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DISCOVERING NEW PUBLIC-PRIVATE PARTNERSHIPS FOR PRODUCTIVE AND TECHNOLOGICAL DEVELOPMENT IN EMERGING MINING COUNTRIES

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Since the 1980s, the mining industry has experienced vertical disintegration along with an increasing knowledge-intensity of their activities. This change is creating new opportunities for innovative local suppliers based in developing mining economies to enter into global supply chains of knowledge-intensive products and services offered not only to the mining industry but also to other industries. In Latin America, some countries are currently looking for ways to take advantage of this opportunity, extending the positive causality of the extractive industry via policy measures to support the emergence and development of knowledge-intensive products and services to the mining industry and simultaneously enhance the competitiveness of mining operations and diversify the economy.

This paper tries to illustrate such challenges by studying two current initiatives to develop local productive and technological linkages by enhancing the capabilities of suppliers and their context, namely, the “World Class Supplier Program” in Chile, launched in 2009 by BHP Billiton to later became a national policy that followed a public-private partnership (PPP) approach, and “Developing Suppliers of Excellence” in Peru, run by Antamina without government involvement.

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1. Introduction

Since the 1980s, the mining industry has experienced vertical disintegration along with an increasing knowledge-intensity of their activities. This change is creating new opportunities for innovative local suppliers based in developing mining economies to enter into global supply chains of knowledge-intensive products and services offered not only to the mining industry but also to other industry. However, the success of such emerging opportunities is very dependent on the type of institutions and policies enabling local firms to enhance their innovation and managerial capabilities while effectively linking and embedding such emerging activities in the national economy.

In Latin America, some countries are currently looking for ways to take advantage of this opportunity, extending the positive causality of the extractive industry via policy measures to support the emergence and development of knowledge-intensive products and services to the mining industry and simultaneously enhance the competitiveness of mining operations and diversify the economy.

This paper tries to illustrate such challenges by studying two current initiatives to develop local productive and technological linkages by enhancing the capabilities of suppliers and their context, namely, the "World Class Supplier Program" in Chile, which was launched in 2009 by BHP Billiton and later became a national policy that follows a public-private partnership (PPP) approach, and "Developing Suppliers of Excellence" in Peru, which is run by Antamina without government involvement.

First, this paper reviews the literature on natural resource-based development and recent discussion on industrial policy to create a framework to understand the relationships between productivity enhancement in the extractive sector and technological development in Latin America and the sector.

Second, it describes the existing supplier development programs in Peru and Chile and identifies current challenges that both programs face in order to be able to support a process which leads to the transformation of the supplier sector into a knowledge-based, internationally competitive and technology exporting sector.

Based on this understanding, a conceptual framework is created to establish hypothesis of possible barriers these programs need to overcome in order to successfully drive the development of knowledge-intensive suppliers for the mining industry.

The following section will describe the results and analysis of several interviews with stakeholders to identify these barriers. The last section aims to provide suggestions on how to strengthen Public and Private Partnerships to make such programs more effective, leading to long-term, sustainable productive and technological development for local suppliers involving local capacity-building.

2. Theoretical considerations on natural resources and productivity development

2.1 Curse of natural resources revisited: natural resources/ mining sector as an engine of productivity development

2.1.1 Theoretical review

For many scholars, natural resources (NRs) were considered a 'curse' for development. This was due to:

- First, the belief that the volatility and uncertainty of NR demand creates fiscal and macroeconomic problems (Gylfason, 2012);
- Second, Dutch disease discourages the growth of other export sectors due to exchange rate appreciation (Corden & Neary, 1982);
- Third, the reliance on 'commodities', as inferior goods, causes negative trade terms leading up to trade imbalances over the long-term (Prebisch, 1950; Sachs & Warner, 2001; Singer, 1949);
- Fourth, NRs are considered an 'enclave' activity – lacking forward and backward linkages– and therefore generate relatively little employment and minimal impact on other economic activities (Hirschman, 1958);
- Fifth, NRs also lack linkages with technological and scientific knowledge through 'supplier-dominated industrial activities' (Pavitt, 1984); and
- Sixth, they cause political conflicts and corruption over 'access' to resources (Auty, 1990, 1993).

The 'pessimistic' views on NRs are now increasingly being questioned and reconsidered from different perspectives. For instance, the negative terms of trade argument, suggested by Prebisch (1950) and Singer (1949), and in subsequent empirical analysis such as Sachs & Warner (1995, 1997) among others, is increasingly considered inconclusive (Brunnschweiler, 2008; Cuddington, 1992; Ellsworth, 1956; Tilton, 2013). Many of the discussions focus on methodological issues such as choice of indicators (Brunnschweiler, 2008; Cuddington, 1992; Ellsworth, 1956), time periods analyzed (Cuddington, 1992; Ellsworth, 1956) and analytical methods applied (Brunnschweiler, 2008).

Critics have also expressed concern that earlier discussions excluded other important factors such as human capital, physical infrastructure and institutional capability in explaining the trade and growth link (Brunnschweiler, 2008). Others argue that more fundamental changes are taking place in NR activities regarding the use of scientific knowledge and technology (M Iizuka & Soete, 2013; A Marin, Navas-Alemán, & Pérez, 2015; Pérez, 2010).

Furthermore, several historical case studies have shown that NR - based activities can bring about the enhancement of productivity, diversification of activities and generation of employment with specialization and increased knowledge intensity (David & Wright, 1997; Wright and Czelustra, 2004, Upstill & Hall, 2006; Urzúa, 2011; Ville & Wicken, 2013).

2.1.2 Knowledge intensity in the mining sector

The mining industry has increased knowledge intensity and changed its structure drastically in the past few decades (Scott-Kemmis, 2013). For instance, in Australia, over 30 years since the 1970s, the sector evolved from having low levels of innovation to becoming a highly innovative and R&D intensive sector. As part of this process, leading mining firms (BHP Billion and Rio Tinto) scaled up the use of technology and the number of suppliers increased, forming a competitive mining cluster. Suppliers accompanied the trend towards more 'innovative and technically advanced' activities with the majority of suppliers (75%) carrying out in-house R&D to meet global market demand. In fact, several authors discuss recent developments within the mining industry with regards to global value chains because mining multinational enterprises' (MNEs) new strategy of decentralization and specialization opens opportunities for local suppliers to join Global Value Chains (GVCs). In this context, it is possible to sustain that the future success of the mining industry will depend on building capabilities to follow the global trends towards increasing the knowledge intensity and productivity of local firms.

The existing experiences of advanced NR-based countries such as Australia and Norway demonstrate the importance of establishing technological capabilities and enabling institutions. Both countries developed knowledge infrastructure such as universities (i.e. School of Mines in Norway) and public laboratories (Commonwealth Scientific and Industrial Research, or CSIR, and later the Commonwealth Scientific and Industrial Research Organisation, CSIRO, in Australia) which support the technological capability enhancement of mining firms. Furthermore, sector-based associations were created as a mechanism to link creation and diffusion of knowledge, while strengthening ties among local firms to coordinate and negotiate a sector-wide strategy (university-industry linkages, lobbying government for investment in sector-wide public services such as physical infrastructure).

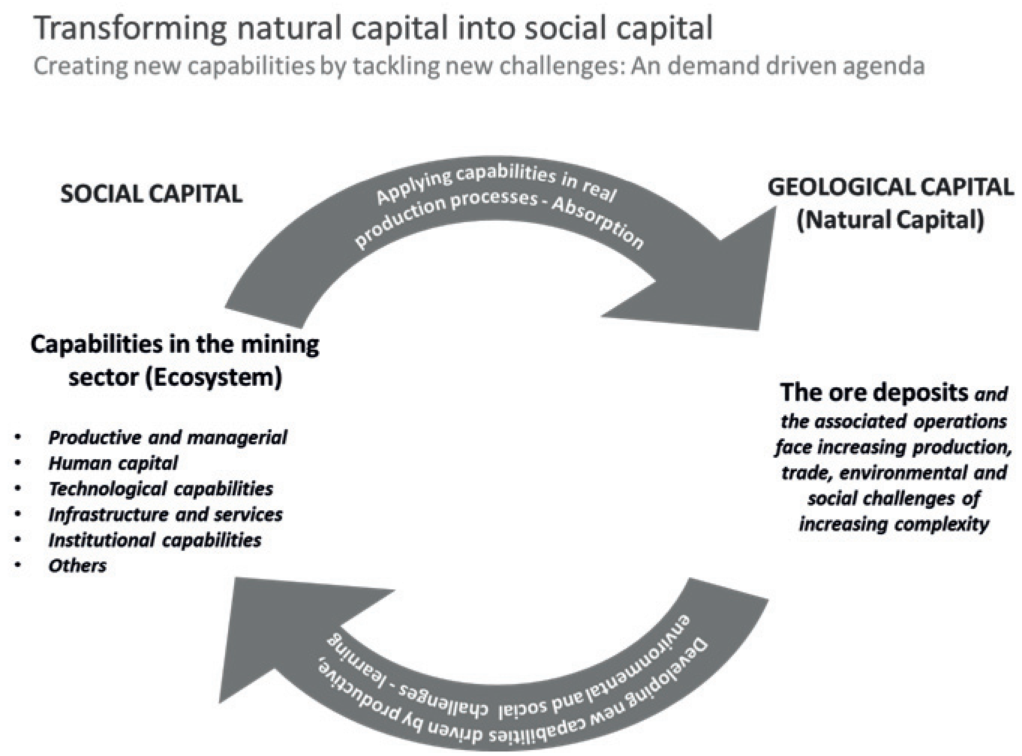
Building local specific capabilities are deemed important for NR-based activities such as mining (Anlló, Katz, & Bisang, 2015; Bravo-Ortega & Muñoz, 2015; Michiko Iizuka & Thutupalli, 2014; Kaplan, 2012; A Marin *et al*., 2015; Anabel Marin, Stubrin, & da Silva Jr., 2015; Michiko Iizuka & Katz, 2015) because operational productivity is often affected by the diversity and variability of natural conditions. In other words, despite an expansion in the globalization of mining activities over recent decades, some technology or know-how to enhance productivity remains very dependent on the local natural conditions of the mineral deposit. This local niche for knowledge and productivity creates an opportunity for the development of specialized local suppliers by increasing technological competencies to address local challenges, which require develop novel solutions or technologies (Urzúa, 2011).

For instance, the literature provides examples of techniques for overcoming location-specific problems that later resulted in productivity gains, such as the following:

- Technology to drill deep sea oil in Norway (Upstill & Hall, 2006);
- Technology to liquefy oil to allow long-distance transportation in Australia (Ville & Wicken, 2013);
- Advanced coal washing technology in South Africa (Kaplan, 2012; Pogue, 2008);
- Open pit mining technology in the US (Wright and Czelusta, 2004, Urzúa, 2011) to deal with the poor quality of deposits/ores, among others.

These cases demonstrate that continuous learning and technological efforts to overcome specific local disadvantages through the organization of stakeholders at a systemic level holds the key to the dynamic transformation of productivity.

Figure #1. Transforming geological capital into social capital



Source: Urzúa (2015).

Based on this understanding, current location-specific challenges for mining in Chile, such as efficient water use (Fundación Chile, 2014), among others, can be considered as an opportunity for innovation with potentially wider scope for technological and productive development with positive externalities for other industries and even to the society. Figure 1 shows the link between the increasing challenges faced by mining companies and the skills accumulation process that is driven by the technological learning and innovation processes set up to tackle these challenges. This process should be accompanied by technological learning and well-coordinated support institutions for knowledge generation (such as university-industry collaboration or consortiums of firm consortium to develop new technology), and the scaling up of innovations created by local suppliers (i.e. knowledge-based supplier development programs)

The type of support required very much depends on the existing capacity of local firms and the institutional context, including the provision and quality of the learning environment and the physical (roads, electricity, water, etc.) and institutional infrastructure (law, regulations, public goods, policy, etc.), among others.

2.2 Institutions and policy interventions in the mining sector context

2.2.1 Capabilities and learning in systemic context: reference to mining sector

The innovation system (IS), "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies (Freeman, 1987)", is a useful 'focusing device' for policy intervention by illustrating how the creation and diffusion of knowledge/technology generates productivity changes (Freeman, 1987; Lundvall, 1992; Nelson, 1993). The framework is also useful in identifying stakeholders, components and interactions (Edquist, 2005). The type of policy discussed in relation to IS often goes beyond just fixing the market failure to addressing coordination and systemic failures.

Viotti (2002), noticing the difference in knowledge creation stages between late industrializing countries and developed ones, extends the national IS (NIS) framework to the 'National Learning System' (NLS). Viotti (2002) unpacks capabilities into progressive levels of learning –production capability, assimilation of product/process technology, improvement capability, mastering of product or process technology, innovation capability and innovation of product/process technology– to understand how a learning style (active/passive) can influence technological acquisition. The emphasis of the NLS is placed on "learning", rather than innovation based on R&D, hence the focus is placed on efforts relating to the provision of absorption capacity, marking the difference from the NIS. The NLS is a useful framework for understanding 'catching up' stages when the technological trajectory is already laid out to conduct either "path-following" or "path-skipping" innovation (Lim & Lee, 2001).

Both NSI and NLS are suitable frameworks for maximizing knowledge creation and diffusion within already determined pathways by identifying the supply side at a systemic level. Nevertheless, tackling the mining sector's current challenges poses the following challenges to this approach:

- First, a 'local specific' solution for NR-based activities requires the transformation of organizations or industrial set-ups for "path creating" innovations to respond to changing conditions (Lim & Lee, 2001; Weber & Rohracher, 2012).
- Second, as the mining industry is placed in an increasingly global and economically open setting, the supply side capacity-building exercise needs to be dynamic, adapting to new situations through interactions with the demand side.
- Third, the large and often oligopsonic mining sector –due to the inevitable need for large-scale and long-term investment– requires a certain level of scale and capability from suppliers to make a business relationship feasible.

Furthermore, although NSI and NLS are not mentioned explicitly, huge heterogeneity is observed in firms' capability levels and the degree of diversity is increasing in the global, economically open context. In emerging countries, a 'small pocket of excellence' often exists; however, the critical challenge is how to "scale up" and link such firms with the rest of the economy. This requires a holistic and systemic approach that goes beyond the capacity-building of individual firms. In other words, the transformation towards an innovation-based economy ultimately hinges upon creating good institutions that drive continuous learning and innovation, focusing on both supply and demand at a systemic level.

