# Productive Development Policies in the Mining Value Chain

## Policy Opportunity and Alignment

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# ABSTRACT

Natural resources are an important source for development, and Latin America is one of the regions with the highest endowment. This calls for a reconsideration of resource-based development. Ambitious countries are moving toward high-value activities and more diversified economies to continue moving up the development ladder. In this sense, the resurgence of industrial policy can correct market failures and lead to the implementation of mission-oriented policies. This document analyzes opportunities to design and implement integrated policies through a revised taxonomy of mining-related policies, applying it to Australia, South Africa, and Chile. The mining sector has been a fertile field, characterized by high technology niches, growth, and innovation. Demand and supply policies can shape the path for development within the sector and across the economy due to the potential of vertical and horizontal linkages.

**JEL Codes:** F63, L52

**Keywords:** mining supply chain; industrial policy; economic development; productive development policies.

# INTRODUCTION

During the past two decades, the world economy has undergone important changes, with new actors reshaping the structure of economic and political dynamics. The rise in influence of China and of other Asian countries, such as Indonesia, Malaysia, Thailand, and India, has been extraordinary and without comparison in any other part of the world. Most of countries in Africa still experience political instability and a lack of economic growth, and except for South Africa and more recently Ghana and Ethiopia, Africa is still far from advanced countries in socioeconomic development.[1]

In contrast, after the commodity boom and the relative bonanza that followed, Latin America —especially Brazil, Chile, and Argentina—still faces premature de-industrialization due to a decrease in employment in manufacturing. This trend has emerged at much lower levels of income than in more developed countries (Brady, Kaya, and Gereffi, 2008; Castillo and Neto, 2016; Palma, 2014; Rodrik, 2015). In this scenario, the role of natural resources is still prominent, especially in Latin America, one of the regions with the most mineral resources. The fact that the export of raw materials is still present in the balance of payment of many Latin American countries calls for the reconsideration of resource-based development paths and for a broader analysis of the opportunities these countries have to capture more value from their resources.

This report contributes to the ongoing debate on productive development policies (PDPs) for the mining sector. Moving toward high-value activities and a more diversified economy is a priority for countries that want to move up the development ladder. In this context, the resurgence of targeted policies in the mining sector can be seen both as a way to correct market failures and as a way for public bodies to undertake mission-oriented policies. The specificities of the mining

1 Socioeconomic development stems from the idea that economic development cannot be fully explained by economic factors and that development includes much more than mere changes in economic indicators. See Szirmai (2015) for a detailed explanation of the socioeconomic development concept.

sector make it an even more suitable candidate for targeted policies. The sector is characterized by long-term projects, by the need for huge capital investments at the beginning of the exploitation phase, and by a series of challenges related to both the internal and external trends of the industry.

On the internal side, mining companies are not keen on taking risks in the production process, and this reticence prevents learning and technological upgrades and prevents new suppliers from entering the market. On the external side, environmental and social concerns are increasingly gaining consideration from private and public stakeholders.

A further element to consider is that while mining has long been regarded as a low-tech enclave sector, in the past two decades it has been at the center of the debate on natural resources because of the advanced technologies involved in the process and the innovation and adaptation that are increasingly necessary for more specific in situ applications. With the increase in outsourcing, countries close to mining sites have been at the center of innovation in mining capital goods and, especially, mining services.

Against this backdrop and considering the important vertical and horizontal linkages that mining has to the rest of the economy, this report considers the opportunities to design and implement packages of integrated policies to foster the mining sector. We build a revised taxonomy of mining-related policies and apply it to Australia, South Africa, and Chile to better understand the importance of coordinated and consistent policies.

The next section briefly reviews the literature on resource-based growth. Next, we analyze PDPs and their role in the mining sector, touching on the dynamics between opportunities and constraints for spillover development. Following that is the core of the report—a taxonomy of different types of mining PDPs focusing on supply and demand policies. We conclude with policy implications with a specific focus on Latin American countries and their opportunities.

# DEBATES ON NATURAL RESOURCES-BASED DEVELOPMENT

The role that natural resources play in economic development is an old topic in economics. Its recent resurgence is giving a prominent role to technological change and to the opportunity such change presents to overcome natural resource scarcity and production constraints.

Marginalist and neoclassical theories had for a long time favored a pessimistic approach to the perspective of natural resource industrialization. On theoretical grounds, the Prebisch (1950) theory of deterioration of the terms of trade and the Dutch disease (Cordon, 1984) argument looked at natural resources from a macroeconomic point of view. Also, the more general resource curse (Auty, 1994) theories are based on the fact that from the end of the 1970s to the beginning of the 1990s, many resource-rich countries had negative experiences and suffered significant shocks at the macroeconomic level. On more empirical grounds, the work of Sachs and Warner (1999) econometrically tested the theoretical hypothesis of the resource curse. Although this debate is beyond the scope of this report, it is important to note that even on more empirical grounds, these studies have been highly criticized from a methodological point of view (for a review of this literature, see Anzolin, 2018).

This general idea that natural resources are an obstacle to development is not consistent with other development experiences, and it coexists with a more positivist perspective. This latter view sees natural resources as an important trigger for development and a crucial runway for industrial take-off (Balassa, 1980; Rostow, 1960). The experiences of both developed and developing countries show that the resource curse is not inevitable. In contrast, the experiences of Australia with iron ore and coal (among other minerals), the United States with its iron ore–based industrialization, and several Nordic countries are a tangible sign of the impact that natural resources can have on economic growth. The reality also holds for some developing countries. For instance, Botswana's diamond processing industry and Malaysia's tin, rubber, and gas-based manufacturing industries are examples of how natural resource development, when promoted in the right way, can sustain development (Chang, 2010).

The analysis of resource-based growth has also benefited from the structuralist approach. The scarcity that characterizes non-renewable natural resources represents an obstacle that can be overcome through progress and technical knowledge. The importance of opening the "black box" of resource constraints could lead to the rediscovery of technological opportunities (Andreoni, 2015). This process of rediscovering natural resource potential has also been fostered by the resource-based industrialization literature, which contributed to the shift from a low-tech enclave vision to a more dynamic one. Within this new perspective, natural resources can present a vision of economic growth (Perez, 2016) and could constitute a way to escape the resource curse (Joya, 2014).

The pessimistic view has been challenged in the past two decades as a result of changes related to two global factors. First, the increase in the demand for, and thus the price of, commodities put some Latin American and African countries at the core of new trade patterns where China, and to a lesser extent India, played a significant role (Morris, Kaplinsky, and Kaplan, 2011). The surge in demand for raw materials also triggered demand for mining products, which imposed the necessity of finding new and better techniques to become more productive. Obstacles in terms of scarcity and adaptation requirements led to improvements in techniques to find new deposits and better and more sustainable techniques. For example, the Australian mining industry experienced productivity growth of 130 percent between 1986 and 2003, four times faster than growth in other sectors, mainly due to its introduction and deployment of new technologies (Urzúa, 2012).

The second global factor, the fragmentation of production and the consequent deverticalization and outsourcing, led to the emergence of global value chains where power and opportunities differ from the previous context (Gereffi, 1994; Milberg and Winkler, 2013). Traditional process and organizational models close to users are putting a premium on proximity to the source and in situ applications where opportunities rely on the countries that can process materials competitively and innovatively (Bravo-Ortega and Muñoz, 2015; Perez, 2016). In this sense, for multinational companies, the presence of competitive local suppliers is not only a choice or an opportunity, but it increasingly becomes a necessity (Morris et al., 2011).

Natural resources underwent a series of transformations that shed light on sectors that present new technological opportunities (Perez, Marian, and Navas-Aleman, 2014; Pietrobelli, Marin, and Olivari, 2018; Stubrin, 2017). This dynamic way of looking at natural resources, where one size does not fit all, opened up new waves of theoretical and empirical studies. The latter are based on the consistent evidence of synergetic links between natural resources and high-value activities, where restructuring at the global level increased and reinforced the scope for linkages development (Morris et al., 2011). Resource-based growth is based on a diversification concept that stems from a path dependence process with several constraints imposed by past technological achievements (Andersen et al., 2015). It is important to consider that, because of the presence of these obstacles and possible technological lock-in, a mere link with a global value chain needs to be combined with the development of local linkages (Morrison, Pietrobelli, and Rabellotti, 2008; Pietrobelli and Rabellotti, 2011) to undergo high-quality development.

# PRODUCTIVE DEVELOPMENT POLICIES: THE CASE FOR PRODUCTIVE POLICY IN MINING

## PDPs Are Back on the Development Agenda

The commodity boom, with its enormous revenues available to foster other sectors, and the financial crisis at the end of the 2000s helped reopen the debate on the role of the state in fostering economic growth and innovation (Skidelsky, 2009). The financial crisis, in parallel with the growth of China and the other BRICS countries (Brazil, Russia, India, and South Africa), played an important role in putting production back on the development agenda (Primi, 2013; Andreoni and Chang, 2019).

If there is little debate on the fact that industrial policy is back (Wade, 2012) in both developed and developing countries, the role of the so-called developmental state has been very diverse in different countries (Chang, 2010). The work on the developmental state stressed the importance of the "visible hand" of the state in promoting development and technological change. Especially in a time when, for the so-called latecomers, learning does not occur purely via market mechanisms, capability-building policies need to be at the core of the development trajectory (Amsden, 2001).

The basic argument is that it is not only possible, but possibly also convenient, to go beyond the current static comparative advantage and seek the development of the industrial sector and/or higher-value-added activities enjoying a dynamic comparative advantage. Historically, PDPs (more generally called industrial policy) are often understood with a focus on the manufacturing sector, although they often regard the wider target of promoting structural transformation (e.g., productivity, the development of new sectors, and education). Crespi, Fernández-Arias, and Stein (2014) attempted to classify these policies, as reported in Table 1.

