidden Business Risk.* Queensland.

Toto, J., Requena, I., & Zamorano, M. (2010). Environmental impact assessment in Colombia: Critical analysis and proposals for improvement. *Environmental Impact Assesment Review*, 247 - 261.

Triscritti, F. (2013). Mining, development and corporate–community conflicts in Peru. *Community Development Journal 48(3)*, 437–450.

Unruh, G. (2000). Understanding carbon lock-in. *Energy Policy 28(12)*, 817 –830.

Walker, R. (2008). An empirical evaluation of innovation types and organizational and environmental characteristics: towards a configuration framework. *Journal of Public Administration Research and Theory 18 (4)*, 591–615.

Youl Lee, S., Florida, R., & Gates, G. (2010). Innovation, Human Capital, and Creativity. *International Review of Public Administration, 14*(3), 13-24.

# Annex

## Annex 1: Peru mining production relative to world production

| Metals | Peru in the world ranking of mining production | | Production | | Participation in world production |
|---|---|---|---|---|---|
| | LA | World | Peru | World | |
| Silver (MT) | 2 | 2 | 4,375 | 4,304 | 17% |
| Copper (millions of MT) | 2 | 2 | 2,45 | 19,76 | 12% |
| Zinc (millions of MT) | 1 | 2 | 1,47 | 13.26 | 11% |
| Lead (millions of MT) | 1 | 4 | 307 | 4,710 | 6.5% |
| Molybdenum () | 2 | 4 | 28,141 | 293,091 | 9.6% |
| Gold (MT) | 1 | 6 | 151 | 3,146 | 4.7% |
| Tin (MT) | 3 | 6 | 17,790 | 289,960 | 6.1% |

Source: 2017 Mining Annual

## Annex 2: Mining GDP and Growth 2010 -2017 (Million Soles; %)

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|
| **Mining GDP** | 33,929 | 33,210 | 34,044 | 35,494 | 34,702 | 40,156 | 48,662 | 50,708 |
| **Growth of mining GDP** | -3% | -2% | 3% | 4% | -2% | 16% | 21% | 4% |
| **Total GDP** | 382,380 | 407,052 | 431,273 | 456,449 | 467,433 | 482,890 | 502,341 | 514,927 |
| **Growth of total GDP** | 8% | 6% | 6% | 6% | 2% | 3% | 4% | 3% |
| **Participation of mining GDP** | 9% | 8% | 8% | 8% | 7% | 8% | 10% | 10% |

Source (BCRP)

## Annex 3: Mining GDP and Growth 2010 -2017 (Million Soles; %)

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|
| **Mining Exports** | 21903 | 27526 | 27467 | 23789 | 20545 | 18950 | 21777 | 27159 |
| **Total Exports** | 35803 | 46376 | 47411 | 42861 | 39533 | 34414 | 37020 | 44918 |
| **Mining participation in exports** | 61.2 | 59.4 | 57.9 | 55.5 | 52.0 | 55.1 | 58.8 | 60.5 |

Source (BCRP)

## Annex 4: Mining production by Metal and Mining Size

| | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| **Copper (TMF)** | **1,375,641** | **1,377,643** | **1,700,817** | **2,353,859** | **2,445,585** |
| Large and Medium | 1,371,814 | 1,373,418 | 1,696,883 | 2,350,513 | 2,443,036 |
| Small | 3,827 | 4,225 | 3,934 | 3,346 | 2,549 |
| Artisanal | 0 | 0 | 0 | 0 | 0 |
| **Gold (Grams)** | **136,088,477** | **132,229,626** | **134,648,392** | **127,921,125** | **130,408,826** |
| Large and Medium | 127,913,500 | 122,795,899 | 125,760,849 | 117,022,324 | 120,098,706 |
| Small | 8,173,018 | 9,433,727 | 8,739,973 | 10,680,604 | 10,027,468 |
| Artisanal | 1,959 | 0 | 147,570 | 218,197 | 282,652 |
| **Zinc (TMF)** | **1,351,274** | **1,315,475** | **1,421,218** | **1,337,082** | **1,473,037** |
| Large and Medium | 1,343,039 | 1,305,763 | 1,413,186 | 1,325,456 | 1,462,081 |
| Small | 8,235 | 9,712 | 8,032 | 11,626 | 10,956 |
| **Silver (Kg)** | **3,674,283** | **3,768,147** | **4,101,568** | **4,375,337** | **4,303,541** |
| Large and Medium | 3,577,898 | 3,649,560 | 4,009,225 | 4,210,098 | 4,146,868 |
| Small | 96,385 | 118,587 | 92,343 | 165,239 | 156,673 |
| Artisanal | 0 | 0 | 0 | 0 | 0 |
| **Lead (TMF)** | **266,472** | **277,294** | **315,525** | **314,421** | **306,794** |
| Large and Medium | 260,979 | 270,533 | 310,837 | 307,806 | 300,767 |
| Small | 5,493 | 6,761 | 4,688 | 6,615 | 6,027 |
| Artisanal | 0 | 0 | 0 | 0 | 0 |