2.2.2 New form of policy interventions: balancing the demand and supply side

1. Policy challenges in building capabilities at firm level

Knowledge has some characteristics of public goods, for example, non-excludable and non-rival. These characteristics tend to deter firms from investing in knowledge-creation activities, namely research and development (Nelson, 1959, Arrow,1962). To make such investment attractive, different types of public intervention are required to lower the private threshold for knowledge investments.

The lack of appropriability of knowledge and ease of free-riding can influence knowledge absorption and diffusion as well as the technological activities of firms. Indeed, a firm that introduces a foreign technology for the first time to a local economy may lower the perceived risks for competitors or other companies.

Several uncertainties and risks exist for knowledge-related activities. These discourage firms from pursuing knowledge-related activities:

- First, the directionality and timing of the research and the final outcome of R&D projects are harder to predict.
- Second, the acquisition of new technology involves uncertainty (although lower than R&D) based on its suitability to the firms' capabilities and the local market and geography. There are also commercial risks to innovations. Indeed, the output of technological activities may not necessarily be preferred by potential customers, which in turn could harm firms' market share and profitability (Audretsch *et al.*,2002).

Information asymmetries also play a crucial role in firms' technological decisions. Innovative firms have better information regarding their technological projects than potential investors. This information gap leads to a lower number of projects implemented than would be socially desirable (Hall & Lerner, 2010). Also, information asymmetries between knowledge users and producers hinder the emergence of research joint ventures. In particular, potential user firms have imperfect information regarding all the possible sources of valuable knowledge for technological projects (Klerkx & Leeuwis, 2009). At the same time, knowledge producers may have imperfect information regarding the potential market value of their research output.

In addition to information asymmetries, bounded rationality and transaction costs play a role in coordination or system failures. Such conditions are caused by the lack of linkages and interaction among the agents in the system. This can potentially create serious barriers for firms to enter into knowledge-intensive activities:

- First, interaction is needed on starting complex activities because the combination of several strands of technological and commercial knowledge is rarely present in a single firm, especially for young businesses.
- Secondly, the lack of interaction between firms decreases the likelihood of cooperative research projects that can tackle shared technological challenges. A good example is pre-competitive research agreements, which can co-create new activities until these are brought to the competitive level without duplicative research efforts.

Furthermore, lack of market interaction between innovation suppliers and clients harms the total technological gains of an economy. In such a context, the role of innovation suppliers, specifically Knowledge-Intensive Business Services (KIBS), is crucial because they usually act as co-innovators with their corporate customers (Den Hertog, 2000). To operationalize co-creation between the producer and user of innovation, van Lente, Hekkert, Smits, & van Waveren (2003) highlight the emergence of systemic intermediaries that attenuate the sources of coordination failures, in knowledge production, innovation and market interactions. Indeed, such institutions play an important role in large-scale transformative projects, but the optimal organizational setup is largely dependent on local system conditions. The operation and coordination of applied knowledge requires an intermediary function between knowledge demand and supply based on transparent institutions to ensure its credibility and generate trusting relationships.

Certainly, the above-mentioned sources of technological shortcomings are acting simultaneously in any system. However, not all of them are active constraints for each firm. In particular, firms apply technological strategies based on their resource endowments. According to Wernerfelt (1984), it is the combination of tangible and intangible assets of a firm that defines its actions for maintaining or increasing profits. In this context, the composition of firms, according to its resources, define the main binding constraints for knowledge creation, technological absorption, innovation and commercialization in a system. Therefore, capabilities failure may play a crucial role in defining the trajectory of the development of a technologically lagging system (Weber & Rohracher, 2012).

Indeed, the absence of required technical capabilities can limit knowledge production, as well as the capability to learn from superior technologies (active technological absorption) and innovation activities. Furthermore, firms with technical skills but lacking the required managerial capabilities to properly exploit knowledge outcomes or innovations may produce suboptimal economic output. In addition, capabilities failure can also harm the potential gains from knowledge dissemination and networks since the cognitive distance between lagging firms and knowledge sources is too large to be productive (Noteboom, 2000). In the context of emerging countries, the disproportionate distribution of knowledge would prevent its effective application and the creation of synergies among industries from the use of knowledge.

As can be seen, the nature of challenges faced by firms is extensive. Building technological, managerial and commercial capabilities at firm level may increase the possibility of overcoming some of these challenges; however, this may not solve the problem of high risks faced by firms caused by information asymmetry, bounded rationality and high transaction costs. These challenges must be dealt with at a systemic level through the state's much stronger involvement to lower the risk through resolving currently costly 'user-producer' interaction.

2. Supply and demand side policy instruments

An interesting feature of recent discussions on policy interventions is the increasing attention on balancing the role of the state and market, with a greater focus on how policy can take advantage of market forces. For instance, recent discussions on industrial policy (Cimoli, Dosi, & Stiglitz, 2010; Foray, David, & Hall, 2009; Hausmann, Klinger, & Wagner, 2008; Lee, 2013; Lin, 2015; Rodrik, 2004) emphasize the need to go beyond the limited framework of the so called "Washington-consensus" approach (no industrial policy is the best industrial policy), prevalent in the 1980s, to a more nuanced approach. In other words, the policy domain is currently expanding from "just stabilizing the macroeconomic environment and fixing market failures" to dealing with "coordination", "systemic" (Klein Woolthuis, Lankhuizen, & Gilsing, 2005)[1] and "transformative" failures (Weber & Rohracher, 2012)[2].The aforementioned shifting aim of industrial

1. Systemic failure includes infrastructural, institutional, interaction (network) and capability failures (Klein Woolthuis *et al*., 2005).

2. Transitional failure includes: 1) directionality failure (lack of direction because policy orientation is determined by political negotiations rather than market forces), 2) demand articulation failure (all demands are not clearly articulated in the market, leading to underinvestment in particular areas); 3) policy coordination failure, lack of understanding of policy mix; and 4) reflexivity failure, lack of corrective mechanisms, i.e. monitoring and evaluation (Weber & Rohracher, 2012).

policy –going beyond correcting macroeconomic imbalances– accompanies the changing combination of horizontal and vertical policy tools (Perez and Primi, 2009, Cimoli *et al.*, 2005) with a more nuanced approach, whether to defy or follow comparative advantages (Lin and Chang, 2009). In another words, current discussion on 'industrial policy' clearly recognizes the pivotal role played by market demands and the important function of the state to coordinate the market both dynamically and reflexively via policy interventions (Lin & Chang, 2009; Radosevic, 2016; Rodrik, 2007; Lin, 2012). This view change stems from the fact that industry is increasingly operating in an economically open and global environment, making successful policy intervention impossible without taking market demand forces into consideration.

Recognition of the critical role played by the market is reflected in the type of innovation policy instruments. Since the 1990s, innovation policy has been dominated by supply side policy instruments aimed at improving the performance of the innovation system and scant attention has been given to the demand side (Edler and Georghiou, 2007).

These supply side policy instruments comprise financial and service support, such as tax incentives, support for public research, training and personnel mobility, technical assistance to SMEs, grants for industrial research, knowledge sharing and networks formation. These are aimed at overcoming broadly defined market failures: information asymmetry, suboptimal investment in knowledge and coordination failure, the typically discussed rationales for policy interventions.

On the other hand, supply side policy instruments work directly to boost or create market demand. These instruments involve policies that encourage systemic linkages to expand market demand (i.e. cluster and supply chain policies), regulations (regulation to create market, i.e. environmental regulation), financial instruments (demand subsidies and tax incentives, i.e. subsidies for the purchase of solar panels) and public procurement (government or business consortium purchasing prototypes). With the increased realization of the importance of demand in stimulating innovation processes, attention to supply side policy instruments as well as interaction between the two are being revived (Edler and Georghiou, 2007; Smits, 2002; Porter, 1990).

Rational for emerging demand side approach are as follows[3]:

- First, it can represent "local" demand in a given location better and promote competitiveness;
- Second, it can translate market needs better to potential producers with lower transaction costs to encourage innovation;
- Third, it can contribute to achieving state functions along with strengthening competitiveness (Edler and Georghious, 2007).

The presence of sophisticated demands in a firm's proximity is considered as one of the important conditions for enhancing competitiveness, along with factor endowment, industrial structure and firm strategy (Porter, 1990). However, potential suppliers of

3. Edler and Georghiou (2007) give following as the rational for public procurement in driving innovations; but these arguments are applicable to most supply side approaches.

goods and services are often not explicitly informed of such demand due to information asymmetry and high transaction costs and these eventually create a high risk environment for a firm to invest in innovation.

Demand side policy instruments provide better translation and coordination of the existing market demand “signal”, thus lowering risks and nudging actors towards innovation. Instruments such as public procurement can create “lead users” who can gain from having advance access (at expense of risk) to new products or services (prototypes) to solve their existing problems while suppliers can benefit from users’ insights to optimize the products/services through better “user-producer interactions” (Lundvall, 1992). In another words, unlike the supply side approach, where R&D is induced by financial instruments to enhance technological capability, the demand side approach can also enhance production capacities.

Table #1 Taxonomy of innovation policy tools

Supply side measures		Demand side measures	
Finance	Examples		Examples
Equity support	Public venture capital funds; Mixed or subsidized private venture funds; Loss under writing and guaranteed tax incentives	Systemic policies	Cluster policies; Supply chain policies
Fiscal measures	Corporation tax reductions by volume or increment in R&D; Reductions in employers’ payroll tax and social contributions; Personal tax incentives for R&D workers	Regulations	Use of regulations and standards to meet innovation targets; Use of technology platforms to coordinate development of new industry/technology
Support for public sector research	University funding/ laboratory funding collaborative grants; Strategic programs for industry; Support for contract researches; Sharing equipment	Public procurement	R&D procurement; Public procurement of innovative goods
Support for training and mobility	Tailored courses for firms; Entrepreneurship trainings; Subsidized secondment; Industrial research student ships; Support for recruitment of scientists	Support of private demand	Demand subsidies and tax incentives; Articulation of private demand; Awareness raising and training; Catalytic procurement
Grants for industrial R&D	Grants for R&D, Collaborative research grants; Reimbursable loans; Prizes to spend on R&D		
Services	Examples		
Information and Brokerage support	Contact databases; Brokerage events; Advisory services; International technology watch; Patent databases; Benchmarking		
Networking measures	Supports for clubs; Foresight to build common visions; Co-location in incubators; Science parks		

Source: Based on Edler and Georghiou, 2007.

As mentioned earlier in this chapter, products/services that result from local demand, “locally designed products”, may not immediately become “global products”. However, for these products/services there is no solution available at international level because they required some level of R&D and/or innovation, which enabled a technological learning process that would lead to the development of capabilities to tailor the design of solutions to meet the local conditions. In particular, if the “lead users” are of sufficient size.

Additionally, it is important to bear in mind that in the demand the "client" or "lead user" is taking a substantial risk for potential direct benefit but also for positive externalities: long-term and intangible (non-pecuniary) societal benefits (i.e. employment generation, capacity development, environment protection, energy efficiency). Public policy might be required.

3. Mining sector

With regards to the mining sector, the importance of supply side interventions on sector-specific capacity building and the provision of sector-specific public goods (i.e. human capital and physical infrastructure) –so-called "investing in investing" by Collier, (2010)– is well accepted (Collier & Venables, 2011; Stigliz, 2007). At the same time, the importance has also been emphasized of developing capabilities in the use of comparative advantages as well as preventing future market uncertainties and risks. For instance, starting up and/or scaling up new activities to transform an agglomeration of firms into a cohesive cluster must leverage existing comparative advantages (Lin & Chang, 2009). While these understandings are present in the mining sector in emerging countries, there are few examples of the implementation of demand side policy instruments as well as the combination of both demand and supply side policy instruments.

2.2.3 Regional and sectorial background for productive development

I. Latin American setting

In the 2000s, Latin American (LA) countries increasingly recognized the important role played by knowledge (more specifically science, technology research and innovation) in economic growth, creating institutions to support policy interventions to meet the challenge of productivity enhancement, economic diversification and welfare and distribution improvements (Crespi & Dutrénit, 2014, Cimoli *et al.*, 2005).

The following questions were further identified to address the above questions:

1) How to encourage knowledge creation activities (i.e. science, technology, research and innovation) and learning (i.e. enhancing technological capability, absorption capacity, technology transfer and engineering and design capabilities)?

2) What are the barriers to making extractive activities (i.e. mining) more knowledge intensive?

In the discussion of science, technology and innovation (STI) policies, non-linear and co-evolutionary policies that are not exclusively based on either private technology demand or public technology supply occur in Latin America (Cimoli *et.al.*, 2005). This embraces the systemic approach to stimulating innovation in firms by assigning the key role to government to coordinate and articulate the system strategy with firms and research institutions. In fact, in the 2000s, many LA countries strengthened institutions to address the aforementioned challenges and introduced necessary policy interventions (i.e. by establishing the National Council for Research and STI public policies etc.). However, these newly established institutions are confronted with various issues including a lack of capable human resources, capacity to foresee the technological frontier and managerial skills to allocate appropriate resources at the right time and right place.

II. Sectorial policy background of mining

At the sectoral level, policy debate on mining sector development is around three issues (Dietsche, 2014).

- First, how to attract foreign investment: this question emerged when many low- and middle-income countries experienced severe economic crises in the aftermaths of the economic shocks that they suffered in the early 1970s.
- Second, how to avoid the resource curse: this question was prompted by studies published in the mid-1990s putting forth the proposition that countries producing mineral resources were more likely to experience negative economic, political and social outcomes.
- Finally, how to build linkages: this question has received attention more recently and seeks further industrialization and economic diversification on the back of the exploitation of natural resources.

Much literature after the 2000s focuses on the third point of how to build linkages. Upstill & Hall (2006) write about innovation in the minerals industry, focusing on the experience of Australia. They describe how the pattern of innovation in the global minerals industry is changing, as the industry becomes increasingly globalized. Additionally, they look at trends in R&D expenditures, at the shift towards more collaborative innovation, at the uptake of new information and communication technology (ICT), and at a mooted downturn in large, step-change innovation projects. Current challenges for the minerals industry, calling for major technological innovation, include the pressing need to discover new mineral deposits to replace depleted resources, requirements for safer and more efficient methods of mining and processing, and step-change process improvements in addressing the environmental impact and social acceptability of large new mining operations (Hitzman, 2002; Wagner & Fettweis, 2001). Overall the changes point to the need for new innovation management capabilities to improve existing processes, to tap into the potential of new technologies to improve efficiency all along the industry value chain, and to develop inter-company and interpersonal links to draw on external knowledge for innovation. The required skills include scanning globally for people and technologies, building cross-organizational teams, managing outsourced and collaborative research, and exploiting pre-competitive research alliances to build technologies to be used later for competitive advantage.