**Table 1.** A First Classification of Productive Development Policies

| | Horizontal Policies | Vertical Policies |
|---|---|---|
| **Public inputs** | • Infrastructure improvements<br>• Property rights protection | • Phytosanitary controls that prevent disease from contaminating food products<br>• Creation of universities |
| **Market interventions** | • Matching grant scheme for research and development<br>• Tax incentives for specific sectors | • Subsidies (the rent-seeking argument) |

*Source:* Author's elaboration of Crespi et al. (2014).

The classification explains how the role of the state and the challenges are different in each of the quadrants. The classification also conceptualizes the market failure argument as the first justification for state intervention. Generally, "the net social benefit of productive activities differs from the net private benefit perceived by market agents that control those activities, that is, these productive activities generate spill-over effects that may benefit or impose costs on other agents" (Crespi et al., 2014:36).

Although the softer approach of horizontal policies is less controversial, these policies also present some critical challenges, especially for emerging and developing countries. For instance, horizontal policies are more difficult to design, monitor, and evaluate because their targets are more dispersed. This dispersal is even more relevant when referring to developing countries that do not have long experience in policy implementation. This type of policy, despite cutting across sectors, in many cases tends to favor specific sectors: "in a world of scarce resources, every policy choice you make, however general the policy involved may look, has discriminatory effects that amount to implicit targeting" (Andreoni and Chang, 2016). For instance, general measures such as promoting research and development (R&D) or any education-driven policy is targeted to specific areas; in this sense, more R&D-intensive sectors would benefit from incentives for R&D processes, and specific subjects (and thus sectors) would benefit when an education policy is created (e.g., mechanical or electronic engineers). In other words, most public inputs, by their nature, tend to be specific to particular sectors (Chang, 2010; Hausmann and Rodrik, 2003).

Softer measures have long been (and still are in many cases) preferred in Latin America, even though the experience of this region shows that these policies had limited scope and impact in an area characterized by structural heterogeneity (Primi, 2013). In the past, there were mixed results from industrial policies focused on the controversial import substitution industrialization. Although industrial policy in the region was not all "excess and failure" (Crespi et al., 2014:15), its use went down in history as a period that caused negative consequences, which also resulted from targeted and risky policies.

More recently, the region has witnessed a (slow) return of industrial policy (Perez, 2010). In 2003, Brazil, with its strategy-driven approach, was the first country to introduce integrated industrial, technology, and trade policy, followed by Colombia and its more demand-driven approach, with a strong focus on public–private partnerships (Melo and Rodriguez-Clare, 2006).

Chile implemented a softer approach by promoting cluster development in sectors (e.g., copper mining) where the country already had important capabilities. Nowadays, the question seems to have shifted from whether to adopt PDPs to how to adopt them (Crespi et al., 2014).

Addressing specific sectors is fundamental to designing and implementing the policy itself and for the spillover effects it may have on the rest of the economy. Nonetheless, this work is challenged by the current political situation in countries such as Chile and Brazil, where right-wing governments that have historically been more conservative in using industrial policies could represent a shift toward softer measures.

Another interesting policy perspective emerged in the past few years. In a world that is far from being governed by perfect market forces, public instruments could have a broader and more powerful scope for fostering economic growth and development. The importance of complementing the market failure argument opens the way to a different analysis in which public incentives may not only fix market failures, but also actively create new markets and technological opportunities across the entire value chain (Mazzucato, 2013).

In this approach, public banks play a central role: Mazzucato and Penna (2016) listed four types of more dynamic investments that the state can make:

1. countercyclical finance,
2. funding for long-term projects, industrialization, and capital development of the economy,
3. targeted investments in high-risk R&D, and
4. promotion of investments in complex societal problems such as climate change.

This framework, although used for a general discussion on public banks, could also be adapted and applied to general state intervention in the mining sector, which is highly volatile, is in need of long-term investments, is experiencing important social challenges (e.g., consideration of Indigenous populations and climate change), and has a high level of innovativeness to be explored. In this sense, mission-oriented policies could target the "development of particular technologies to address a given societal challenge" (Mazzucato and Penna, 2016:16) in the mining sector.

The next section is a brief overview of the global mining sector and an analysis of the mining value chain in relation to where countries could have the opportunity to tap into value-added extraction.

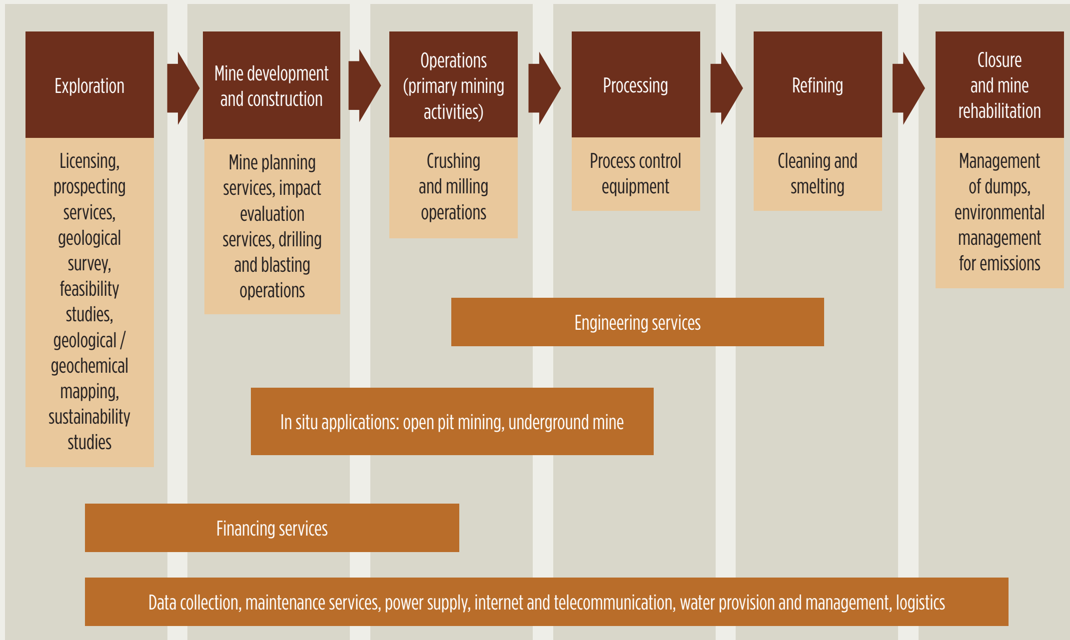
# THE MINING VALUE CHAIN AND OPPORTUNITIES FOR PRODUCTIVE DEVELOPMENT POLICIES

When referring to the two industrial policy arguments explained above (i.e., horizontal and vertical), the importance of complementing market failure policies with more targeted policies is even stronger. Mining is an industry in which the long time horizon of not only capability accumulation but also business and production processes requires a long-term commitment. This long horizon is also one reason behind the consolidation trend that has reshaped the mining sector through large mergers and acquisitions since 1990: big companies are more likely to have the financial capacity to sustain the investment. For instance, during the preliminary step of exploration, sunk costs are very high because of the investment in equipment and the long licensing process with governments. Investments have to be sustained for long periods, since a new mine can take 10 years or more to develop (Lundmark and Wårell, 2008).

Figure 1 presents a mining value chain. Despite important differences between the various types of minerals, this figure shows the different segments that underlie opportunities from various types of inputs.

Observing the value chain prototype, note that linkages related to inputs at each stage of the chain can be related to both capital equipment (manufacturing) and mining services, and the two are likely to be interrelated. The mining sector is becoming increasingly service-based, and many services are related to activities that have been increasingly outsourced (Korinek, 2018). Specifically, this shift has been triggered by the fragmentation of production and by an increasing opportunity—and necessity—to find in situ applications. Mining services constitute 23 percent of the value-added of exports, on average, and most services are produced domestically (with differences among countries; e.g., Australia, 26.5 percent; South Africa, 20 percent; and Chile, 21 percent). The debate on manufacturing versus services has been shifting toward low- and high-value-added activities. Some aspects related to different types of services will be considered in the second part of this report.

**Figure 1.** Prototype of the Mining Value Chain




*Source:* Author's elaboration.

More generally, it is acknowledged that services are, by definition, less tradable than manufacturing and that the manufacturing sector drives the growth of the service sector, especially in developing middle-income countries (Andreoni and Gregory, 2013; Park and Chan, 1989; Su and Yao, 2016). Although the service industry has gained momentum in the past couple of decades in terms of technological upgrading for innovation, we stress the importance of going beyond the dichotomy of services and manufacturing to consider the interdependencies and complementarities of the two sectors. Different studies explore how innovative potential can only be fully explored in conjunction with complementary manufacturing (Andreoni and Gomez, 2012).

More specifically, looking at different types of services along the mining value chain we can observe that services are not all equal and that specialization in mining does not imply specialization in mining-related services. For instance, wholesale and trade services are not the same as scientific and technical services, which add more value. The latter more sophisticated services are provided by countries that are also home to top providers of mining equipment; in fact, in terms of revenues, the most important services are exploration and mining services, followed by scientific electronic and other machinery equipment services (Korinek, 2018; Thorburn, 2005). Thus, although mining services represent a fundamental channel to tap into the global mining value chain, their link with the manufacturing sector has to be considered when designing policies (Haraguchi, Cheng, and Smeets, 2017). Interestingly, in value-added terms, none of the top mining countries is among the top mining services exporters (Korinek, 2018); instead, among the top mining services exporters, we find the most important producers of mining equipment.

Moreover, the mining sector has opportunities for a series of horizontal linkages related to the high-volume and high-quality infrastructure it requires, especially in relation to infrastructure, and water and power management. The increasing acknowledgment of environmental issues and the consequent standards countries impose could act as another trigger for more sustainable development. For instance, legislation requiring mining companies to purify the water they use in mining processes and return it to the community could push development toward other sectors (e.g., water pumps, pipes, water purification systems). Such a dynamic creates a series of complementary opportunities for other apparently unrelated sectors—in this case, water management.