Source (Anuario Minero 2017)

## Annex 5: Mining Investment (Thousands UDS dollars)

| **Mining Companies** | **2016** | **2017** | |
|---|---|---|---|
| | **USD** | **USD** | **%** |
| Southern Perú Copper | 581,692 | 672,814 | 17% |
| Sociedad Minera Cerro Verde S.A.A. | 154,876 | 302,612 | 8% |
| Shougang Hierro Perú S.A.A. | 129,183 | 285,304 | 7% |
| Antamina Mining Company S.A. | 247,866 | 214,036 | 5% |
| Buenaventura Mining Company S.A.A. | 176,191 | 205,412 | 5% |
| Antapaccay Mining Company S.A. | 542,458 | 198,291 | 5% |
| Anglo American Quellaveco | 138,330 | 164,342 | 4% |
| Mine Las Bambas | 299,434 | 157,992 | 4% |
| Hudbay Perú S.A.C. | 135,820 | 157,537 | 4% |
| Mine Chinalco Perú S.A. | 146,076 | 127,187 | 3% |
| Others | 781,637 | 1,442,489 | 38% |
| **Total** | **3,333,563** | **3,928,016** | **100%** |

Source: Dirección General de Minería, "Perú 2017: Anuario Minero".

## Annex 6: Interviews to relevant actors of the mining sector

| Institution/Firm Name | Interviewee Name | Position | Year Interviewed |
|---|---|---|---|
| **Mining Experts** | | | |
| CEMS, Universidad del Pacífico | Carlos Casas | Former Director CEMS | August, 2018 |
| GRADE/CONCYTEC | Juana Kuramoto | Associate Researcher (GRADE)<br>Director of Plans and Programs (CONCYTEC) | September, 2018 |
| MINEM | Ricardo Labó | Former Principal Advisor, Latin American Global External Affairs, Rio Tinto<br>Former Vice-Minister, Ministry of Energy and Mines | September, 2018 |
| Ministry of Energy and Mines | Tamiko Hasegawa | Vice-ministerial adviser | September, 2018 |
| Emprende UP, Universidad del Pacifico | Javier Salinas | Director | October, 2018 |
| SNMPE/Anglo American | Luis Marchese | President/ Senior Advisor to CEO and GMC | September, 2018 |
| SNMPE | Pablo de la Flor | General Manager | September, 2018 |
| SNMPE | Enrique Ferrand | Manager of the Mining Sector | September, 2018 |
| **Mining Firms** | | | |
| AngloAmerican | Luis Marchese | General Manager, AngloAmerican; President SNMPE | December, 2018 |
| El Brocal | Raul Ponce de Leon | Logistics Manager | December, 2018 |
| Yanacocha | Ricardo Sáenz | General Chief of suppliers and local staff | November, 2018 |
| **Supplier Firms** | | | |
| Dinamo Tecnologias SAC | Davy Olivera | General Manager | December, 2018 |
| Green Mining Nueva Minería SAC | Francisco Cárdenas | R&D Manager | December, 2018 |
| Green Metallurgy Technologies S.R.L. | Silvana Flores | General Manager | December, 2018 |
| QAIRA | Monica Abarca | Co-Founder and CEO | December, 2018 |
| Exsa | Darío Villalobos<br>Valeria Bruno | Chief of Tajo Technical Assistance<br>Head of Innovation | November, 2018 |

## Annex 7: Main mining projects paralyzed

| Main mining projects paralyzed | Extracted minerals | Projected investment (US$ M) |
|---|---|---|
| Minas Conga | Copper and gold | 4 800 |
| Tía María | Copper | 1 400 |
| Río Blanco | Copper | 2 500 |

Fuente: MINEM

## Annex 8: Main Characteristic of Mining companies

| Mining Company | Region | Income 2017 (US$ Million) | Products |
|---|---|---|---|
| Antamina | Ancash | 2,504 | Copper, Silver, Lead, Molybdenum |
| Souther Copper Corporation | Moquegua | 2,482 | Copper, Molybdenum |
| Yanacocha | Cajamarca | 1,210 | Gold, Silver |
| El Brocal | Pasco | 223 | Silver Sulfide, Lead, Zinc, Copper |
| AngloAmerican | Moquegua | Project in development | Copper |
| Milpo | Junín | 104 | Zinc, Lead, Copper |

Source: 2017 Mining Annual