Some mentions about the knowledge-intensive potential of NR activities (Ville & Wicken, 2013) describe the dynamics of resource-based economic development in Australia and Norway. The authors develop a resource-based diversification model that analyzes the interaction between *enabling sectors* (organizations producing novel efficiency-enhancing products to be used in other sectors or the same sector) and resource industries and apply it to the historical experience of the two countries. Australia and Norway emphasized the role of learning and knowledge creation to facilitate innovation in these industries and spillovers into others sectors. The case studies indicate that there are many forms of institutions that can foster collaboration between resource-based industries and knowledge organizations or enabling sectors. They emphasize the important role of a knowledge generating and disseminating institutional structure.

In this vein, Urzúa (2011) focused on the emergence and development of knowledge-intensive mining service suppliers (KIMS) in the late twentieth century and investigated the overall role of mining industries in developing countries and in Chile and Australia. This study illustrated the importance of developing human capital and more knowledge-intensive economic activities, reflecting similar arguments set forth in other studies on NR activities (De Ferranti, Perry, Lederman, & Maloney, 2002; Maloney, 2007). Urzúa (2011) emphasized the importance of sustained investment by firms in explicitly-managed training and learning over the career development paths of KIMS professionals and the importance of learning-intensive interactions, and not just transactional procurement relationships, between mining companies and knowledge intensive suppliers.

4. Recent characteristics of mining suppliers in Chile and Peru

a. Chile

Chile's mining sector plays an important role in the economy. The sector accounted for 12% of GDP in 2013 after its peak in 2001 of 21%. It also attracts substantial amounts of investment reported to total US$ 50 billion between 2013 and 2017 (COCHILO, 2013). From 2010 to 2012 the sector grew by 43%, providing 300,000 jobs, an estimated 13.3% of the country's total employment.

Studies by Fundación Chile Innovum (2012, 2014) indicate a growing trend of mining suppliers. Since the mining sector's growth potential was recognized in the early 2000s (Korinek, 2013 among others), with the mounting need for productive suppliers to ensure sectorial competitiveness, efforts have been made to improve suppliers' capabilities. One of the seminal examples is the implementation of the "World Class Suppliers Program" designed by BHP Billion in Chile in 2008[4]. Indeed, mining suppliers play an ever more dynamic role in Chile's economy compared to other sectors as they increase the number of innovations, amount of exports, proportion of firms with sales of more than 100,000 UF (Chile's inflation-indexed currency unit, equivalent to approximately US$ 4,000,000) and proportion of professional employees per firm. This naturally means the mining sector generates higher economic impacts (Fundación Chile Innovum, 2012, 2014).

Details of the programs are explained in section 5; however, it is worthwhile noting here some positive changes observed among mining suppliers in Chile, where the program has existed for longer period of time. First, the number of local mining suppliers increased

4. A similar program was established in Peru, "Developing Suppliers of Excellence", by Antamina in 2012

from 3,443 firms in 2007 to 5,998 firms in 2012 (Fundación Chile Innovum, 2012, 2014), creating a larger basis for innovative firms. These improvements were also said to be accompanied by an increasing sophistication, or knowledge-intensity of activities (Bravo-Ortega & Muñoz, 2015).

Mining industry suppliers are defined by Fundación Chile Innovum (2014) as "firms that sell goods and services to mining companies; including contractors, suppliers of goods and services and consulting companies". As mentioned earlier, from 2007 up until 2012, the number of suppliers increased, together with a rise in the mining sector's contribution to GDP from 27% to 34%.

The type of 'suppliers to mining companies' also show trends of technological sophistication that still have room for improvement. Fundación Chile Innovum (2012, 2014) separates supplier types into "Equipment and Input", "Support Services" and "Engineering and Consultancy".

b. Peru

Peru's context is similar to that of Chile though at a slightly different stage. As in Chile, the presence of large-scale mining activities means that development of the supplier sector is critical for the country's further growth. The majority of Peru's mining equipment firms are currently focused on components manufacturing with metal casting and metalworking operations (similar to the 'equipment and suppliers' in Chile). Very few firms undertake R&D and assembly activities while only a small number have started to export since the early 2000s, mainly since 2007. As in Chile, there are small groups of highly competitive equipment suppliers such as Fima, Mepesa and Fundición Callao in the mineral processing segment and Tumi Rais Boring and Resemin in the surface and underground mining segment (Bamber, Fernandez-stark, & Gereffi, 2016).

Table #2 Peru's metal mechanics exports by product category and supply chain stage, by value, 2003-2013.

	Value (S, Millions)					Share (%)					
Category	2003	2005	2007	2009	2011	2013	2003	2005	2007	2009	2011
Total	11	42	51	78	91	103					
By Product Category											
Surface & Underground Mining	4	16	16	26	57	60	40,3	39,3	31,4	33,5	62,4
Mineral Processing	6	24	33	48	32	41	54,1	57,4	65,7	62,1	34,7
Materials Handling	1	1	1	3	2	2	5,6	3,2	2,8	3,4	2,8
By Product Category											
Surface & Underground Mining Intermediates	2	8	9	19	39	30	20,3	19,2	17,5	24,2	42,6
Surface & Undergorund Mining Final Equipment	2	8	7	7	18	30	20	20,1	14	9,4	19,8
Mineral Processing Intermediates	5	21	29	40	27	33	48,2	51	56,5	51,1	29,3
Mineral Processing Final Equipment	1	3	5	9	5	8	5,9	6,4	9,3	11	5,4
Materials Handling Intermediates	1	1	1	2	2	2	5,5	3,1	2,5	2,5	2,6
Materials Handling Final Equipment	0	0	0	1	0	0	0,1	0,1	0,3	1,9	0,2

Source: UNCOMTRADE, HS92, Perús exports represents by partner imports

Source: Bamber *et al.* (2016)

C. Summing up sectorial challenges in Peru and Chile

The mining sector in Peru and Chile is facing several challenges, such as lower ore grades water shortages or increasing energy costs. To tackle these challenges, mining needs to find novel solutions and increase productivity. As discussed earlier, it is increasingly understood that enhancing value chains by strengthening productive linkages in the mining sector can contribute to overall productivity improvements (Korinek, 2013). Additionally, mining suppliers, in particular providers of knowledge-intensive services, have demonstrated higher growth potential in terms of sales, exports and innovative activities, which can lead to the development of a knowledge-based sector that supports the diversification of the economy in developing mining countries (Scott-Kemmis, 2013).

As briefly illustrated above, the entry and development of mining sector suppliers has shown positive impacts. The programs reviewed in this paper –"World Class Suppliers" and "Developing Suppliers of Excellence"– aim to support this process in order to increase productivity and economic diversification impacts. To deliver a higher impact, both programs need to be enhanced, in particular they need to escalate the emerging pocket of excellence associated to the mining industry's knowledge-intensive suppliers. The anecdotal evidence regarding to these programs suggest that there is a potential of productivity gains and economic diversification to be delivered if these efforts get bigger.

Escalating comprises several components, such as increasing the quantity of innovation developed by suppliers and speeding up the innovation cycle or reducing innovations' time-to-market. This paper tries to identify the barriers that hinder this scaling up process based on the experiences of these two supplier development programs.

3. Conceptual framework

3.1 Research questions and key factors

The aim of this paper is to contribute to the understanding of how the mining industry can drive the enhancement of productive and technological development in emerging mining economies by fostering the emergence and development of knowledge intensive suppliers to the mining global industry, leading to diversification in knowledge-intensive sectors (Korinek, 2013; Urzúa, 2015).

In particular, the research focuses on understanding the barriers to developing knowledge-intensive suppliers to the mining industry in Chile and Peru. It is expected that policy solutions will be more accurately found by identifying the barriers to create suppliers' technological and productive capabilities, which are described as follows (Viotti, 2002):

i) Production capability: The knowledge, skill and other conditions required to run production processes.

ii) Improvement capability: The knowledge, skill and other conditions required for the continuous and incremental upgrading of product design, performance features and of process technology.

iii) Innovation capability: The knowledge, skills and other conditions required for the creation of new technologies, i.e., major changes in the design and core features of products, services and production processes.

It was considered that policy interventions to enhance the capabilities listed above could be achieved by encouraging the learning process. While the so called "active learning style" of a firm is critical for upgrading capability in emerging countries, firms' individual initiatives are constrained by conditions at the systemic level.

The constraints that prevent firms from enhancing capabilities through learning are broadly categorized as:

- First, a market failure to deal with information asymmetry and uncertainty (risks) for investment in knowledge, amongst others.
- Second, coordination and systemic failures to deal with the mismatch of policies to tackle the lack of effective collaboration or interaction among the system's different stakeholders. For instance, lack of access to financial resources, difficulties in accessing the market due to inadequate physical and institutional infrastructure and lack of sector-specific public goods (infrastructure, institutions, standards etc.).
- Third, the transformative failure which is absent from long-term strategies or standard plans. For example, lack of government capacity to develop a long-term plan and mobilize actors and resources at a systemic level to change firms' path-following dependent behavior. However, it is also true that firms are more inclined to change habitual behaviors as a reaction to market demand.

3.2 The operational context of the mining supplier development program

The geographical proximity between user and producer of technology (Lundvall, 1992) provides opportunities for learning about cutting-edge technology in addition to generating employment and economic gains. However, as the NLS illustrates, if local firms do not have the absorption capacity or succeed in acquiring the necessary capabilities, learning will not take place and many local firms will continue to just provide basic services and inputs. Thus, geographical proximity of local supplier to mining operation can be an advantage that potentially provides opportunities for building up capabilities at the local level if appropriate institutions and policies are put in place.

Based on the literature in the previous section, efforts to enhance conscious (active) learning should be made systemically at the national level, providing necessary investments in infrastructure (legal, social and economic) for firms to upgrade absorption capacity.

Urzúa (2011) describes that learning opportunities and technological upgrading arise from the interaction of two set of factors:

1. Industry-level factors, which define the potential of innovation and active learning opportunities and that is shaped by the scale of the operations, the industrial organization of the industry and technical challenges faced by industry; and
2. Micro-level factor, which are the array of actions and efforts that firms perform in order to increase learning and innovation capabilities.

Urzúa (2011) recommends some policy measures to enhance learning and innovation process, such as:

- Policies that encourage both local and international mining companies to strengthen their internal technological capabilities and innovation activities in developing countries, and to engage young professionals in challenging roles.
- Policies that encourage international knowledge-intensive mining suppliers (KIMS) to make greater use of their projects and operations in developing countries and elsewhere as part of training programs for local professionals.
- Policies that take advantage of the interaction with large users to engineer and design tailor-made solutions to address local challenges that can be tested in real operations.
- Policies that encourage universities and research centers to develop stronger alliances with large KIMS suppliers and mining companies as a basis for much more extensive collaborative graduate and postgraduate programs
- Policies that encourage more knowledge-rich relationships in KIMS supply chains.

Both programs studied, "World Class Supplier Program" in Chile and "Developing Suppliers of Excellence" in Peru, use similar incentives and aim to support long term active learning trajectories of knowledge-intensive mining suppliers by working in collaboration with large mining companies.

However, while the programs have led to some achievements –over 100 collaborative innovation projects have been developed and around 20% of them have been successful– the scale and impact of them have not been able to deliver the full learning and innovation potential the suppliers sector to the mining industry, which can support a broader structural change of the economy.

According to Navarro (2015), in Chile the "World Class Supplier Program", (WCSP) despite of several achievements, faces challenges to grow over time to meet its goal of generating exports from participant suppliers worth US$ 4 billion by 2035. Bravo-Ortega & Muñoz (2015) emphasize how supplier-centered programs have improved knowledge of the structure and needs of this sector in Chile. They describe how supplier participation in R&D intensive activities remains low, leading to a situation where many suppliers have a low capacity to develop technological solutions.

By comparing the Chilean and Peruvian programs, Molina (2015) argues that in the Chilean case, the involvement of the government through its economic development agency CORFO and Fundación Chile might enable to expand the WCSP to the entire sector. He further suggests the deepening of partnerships between technologically-capable universities and industry as these are still considered lacking both in terms of collaboration as well as in capabilities.

While the program addresses relevant challenges, the existence of barriers is reported to be hindering stakeholders from taking actions towards learning and capacity-building. This study, therefore, tries to identify the barriers that are holding back stakeholders from taking the actions intended by the respective program.

4. Methodology

In order to identify the barriers that prevent firms from fully participating in the programs to enhance the capabilities of mining service and input suppliers, semi-structured interviews[5] were conducted with key stakeholders in the sectorial innovation system. These are: i) Mining firms; ii) Supplier firms; iii) University or research centers; and iv) Experts involved in the mining sector and in the program. The interviews were conducted from May to June 2016 in person as well as via skype-calls. A semi-structured interview format was used to collect information in a uniform manner for the ease of analysis (see Appendix 1) while remaining sufficiently open to explore understandings regarding the barriers. As a result, 35 interviews were conducted (list of interviews by type of person in Appendix 2).

The main objective of the semi-structured interviews was to identify the main challenges and bottlenecks that both programs (Chile and Peru) face in order to grow and escalate.

By 'escalating' we mean:

I. **Number of collaborative innovation projects:** Increase the number of collaborative innovation projects (co-innovation) between mining companies and suppliers.

II. **Balanced innovation portfolio:** Widen the scope of innovation projects to include a higher share of complex initiatives (technological challenges) in the innovation project portfolio.

III. **Accelerating innovation:** Accelerate innovation processes, reducing time-to-market of innovations.

IV. **Increase exports:** Increase the number of suppliers that export newly-developed goods or services.

V. **Diversification:** Increase the number of suppliers that diversify their client portfolio to other industries.

Although most of these five points are intertwined, they were addressed separately through different questions in order to identify common trends without losing specific information.

The method of semi-structured, open-ended questions was chosen to gather competing hypothesis about barriers and obstacles that hinder the programs' escalation without a set of preconceived notions coming from existing literature. This follows the mixed methods, partially adapting the logic of grounded theory (Strausse & Corbin, 1998), which uses exploratory research to formulate hypothesis. The grounded theory approach does not use theory to identify the issue for inquiry prior to the query. It tries to identify the hypothesis based on information from interviews. This study, however, uses partially theoretical understandings to outline the important questions to address and the results of interviews are cross-references with the information obtained

5. Interviews were carried by the researcher and also by a student of Mining MBA of the University of Chile (2016), given the access this group have to executive of large mining companies.

from the literature. In grounded theory, validation of evidence does not follow the logic of statistical inferences. Instead, it follows the logic of saturation, or repeatedly getting a similar answer as the selection of interviewees did not conventional random sampling methods, the saturation is applied as the means of validation.