As mentioned, there is a new focus on the mining industry because of its potential to trigger growth and innovation and because it has been fertile field for technological transformation and innovation in recent decades (Kaplan, 2012; Katz and Pietrobelli, 2018; Morris et al., 2011). The increased level of technology used in mining (e.g., advanced robotics, artificial intelligence, sensors, and big-data analytics) constitutes an important "window of opportunity" (Perez, 2016) for natural resource–rich countries that are already looking to construct "intelligent" mines.

For example, the construction of the new S11D iron ore mine in Brazil is a high-technology project that led to the first completely integrated "smart" mine in Latin America. At the mine, processes are data-driven and the interconnections among different machines and stages of the mining process enable high productivity and efficient management of the resources (Andreoni and Anzolin, 2020). The extensive use of PDPs is an important tool to fully exploit these opportunities and to drive the country toward natural resource–based growth. Public bodies have (and could increasingly have) a role in shaping policy and national objectives to both mitigate market failures and move toward technological upgrading through more mission-oriented policies.

Two final considerations regarding mining value chain opportunities. First, resource-based development has been pursued not only to fulfil domestic demand but also to learn to compete globally. For instance, Australia and more recently South Africa compete at the global level in specific segments of the mining value chain. Australia is one of the leaders in mining, equipment, technology, and services (METS); South Africa is a leader in mining inputs such as spirals for washing coal, tracked mining, pumping up water, and other technologies related to the deep-level mining that characterizes South African deposits (Kaplan, 2012).

Second, the window of opportunity for resource-rich countries has to be considered in light of the multiple challenges resulting from climate change. However, the increasing scarcity of non-renewable resources and geography-related challenges—worsened by climate change disasters—are obstacles that trigger new and more advanced techniques. For instance, in South Africa, new programs were launched in 2018 to tap into gold and platinum mines that are characterized by predominantly narrow vein deposits. These deposits require development of products and technologies that will serve the future needs of the industry (James, 2018).

Climate change, however, creates significant challenges for the mining sector. For instance, disasters created by floods and storms damage transportation infrastructure and affect the reliability of this highly logistics-dependent value chain. Adapting to climate change means finding more efficient ways to use resources to improve productivity and make processes more sustainable. For example, a lot can be done on the energy side considering that 4 percent of the world's power is used in crushers and grinders (EBRD, 2017).

# PRODUCTIVE DEVELOPMENT POLICIES IN ACTION: A NEW TAXONOMY FOR THE MINING SECTOR

This section presents a new taxonomy of PDPs in the mining sector, focusing on the importance of designing consistent and integrated (systemic) policies in which demand incentives are matched by supply capabilities and vice versa. As shown by many historical experiences, the lack of complementary assets hinders innovation where it is most needed (Cirera and Maloney, 2017). Upgrading in the mining sector requires increasing high-value manufacturing and/or services, where the adoption of foreign technologies and the ability to create new technologies is neither exogenous nor automatic, but is the result of technological effort to build up capabilities (Fessehaie and Rustomjee, 2018; Morrison et al., 2008).

There are three main reasons to use sector-specific policies:

1. As noted, the industry is characterized by long-term projects with important lump-sum investments, foreign technology acquisition, and highly skilled personnel. Training these workers through education and shop-floor experience is difficult and takes time (Fessehaie and Rustomjee, 2018).
2. The mergers and acquisitions that occurred in the past three decades increased the concentration of the industry. As a result, some stages of the mining supply chain are difficult to enter, while others, more related to in situ applications and newer technological trends, may constitute an area in which to target productive development policies.
3. The recent rejuvenation of the industry (Perez, 2016), characterized by innovation-based high technology, increased the need for local applications and solutions, which call for building up specific capabilities.

Thus, a series of coordinated mechanisms and long-term processes that are rarely left to the market are required. Table 2 illustrates a new taxonomy that encompasses different types of public policies. The table shows that supply-side policies are those that affect innovation and technology acquisition processes, as well as education and training. Technological infrastructure and capital access policies are also supply-side interventions. Demand-side policies are those related to standard forms of public procurement that can influence both the provision of goods and services and the type of employment. Companies can also be influenced through specific measures aiming at either giving national companies access to external markets or developing new markets (see also Andreoni, 2015).

**Table 2.** Productive Development Policy Taxonomy: Demand and Supply Equilibrium

| | | Supply Side | Demand Side |
|---|---|---|---|
| Market interventions | | • Tax incentives (on capital)<br>• Tax concession (R&D)<br>• Access to venture capital<br>• Grants to overcome the "valley of death"* | • Internal demand from large firms through<br>• local content policies<br>• rebate policies on local production<br>• Incentives to export mining goods and services |
| Public goods | Skills development | • Training centers<br>• Degree programs (specific to mining sector, geology/engineering, etc.) | • Local employment target<br>• Local training required for mining companies |
| | Innovation infrastructure, R&D platforms | • Skill councils<br>• Incubators<br>• Collaborative R&D projects | • Matchmaking platforms to meet demand and supply (e.g., potential suppliers) |

*Source:* Author's elaboration.
*The valley of death is that period between lab-based innovation, and commercialization and scaling up. In the absence of proper institutions and coordination mechanisms, lots of innovations get lost during this period.

Generally, supply-side interventions are more common in advanced countries, which tend to focus more on the attractiveness of R&D-intensive activities and the creation of institutions that coordinate different stakeholders. In contrast, demand-side policies are used more in developing countries, where interaction with foreign multinational companies and influence over their procurement strategies are of crucial importance. Multinational companies are the final customer and the most powerful actors in the supply chain to trigger the development of new and existing capabilities. Nonetheless, when referring to the mining sector, both demand -and supply- side policies are common across countries at different stages of development.

As an example of the importance of designing and implementing consistent and balanced policies, Ghana has adopted a local content strategy that imposes quotas on employing local people that gradually increase over a 10-year period up to 90 percent of total employment (Ackah and Mohammed, 2018; Ramdoo, 2016). In developing countries, these policies can often act as severe constraints on businesses because targets for local employment are difficult to achieve because of skills gaps (Tordo and Anouti, 2013). This mismatch could be balanced by education policies on the supply side, as has been done in countries such as Angola, Qatar, and the Philippines, where there are mandatory training requirements along with provisions to employ locals (Korinek, 2013; Macatangay, 2016).

Often, the misalignment between demand- and supply-side policies results in undesired outcomes or policy failures. Three examples from Sub-Saharan Africa that were analyzed by Fessehaie and Rustomjee (2018) clarify the point.

1. Zambia promoted friendly foreign direct investment (FDI) policies to attract multinational companies to the country through Multi-Facility Economic Zones. The incentives for foreign firms were not always consistent with the localization agenda that would be the ultimate aim of FDI investments. In this sense, FDI policies were not matched with skill development programs.
2. Zimbabwe tried to implement demand-side policies imposing local content requirements, but supply-side constraints hampered its resource-based development, mainly owing to a lack of access to financing, the high cost of inputs, and unstable power and water supply.
3. Botswana succeeded in promoting skill transfer programs in order to foster local employment in the cutting and polishing industries (Fessehaie and Rustomjee, 2018; Fessehaie, Rustomjee, and Kaziboni, 2016).

Finally, although it is beyond the scope of this report, it is important to consider the role that monitoring and evaluating mechanisms have in the deployment of policy programs. A comparative study of oil and gas policies found that the positive experiences in Brazil, Mexico, Angola, and Nigeria were related to the existence of implementation and monitoring mechanisms. Those countries were the only ones from a pool of 14 African and Latin American countries to have monitoring systems (ELLA, 2017).

# ANALYSIS OF COUNTRIES' EXPERIENCE: AUSTRALIA, SOUTH AFRICA, AND CHILE TAXONOMIES

This section applies the new taxonomy to three countries chosen to compare similarities and differences across different mining experiences, and to derive potential policy lessons for Latin American countries. Being an advanced economy and at the technological frontier of mining activities, Australia is a good comparison, especially for Chile, because of Australia's investments in and focus on mining technology services. South Africa is at a similar stage of development compared to many Latin American countries, including Chile, Brazil, and Argentina. Nonetheless South Africa undertook a completely different approach, with extensive use of industrial policy both on the demand and supply sides. The state openly referred to industrialization and to the importance of building a wide production base. Finally, Chile was chosen because it is an important reference point in Latin America and because of the expansion of its mining sector.

## Australia

Australia is a mature economy with remarkable success in natural resource–based development. Mining is a strategic sector for the country: it typically makes up 7 percent of GDP (e.g., in 2014 it contributed 8.7 percent of GDP, the equivalent of around US$94 billion). Total export earnings from commodity and energy resources is around 50 percent of total exports (OECD, 2017). Australia's mining, equipment, technology, and services (METS) sector contributes approximately US$60 billion annually to the economy, with annual exports of at least US$18 billion.[2]

The country is also home to some of the world's largest mining firms (e.g., BHP Billiton), which is considered an enabling factor for mining development. Moreover, to catch up in terms

2 Australian Trade and Investment Commission. https://www.austrade.gov.au/australian/export/export-markets/industries/mining-equipment-technology-services

of capabilities, Australia undertook extensive investments in R&D and in engineering education (Fessehaie et al., 2016). The government's incentives are considered a success, placing the country among the leaders in terms of mining companies, mining capital goods and, especially, mining technology–related services (MTS[3]). According to the Australian Mining Technology Services Action Agenda (MTSAA) implementation committee, organizations providing MTSs identify themselves principally with the provision of goods and services for the mining industry, including equipment, software, consulting and engineering services, and R&D. There are between 500 and 600 such organizations in Australia, 10–15 of which are public research organizations; the others are companies. The most important MTS companies in terms of revenues are exploration and mining services firms, followed by scientific, electronic, and other machinery equipment services (Thorburn, 2005).

Australian policies have recently focused mainly, though not exclusively, on the supply side because of the local presence of the headquarters of important mining companies that have global operations, which are the main customers of mining goods and services, the presence of mines, the rich geological resources, and the overall positive outcome of an already educated workforce and a solid industrialized base (Heum, 2008).

Three levels of legislation regulate mining operations: government, state, and territory. There are different classifications at the sub-government level, but the most common are mining acts, state agreements, and Indigenous land use agreements (OECD, 2017). The country implemented a series of consistent policies to attract R&D and tap into new segments of the mining value chain. Significant effort has been made in R&D, which has been fostered through incentives for public–private collaboration.

A high educational level combined with public sector research contributed to the creation of the Commonwealth Scientific and Industrial Research Organisation and the Cooperative Research Centre Programs. Continuous skill development is ensured through the Australian system of universities and vocational training colleges, with the Resources and Infrastructure Industry Skills Council playing a coordinating role. Moreover, there are eight mining-related research centers (ISA, 2016). According to data from the Australia Trade Commission, the country's mining industry injects huge amounts of money into R&D—an average of US$2.5 billion annually (OECD, 2017).

3 The acronyms METS (mining equipment, technology, and services) and MTS (mining technology–related services) are both used in mining policy documents. In this report we maintained the distinction we found in policy documents and academic papers; otherwise, we tend to use the two acronyms interchangeably.

**Table 3**. Productive Development Policy Taxonomy for Australia

| | | Supply Side | Demand Side |
|---|---|---|---|
| Market interventions | | • Tax incentives, Enhanced Project by Law Scheme: duty free tariff concessions for goods not available in Australia<br>• Tax concession for R&D expenditures, deduction up to 125% from taxable income + a tax offset and 175% premium tax concession<br>• Grants to overcome the valley of death, Backing Australia's Ability–Building Our Future through Science and Innovation ➔ to help SMEs scale up<br>• Access to venture capital; for example, assistance to SMEs given through the AusIndustry program | • Internal demand from large firms already present in Australia + InvestAustralia plan to attract FDI in leading segments<br>• Local content policies, Australian Jobs Act 2013 ➔ proponent of projects ➔ AU$500 million to drive local procurement<br>↓<br>• Australian Industry Participation Plan (key mechanism to drive local procurement)<br>• AIPNF (2001): breaking down big contracts to enable local smaller suppliers to participate |
| Public goods | Skills development | • Universities have METS-focused state-sponsored programs | • Local employment target at state level and especially for Indigenous people* |
| | Innovation infrastructure, and R&D platforms | • Skill Council, Industry TechLink (access to consultancy is needed)<br>• Incubators, Innovation Xchange (joint program with government to assist business)<br>• Collaboration R&D projects, CSIRO (large R&D organization with focus on MTS)<br>• AusIndustry program encompasses<br>i. commercial readiness<br>ii. commercialization of emerging technologies<br>iii. Pooled Development Fund Program<br>iv. Innovation Investment Fund Program | • Match making platform to meet demand and supply, Supplier Access to Major Projects |

*Source:* Author's elaboration.
*For example, in Western Australia, a mining project also has to state how it will benefit from an employment point of view. For a review of these policies see International Institute for Sustainable Development (2018).
*Notes:* SME = small- and medium-sized enterprises; FDI = foreign direct investment; AIPNF = Australian Industry Participation National Framework; METS = mining, equipment, technology, and services; CSIRO = Commonwealth Scientific and Industry Research Organisation; MTS = mining technology–related services.

To develop upstream linkages (i.e., with industries closer and more related to material inputs), the Australian government implemented a combination of supply- and demand-side policies (IGF, 2018a). The most important policy, adopted in 2001, is the Industry Action Agenda for MTS, which was endorsed by the government in 2004 with the Australian MTSAA after a consultation with major stakeholders (Austmine, 2014; Thorburn, 2005).

Generally speaking, the Industry Action Agenda is a government-led initiative to provide a collaborative framework so that government and industry can come together to address the major market impediments to foster MTS, with a special focus on R&D, commercialization, access to venture capital, and supply of specialized staff. In 2004, a couple of years after the Industry Action Agenda was implemented, the Australian government launched a US$3.5 billion package called Backing Australia's Ability—Building Our Future through Science and Innovation. Although the initiative was not confined to mining, mining companies could access programs that were established with the idea of helping small- and medium-sized enterprises (SMEs) to scale up early-stage inventions and enhance international competitiveness.

In parallel, AusIndustry, the program delivery division of the Department of Industry, Tourism and Resources, planned to deliver different forms of innovation grants, concessions, and investments to more than 10,000 businesses annually (OECD, 2005; Thorburn, 2005).

Table 4 lists the main measures approved under Australia Industry's Action Agenda.

**Table 4.** Major Programs Implemented under the Australia's Industry Action Agenda in 2004

| Program | Description |
| --- | --- |
| Small Business Assistance Program | Awards granted in three categories: small business incubator, small business enterprise culture, and small business answers |
| Commercial Readiness | Provides grants for early-stage commercialization activities |
| Commercialisation of Emerging Technologies | Provides grants for innovative products |
| Pooled Development Fund Program | Offers funding to increase the supply of equity capital for growing Australian small- and medium-sized enterprises |
| Innovation Investment Fund Program | Promotes the commercialization of Australian R&D through providing venture capital to small high-tech companies at the seed, start-up, or early expansion stages of development |
| Industry TechLink | Provides access to technology consultants |
| Invest Australia | Attracts direct foreign investment, builds capacity by creating leading edge customers for the industry |

*Source:* Author's elaboration of Thorburn (2005).

Another measure Australia has adopted is the InnovationXchange, a joint government–industry program. It is a web-based data exchange designed to provide a reliable intermediary to help businesses to gain access to new technologies, research, patents, education and training, financial services, etc.

The government-led push for R&D has been quite strong in Australia (Francis, 2015; Martinez-Fernandez, 2010; Thorburn, 2005). Firms in the industry benefit from tax deductions of up to 125 percent of R&D expenditures, a tax offset, and a 175 percent premium tax concession. SMEs benefit from even further tax concessions and have access to the government's industry and innovation programs to become established and to commercialize new technologies. According to a government document, such access to government innovation programs is fundamental because SMEs "need patient early-stage capital, access to markets, and access to government and large business contracts" (Australian Government, 2005).

On the supply side, it is also important to mention the crucial role of the Commonwealth Scientific and Industry Research Organisation (CSIRO), which is one of the largest research organizations in Australia. CSIRO includes MTS in its portfolio. According to a study conducted by Australian Bureau of Agricultural and Resource Economics (ABARE), MTS companies consider CSIRO the most important provider of collaborative R&D projects. CSIRO is also closely related to the other eight mining-related research centers in the country. In 2015, a growth center for METS was established, METS Ignited, as an industry-led, government-funded initiative to foster the METS industry (OECD, 2017).

Australia has also passed crucial legislation on the demand side of the taxonomy. As part of this government-led effort, in 2011, the Australian Industry Participation National Framework was approved. Under this framework, mining companies must break down ("unbundle") large contracts into small agreements so that local suppliers can participate and deliver (Australian Government, 2001). In addition, the Australian Jobs Act implemented in 2013 imposes on every proponent of major projects a minimum capital expenditure of AU$500 million (around US$337 million) to provide opportunities for Australian suppliers to bid to provide key goods and services (Australian Government, 2013; IGF, 2018a). This federal legislation, which is considered a key mechanism to drive local procurement, introduced the Australian Industry Participation Authority, which monitors and enforces the Jobs Act by providing guidelines on the obligations, and information and assistance on the plan.

In 2018, the government commissioned Quantum Consulting Australia to assess the Australian Jobs Act. This in-depth impact assessment found, overall, positive results of the program (Quantum Consulting Australia, 2018). Stakeholders were satisfied with the administration processes and confirmed that Australian Industry Participation plans effectively promoted understanding for suppliers, although there was more struggle in the capacity to enhance capability. Moreover, project proponents felt well-supported by the Australian Industry Participation (AIP) plan development, approval, and compliance processes. The review also suggested there had been an appropriate level of regulation through effective monitoring.

The assessment revealed two challenging aspects. First, more transparency and information-sharing could better help stakeholders to understand their obligations and meet their expectations. Second, demonstrating compliance with the approved AIP plan was considered too cumbersome and bureaucratic; more guidelines are needed to support understanding of the ability to comply (Quantum Consulting, 2018).

The Australian Government has been developing a consistent incremental approach to foster suppliers' participation over the years. One important measure addressed to suppliers is the Buy Australia at Home and Abroad Programme, which includes the Supplier Access to Major Projects (SAMP) subprogram. SAMP was approved in 1997 and provided more than AU$18.5 million (around US$12.7 million) to create linkages between Australian suppliers and project developers. SAMP's major role was to provide funding to the industry to foster a capability network through assistance in identifying competitive Australian suppliers for major projects.

In the late 1990s, there were important challenges related to supporting the development of MTS. For example, despite the high level of literacy in Australia, SAMP strongly supported the implementation of policies to ensure that the country's education system was aligned with the needs of the MTS sector. Universities started to focus on MTS through state-sponsored programs. According to the latest estimates, SAMP supported 162 projects worth over AU$4 billion in contracts that would otherwise have gone to foreign competitors. Innovation complements learning and the adoption of foreign technologies. The Enhanced Project by Law Scheme (EPBS)—adopted in 1995 and still in force—provides duty-free concessions on goods used in the mining and resource processing industries that are not available in Australia.[4] This program was extended to New Zealand to facilitate regional linkages (OECD, 2017).