Once the information from the interviews was collected, it was used to identify the barriers obstructing the success of the program. Barriers were defined when they hindered the achievement of the following objectives:

1) Increase number of collaborative innovation projects
2) Increase the share of complex innovative projects (balanced portfolio of innovation)
3) Reduce the time-to-market of collaborative innovation projects
4) Increase exports to new markets and new clients

Although the questions in the semi-structured interviews were asked in general terms, prior to conducting the interviews, the interviewers discussed the following points:

- **Mining companies:** The capabilities, resources and behavior of big mining companies that affect the scalability of the program. For instance: risk aversion to using new technologies, high costs of pausing mining operations to test new solutions, closed mode/culture of innovation.
- **Suppliers:** The capabilities, resources and behavior of the firms that provide goods or services to large mining companies. For instance: lack of managerial skills to commercialize innovations, deficient technological skills to develop quality goods/services, low number of mining supplier start-ups.
- **Universities, laboratories and research centers:** Availability, accessibility, capabilities, resources and behavior of the regional and national organizations focused on producing high-skilled human capital and scientific and technical knowledge. For instance: focus mainly on academia, lack of specific human capital formation knowledge/skills, lack of laboratories or specialized equipment, technology transfer deficiencies.
- **Physical and institutional infrastructure/government policy:** Availability, accessibility and quality of: (i) General infrastructure, such as roads, ports, energy, airports or connectivity; (ii) Human capital pool features, such as size, composition (high/low skill), and specific knowledge (particular technologies, innovation management); iii) Government capabilities for setting standards and norms, to enforce regulations, timely provision of public goods; iv) Financial instruments for risky projects, venture capital, seed capital and public funding.
- **Markets and interactions:** Barriers or obstacles (market or systemic failures) that hinder required interactions among stakeholders. For instance: information asymmetries about innovation projects between firms and investors cause

higher perceived risk for the investor (therefore higher credit costs), lack (or perceived lack) of complementary knowledge between scientific institutions and companies produces few university-industry linkages, small potential market for complex and high-cost mining innovation projects reduces willingness to participate, monopsony power of mining companies reduces expected returns on investments of suppliers, high-cost of screening new potential suppliers make it efficient to stick with incumbent suppliers.

The information samples and type of information collected were not randomly selected; nor were they subject to statistical analysis to infer logic. However, basic counting methods were applied following the logic of saturation in grounded theory.

5. Description of cases studied in this paper

5.1. Supplier development programs in Chile and Peru

This section briefly describes the programs which are the subject of this study, the "World Class Supplier Program" (WCSP) in Chile and "Developing Suppliers of Excellence" program in Peru. The program in Chile began in 2009 while Peru's program is still in its early days. It is noteworthy that the Chilean program was followed by the development of the *Programa Nacional de Minería Alta Ley* (National Mining Program - High Grade) in 2015. This program is a core component of the Chilean government's national long-term agenda and is closely linked to WCSP, especially in providing a platform for stakeholder interactions and for the program escalation.

5.1.1 Chile

This section describes in detail our Chilean case study, the "World Class Supplier Program" (WCSP), and summarizes the most important aspects of the more recent *Programa Nacional de Minería Alta Ley.*

The World Class Suppliers Program
Background

Korinek (2013) argued that Chile's comparative advantage does not lie in the promotion of downstream industries (i.e., the further refinement of copper) but rather in enhancing the capabilities of suppliers servicing the mining industry. The suppliers' proximity to the world's largest copper mining operations gives these firms a comparative advantage: "World-class suppliers are defined by their ability to export knowledge intensive services and technology to other mining countries and sectors of the Chilean economy" (Korinek, 2013: 43).

Two specific characteristics of Chile's mining industry are particularly important for the design of the WCSP:

- Innovations implemented by Chilean firms are to a large extent *adaptive*, meaning that existing technologies are adapted to the Chilean context instead of the development of entirely new technological solutions (see Eyzaguirre, Marcel, Rodríguez, & Tokman, 2005.
- Innovation takes place in *close proximity* to mining operations, meaning that solutions have to be developed for problems arising from operations on the ground. This is a niche that global supplier and equipment manufacturers cannot serve or are less interested in doing so.

The WCSP builds on these specific Chilean conditions and aims to make them a competitive advantage by supporting specialized suppliers so that their services become sufficiently competitive to be applied to other mining operations or even exported (Korinek, 2013).

The program (see Box A), in turn, depends on the commitment of mining companies to use their purchasing power to create more demand for innovative business solutions, thus stimulating local companies to enhance their services. This implies a significant change in procurement practices. Formerly, suppliers were expected to deliver standardized goods and services at low cost and in a highly reliable manner. Thus suppliers were not given sufficient incentives to develop creative technological and innovative solutions on their own. Therefore, new procurement practices were designed to bring together mining firms and selected suppliers in order to solve previously identified problems. This potentially creates a win-win situation, in which suppliers can enhance their capabilities and become more technologically advanced, while mining companies can rely on customized solutions for specific local challenges arising in their operations. Apart from encouraging the testing of problem-solving services in real-time operations, the framework of the WCSP also provides support services for suppliers and fosters links with local research institutions (Korinek, 2013). These services were originally provided by consultants and are now part of an open innovation platform run by Fundación Chile.

Box A: Overview of WCSP

- The World-Class Supplier Program was designed to develop new solutions to the operational and environmental challenges faced by Chilean mining companies while strengthening Chilean suppliers.
- The program provides opportunities for suppliers to develop innovative technology that can solve problems for which no solutions are currently available and helps them grow into “world class” knowledge-intensive businesses that can sell their expertise internationally. By doing this, mining companies improve their own performance while helping Chile transform natural resource wealth into social capital for the country’s future sustainable development, ultimately reducing the economy’s dependence on the domestic mining industry for growth.
- With more than 100 innovation projects currently in operation, the Programme is already improving participants’ growth as well as their safety, environmental and labour standards.
- The Programme was developed in close collaboration with the Chilean government and illustrates the potential of successful public-private partnerships.

The WCSP is based on BHP Billiton’s earlier Cluster Program that sought to create more innovation-intensive links between local suppliers in Chile and its own mining operations. In this context, BHP Billiton built on the experience of emergence and development of knowledge-based suppliers that took place in Australia during the 1980s and 1990s when several factors, including interaction between mining companies and suppliers, led to the emergence of world-class suppliers (Barnett & Bell, 2011). In Chile, the company sought to enhance the competitiveness of its own mining operations through the improvement of local supplier capabilities. It began a problem identification and supplier selection process in 2008 that led to the start of five projects in 2009. Then, in 2010, state-owned copper company CODELCO joined the program and Fundación Chile was invited to act as a facilitator to reduce the transactional costs of collaborative innovation projects and decrease information asymmetries, among other activities (Ingenieros del Cobre & Minería, 2014; Korinek, 2013).

Implementation

About a year after BHP Billiton and CODELCO signed the agreement on the mutual development of the world class suppliers program (CODELCO, 2011), the WCSP was launched officially by CORFO and the Ministry of Mining in April of 2011 (CORFO, 2011). This happened in the context of a conference on the development of world class suppliers to the mining industry in which BHP Billiton, CODELCO, CORFO and the Ministry of Mining formalized their cooperation. The objective of the program is to create 250 world class suppliers by the year 2035 (Comisión de Minería y Desarrollo de Chile & Consejo Nacional de Innovación y Competitividad, 2014).

A private non-profit corporation founded in 1976, Fundación Chile joined the initiative as a neutral actor to facilitate the coordination required for collaborative innovation projects. It has taken on several roles including informing suppliers about the challenges facing mining operations in Chile with the aim of reducing information asymmetries between suppliers and the industry. Among the identified challenges are issues relating to the difficulties of mining less accessible copper reserves and higher environmental standards (Cambiaso, 2014; Fundación Chile & VTT Finland, 2012).

Currently Fundación Chile is developing an open innovation platform to support the escalation of the WCSP by selecting suppliers that have capabilities to meet mining companies' challenges; monitoring the collaborative innovation process; and assisting suppliers to obtain financial resources to develop projects, among other services. This platform will also facilitate links between suppliers and expert knowledge, as required, in order to enable collaborative innovation and support supplier growth.

In 2014, Fundacion Chile (2014) published a study on mining suppliers. It found that employees of WCSP participating companies had a higher level of education. Moreover, 50% of these companies export their services compared to 34% of companies not participating in the WCSP program. With regards to innovation capabilities, Fundación Chile found that WCSP participating companies demonstrated far higher capabilities, in particular among micro and small companies.[4]

As of March 2015, 100 suppliers had participated in the program. One of the mayor challenges identified is the implementation of a commercial strategy for the developed solution (Agenda de Productividad Innovación y Crecimiento, 2015). In particular, when a suppliers succeed in the development of a prototype of a novel solution, it faces significant challenges in planning and executing scaling up the solution, including the business model associated to the new product.

National Mining Program High Grade (Programa Nacional de Minería Alta Ley). This program is an initiative of CORFO and the Ministry of Mining, coordinated by Fundación Chile, and is developed within CORFO's portfolio of strategic programs. The main objective is to strengthen the productivity, competitiveness and innovation of the Chilean mining industry and its suppliers. The initiative was outlined in an analysis by the *Comisión de Minería y Desarrollo de Chile* (Chile's national mining and development commission) together with the *Consejo Nacional de Innovación para la Competitividad* (CNID, or the national council of innovation for competitiveness in English). They presented their report "*Minería: Una plataforma de Futuro para Chile*" ("Mining: A future platform for Chile") in December 2014 to President Michelle Bachelet (Comisión de Minería y Desarrollo de Chile & Consejo Nacional de Innovación y Competitividad, 2014). The Program itself was launched on 15 January 2015 in Antofagasta and it has been divided into technological streamlines (foundry, refinery, tailings, hydrometallurgy, concentration of minerals, planning and mining operations) and enabling conditions (human capital, suppliers, R&D, infrastructure, institutions). It supports a series of initiatives and projects, some of which have already been described above:

1) **The WCSP:** High Grade aims to escalate and consolidate the WCSP. Based on experience gained since its inception, the work of the WCSP is organized on four pillars: (i) Strategic challenges; (ii) WCSP2.0; (iii) Incorporation of medium sized mining; and (iv) Research centers[6].

2) **Human capital:** The program aims to increase the number of skilled people or professionals working in the mining industry to 600 individuals within three years. At the moment, there are 350 highly qualified researchers in the mining industry. This part of the program is supported by CONICYT[7].

3) **Roadmap mining 2035 (Hoja de Ruta de la Minería 2035):** This roadmap seeks toidentify opportunities, requirements for R&D, and the challenges to generate technological capabilities and a technologically-upgraded suppliers sector. Additionally, this initiative aims to establish a common perspective and consensus among mining companies and suppliers. Certain areas have been prioritized based define the need for human capital, R&D infrastructure and technology (Fundación Chile & CORFO, 2015).[7]

4) **Study of mining suppliers:** The program also supports Fundación Chile's studies on mining suppliers mentioned in the previous section on the WCSP (Fundación Chile Innovum, 2012, 2014). The WCSP has a commitment to continuous improvement.

5) **Entrepreneurship:** The program seeks to maximize innovation, technological development and knowledge in the entire ecosystem of the industry. For that purpose, entrepreneurship is crucial for the future of the industry. Fundación

6. For more information see:http://programaaltaley.cl/archivo-iniciativas/programa-de-proveedores-de-clase-mundial/ and http://programaaltaley.cl/proveedores/.
7. For more information see: http://programaaltaley.cl/archivo-iniciativas/capital-humano/.

Chile supports this goal through its entrepreneurship platform *emprendeFCh*[8]. In this framework, the program *Think Big Mining*[9] was created, which seeks to attract and support initiatives through open tenders for entrepreneurs that offer innovative solutions. This program is financed through agreements between Fundación Chile, CORFO, the International Development Bank (IDB), the Ministry of Mining and the sponsorship of Engie, a French multinational electric utility company.

5.1.2 Peru

Developing Suppliers of Excellence for the Mining Industry

In 2012, the program "Developing Suppliers of Excellence for the Mining Industry" was launched by the mining company Antamina (owned by BHP Billiton, 33.75%; Glencore, 33.75%; Teck, 22.5%; and Mitsubishi, 10%). The Antamina program aims to overcome communication problems and diminish entry barriers for local suppliers. The program's strategy is to identify and solve High Value Challenges (HVC) in the mining operation in a cooperative relationship with suppliers, who have the opportunity to play a fundamental role in finding new solutions to these challenges. The idea is to create spaces where suppliers and Antamina can co-design solutions. Compared to the supplier programs present in Australia and Chile, the Antamina program has some novelties. For instance, universities are included and interact with clients (Molina, 2015).

The program's first step is for the company to identify operational challenges through interviews with employees from different work areas. Based on the strategic needs of the customer and supplier, and the alignment of those needs with the identified challenges, a list is created of HVCs that need to be solved. In a second stage, these challenges are presented to suppliers and universities. The intention is that suppliers and universities create alliances and work in close cooperation on the design of innovative solutions. Finally, the company selects the solutions which offer the greatest economic benefit and that have the most innovative components.

Three different portfolios have been developed since 2013, with a total of 29 HVC projects, involving 150 suppliers and 10 Peruvian leading universities. Antamina does not receive any direct monetary compensation from the economic gains made by the suppliers but benefits indirectly by operational cost reductions due to the efficiency enhancing solutions developed by suppliers and universities (Molina, 2015).

Three parties have been defined for the execution of this program:

1) **Compañía Minera Antamina:** It is the party which introduces the High Value Challenges (HVC) and invites suppliers to co-design innovative solutions that increase operational productivity, and provides them with assistance to conduct the field tests needed to find solutions.

8. For more information see: http://fch.cl/emprende/hacemos/.
9. For more information see: http://piensaengrande.fch.cl/mineria.

2) **The suppliers:** They participate as the primary actors to find a solution by working with Antamina and have the potential to grow as a result of their involvement, increasing their capabilities and developing new, more sophisticated and exportable products and services.

3) **Country and the industry:** This is a shared value program that generates economic benefits for the mining company and suppliers, together with fostering social value in the country through the development and growth of competitiveness and innovation on the part of suppliers, thus driving replicable solutions in the mining industry.

The program "Developing Suppliers of Excellence for the Mining Industry" can be considered an embryonic version of the WCSP, since it has only been operating for three years and is still mostly dependent on one company (Antamina).

6. Results of semi-structured interviews

6.1 Description of semi-structured interview results

The semi-structured interviews with 32 people in Chile and three in Peru identified a total of 322 possible barriers that hinder the escalation of both programs (WCSP and DSOE). To aid analysis, we grouped these possible barriers into 11 types[10]:

1. **Market failure:** This includes failures such as information asymmetry and lack of protection of intellectual property right.
2. **Coordination/system failure:** Lack of coordination and interaction among policymakers and stakeholders.
3. **Transformative failure:** Lack of long-term strategy and a shared vision.
4. **Path dependence:** This comprises historical behaviors such as lack of innovation culture, lack of trust, risk aversion and uncertainty regarding activities that are different from normal routine.
5. **Lack of financial resources:** Market failure related to the limited access to financial resources to scale up solution and support innovation.
6. **Lack of firm capability:** Lack of capacities and ability to carry out innovations taken into account the entire innovation cycle, from generating and idea up to having a new product and service in the market.
7. **Lack of government capability:** lack of clear government actions or inappropriate policy provisions.
8. **Lack of sector specific public goods:** This comprises public goods such as lack of testing ground, certifications, laboratories and infrastructure that are sector specific (this can also be considered a specific market failure).
9. **Lack of university/research capability:** Lack of research capability along with ability to produce the research and provide services needed by the industry;
10. **Governance and structure of global value chain:** Barriers to entering into global value chain and export markets.
11. **Timeliness:** Significant time to market or market lead time of innovation.

10. For the purpose of linking the interview results into the theoretical discussion, these 11 groups follow literature reviews mentioned earlier. Some of the barriers may belong to two groups. For instance, if the interviewee mentions "the lack of government's long-term vision", this would belong to group 3 and 7. The assigning of the group for each hypothesis was done ex post, after examining all the hypotheses. The assignment of groups was done twice and adjusted after checking whether a similar outcome was obtained according to selection criteria.Please refer to the Appendix for how groupings are done

Due to the reduced number of interviewees, it is not possible to apply statistical inferences to the interview results; however, the frequency in which issues were raised gives a certain indication of the magnitude of its importance. Furthermore, due to the small number of interviews conducted in Peru, the analysis relies heavily on Chilean interviews. However, as the Peruvian program is at an earlier stage than the Chilean one, it is expected the analysis mainly based on Chilean cases may be a useful reference for Peru.

The following section focuses mostly in the Chilean experience and analyzes the barriers by stakeholder and by the different aspects of the program's expected outcome (escalation). The stakeholders are mining firms, suppliers, research institutions and other aspects of the systemic context (physical and institutional infrastructure, government policy and market) were also considered.

6.1.1 Barriers identified in the system

1. Mining firms

- For mining companies, the most frequently mentioned barrier category was "path dependence, lack of trust and culture". The detailed comments under this category include: "lack of innovation culture", "risk aversion", "lack of trust", and "easy profits due to high commodity prices prevent innovation risk".
- Other barrier categories mentioned by mining firms include "coordination and system failure", " transformative failure - lack of long-term vision/plan", and " lack of firm capability".
- Under "coordination failure", detailed comments indicate a misalignment of managerial decisions within mining firms to participate in the suppliers´ development program. This misalignment seems to be caused by "managerial decision-making practices based on key performance indicators (KPI)", which do not include the "positive externalities" of the supplier development program as a source of productivity and to enhance social license to operate. For mining firms, whose incentive mechanism is to focus on profit-making, participating fully in the supplier development program requires either mainstreaming this idea in the managerial decision-making mechanism (i.e. KPI) and/or providing an alternative incentive mechanism to lower the risk averse/non-innovative culture present within firms.
- Detailed comments under the "transformative failure - lack of long-term vision/plan" underline the above view by mentioning the "need for clearer long-term commitment by government to strengthen local capabilities", as well as mining firms' focus on "short-term outcomes" for the business rather than long-term.
- As for the "lack of firm capability", references were not regarding mining companies' technological/innovation capabilities but lack of capacity to manage collaborative relationship with suppliers.

2. Suppliers

- For suppliers, the most frequently mentioned barrier category was "lack of capability".

  Detailed comments under "lack of capability" reveal the skills they claim to lack are most areas: technological, managerial, innovation, IPR management, marketing and collaboration/networking. Some are caused by lack of experience, such as lack of international exposure, identifying mining sector needs and entering new markets.

- One comment worth mentioning in this category is suppliers' lack of scale for obtaining mining firm contracts.

- The second most frequently mentioned barrier categories was "path dependence, lack of trust and culture" and "lack of financial resources".

- Comments mentioned includes shortage of long-term finance for R&D, and one specifically refers to financing for bringing the prototype to market. These conditions re-enforce the "lack of culture" to invest in innovation, cooperation and entrepreneurship among suppliers.

- On a different note, under "the lack of public goods" category, a small group of suppliers commented that the lack of a testing site for their prototype was a problem.

In sum, suppliers' observations of barriers indicate that lack of capability is a major barrier for which improvement measures are still scarce.

3. Universities, laboratories and research centers

- Only two major groups of barriers stood out: "coordination and system failure" and "path dependence, lack of trust and culture".

- Detailed comments under "coordination and system failure" for research institutions indicate the general misalignment and lack of interaction with the public and private sector on productive challenges due to existing incentive mechanisms currently in place for academic research. Other comments support this finding by indicating a historical lack of collaborative mission-focused research and knowledge flow between university-industry and with external laboratories.

4 and 5. Barrier related to government action

- Noteworthy barrier categories caused by "physical and institutional infrastructure and government policy" are due to "lack of government capability, inappropriate policy" and "coordination and system failure". The detailed comments for both categories address government policy shortcomings in creating sufficient incentives for mining companies and suppliers to collaborate on local supplier development. For instance, one comment refers to lack of local regulations to create incentives for local capacity-building and others mention the lack of government subsidies and complementary policies (policy mix) to create incentives. Many comments focused on the inappropriate nature of government interventions and misalignment of other policy incentives (lack of policy mix).

- The major market and interaction barrier categories were "coordination failure" and "market failure". Detailed comments indicate that the current program still needs to address information asymmetry and uncertainties.

The review of barriers suggests a misalignment of incentive mechanisms among the stakeholders. Thus, to succeed the program need to assess this barrier and analyze whether they are tackled and if necessary made the required improvements. At a systemic level, this hinders the overall expected results.

Table #3 Type of barriers by stakeholders in the system

Type of barrier hypothesis	Of which mentioned					Total number Barrier Hypothesis suggested Withineach category	%
	Mining Companies	Suppliers	Universities, Laboratories and Research Centres	Physical and Institutional infrastructure / Government policy and strategy	Markets and Interactions, including market failures		
Market failure	3	8	0	0	6	17	5.3
Coordination /system failure	8	8	13	6	11	46	14.3
Transformative failure	8	4	1	4	1	22	6.8
Path dependence, lack of trust and culture	62	15	12	1	1	94	29.2
Lack of financial resources	8	12	3	7	1	35	10.9
Lack of firm capability (absorptive, technological & managerial)	3	18	4	0	1	34	10.6
Lack of government capability, inappropriate policy	6	2	1	11	4	31	9.6
Lack of public goods at sectorial level	0	5	1	2	1	15	4.7
Lack of university/research capability	1	0	6	0	1	10	3.1
Governance and GVC suppliers relations	4	5	0	0	2	11	3.4
Lack of timeliness; slow administration, results,	2	2	0	0	0	7	2.2
Total	105	79	41	31	29	322	100.0

Source: Authors based on semi-structured interviews, 2016

6.1.2 Barriers by different aspects of expected outcome of the program

The next table looks at how each type of barrier hinders the achievement of the program's expected outcomes. The outcome dimensions are broken down into: i) Number of collaborative innovation projects; ii) Complexity (sophistication) of innovation projects; iii) Time-to-market of innovations; and iv) Scaling up of innovations to new market and/or client.

The specifically mentioned barriers affecting the different aspects of program outcome are described below.

1. Barriers that affect the number of collaborative projects

- The most frequently mentioned barrier categories that hinder the growth of numbers of collaborative innovation projects are "path dependent, lack of innovation culture and trust", "coordination failure", "lack of government capability, inappropriate policy" and "lack of financial resources" among others.

  A detailed look at the 'path dependent, lack of innovation culture and trust' barrier category revealed that many barriers concerned the misalignment of incentives within mining firms and research institutions that oppose the growth in numbers of collaborative innovation projects. For instance, many comments under this category mention that incentive mechanisms do not encourage collaborative partnerships. This may be partly due to 'lack of financial resources' to support collaborative innovation activities, especially for the long-term.

  Suppliers expressed comments on the lack of trial sites for prototype testing and mining firms' excessive governance power on agreeing contract terms as barriers to increasing the number of collaborative innovation projects.

2. Barriers that affect the complexity of innovation projects

- The most frequently mentioned barrier categories that hinder the complexity of innovation project are "path dependence, lack of culture and trust", "coordination failure", "lack of financial resources" and "lack of capabilities".

  The detailed comments on "path dependence, lack of trust" and "coordination failure" reveal a misalignment of incentive structures for both mining firms and research institutions to increase the complexity of technological components. The comments reveal that mining firms take decisions based on firms' incentive mechanisms which do not necessarily coincide with the aim of increasing the complexity of the program's innovation projects. This is because mining companies' risk aversion tendencies stem from the managerial practice of making decisions based on key performance indicators (KPIs); the distinctive firm strategy of conducting R&D in their home country; and no prior practice of purchasing new technology from Chilean suppliers.

  Research institutions also reveal that similar yet different incentive mechanisms exist within universities that suggest a mistrust of working with the business sector (for example the issue of managing IPR) and the lack of motivation to work on productivity issues with industry because incentives are oriented towards academic research.

- The "lack of capability" barrier category mainly concerns suppliers, which lack technological/innovation capabilities, in particular to take prototypes to market. These suppliers have difficulties in building capabilities partly due to the lack of ability to finance long-term projects.

3. Barriers that affect market lead times

- The most frequently mentioned barrier categories for reducing the amount of time it takes to deliver an innovation to market are "path dependent, lack of culture and trust", "transformative failure", "lack of firm capability" and "lack of financial resources".

  For the "path dependent, lack of culture and trust" category, mining firms'risk aversion and lack of collaborative culture with suppliers were mentioned.

  Under "transformative failure", the lack of a long-term strategy, commitment and means to finance innovation were mentioned as the major barriers by all the stakeholders.

  Under the "lack of firm capability", suppliers' skills for forming external networks and linkages as well as experience of bringing prototypes to market and long-term ability to finance projects were mentioned as lacking.

  Under the "lack of financial resources", suppliers mentioned the specific difficulty of mining firms agreeing to mobilize finances in a timely manner (timely payment) to carry out the innovation.

4. Barriers that affect developing new market and/or client

- The largest barrier categories identified under this aspect are "path dependence, lack of culture and trust" and "lack of capability".

  Under "path dependence", detailed comments indicate that mining firms are "risk averse" while suppliers lack entrepreneurial spirit, experience and access to external linkages.

  The "lack of capability" mainly referred to suppliers due to this sector's lack of relevant capabilities to develop new markets and clients. These are: IPR management, entering other markets, packaging solutions and commercialization.

Table #4: Type or barrier with respect to escalation

Types of Hypothesis	Type of barrier with respect of scaling up				Total number of barriers	%
	Barriers that hinder the total number of collaborative innovation projects	Barriers that impede a higher share of implementation of complex innovative projects in the portfolio of the program	Barriers that slowdown the time-to-market of the collaborative innovation projects	Barriers for exporting the newly developed solutions or finding new clients in other industries faced by the mining suppliers		
Market failture	10	2	1	5	18	5.0
Coordination /system failure	31	18	7	5	61	16.9
Transformative failture	10	6	11	0	27	7.5
Lack of culture, trust, path dependence	43	23	25	16	107	29.6
Lack of financial resources	12	13	10	0	35	9.7
Lack of firm capability (absorptive, technological, managerial)	11	11	10	10	42	11.6
Lack of government capability, inappropriate policy	16	6	3	5	30	8.3
Lack of public goods	4	6	2	4	16	4.4
Lack of university/research capability	2	2	4	2	10	2.8
Governance and GVC suppliers relations	5	1	1	1	8	2.2
Slow administration, results, Lack of timeliness	1	1	5	0	7	1.9
total number of causes for each barriers	145	89	79	48	361	100.0
% share by each barrier	40.2	24.7	21.9	13.3	100.0	

Source: Own elaboration

The above analysis describes stakeholder-specific and issue-specific barriers to successfully carrying out the program. It suggests that for the success of these program, the misalignment of incentive mechanisms is hindering the further escalating of the program.

It is not possible to analyze the Peruvian case due to the very limited number of interviews. However, as can be seen in tables 3 and 4, results seem to follow similar trends. The detailed comments also indicate the "risk averse" nature of mining firms and lack of capability (technological, managerial and financing abilities) of suppliers. The research institutions are not interested in working with industry. Overall, coordination failure is mentioned on the whole.