In addition to these national provisions, each state can create additional legislation. In Western Australia, for instance, the state government asks for a complete description of the project, including where it will be situated; its direct economic impact on Australian industry in terms of employment and skill transfer for regional development; the type, number, and size of procurement packages; its use of competitive businesses in goods, and services, etc. (Government of Western Australia, 2015; IGF 2018a).

According to trade data, Australia was not only able to tap into the modernization of the industry, with focus a on MTS and knowledge-intensive services, but also to respond to demand coming from Asia and Latin America for sophisticated underground communication equipment, remote control systems, and mine planning software (Martinez-Fernandez, 2010). For instance, as reported by Austmine's 2015 METS sector survey (the latest available), 42 percent of Australian METS were exported to South America, mainly Chile and Brazil.[5]

Education programs seem to produce highly skilled workers who are absorbed by the industry. The aforementioned study by ABARE confirmed that 62 percent of people employed in the Australian mining sector are high-skilled. Moreover, companies declared that information technology consulting staff were fundamental to competitiveness, enabling important products such as virtual prototyping and 3D design. The role played by R&D emerged as a key aspect for change, and 84 percent of firms indicated that they built capability through collaboration with large clients and multinational companies (Martinez-Fernandez, 2010).

The importance of mining services in Australia has increased since 2001, a time of crucial policy programs at the beginning of the commodity boom. The aforementioned policies related to innovation services were also important from a horizontal linkages perspective; for instance, the ICT Incubator Program assists the information and communications technology sector, which is important to mining technology services.

Emerging from these policies, the interaction between the government and industry has been crucial for the development of the Australian mining sector. This "takes two to tango" dynamic (Fernandez-Arias et al., 2017) can be considered a positive interaction through which information asymmetry and principal–agent problems could find common ground in the policy design and implementation processes. Government collaboration was crucial because it funded institutional R&D on targeted projects and provided access to the pre-competitive research that gives the industry attractive mechanisms to increase leverage on R&D investments by sharing the cost (Australian Government, 2005).

4 For more information on this program, see the Australian Border Force's Trade and Goods Compliance—Industry engagement at https://www.abf.gov.au/importing-exporting-and-manufacturing/trade-and-goods-compliance.

5 See http://austmine.wonderwebs.org/News/webinar-recording-expanding-into-latin-america-tips-and-insights-for-australian-mets.

Rio Tinto provides an interesting example of the "two to tango" mechanism that shows how the participation of the private sector has always been important in the Australian context. The company invested AU$2 million just to train workers for the digital future. The company, after having started the Mine of the Future Initiative in 2008—one of the first in the world using automated technologies—also invested in training workers with skills for the digital revolution, working with public institutions and the government (Francis, 2015).

Despite the lack of official impact evaluation on this policy package, some interesting figures demonstrate Australia's high performance in the sector. In terms of METS, it is estimated that around 60 percent of the world's mines use Australian-designed software. This sector grew fivefold in the past 15 years. A study by Francis (2015) showed the importance of the MTS sector in the innovation and upgrading processes in Australia. Francis analyzed Australian mining innovations between 1994 and 2011 in three sectors: MTS, operating mines, and publicly funded entities. MTS ranked first in terms of patents, demonstrating a strong propensity to innovate. Of the total MTS sample, 84 percent of the companies were Australian (and the majority were SMEs) and 55 percent were exporting. As expected, these companies invest strongly in innovation (US$1 billion in R&D just in 2011–12). The three main areas where MTS have more patent applications are dredging and soil shifting, gearing, and electric switches. According to the study, most patents are filed by companies that produce mining equipment, bringing to mind the complementarity of manufacturing and the service sector.

To conclude, it is important to mention that the key feature of the Australian approach is that its policies have always been oriented toward "measurable and meaningful outcomes," so it has a strong focus on monitoring the number of local contracts and jobs created. Firms have the obligation and responsibility to report regularly on a number of issues and this ensures the government has control over its policies.

## South Africa

South Africa is a fast emerging economy that represents a positive experience at least for the successful development of certain manufacturing-related linkages. In fact, local deployment of a number of sophisticated technologies in a system characterized by a particular mining industry structure and by a proactive state permitted the early development of a number of technologies (Kaplan, 2012). South African companies were able to link up with global value chains in areas where the country's expertise is particularly advanced and at the global frontier, such as in deep-level mining (e.g., for gold) and associated competencies.

After the apartheid period, the government implemented a series of policies to rebalance the country's socioeconomic conditions. On one hand, a series of policies was designed to support broader industrial upgrading and to empower historically disadvantaged people, such as black, colored, Indian, and other groups of people that were present in the country before 1994. Because of the high level of unemployment, South Africa gave priority to local content policies for South African workers and targeted categories such as black people and women.

On the other hand, from an economic perspective, South Africa engaged in a series of policies with the aim of forming clusters of firms in mining equipment and services that resulted in sophisticated goods and services at the technological frontier (Kaplan, 2012). Overall, owing to the abundance of natural resources in the country, South Africa envisioned mining-based growth as a way toward socioeconomic development.

It is important to note that, similar to the situation in the United States, South African deposits were not especially rich, and their profitable exploitation was due to the application of high-technological knowledge. Only in this way could the life of the deposits be extended, justifying large-scale investment and permitting a transition of the South African supplier base toward specialist equipment and services. As Kaplan (2012) noted, "the much-acclaimed Scandinavian model whereby competencies in raw material extraction are increasingly shifted to the development of competencies in the supplier industries—capital equipment and specialist services—is evident in South Africa."

The decline in global mining output (especially in certain minerals, e.g., gold) was in parallel with an upsurge in specialist services such as consulting and exploration. According to Kaplan (2012), South Africa was able to tap into these new global value chain opportunities. The development of these new capabilities is something South Africa had to consider in order to break the decreasing trend of its mining industry. In fact, over the past decade, the mining industry has stagnated: as reported by Goodman, Rajagopaul, and Cassim (2019), between 2007 and 2017, the sector's value declined by 4 percent with a corresponding job loss from 518,000 jobs in the industry 2008 to 464,000 in 2017. The reasons behind this declining trend include a severe lack of productivity increase (especially in relation to other mining countries that increased mining productivity) and high volatility in both prices of the major metals produced in South Africa and currency (Baxter, 2016; McKinsey, 2019).

This sectoral situation mirrors a more general trend in the country, in which capabilities developed before and just after the apartheid regime were deeply eroded by the crisis and the country's deindustrialization trajectory (Andreoni and Tregenna, 2018). This erosion is particularly evident at the lower end of manufacturing and at the higher end of R&D and product development. New firms are also constrained by different forms of technology and lack of financial capital.

## Main Policy Measures

Starting with the new century, and to face these new challenges, the South African government adopted a series of measures with a twofold aim: i) trigger the development of a mining manufacturing equipment cluster; ii) promoting a collaborative and innovative R&D environment. Table 5 presents the PDP taxonomy with reference to South African policy measures.

**Table 5.** Productive Development Policy Taxonomy for South Africa

| | | Supply Side | Demand Side |
|---|---|---|---|
| **Market interventions** | | • Tax concession (R&D): Income Tax Act, deduction up to 150% of income if R&D expenditure is on specific areas, e.g., beneficiation | • Local content policies (from the Mining Charter, BBBEE related):<br>i. capital goods (40%)<br>ii. consumables (50%)<br>iii. services (70%)<br>• IPAP envisages minimum beneficiation levels for 10 selected commodities<br>• Export scheme for specific minerals (not just raw materials) |
| **Public goods** | **Skills development** | • Mineral Council involvement in all levels of skills development<br>• (e.g., technical vocational education and training)<br>• Skill Development Act 2008<br>• Mine Health and Safety, 1996<br>– Universities, degree programs (specific to mining sector: geology/engineering, etc.) | • Mining Charter, BBBEE target for ownership, employment, and procurement<br>• Mining Charter requires that mining companies invest 5% of total wages into skills development<br>• Mining Qualification Authority supports/monitors companies |
| | **Innovation infrastructure, R&D platforms** | • Collaborative R&D projects<br>• Most important mining-related R&D centers: SAMERDI, CSIR, Mintek<br>• Mandela Mining Precinct:<br>– facilitating role that brings stakeholders together<br>– serves as nerve center for R&D activities | • Match-making platforms to meet demand and supply (e.g., potential suppliers)<br>↓<br>• SACEEC, export-oriented platform |

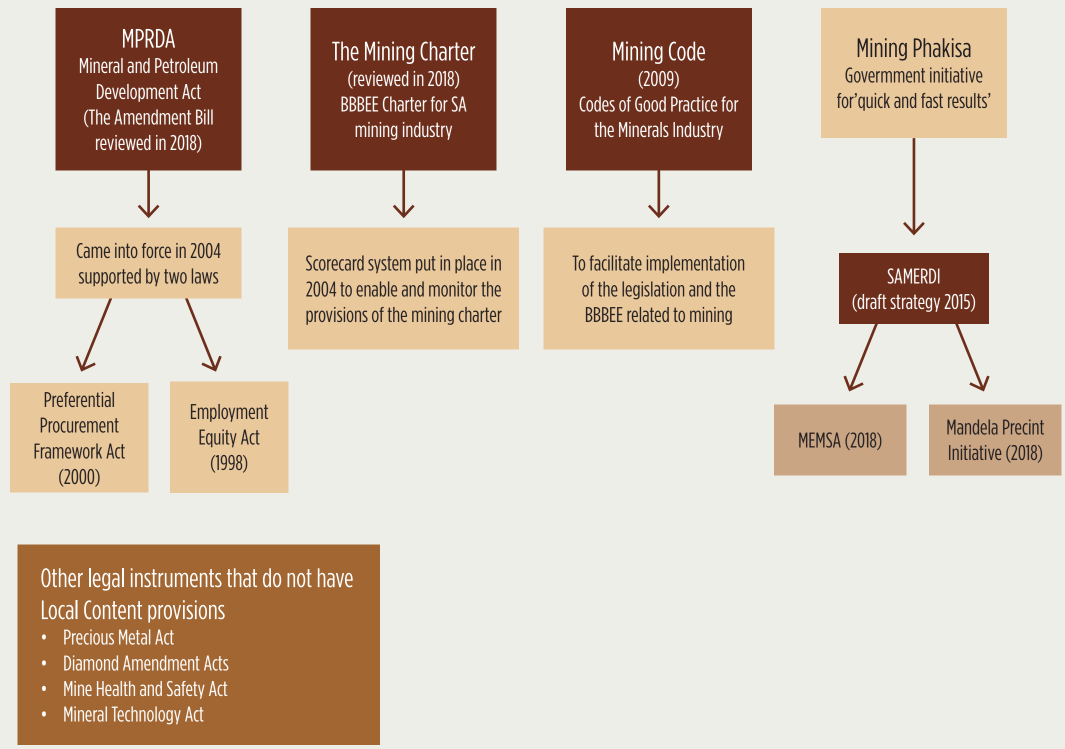
*Source:* Author's elaboration.
*Notes:* BBBEE = Broad-based Black Economic Empowerment; IPAP = Industrial Policy Action Plan; SAMERDI = South African Mining Extraction Research, Development and Innovation; CSIR = Commonwealth Scientific and Industry Research Organisation; SACEEC = South African Capital Equipment Export Council.