Table #5 The Peruvian Case – Barriers by Stakeholder in the system

Type of barrier hypothesis	Of which mentioned					Total number barrier Hypothesis suggested within each category	%
	Mining companies	Suppliers	Universities, Laboratories and Research Centres	Physical and institutional infrastructure/ Government policy and strategy	Markets and interactions, including market failures		
Market failure	0	0	0	0	0	0	0.0
Coordination/ system failure	0	0	2	0	1	3	13.0
Transformative failure	1	1	0	0	0	2	8.7
Path dependence, lack of trust and culture	3	1	0	0	1	5	21.7
Lack of financial resources	1	3	0	0	0	4	17.4
Lack of firm capability / absorptive, technological, managerial)	0	3	0	2	0	5	21.7
Lack of government capability, inappropriate policy	0	1	0	0	0	1	4.3
Lack of public goods at sectorial level	0	0	3	0	0	3	13.0
Lack of university/ research capability	0	0	0	0	0	0	0.0
Governance and GVC suppliers relations	0	0	0	0	0	0	0.0
Lack of timeliness; slow administration, results.	0	0	0	0	0	0	0.0
Total	5	9	5	2	2	23	100.0

Source: Own elaboration

Table #6 The Peruvian Case – Type of barriers that hinder the escalation

Types of Hypothesis	Type of barrier with respect to scaling up				Total number of barriers	%
	Barriers that hinder the total number of collaborative innovation projects	Barriers that impede a higher share of implementation of complex innovative projects in the portfolio of the program	Barriers that slowdown the time-to-market of the collaborative innovation projects	Barriers for exporting the newly developed solutions of finding new clients in other industries faced by the mining suppliers		
Market failure	0	0	0	0	0	0.0
Coordination/system failure	2	3	0	0	5	13.5
Transformative failure	2	2	0	0	4	10.8
Lack of culture, trust, path dependence	4	2	0	1	7	18.9
Lack of financial resources	3	5	0	1	9	24.3
Lack of firm capability (absorptive technological, managerial)	1	1	1	1	4	10.8
Lack of government capability, inappropriate policy	1	1	0	0	2	5.4
Lack of public goods	0	0	0	0	0	0.0
Lack of university/ research capability	3	3	0	0	6	16.2
Governance and GVC suppliers relations	0	0	0	0	0	0.0
Slow administration, results, lack of timeliness	0	0	0	0	0	0.0
Total number of causes for each barrier	16	17	1	3	37	100.0
% shared by each barrier	4.4	4.7	0.3	0.8	10.2	

Source: Own elaboration

6.2 Underlying factors behind the barriers that constrain the impact of mining supplier development programs

In the previous section we analyzed the interviews examining the barriers by stakeholders and by aspects of expected outcomes of the program in Chile and briefly for Peru. In this section, we attempt to link findings to earlier theoretical discussions. Hence, we break down the barriers into three groups:

1. Barriers related to the supply of knowledge and innovation to the system;
2. Barriers related to the demand for knowledge and innovation; and
3. Barriers related to market interactions.

We are aware that some of the factors here overlap but we believe this classification contributes to clarifying policy recommendations.

6.2.1 Supply of knowledge and innovation

In this section, we discuss the constraints and failures of the system that prevent it from producing the required levels of productive knowledge and innovation. In general, many comments on barriers mentioned in the previous section refer to the poor performance on the provision of knowledge, which restricts the potential growth and development of suppliers.

a. Mining companies:

R&D and innovation shortages: Coordination failures and thin local knowledge pool

A common argument that tries to explain the lack of high-technological development in Chile and Peru's mining industries refers to the scarce level of local R&D and innovation efforts by large mining companies operating in these countries. The lack of local involvement in these activities prevents other scientific and economic agents from engaging with or benefiting from knowledge spillovers. Although the potential gains of developing locally-related scientific knowledge have been reported, specifically in the case of natural resource-based activities, it can be argued that there are not sufficiently high enough incentives for large mining companies to engage more intensively in these activities in the locations that host their operations. Of course, this is not the only explanation. Putting aside the classic explanation of R&D and innovation investment shortages related to appropriability and financial constraints (which is not the case for large companies), the implementation of R&D and innovation activities in host countries has been studied in different MNE industries and these results are useful to understand the observed lack of R&D activities in the countries which host operations.

Indeed, from the MNEs point of view, it is desirable to concentrate R&D efforts in their home countries, targeting research on objectives that can solve global productive challenges that can be applied to operations in different environments. In this way, the cost of R&D and innovation can be spread over a larger base of income sources, increasing their profitability. Furthermore, through this strategy, MNEs minimize the transaction costs of internal knowledge transfer. Therefore, host countries perform marginal efforts that help to adapt technologies to local environments or to solve marginal operational tasks. However, Belderbos, Lykogianni, & Veugelers (2008) note that the availability of local knowledge is a factor that can alter the result of the location of R&D and innovation efforts by MNEs. If local capabilities are high enough, MNEs may invest in R&D in their host countries as a means of increasing their absorption capacities and obtaining access to new knowledge sources. Therefore, incentives for mining MNEs to increase local R&D are influenced by both the potential benefits that research projects can provide the whole company, but most importantly the gains that can be obtained from working with the local knowledge-intensive community. The latter level needs to be high enough in order to also compensate for the transaction costs of developing R&D projects in different locations.

Although large mining companies could benefit from each other by placing R&D facilities in the same region where they operate, aiming to solve common productive challenges, in a collaborative manner, and decreasing the risk of duplication efforts and lowering costs, these cooperative efforts are not observed, giving rise to coordination failures. It is worth noting that these coordination failures may be hard to solve even when new incentives are put in place since the historical component identifies some failure-persistence (Ádsera & Ray, 1998).

b. Suppliers:

Mining suppliers also face market failures and systemic constraints that restrict the potential benefits that supplier development programs can generate. We start by acknowledging that local suppliers are highly heterogeneous not only according to the type of economic activities they perform but, of more relevance to our study, in their productive, innovative and marketing capabilities. We consider that these are the most critical barriers that the system needs to overcome in order to achieve higher levels of development. Even though firms' growth is affected by restricted credit access to finance investments and learning activities, firms first need to have the capacity to detect opportunities, design projects, adopt technologies, develop new innovative products or reach new markets. Therefore, we argue that liquidity constraints are secondary restrictions which only become relevant after firms reach critical capability levels. For the rest of firms, relevant restrictions are related to real production factors.

Capabilities failure

As mentioned earlier in the document, the basic capabilities required are related to firms' learning capacities. Although we are not suggesting that all firms need to follow a common path to developing high technology skills, we acknowledge that the capacity to discriminate between suitable technologies and practices, together with the application of efficient methods of production and service delivery, are the basic requirements for a firm to accomplish. Currently, market mechanisms allow for the existence and survival of firms with low productivity levels.

The lack of certain productive capacities that impede firms from achieving higher productivity levels can be seen. Among them, restricted access to better managerial practices and superior technological methods constrain these firms into low technology problem-solving routines that, in the best case scenario, are slowing down the learning process.

In some cases, firms that master productive methods may lack innovative capacities. In this sense, some suppliers may have an efficient production model that is restricted to current products and marginal improvements. The capacities needed to develop new products or processes require high levels of internal knowledge, engineering expertise and innovation routines that cannot necessarily be endogenously overcome. The availability of better quality production inputs, specifically advanced human capital, plays a role in closing the knowledge gap. However, the latter is not necessarily available in the local labor market. At the same time, suppliers' senior management decisions define, to some extent, the observed technological frontier that the firm can reach. When senior managers are shortsighted in the technological space, suppliers may remain at profit-creating suboptimal technological levels.

Finally, other suppliers are capable of creating innovative solutions for mining companies but show weakness in their capacity to market their developed innovations on a larger scale. Here we are referring to suppliers' capacity to create new business lines, markets or models enabling firms to exploit, to a greater extent, the innovations introduced for the local mining industry. This capacity intersects with the need for proper management of intellectual property rights. However, it also includes the commercialization of products, such as services, that are less suitable for protection through formal mechanisms. The capacity to develop new service lines to attend different customers and other markets is crucial for innovation-driven suppliers' growth.

The existence of these capabilities failures translates into firms trapped in low-technological development paths that hinder the type of solutions and products that can be provided to local mining companies, and the leverage to be obtained from the created knowledge to diversify products, customers and markets.

Frictions in access to credit

In the case of firms that have the capacity to detect suitable technology upgrades and the type of knowledge that needs to be incorporated, or to design a highly profitable R&D and innovation project, funding is certainly an enabler that can drive technological development and firms' growth. As has been widely studied, innovation-related investments are subject to more pronounced market failures that cause higher restrictions to a desirable innovation strategy. The latter is even more relevant for SMEs, which do not have sufficient internal financial resources. Current development of innovation-oriented financial markets, including public support, is at an early stage. Administrative costs, the size of the loans and/or subsidies and the cost of the credit, particularly when collaterals are restricted, further impacts suppliers' credit constraints.

Credit constraints are also a critical obstacle for the entry of new firms to the market. This case is particularly relevant for new high-tech firms which are usually capital-intensive and therefore face large entry costs. Furthermore, the type of financial instrument that a supplier may need depends on firms' orientation. While venture capital and early-stage funding are needed to support the emergence of new mining suppliers, credit and regular loans are needed for innovation and R&D and innovation projects which will also vary according to how close a project is to market (from research to piloting), while private equity may be the required instrument to accelerate a company's growth stages. Indeed, the collaborative nature of innovation in the knowledge-intensive segment of mining suppliers brings new challenges to financial instruments. The latter will be developed in the following subsection.

c. Universities and scientific organizations

Scientific production is considered a precondition for further technological development in the industrial sector. Mining suppliers are not an exception. There are potential benefits from interaction between the private sector and universities and, furthermore, the involvement of universities in the provision of certain services to industry that go further than just the provision of human capital. The evidence from the interviews emphasizes the missing linkages between scientific institutions and the mining industry in general, and particularly with mining suppliers. This may have much to do with existing incentive mechanisms within universities.

Extreme focus on academia: Externalities not incorporated

We argue that the main obstacle to increasing the involvement of local universities and scientific institutions in the mining sector is that these institutions, particularly universities, have not incorporated the positive externalities relating to public welfare that linkages between science and industry produce. Currently, the normal business model of universities, both public and private, is based on increasing income from tuition fees, and for those that also conduct research, increasing publications and the academic citation impact. In this context, research conducted with or for the mining industry can be seen as a source of extra income but not necessarily of value for academic research output. Requirements to protect new knowledge, valued by the industry, can make this type of collaborative project less attractive to universities.

Furthermore, even if universities decide to participate and engage more intensively with the industry through external R&D projects, collaborative research or technology transfer activities, it will remain a principal-agent problem. Normally, university academics pursue academic career paths that do not necessarily benefit from work with the private sector in unpublished research. Therefore, there is a contract problem in which incentives to increase linkages with industry need to include the social benefits of these activities.

6.2.2 Demand for knowledge and innovations

Although mining suppliers can also act as buyers of innovative capital goods or technical services, we concentrate the analysis on what has been commonly mentioned as the opportunity that mining countries have to drive high-tech economic growth. In this context, the large purchasing power of local mining companies can act as an accelerator of firms' development by demanding high-technological solutions for their innovation processes. Even though this has been the main justification for creating suppliers' development programs, the feasibility of the mechanisms through which these opportunities can be brought to fruition has not been properly explored. Here, we put forward the two main constraints that restrict the success of this model.

a. Mining companies

Externalities not incorporated in buying decisions

One of the most frequently mentioned barriers in the semi-structured interviews is regarding the characteristics of large mining companies' decision-making processes. This argument refers specifically to these companies' risk-adverse natures, leading them to be essentially less willing to engage in relationships with new suppliers and less likely to incorporate new technological developments. However, the roots of observed risk-averse procurement decisions are related to the high cost of pausing operations to try and incorporate new untested technological solutions. As reported in Navarro (2015) and Bravo-Ortega & Muñoz (2015), huge losses are estimated from mining plant suspensions, therefore encouraging a conservative approach to minimize potential losses. In this regard, large mining companies adopt a strategy of continuous marginal improvements rather than radical changes to the production process. Whether the circumstances described above is a situation that requires government intervention is a matter of debate.

On the other hand, the technological development of the locality or country where large mining companies are located is not only perceived as something desirable for governments but is also highly correlated with higher welfare levels and rising living standards of the host population. These benefits are not incorporated into large mining companies' decision-making processes. Thus the key obstacle to escalating supplier development programs is more closely related to the fact that the positive externalities of mining regions' local technological development are not internalized in the evaluation process. Indeed, a valuation of the programs' benefits by local procurement departments could create new incentives to promote linkages with more and new local providers. The programs studied in this paper have tried to solve part of this market failure through engaging large mining companies to consider some of the social gains in their decision-making processes. The increasing number of collaborative innovation projects that the programs have driven suggests that some of the societal value produced by local linkages is incorporated by program participants. Whether the current "partnership" approach is enough to produce a sufficient number of incentives to close the gap with the social optimum, or only acts as a marginal incentive, is still a matter of debate and unfortunately we do not have enough information to determine this.

Principal-agent problem

Furthermore, even when mining companies include the positive externalities of local technological development in their procurement and innovation strategies, an additional obstacle still remains within firms. In particular, the principal-agent problem exists in the programs' current development stage. In this case, senior managers and directors of mining companies may support supplier development programs but procurement and operational decision-making is performed at a lower administrative level where incentives may not necessarily be aligned with the view of senior leaders. Indeed, currently, pecuniary incentives to mid-level procurement managers are more related to efficiency gains than rewards for engaging in new local solutions. The review of large mining companies' contract mechanisms needs to be addressed in order to drive supplier programs to a higher development stage.

6.2.3 Market interactions:

Even if demand and supply of innovation reached higher, perhaps "optimum" levels, the nature of the market in which these firms operate present other challenges that need to be resolved to increase the impact of supplier development programs. The main goal of the programs studied here has been to tackle the consequences of these market failures.

Coordination failures

The interactive nature of innovation projects between mining companies and suppliers requires co-innovation activities in which both parties actively engage in innovation. Assuming a traditional view of product-development processes, both parties face a common constraint on getting to the testing and prototyping stage, which is the high cost of pausing mining operations to test newly developed solutions or the large potential loss incurred from incorporating an untested productive solution. This situation is shared by large mining companies and high-tech suppliers. The costs involved or the size of the potential loss, together with the number of potential beneficiaries, would make an insurance market unprofitable that could cover innovation or co-innovation projects in case of operational losses. Despite that both programs aim to provide real operational environment to test prototypes, frequently these activities are hard to coordinate. However, there is room to combine the willingness to pay of mining companies and suppliers to provide the missing real scale "labs" or testing facilities in this market. The absence of this causes suppliers and buyers a loss of innovations, profit and productivity gains.

Asymmetries of information

Co-innovation projects between large mining companies and mining suppliers are also subject to market failures as a result of information asymmetries. As explained earlier, large mining companies' focus on loss avoidance leads them to take low-risk decisions when assessing and buying from new suppliers. When new entrants arrive, or suppliers develop new products, there is an information asymmetry between the supplier and the buyer. In these cases, the latter tends to base decisions on reputation rather than, for example, the actual suitability of technological solutions for its operations, thus hindering suppliers' growth. Although solving this transaction cost is desirable for both buyers and suppliers, there is a lack of adequate market signaling instruments that can help to smooth these frictions.

On the other hand, the needs and productive challenges faced by mining companies are not necessarily known by the suppliers, who might be able to provide a solution. This impedes a transaction that would be mutually beneficial to both parties.

7. Discussion and conclusions

As stated earlier, the public sector –and in particular the private-public partnership model (PPP)– has a larger role to play in enhancing productive and technological development, while public policy should also address the demand side, or market incentive, by making it the active ingredient of the policy package. In order to formulate balanced public policy, it is pertinent to explore new ways to coordinate the program's public and private efforts in order to identify improvement areas.

This paper has explored the question of how to enhance supplier development programs by looking at two supplier development programs in Chile and Peru and attempting to understand the challenges these programs face to achieve their goals. Due to data accessibility, the case of Chile is examined in more detail than that of Peru. Based on interviews conducted with key stakeholders, the paper identified barriers by each stakeholder and by each aspect of the programs' expected outcome.

The results reveal that many barriers are related to path dependency, mistrust and risk avoidance as well as the lack of capability and financial resources.

In addition, the findings indicate that many barriers are due to the misalignment of existing incentive mechanisms within stakeholders' operating environments. As the demand side approach is largely led by societal goals via mobilizing market forces, it is pertinent to identify the areas where the public and private sector can cooperate so that incentives can be better aligned towards the desired goal.

The world class supplier development program is one of the few demand-side policy measures implemented in Chile with the leadership of BHP Billiton and Codelco. This program provided a solution to the initial stage of information asymmetry –"market failure" – by identifying and coordinating information on technology supply and demand using Fundación Chile as intermediary accelerator platform of collaborative innovation projects.

Currently, the program is facing restrictions to escalate further. The interview results lead us to consider that this is partly due to the misalignment of incentive mechanisms which do not encourage mining firms to buy and collaborate with local suppliers; at the same time, suppliers are not investing in capability-building due partly to financial shortages. This misalignment may be caused by undervaluing the program's gains and cost from externalities, or its contribution to societal welfare.

Both the private and public sectors can benefit from the program; however, as each stakeholder has a different set of incentive mechanisms, the cost-sharing mechanisms are not articulating and encouraging stakeholders to work together. Hence, further work is required to understand the different incentive mechanisms. This may involve evaluating the programs' positive externalities –capability development of local industries, employment generation and impact on local economy, to name a few– and to correctly share the costs among the stakeholders that benefit from positive externalities.

For instance, a new incentive mechanism should be considered to lower the short-term cost for the mining sector of being a 'lead user' by creating some kind of insurance mechanisms to lower risks. Likewise new incentive mechanisms could be considered for universities. Both legislative as well as financial means can be applied to change the behavior of research institutions with regards to their involvement in productive activities.

The program aims to enhance firms' learning processes to strengthen production, imitation, absorption, technological and innovation capabilities so that the program can be expanded in terms of numbers, complexity, efficiency (market lead time) and extensions to new markets and/or clients;

- Below are some of the examples considering the interview results on mechanism to overcome the potential barriers:
- Establish Technology Transfer Office (TTO) for in- and out-licensing, venture capital fund to encourage new entrants.
- Strengthen university-industry linkages, creating university mining chair or mining- focused industry-university personnel exchange programs. Provide specifically-targeted funds to university-industry research on topics of interests for mining firms.
- Develop better incentive mechanisms in universities to encourage academics to work for productive development in Chile and elsewhere.
- Build mining equipment test site, a type of public laboratory.
- Create common financial scheme or revolving fund (long-term) for sector-specific technology development fund audited by public and private representatives.
- Continue Road Map activities and make the long-term goals more clear and align the different efforts and program with the road map aiming to avoid fragmentation.
- Create incentive mechanism and regulation (particularly mining FDI) packages (policy mix) that focus on technological upgrading.

While practical application of these policy tools and practices is present in Europe and the US for knowledge-intensive sectors such as the pharmaceutical and biochemical sectors, these are not being fully explored for the extractive industry. The previous study (Urzúa, 2011) suggested the above policy tools might be feasible for increasing the knowledge intensity of mining service suppliers; however, the preparation of appropriate interventions for the sector would require practical insights from mining companies. From this perspective, the "World Class Supplier Program" (Urzúa, 2011) in Chile and "Developing Suppliers of Excellence" in Peru offers interesting experimental experience to identify the required policy instruments to further enable private-public partnerships.

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Appendix

Appendix 1

In the semi-structured interviews we asked the questions below.

Finding hypothesis:

- In your view, what are the main barriers or problems that hinder the total number of collaborative innovation projects of the PROGRAM (i)?
- In your view, what are the main barriers that impede a higher share of implementation of complex innovative projects in the portfolio of the PROGRAM (ii)?
- In your view, what are the main constraints that slowdown the time-to-market of the collaborative innovation projects (iii)?
- In your view, what are the main obstacles faced by mining suppliers for exporting the newly developed solutions or finding new clients in other industries (iv)?

Appendix 2

Analysis of information obtained from the interview.

Open-ended hypotheses were listed in an excel sheet and subsequently groupings of hypotheses were identified by going through the list various times to link hypothesis with existing literature. To ensure the replicability that is essential for the scientific research, the list of hypothesis as meta data and how this was grouped is attached inappendix as the chain of evidence.

In order to discover the real causes that hinders the successful escalating of the program, the questionnaires are asked to key stakeholders. The identification of groups follows the logic of grounded theory (Strauss and Corbin, 1988), which is exploratory methodology to formulate hypothesis. The grounded theory approach does not use theory to identify the issue for inquiry. This methods simply tries to observe the reality without a set of preconceived notions.

Grounded theory is pragmatic in choosing alternative strategies of inquiry and enabling a mix of quantitative and qualitative data to shape and view reality in multipledimensions, answering the queries that arise during the process of inquiry. The grounded theory approach does not use theory to identify the issue for inquiry. This paper applies the mix methods, hence the result of exploratory search for the hypothesis is triangulated with the theoretical approach. In grounded theory, validation of evidence is not done by statistical means but follows the logic of saturation, namely the repetition of similar answers.

The semi-structured interviews conducted with stakeholders of the supplier development program follows this logic. To undertake exploratory hypothesis-building, choices based on theoretical understanding were not given initially to the interviewee. Instead, the collected answers were analyzed based on saturation and the theoretical framework established in the literature review.

Description of the information obtained from semi-structured interviews:

From interviews with35 stakeholders, a total of 322 different views were obtained on potential 'barriers' that hinder the success of the supplier development program. These 322 hypothesis were grouped into 11 groups based on the similarities of the view expressed.

Type of stakeholders

Government-Public Sector	Juana Kuramoto, Claudio Maggi, Mauro Valdés
University/Academia	Lilia Stubrin, Claudio Bravo, Patricio Meller, Lucas Navarro
Research Centers	
Mining Companies	Enrique Alania, Osvaldo Urzúa,
Suppliers	
International Institutions	Claudia Suaznabar
Others	Christian Schnettler, Andres Pesce, María José Araneda, , Pamela Chávez, Rolando Carmona, Expert2, Sergio Flores, Christian Cifuentes, Ronaldo Monsalve, Esteban Galvez, Óscar Beltrán, Paula Quiroz, Manuel Mardones, Alvaro Lavalin, Miguel Espinoza, Jorge Gomez, Silvia Lagos, Felipe Cordero, Raul Nalin, Horacio Meneces, Carlos Villa, Enrique Silva, Rubén Muñoz, Gino Brunetti, Jonathan Castillo

Appendix 3

Coding of the Hypothesis

Below shows how hypothesis were grouped to ensure the replicability of methods.

Type of barrier/categorization (1=market failure which includes information asymmetry; 2=coordination/system failure includes lack of interaction; 3=transformative failure, lack of long-term vision; 4=lack of culture for innovation, path dependence; 5=lack of financial resources; 6=capability of firm (technological absorption, management), 7=capability of government (policy, inadequate); 8=lack of public goods provisions; 9=lack of capability university; 10=governance and GVC suppliers).

Hypothesis Code Hypothesis

Choice made

01	0401	Suppliers are not adequately informed about problems (communication problem)	1
02	0402	Insufficient capabilities of mining suppliers	6
03	0403	No culture of collaborative work, suppliers came with solutions by themselves	4,2
04	0404	Mining companies are reluctant to allow prototype testing	4
05	0405	The mining industry is very risk averse	4

01	0501	The main barrier for suppliers is technology and IPR management	1
02	0502	The operation division within mining companies tends to favor foreign suppliers (as opposed to the corporate cluster development division)	2,4
03	0503	The program lacks flexibility to deal with a dynamic industry	7
04	0504	For suppliers, R&D investment requires some assurance that the mining company will purchase their services	10

01	0601	University training for technical professionals is too theoretical but the labor market demands a more practical orientation	4
02	0602	R&D budgets are comparatively small	5
03	0603	There is a lack of coordination between the public and the private sector	2
04	0604	There is no consensus on a national vision for innovation (systemic and coordination failures)	3
05	0605	Suppliers would find it easier to export their products/services if Chile's mining business had a better reputation concerning its quality	8

01	0701	Mining companies lack a culture of innovation	4
02	0702	Lack of corporate venture capital funds	5
03	0703	Mining companies are too risk averse	4
04	0704	Suppliers lack management skills for innovation	6
05	0705	Suppliers do not have sufficient trial spaces on site	8
06	0706	Suppliers face very long sales cycles in mining companies	11
07	0707	Academia lacks coordination with public sector to focus on productive sectors products	2
08	0708	Academia is oriented to publishing instead of patenting	4

01	0801	Mining companies mainly hire suppliers with proven background	4
02	0802	Academia is in general not aligned well with productive challenges	2
03	0803	Lack of incentives for universities to work with the private sector	2.7
04	0804	Suppliers lack access to real scale mining facilities	8
05	0805	Academia finds working with mining companies too complicated	4
06	0806	Mining companies are risk averse and have an aversion to change suppliers	4
07	0807	Suppliers lack knowledge of IPR management	6

01	0901	Mining companies are too risk averse	4
02	0902	Mining companies have performance agreements focusing on efficiency gains which disincentives hiring new suppliers	4
03	0903	Mining companies conduct R&D in home countries	4
04	0904	Universities lack a focus on patenting and working with the industry	2.6
05	0905	Lack of regulation that encourages increasing the local content share of the mining value chain	7
06	0906	Lack of facilities to test prototypes and innovations at a "real" scale	8
07	0907	Information asymmetries between mining companies and suppliers (no good instruments that can work as "signaling" of the quality of suppliers)	1

01	1001	Mining companies lack of capabilities (know-how) to manage a portfolio of collaborative innovation/learning projects	6
02	1002	In mining companies there is a pre-eminence of transactional procurement processes	4

03	03	Supplier development approach pursued by mining companies used to be seen as RSE, not part of the business	4
04	1004	Risk-adverse culture, in particular regarding incentive to carry out innovation/learning at the local level	4
05	1005	In mining companies investment project contracts do not allow the use of non-proven technology	4
06	1006	Mining companies do not perceive collaborative innovation/learning projects as a strategic effort	2,4
07	1007	Traditional business performance indicators (KPIs) and also executive KPIs do not take into account collaborative innovation/learning program	2,4
08	1008	It is really hard to make a business case if there is not a clear long-term commitment aimed at strengthening local capabilities as a source of productivity and business performance	3
09	1009	Suppliers lack of a long-term strategy to do innovation/learning	3
10	1010	Suppliers lack capabilities to carry out innovation. In particular, the final stage to scale up innovation to industrial scale	6
11	1011	The strategies of International OEM suppliers do not consider innovation/learning at local level	4,10
12	1012	Lack of professional capabilities in supplier's boards to maintain long-term views or strategies	
13	1013	Lack of capabilities and know-how to do at international level (but also at local level) alliances, partnerships or collaborative efforts with firms or organizations that have supplementary capabilities	2,6
14	1014	Suppliers have no capacities, deal flows or work capital to sustain long-term efforts. All capacity is consumed by the short-term	3, 5, 6
15	1015	Suppliers lack entrepreneurial spirit	4
16	1016	Misalignment between industry interest and R&D centers 'hinders set-up of collaborative and mission-oriented innovation/learning projects	2
17	1017	Shallow University- Industry relationship. Firms do it as RSE and university just for funding or some sort of endorsement to apply for public funding	2
18	1018	Lack of process to transfer knowledge from university to inform innovation processes	2
19	1019	There is no incentive in universities to innovate (researchers just seek to publish)	4
20	1020	Mistrust and reluctance to have business oriented projects	4
21	1021	There is a gap of engineering and design capabilities. The gap will be filled by bridging universities and private sector	2
22	1022	People in academia have not received training on how to innovate	9
23	1023	Lack of long-term policies to enable long-lasting efforts	3
24	1024	Reluctance to define strategic targets (in collaboration with the industry) and set up long-term programs (Industrial policies)	3,2
25	1025	Lack of infrastructure to carry out innovation piloting and industrial scaling up	8
26	1026	Lack of financial instruments to support innovation process and in particular portfolio	5

27	1027	Subsidies or government support have design failures	7
28	1028	There is no link (incentive) between FDI attraction and building local capabilities	2
29	1029	Weak connection with the local stock market and institutional investors	2
30	1030	Asymmetries of information	1
31	1031	Coordination failures, which increases transactional costs	2
32	1032	Parliamentarians, think tanks, policymakers have vague understanding of the technological potential of the mining industry	7
33	1033	Barriers related to the structure of global value chains. In particular value chains governed by few OEMs	10

01	1101	Lack of positioning of the program as a core activity	4
02	1102	Origin of the program as a RSE activity (it's nice to have it)	4
03	1103	Seen by other mining companies as a marketing initiative	4
04	1104	Mining companies do not see the return of their investment	4
05	1105	Not enough projects to nurture a pipeline	7
06	1106	Incentive scheme (KPI) for employees oriented toward volume	4
07	1107	Asymmetry in the relationship with suppliers	1.10
08	1108	Risk aversion as part of the culture	4
09	1109	Transactional dominance of interactions and short-term view	5
10	1110	Misunderstanding on the meaning of innovation and technology-based entrepreneurship	4
11	1111	Lack of management skills for innovation	6
12	1112	Program seen as an avenue to sell to mining companies without innovation effort	7
13	1113	Asymmetry in the relationship with mining company	1.10
14	1114	Lack of trial spaces at site	8
15	1115	OEM does not consider local suppliers for innovation or learning at local level	10.4
16	1116	Lack of international exposure	6
17	1117	Lack of networking abilities	6
18	1118	Capital constraints for long-term investment efforts	5.3
19	1119	Historical disconnection between universities and productive world	2.4
20	1120	Research incentives for publishing papers - no incentives to innovate	4
21	1121	Ideological reluctance in the academic world to get involved in business-oriented projects	4
22	1122	Political cycle affects medium/long term planning	3
23	1123	Lack of financial instruments for innovation processes	5
24	1124	No connection with local stock market	2
25	1125	No risk funds	5
26	1126	Lack of complementary policies	7
27	1127	Value chains owned by few players	10