In South Africa, mining legislation is dense and is characterized by different sources of regulation. Figure 2 summarizes the most recent regulations adopted as a broader government strategy to bring the sector back to its past competitiveness, productivity, and innovativeness.

The most relevant regulations are:

- The Mineral and Petroleum Resources Development Act*,* which came into force in 2004 with the aim of establishing an environment able to foster the development of the mining industry while transferring sovereignty to the state. The socioeconomic empowerment defined in the Act is supported by two laws: the Preferential Procurement Act (2000) and the Employment Equity Act (1998). In 2018, after five years of discussion, the provision was amended and given a new name, The Amendment Bill*.* The main aim was to lead the country toward local beneficiation of goods, thus climbing up the mining value chain.

**Figure 2.** Recent Relevant Strategies to Promote the South African Mining Sector




*Source:* Author's elaboration.

- The Mining Charter was released in 2004 and revised in 2018. This regulation is sustained by a system of scorecards, introduced in 2004, to give effects to and monitor the provisions of the Mining Charter. The Mining Charter is an effort to increase comprehensiveness and consistency on a number of measures that could be considered part of the complex legislation of South African local content policies. This document was revised in 2010 to quantify minimum thresholds and targets. The core objective is to push the commitment of mining companies to offer each employee the opportunity to become functionally literate and numerate (IGF, 2018b; South African Government, 2004). It is important to consider that non-compliance with any of the above requirements can lead to withdrawal or suspension of the mining permit. The scorecard has five main criteria:
  1. Ownership participation
  2. Employment equity
  3. Human resource development and capacity building
  4. Preferential procurement and enterprise development for compliant BBBEE suppliers; preferential procurement rates apply to capital goods (40 percent), consumables (50 percent), and services (70 percent)
  5. Integrated socioeconomic development for host communities

Two more provisions were added in 2018:

1. Beneficiation
2. Housing and living conditions

- The most recent batch of legislation was fostered by the government through the Mining Phakisa Project,[6] a South African initiative based on "quick and fast results" that united all stakeholders in the industry in a discussion forum ("lab") with the objective of identifying constraints and building a shared vision for long-term development. During the Mining Phakisa Project, the Council for Scientific and Industrial Research (CSIR) played an important role. It was in charge of developing a consolidated mining strategy with the collaboration of the Department of Science and Technology and the Department of Mineral Resources. The resulting document was entitled the South African Mining Extraction Research, Development and Innovation (SAMERDI) Strategy (Singh, 2017). Work on drafting SAMERDI started before the Mining Phakisa Project, and it served as a catalyst to develop collaborative initiatives. After the Mining Phakisa Project, two main focus areas were developed. The first aimed at forming a collaborative R&D model with a focus on core technologies (the Mandela Mining Precinct). The second, the Mining Equipment Manufacturers of South Africa (MEMSA) developed a manufacturing equipment cluster that ensures development requirements are translated into coherent R&D programs (Singh, 2017).

As for the first focus area, the Mandela Mining Precinct was established acknowledging that South Africa had lost R&D capabilities starting from the 1990s. The idea is that the Precinct would have a facilitating role that brings stakeholders together and that it will serve as a nerve center for R&D activities (Singh, 2017). With this aim, the Mining Precinct office has research as well as administrative functions. More importantly, it is intended as a learning center, and it already houses testing facilities for rock engineering, support systems, and ventilation services. The fragmentation that existed in the past, where each mining firm was developing the same solution in isolation and with its own competencies, has been replaced by collaboration. There was a substantial increase in government funding: While in 2015, R&D funding for mining was R750,000 (around US$50,000), the Department of Science and Technology allocated R210 million (around US$14 million) for three years until 2021 for R&D in hard-rock, narrow-reef, metalliferous underground mining. The Mining Precinct pledged R33 million (around US$2 million) for 2018, with a delivery mechanism that follows the ratio of R1[7] from industry for every R2 from government (Creamer, 2018).

The Mandela Mining Precinct was launched with MEMSA, which constitutes the second focus of the strategy. MEMSA has a particular role in assessing technology readiness and aligning possible initiatives with the key points identified by the Mining Pakhisa Project and SAMERDI initiatives. To do this, a Technology Availability and Readiness Atlas was developed to map technologies that are already developed and describe the extent to which they are present, with the ultimate aim of creating a database of technologies. MEMSA has helped position South African

6 The practice was developed in Malaysia; see Singh (2017).

7 Rand is the South African currency. US$1 is equal to around R14.5.

mining equipment as world class through the development of an innovative cluster able to export mechanized narrow-reef hard-rock mining equipment (Singh, 2017). In 2019, MEMSA received R8 million (US$500,000) from the Department for Trade and Industry.

The new funding allocated to these projects has different objectives. At the core of the initiative is the idea of "local solutions for local problems." As mentioned, South African deposits are characterized by steep orebodies and narrow reef packages; important investments are required to understand and meet those challenges (James, 2018; Kaplan, 2012). Overall, from a technical point of view the objectives can be grouped into six main areas (Mamaila, 2019):

1. Improve the longevity of current mines (mines are not making profits because of price fluctuations in platinum, the high cost of electricity, and the cost of extraction because of the specificities of the deposits).
2. Explore opportunities to mechanize drilling and blasting programs.
3. Expand nonexplosive rock breaking.
4. Advance orebody knowledge.
5. Develop real-time information management systems to allow proactive decision-making.
6. Expand the application of technology centered on people.

The overall goal is the creation of decent high-tech jobs and the formation of a highly skilled workforce (James, 2018).[8] It is important to consider that after the Mining Pakhisa Project, the research system changed considerably. There are three key public mining-related research institutions in South Africa: (i) CSIR, (ii) Mintek, and (iii) universities. CSIR is the institution that underwent the most significant changes. It inherited the mandate of the Chamber of Mines Research Organisation (COMRO) after the two merged in 1992 (Pogue, 2006). COMRO had the important coordinating and enabling role of channeling large-scale R&D funds from industry into pure R&D. In the 1990s COMRO declined in importance: until the 1980s the co-investment between COMRO and member companies amounted to around R400 million (US$27 million) per year, but the funding situation worsened until in 2014, only R5 million was allocated for mining R&D. This decrease was due to the shrinkage in total R&D annual budget of R750 million per year (around US$50 million), and mining-related R&D was marginalized. It was only the Mining Phakisa Project that gave CSIR a new role for policy implementation (Fessehaie et al., 2016).

On the export side of the equation, acknowledging the importance of becoming a global leader and linking into high-value segments of the value chain, the South African Capital Equipment Export Council (SACEEC). SACEEC began its mandate as a capital equipment cluster in 1998 and became the first Department of Trade and Industry Export Council in 2000. It provides a platform for capital equipment exporters, supplying information and services to promote exports. "SACEEC facilitates the sharing of export related facilities and manpower, researches new markets and disseminates export leads, and encourages the development of export consortia and the sharing of facilities in global markets" (SACEEC, 2016).

8 The concept of decent work was adopted by the International Organisation of Labour with the Decent Work Agenda (see https://www.ilo.org/global/topics/decent-work/lang--en/index.htm) and was inserted into the Sustainable Development Goals (n. 8). It is also widely used in policy debate, especially by developing countries.

On a different level, South Africa adopted a series of export permit schemes for a range of metals. Among the strategic controls on export is the Price Preference System, which states that an export permit is not released unless the metal (or scrap) was previously offered for sale for domestic beneficiation. Many export permits are not related only to raw materials (Government Gazette, 2019). For instance, in the case of lead, the export permit scheme also refers to secondary lead raw material (ore and scrap) and selected lead-based manufactured products. This system also relates to the push South Africa has been giving to the automotive sector starting from the 2000s, and especially to the local transformation of local components (Fliess, Idsardi, and Rossouw, 2017).

### Skills and Education

Within the mining sector, skills development is managed by the Skill Development Act of 1998 and the Mine Health and Safety Act of 1996. Skills and education have always been of major importance in South Africa; as Kaplan (2012) reported, one interviewee put it this way: "in the 1980s all the clever stuff was in South Africa. This was the magnet. We attracted people from all over the world. Now the magnet is in Australia and we are losing our people, our talent and even our companies to them." In terms of policy misalignment, educational measures rightly pointed at developing skilled workers but without considering the level of demand or incentives for demand. In the 2020s, South Africa has an excess of skilled mining engineers, who are only partially absorbed by mining-related companies (Fessehaie et al., 2016). Regarding education, the Chamber of Mines describes training at the universities as "pitiful." The University of the Witwatersrand—once recognized as a leader in producing highly skilled mining and related graduates—and the University of Pretoria have been declining (Kaplan, 2012) along with the decrease in investment and maintenance of specialist research centers.

A number of measures are being implemented to remedy this situation. The Mining Charter requires that mining companies invest 5 percent of total wages into skills development. Mining companies invest in training in a number of ways, and it is estimated that about R5 billion (around US$330 million) per annum are invested; R6 billion (around US$400 million) were invested in skills development in 2018. In making these investments, companies have the support of the Mining Qualification Authority (MQA), which is the training authority in charge of developing learning programs for the mining sector. By law, mining companies must submit their skills development plans to the MQA to demonstrate compliance with the Mining Charter to maintain their mining rights, and they have to pay 1 percent of their payroll as a skills development levy (Ramdoo, 2018).

The most recent assessment of these policies, which was included in the *Mining Trends Report 2018*, highlighted the effectiveness of education and training in the local mining sector (In On Africa and Managing Transformation Solutions, 2018). The sample analyzed comprised more than 13,000 people from more than 45 mining and core contractor companies during 2013–17. During the same period, more than 6,000 students and graduates participated in experiential learning programs. Of the subjects involved in such programs, about 90 percent of learning is in mining (and general) engineering, while around 10 percent is in management and social sciences. Within different types of training, developing trade workers is a key part of the process;[9] during this period, the mining industry enrolled almost 11,000 trade workers in training and development with a total investment of over R3 billion (around US$200 million) (Minerals Council of South Africa, 2018). Nonetheless, the report pointed out that, within the sample analyzed, there were positive employment effects for a large number of unskilled or low-skilled people. The proportion of "general workers"[10] rose from 7 percent in 2012 to 21 percent in 2017 (IOA and MTS, 2018). The study concludes that, despite the increase in employment and training measures, the challenge for South Africa is to upgrade the skills of existing employees.

Within educational policies, there are frequent mismatches between the type of skills taught in universities and those required to ensure the workforce is ready for modernized mining technologies. It is important to tackle these gaps. International pressure in the form of the proliferation of new technologies, which tend to be misaligned with skills and training initiatives, together with low demand, is presenting other challenges to the latest revision of the Mining Charter. As a further indication of this trend, the 2017–18 iteration of the MQA Sector Skills Plan confirmed that occupations such as mine manager, mine planner, mining engineer, and rock engineer, among others, are still very difficult to fill. The country's economic downturn, as well as strong emigration of skilled people, are important elements to consider. As reported by Moodley (2018), "part of the reason for the lack of experienced mine managers, engineers, and planners is the current economic recession in South Africa which has resulted in a high number of skilled and experienced people migrating to other jurisdictions."

### Research and Development Incentives

Although not related only to the mining sector, but instead applying to a whole range of South African sectors, some important R&D tax incentives affect mining. Specifically, every company that undertakes R&D in South Africa qualifies for an automatic 100 percent income tax deduction of its operational R&D expenditures. Beyond this automatic 100 percent, an extra 50 percent (thus a total of 150 percent) applies to expenditures on R&D activities that have been approved by the Department of Science and Technology (South African Government, 2018, 2012). The objective is to encourage companies to spend more in mineral beneficiation. Mining is one of the sectors that can enjoy the 150 percent tax deduction.

Areas that benefited from this incentive include development of old and new mines, logistic modeling, handling and shipment efficiencies, plus other sophisticated technologies such as wireless technology at the mining sites at variable depths and computer programming for real-time monitoring (Taylor, 2013). These programs fall under the Income Tax Act that was approved in 2006 and slowly started two years later—the program faced a series of bottlenecks, especially in terms of a lack of infrastructure for beneficiation. Apart from the National Development Plan

9 Apprentices are trained as diesel mechanics, welders, fitters, maintenance engineers, rigger ropesmen, etc. For a comprehensive list see: https://www.mineralscouncil.org.za/.../742-skills-development accessed ....2019

10 In the study analyzed in *Mining Trends Report 2018*, general workers are the lowest category in terms of education, with either no education or a maximum of grade 9 (completed at age 14, on average).

set up to address these infrastructure bottlenecks, the Income Tax Act was revised in 2018 and programs were made easier to access. It is estimated that 95 percent of applications (1,212 of 1,277) received since 2012 had been evaluated and decisions had been made on 1,054 of them.

As mentioned, South African laws require a high level of local content; nonetheless, the target may be very difficult to reach because of de-industrialization and loss of strategic capabilities in related sectors. Moreover, it is a shared opinion that the country's numerous and complex local content provisions raised the cost of doing business. It has been challenging for the public sector to enforce existing policies and align new ones, which has been a major concern among South African stakeholders. As for the private sector, the major challenges relate to the excessive weakness of the sector in responding to policy incentives, and to the "top-down" nature of most policy initiatives, with the private sector not really involved in policy design (Ramdoo, 2015).

Despite the difficulty of disentangling each policy's impact, South Africa is a global leader in a number of mining equipment goods and services. In particular, the high local content in mining inputs implies the existence of strong backward linkages. Specifically, as noted by Leeuw and Mtegha (2016), local content in input technologies such as technical support services, manufactured products, and machines is relatively high. The inputs include both services and especially capital goods for which South Africa is a global leader, such as spirals for washing coal, water pumping equipment, geological services, hydropower, tracked mining, underground locomotives, ventilation equipment, shaft-sinking, turnkey new mine design and operation, and many others (Kaplan, 2012; Korinek, 2018; Pogue, 2008). According to a study by Korinek (2017), 89 percent of spending by mining firms occurs in South Africa and the local content of exports in the sector is estimated at 90 percent. A last note is on an assessment released by the Department of Mineral Resources on the Mining Charter in May 2015, stating that mining firms made considerable progress in achieving the targets set by the scorecard (Table 6).

**Table 6.** Assessment Results on the Mining Charter, 2015

| Element (scorecard weighting) | Description | Target | DMR Assessment | |
|---|---|---|---|---|
| | | | Comparison to target | % of submissions that met target |
| Ownership | Min HDSA ownership | 26% | 32.5% | |
| | % of firms achieving target | 100% | | 90% |
| Procurement & enterprises development | Capital goods: % of firms meeting target | 40% | | 81.6% |
| | Services: % of firms meeting target | 70% | | 64.8% |
| | Consumables: % of firms meeting target | 50% | | 82.7% |
| Employment equity: management level | Top | All 40% | 54.1% | |
| | Senior | | 50.7% | |
| | Middle | | 52.7% | |
| | Junior | | 62.8% | |
| | Core skills | | 75.2% | |

*Source:* Chamber of Mines of South Africa.

## Chile

Chile is one of the few countries in Latin America that has experienced sustained economic growth. It is one of the richest countries in natural resources, especially copper:

- Chile produces 27.7 percent of the world's copper (Cochilco data from 2017)
- 28.5 percent of all exported copper comes from Chile[11]
- Copper contributed 15 percent of GDP and 50 percent of all exports (Comisión Nacional de Productividad, 2017; Stubrin, 2017).

The sector is of strategic importance to the country and is characterized by five large mining firms, which produce 82 percent of the country's copper output. The state-owned enterprise Codelco produces one-third of Chile's copper (Korinek, 2013).

Chile greatly benefited from the commodity boom at the beginning of the 21st century, and despite the vulnerable position typical of countries that rely heavily on natural resources, and especially copper, Chile managed the last commodity downturn well from a macroeconomic point of view.[12] The improved macroeconomic management is, according to different studies, related to the institution of two funds, the Economic and Social Stabilization Fund and the Pension Reserve Fund, established in 2006 as part of a broader fiscal responsibility law (Solimano and Guajardo, 2017).

Latin American countries are particularly reluctant to apply vertical policies because of the strong drawbacks they can have (and have had in the past) for the socioeconomic fabric of a country. Until the commodity boom at the beginning of the century, Chile was unwilling to adopt targeted industrial policies. Interestingly, this lack of industrial policy adoption is related only to the copper sector. As Lebdioui (2019a) observed, looking at sectors other than copper, including the salmon industry; forestry products; and the fruits, nuts, and seeds sector, Chile successfully adopted a series of vertical policies to diversify its exports, its economy, and its capabilities.

As for the mining sector, the tendency against vertical policies decreased slightly with the sudden increase in demand during the last commodity boom and the parallel need for more specific technologies. These situations made politicians realize that state intervention could foster the mining-led growth of the country. The longstanding neoliberal view that "Chile does not have the comparative advantage in supply of goods and services in mining" was quietly dismantled with the acknowledgment of market failures as the main obstacles for the localization of goods and services (Korinek, 2013; Lebdioui, 2019b).

11 https://atlas.cid.harvard.edu/explore?country=undefined&product=883&year=2017&productClass=HS&target=Product&partner=undefined&startYear=undefined

12 According to a survey conducted in the Chilean METS sector, only 35% of companies responded that the last downturn had impacted them negatively (Austmine and Asia-Pacific Economic Cooperation, 2017).

**Table 7.** Productive Development Policy Taxonomy for Chile

| | | Supply Side | Demand Side |
|---|---|---|---|
| Market interventions | | Access to venture capital, enhanced role of CORFO in managing public funding for suppliers and startups | |
| Public goods | Skills development | Skill councils, Mining Skills Council with the aim to connect the education sector with the industry | |
| | Innovation, infrastructure, and R&D platforms | | Matchmaking platforms to meet demand and supply, Chile Foundation as part of WCSP |

*Source:* Author's elaboration.
*Notes:* CORFO = Production Development Corporation (Corporación de Fomento de la Producción de Chile); WCSP = World Class Supplier Program.