28	1128	Asymmetries of information	1
29	1129	Policymakers and decision takers have no understanding of the potential of the mining industry	7

01	1201	Mining companies are too risk averse	4
02	1202	Mining companies perceive the solutions provided by the program as not very relevant	7
03	1203	No effective pressure from government to miners to engage in PROGRAM even	7
04	1204	The power of mining companies leads to one-sided contracts: suppliers must assume most of the risks and costs	10
05	1205	Lack of effective coordination along the decision-making process within mining co's, makes high-level declared intentions to engage, wane as they sift down to the operational level	2
06	1206	No real accountability from operational level to top management on effective engagement in PROGRAM	4
07	1207	Mining co's are too ready to drop involvement in PROGRAM when they face challenges to their operations	4
08	1208	Extreme asymmetry of power between mining co's and suppliers produce one-sided contracts that shift most of the risk to suppliers	10
09	1209	Mining companies are very reluctant to open their mines for prototype testing	8
10	1210	Too few suppliers with any capabilities to engage in meaningful innovations for mining co's real needs	6
11	1211	Suppliers lack culture of cooperation among each other	4,2
12	1212	Suppliers lack the experience and financial means to change prototypes into final products	5,6
13	1213	Chile's universities have no history of successful engagement with the industry	4
14	1214	Government lacks understanding of and commitment to innovation	7
15	1215	An endemic fear of issuing sector-specific policies results in policies generic	4
16	1216	Government fails to provide funding for taking a prototype to the market	5

01	1301	Mining companies focus on continuous improvement projects that deliver results in the short-term	3
02	1302	Mining companies are reluctant to allow tests that could risk production	4
03	1303	Budget constraints force mining companies to prioritize on what can deliver proven results	5

04	1304	Intellectual property management	1
05	1305	More complex projects are handled by project areas of the company that prefer working with OEMs, instead of local suppliers	4
06	1306	Projects are people's priority, not the area's. So when someone leaves, the project slows down	4
07	1307	The contract that is awarded is only for a phase of the project	3
08	1308	Slow and complex processes within the mining company for contracts	11
09	1309	Because of company policy, there is no authorization for the supplier to mention the company in their communications	4
10	1310	There is no policy within the company to formally endorse a supplier	4
11	1311	Suppliers don't have enough funding or cash flow to go ahead with a long-term project	5
12	1312	Suppliers tend to expect 100% of funding to come from the mining company	5
13	1313	Suppliers fear that their intellectual property will be stolen	4
14	1314	Not many local suppliers have the knowledge or expertise to do these kind of projects	6
15	1315	Mining company delays cause cash flow problems in supplier	5, 11
16	1316	Contracts don't help to get funding, because they are awarded for different stages of the project	5
17	1317	Lack of knowledge of how to enter other markets	6
18	1318	No knowledge in how to "package" solutions	6
19	1319	Universities have their own research agenda that is not linked to industry needs	4,2
20	1320	Universities would rather sell a consulting service, instead of collaborating with suppliers in the creation of a new product	4
21	1321	Not all research facilities are certified, so their results are not valid for some mining companies	8
22	1322	Lack of models of collaboration that foster joint work between suppliers, research facilities, universities, mining companies, etc	2
23	1323	Universities are more interested in writing papers than collaborating with suppliers	4,2
24	1324	Universities and research organizations don't have the networks that would help suppliers get into the world market.	9
25	1325	There are not enough incentives from the government	7
26	1326	Even though the program is part of the public agenda, this is not reflected in adequate financing instruments	5
27	1327	Insufficient collaboration with international laboratories or institutions	2
28	1328	They don't teach how to accelerate suppliers in universities	9
29	1329	No expert support to suppliers in how to get to market faster	9
30	1330	There is no effective transfer of information from mining companies to suppliers and vice versa	1

31	1331	There is no easy access to funding for suppliers that want to scale up their product	5
32	1332	There is not enough access to international networks that might bring new clients to local suppliers	8

01	1401	For mining companies, projects within the program are small, creating low incentive to actively participate	7
02	1402	Disruptive innovation with high uncertainty requiring large resources	5
03	1403	Small incentives for piloting and scaling up	7
04	1404	Too little information about projects with potential	1
05	1405	Little collaboration among suppliers	2
06	1406	Few suppliers with the potential for this type of innovation (high complexity)	6
07	1407	Suppliers lack management capabilities	6
08	1408	Suppliers lack management and commercialization capabilities, have a small production volume, little experience	6
09	1409	Universities lack experience regarding the management of such projects	9
10	1410	Low incentives and programs for collaboration and partnership in innovation	7
11	1411	Comparatively small public investment in R&D	5
12	1412	There is scarcity of information about the potential of investments in such programs	1
13	1413	Uncertainty and the usual characteristics of innovation processes	1

01	1501	Conicyt does not recognize with resources the need for science in this area	5
02	1502	Universities suffer from lack of funding for projects	5
03	1503	Mining companies expect the market to offer solutions to their problems	4
04	1504	A coordinating entity does not exist	2
05	1505	Lack of a critical mass of tops researchers	9
06	1506	Lack of firms willing to invest resources and time to develop highly complex projects.	5
07	1507	Cultural problem, Chilean executives prefer to stick to comfort zone	4
08	1508	No State support to export know-how, supplier must resolve complex tax issues from selling services abroad	7

01	1601	Mining companies regard it as complicated to generate innovation programs in the midst of cost control processes	5
02	1602	Economic resources, current low-price scenario, disinvestment, little support from govt. entities, bureaucracy in fund application processes	5
03	1603	Little importance given by mining operation to innovation project	4
04	1604	Little knowledge of mining investment projects abroad	1

05	1605	Few or no possibilities to participate in mining or technology fairs outside country	1

01	1701	High commodity prices act as incentive to focus efforts on productivity increases rather than efficiency improvements	4
02	1702	Many companies seek proven technologies in other markets	4
03	1703	Many suppliers are input importers, there is no added value in product development	4
04	1704	Main hurdle is ignorance of how to export products/services	4

01	1801	Client company does not assume immediate risks.	10
02	1802	Main barriers are political and environmental	7
03	1803	Decision-making analysis to determine cost/benefit	4
04	1804	Changing philosophy of new markets considering there are viable solutions not recognized in other sectors.	1

01	1901	Although there is a government policy, it is only for arbitration or as a guide	7
02	1902	Lack of tools to promote innovation	7
03	1903	Objectives are short-term	3
04	1904	Innovation objectives are never or rarely a priority	4
05	1905	Many firms do not have the teams, processes or systems to generate new ideas to show investors	4

01	2001	Insufficient incentives and bodies to lead collaborative innovation programs	2
02	2002	Lack of infrastructure and well-paid knowledge to implement highly complex projects	8
03	2003	Lack of incentives and financial resources	5
04	2004	Minimal technology applied to its goods and services.	6
05	2005	Lack of interest in making the effort to expand its market.	4
06	2006	Little integration of foreign markets in mining sector	4
01	2101	Access to information in a transversal manner is the of only one coordinating body.responsibility	1,2
02	2102	Absence of highly complex [technology] centers.	9
03	2103	Often companies do not implement innovation projects due to high cost.	5

04	2104	Complacency of having a profitable industrial sector that is the world's largest producer.	4

01	2201	Lack of management, resources and regulations aimed at generating innovation projects	5,7
02	2202	Lack of expertise, resources and specialized teams/laboratories.	8
03	2203	Lack of management to accelerate and market innovation project.	6
04	2204	Lack of management to market goods and services.	6
05	2205	Lack of expertise to diversify goods and services to other productive sectors	6

01	2301	Impossibility to test new products and/or technologies in the industry, due mainly to risk aversion	4
02	2302	Lack of clear policies to foster innovation at national level	7,3
03	2303	Lack of trust in the national industry	4
04	2304	Little communication between industry and universities	2
05	2305	Lack of culture of innovation and of knowledge transfer cooperation	4
06	2306	Lack of clear policies that drive Technology Development	7,3
07	2307	Lack of Technology Development at national level (with a good basis to have one)	7
08	2308	Lack of technical expertise (experts) in specialist areas among Chilean professionals	6
09	2309	Real chance of testing and putting in practice new technologies at industrial level and in a productive environment	6
10	2310	Aversion to risk and to testing new technologies, including other brands. A tendency to stick to what has been tried and tested	4
11	2311	Lack of culture to leave known path to add value	4
12	2312	Suppliers relaxed and in comfort zone	4

01	2401	Rigid and outdated organizations that punish errors and do not see them as an improvement opportunity	7
02	2402	Chile's mining industry has a conservative culture and is reluctant to innovate like asking for help, and this is growing for complex projects	4
03	2403	Short-term focus. Innovation regarded as long-term, caught by the short-term trap	3
04	2404	People with fear of failure who wish to take the safest path	4
05	2405	In general already tested technical solutions are bought or implemented as companies do not want to take risks with new technologies	4
06	2406	Organizations with "bunker mentality", don't work in teams, don't	2

07	2407	Lack of innovation budget, no clearly defined innovation strategy within organization	5,3
08	2408	Senior executives who take decisions and have high mobility only think on their short-term performance as they know they will be promoted soon or replaced if they don't meet objectives. The industry has a good innovation speech but in practice innovation almost does not exist	3,4
09	2409	Mining companies hope that other companies will make the effort and take the risk of failure before innovating themselves	4
10	2410	Mining industry is regarded as very good business (at least during industry boom years) and it is not attractive to look for other industries where strong competition and lower margins are perceived	4
11	2411	Lack of a real partnership between mining company and suppliers in which successes and failures would be shared	2

01	2501	Lack of communication between mining industry and services supplier firms	1.2
02	2502	Mining industry is a highly profitable industry but with high risks	4
03	2503	The longer the study takes, the less likelihood there is reaching the implementation stage	11
04	2504	Difficulty of entering new niches and businesses	6

01	2601	Difficulty of stopping inertia of doing things the way they have always been done. This is why priority is not given to collaborative innovation efforts and programs	4,2
02	2602	Low innovation applied by most suppliers.	6
03	2603	Effect of commodity price super cycle distorted path of all industry stakeholders. Like the clients, we focused on production to take advantage of the high price, being careless about costs, efficiency and excellence	4

01	2701	Insufficient academia-industry links	2
02	2702	Complacency of both researchers and managers who rest on the known	4
03	2703	Large companies' short-term evaluations that do not consider innovation	3
04	2704	Innovation and research have a greater risk than proven methodology	4
05	2705	Technology adoption curve and validation of "new" procedure	4
06	2706	Cultural barriers	4
07	2707	Government-imposed restrictions	7
08	2708	Local supplier restrictions	6

01	2801	In general company priorities are short-term and associated with production and costs	3
02	2802	Too long approval time required to release resources	5, 11

03	2803	Lack of personnel dedicated to innovation in organizations	6
04	2804	Other productive sectors have lower margins, thus it is difficult to encourage suppliers to change sector	4

01	2901	Very little or no collaboration between suppliers and clients	2
02	2902	Minimal dedication and resources assigned	5
03	2903	Suppliers normally focus on profitable business. Changing implies an effort that may initially lead to decreased profitability focus	4

01	3001	Insufficient formal linkages between universities and mining industry	2
02	3002	Companies expect quick results when development processes usually take time	3

01	3101	Lack of well-developed research centers and company bureaucracy (counterpart)	6
02	3102	Lack of economic resources and trained personnel to undertake complex research	5, 6
03	3103	Lack of experience in knowledge transfer.	6
04	3104	Lack of coordination with firms.	2
05	3105	Absence of contact with other productive industry networks, little knowledge of other industries	2

01	3201	Disconnection between innovation and research programs and business	2
02	3202	Excessive emphasis on “Theoretical Programs” as opposed to applied research programs	7
03	3203	Bureaucracy and inadequate systems to make decisions	7
04	3204	Disconnection of firms with cutting-edge university areas	2
05	3205	Inadequate institutional framework and means to conduct pilot tests in operations	8
06	3206	Slowness and lack of urgency of professionals and executives in charge of the projects	11
07	3207	Lack of capacity to anticipate problems and risks associated to projects	3,6
08	3208	Absence of binding support to suppliers, system bureaucracy	2
09	3209	Development of effective, unbureaucratic program to promote exports	7

01	3301	Contractor firms do not have sufficient resources for innovation	5
02	3302	Mining company culture focus on meeting production and operational cost goals	4
03	3303	Lack of incentives from buyers through tender credits and preferential points	4

04	3304	Tradition and culture of companies	4
05	3305	In low-price commodity cycles there is very little interest in innovation, only on obtaining short-term results	3,4
06	3306	Suppliers form segments and focus on their markets and do not necessarily diversify	2
07	3307	There are no interactions with other productive sectors	2

01	3401	Unattractive prospect of entering a business with uncertain profits	4
02	3402	Engineering company focuses on short-term business and guaranteed returns	3
03	3403	Cost and risk factors generate large barriers for highly complex projects	5
04	3404	A natural restriction is ignorance regarding collaborative innovation	2,4
05	3405	Bureaucracy to obtain resources and collaboration among State organisations	7,5
06	3406	No incentives for exporters	7
07	3407	Difficult access to information on how to form networks and export goods and services	8
08	3408	Mining industry is very focused and it is complicated to extend services to other productive sectors	6

01	3401	Lack of technology transfer capacities in universities and research centers with mining companies	9
02	3402	Absence of technology transfer capacities makes it difficult to develop highly complex projects together with industry	6
03	3403	Absence of regulatory frameworks and incentives for collaborative work	7
04	3404	Lack of sufficient capacity for suppliers to integrate into industry's value chain to identify better opportunities and gaps	10

01	3501	Excessively conservative culture avoiding at all cost risk and using the same suppliers and solutions as always, without considering new solutions	4
02	3502	Lack of trust in innovation projects developed in country	4
03	3503	Lack of innovation culture	4
04	3504	Lack of contributions and economic resources to develop innovation projects, and short implementation times	5, 11
05	3505	Lack of commitment and proactivity to promote technological solutions made in Chile	4
06	3506	Difficulties for researchers and developers of technological solutions to conduct tests required for proper application	9,8
07	3507	Lack of promotion of innovation solutions created within universities and/or research centers	9
08	3508	Lack of facilities to conduct tests to calibrate technological solutions	8

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