## World Class Supplier Program

A first small move toward a more dynamic approach to industrial policy is the World Class Supplier Program (Proveedores de Clase Mundial, or WCSP), implemented in 2008. Begun as a private-led initiative by large mining company BHP (rapidly followed by Codelco), the WCSP was intended to ensure there were reliable suppliers and to strengthen the collaboration between mining firms and suppliers.

The program, "a market solution to solve problems" (Stubrin, 2017), was fostered by large mining companies' needs to find solutions to their problems. In this sense the aforementioned outsourcing trend in the mining industry opened spaces for local in situ suppliers (Chile Foundation, 2014). The WCSP has also aimed at providing Chilean suppliers the opportunities to enter the knowledge-intensive mining services (KIMS) sector. It has been shown by different studies that Chilean firms enter more dynamic segments of the copper value chain in two ways: (i) customized products or services that respond to specific challenges posed by local conditions (that is what is directly addressed by the WCSP), and (ii) using new technologies as a platform to develop unique solutions to unresolved mining problems. Firms entering the value chain in these ways are generally small, young companies created as scientific spinoffs. In both cases, companies use their knowledge base as a platform to develop new market niches and they bear all the risks (Bravo-Ortega and Muñoz, 2018; Pietrobelli et al., 2018; Stubrin, 2017).

The WCSP policy is oriented toward mining firms and has a twofold aim: (i) it intends to solve mining firms' problems and challenges, and (ii) it focuses on suppliers' scaling up to enter the international market. The procedure planned by the policy program, as explained by Navarro (2018), is divided into three phases:

1. The operational issue or problem is detected, and suppliers are informed about it. This information should be provided through the formal channel of the Chile Foundation, but

it is passed on in informal ways most of the time (Molina, 2018). Afterwards, pre-selection and final matching occur.

2. The selected supplier starts a bilateral investment and innovation relationship with the mining firm.
3. The program offers advice to suppliers for scaling up their innovative solutions and trying to tap into the international market. This last step was the first real attempt to provide an export-oriented policy.

Public bodies are involved in these phases, although without extensive controlling or monitoring. The Chile Foundation is a semipublic agency that acts as a sort of intermediary in the process between mining firms and suppliers. It is in charge of diffusing mining companies' challenges, and registering and pre-selecting suppliers; the latter is done with the lead mining firm. Though the Chile Foundation is meant to follow up on the program, it has more of an information-provider role than an explicit mandate to monitor the program and the achievement of its goals (Navarro, 2018).

In 2013, a number of universities started to participate, acting as a sort of business accelerator giving advice to the businesses. Nonetheless, even in this case, as with suppliers, "they [i.e., businesses] do not have any formal commitment to the acceleration process and are not responsible to the suppliers if firms don't offer facilities to test" (Navarro, 2018).

A discussion of the challenges and issues that this program had is beyond the scope of this report. Nonetheless, it is important to mention that one of the biggest obstacles to the full success of the program has been the excessive, almost exclusive, reliance on suppliers' financial resources in the second step, leaving suppliers to bear the entire risk of the operation. Further, there is no sharing of R&D expenditures in the majority of the cases, making the learning opportunity for the supplier quite small. Moreover, even during the third step, failure to create a pool of exporting suppliers led to reconsideration of the whole program.

### Open Innovation Program in Mining

A new version of the WCSP was put forward in 2017 that required a deeper commitment for mining firms to collaborate in the piloting, testing and scaling up phases. The new version included a first important call for greater involvement of the public sector. The WCSP was also reformed because large firms soon realized the amount of effort, coordination, and activity required go beyond the capabilities of a single actor. BHP realized it needed public goods and the participation of other mining companies to scale up within the program (e.g., access to capital, incentives, training, testing facilities, etc.) (Lebdioui, 2019b).

The WCSP evolved into the new program Open Innovation Mining (Programa de Innovación Abierta en Mineria) (Meller and Parodi, 20170, which also became part of the broader 2015 public–private initiative known as Alta Ley. Alta Ley leaves a much stronger role for public participation in these mining projects. For example, external funding is provided by the Production Development Corporation (Corporación de Fomento de la Producción de Chile, or CORFO). CORFO leads these projects and the Ministry of Mining. Its objective is to create 150 local suppliers for the mining sector and it has an export target of US$10 billion by 2035 (Comisión Minería y Desarrollo de Chile, 2014). CORFO plays a leading role especially when it comes to public funding destined for suppliers and startups in the mining industry. Alta Ley has another important objective: together with the Valor Minero program, it was approved with the idea of fostering sustainable development of the mineral sector.

The Open Innovation Program in Mining is important because it changed the role of the Chile Foundation, which has a more effective role in assessing the impact on providers and in assisting with methodology for suppliers' development. The decision to increase participation of public bodies in a resource-based development project was based on both the bottlenecks of a private-sector led program and on the understanding that learning is increasingly happening not only through market channels, but also through public policy support (Primi, 2013).

## Skills and Capabilities

While some case studies show that general mining capabilities are present in Chile (Fernandez-Stark, Bamber and Gereffi, 2011; Stubrin 2017), innovation capabilities are stagnant (Urzúa, 2012). Firms struggle to enter the mining sector for two main reasons:

1. Mining is an industry where there is a high degree of brand loyalty and companies that have been established for many years have a clear advantage.
2. Because of significant mismatches in the policy design and implementation process, businesses do not receive learning opportunities from large firms, which would act as an external stimulus, nor from enabling coordinating public institutions.

Even when suppliers succeed, a major obstacle is the complete risk they assume throughout the process. Hierarchical forms of governance, where power and information asymmetries prevail, characterize the mining global value chain (Morris et al., 2011) and tend to inhibit innovation and learning (Pietrobelli et al., 2018). The long-term project of mining-related innovation entails enormous risk and, in Chile, large companies strongly resist being the first movers and therefore do not tend to spend resources on either testing or providing facilities for testing. Recent studies have found that experimentation at mine sites is one of the most significant bottlenecks for Chilean KIMS innovation strategy (Stubrin, 2017). Also important is the fact that, in contrast to local Australian firms, for which R&D is highly subsidized, in Chile there are no such measures, and the challenges of scaling up persist.[13]

A further crucial element is skills. Skilled human capital shortages are one of the most important factors inhibiting the participation and innovation potential of suppliers. Internal training measures are normally taken but no university offers specific human capital development (Lebdioui, 2019b; Korinek, 2013). In an effort to address this, in 2012, the Mining Council founded Chile's Mining Skills Council (Consejo de Competencias Mineras; CCM) with the aim of connect-

13 According to OECD data, in 2019, Chile was placed among the lower tier of OECD and partner economies in terms of total government support for business R&D, equivalent to 0.03% of GDP. https://www.oecd.org/sti/rd-tax-stats-chile.pdf

ing the education sector with the industry. It is supposed to be a sort of labor-matching platform between demand and supply (IGF, 2018c). On the basis of the successful experiences of other countries, this sort of platform would also offer specific qualification and standard requirement certifications (Villarino, 2016); these mechanisms would allow demand and supply stakeholders to have access to the same information.

CCM collects data from mining companies, education institutions, and training suppliers to further allow it to identify skills shortages and forecast demand. Despite this policy measure, recent case studies conducted by Bravo-Ortega and Muñoz (2018) highlighted the need for skills (and tax incentives) as one of the most significant bottlenecks encountered by suppliers, which are providing specific courses internally because universities do not provide adequate programs.

### A Softer Approach

Table 7 (above) clearly shows that Chile preferred a softer approach than Australia and South Africa. For both education and supplier–customer relations, the instrument Chile adopted is a platform to connect different stakeholders. The first timid attempt to further involve the public sector came under Alta Ley and the Open Innovation Program in Mining, which confer more power in terms of funding management to CORFO.

The government could play a more incisive role in many areas by maintaining the softer approach or by adopting more targeted measures, as in Australia and South Africa. Chile has a historical legacy in its use of softer approaches even considering Latin America, where countries such as Brazil have adopted more targeted policies. For instance, Brazil promoted cluster development in areas where there were already established capabilities like mining, and specifically copper mining (Primi, 2013).

Some recent studies showed that the WCSP worked to a certain extent. Between 2010 and 2012, the overwhelming majority of mining suppliers experienced increases in their sales and there were new entrants in the sector (Bravo-Ortega and Muñoz, 2015). In December 2012, just a few years after its implementation, the WCSP was already working with 36 suppliers (Hidalgo et al., 2014; Korinek, 2013). This program was also important in reducing information asymmetries and encouraging longer relationships between suppliers and lead firms, even if the numbers related to longer term relationships established as part of the program are well below policy goals (Navarro, 2018). In terms of exports, the objective was not reached; KIMS export 20 times less than their counterparts in Australia, despite Chile being one of the top producers of copper (Lebdioui, 2019b).

The Government of Chile could focus its attention on at least two areas for productive development policies. First, together with education policies, which remain lacking according to recent empirical analysis, government could play a decisive role by promoting the introduction of common standards, especially in areas like safety, security, and information technology. Doing so would lead to a reduction in transaction costs for suppliers of mining equipment and services and would contribute to significant overall benefits for mining firms (Korinek, 2013).

Second, a more targeted approach could tap into the bottlenecks of the WCSP with more effective measures, such as R&D platforms and enabling institutions that could help suppliers to adapt the technologies. Institutions could also, in their work with mining firms, decrease the amount of risk that businesses, especially SMEs, bear. These supplier firms have to sustain other costs without the support of mining firms, such as for skilled employees, physical assets (e.g., for testing), and IT infrastructure.

# POLICY IMPLICATIONS FOR LATIN AMERICA

Policies are always time and context specific, but they are also shaped by regularities and general principles that make the sharing of practices and challenges in design and implementation a valuable exercise (Primi, 2013). For instance, resource-based development experiences often proceed along a known path: (i) initial adoption of foreign technologies, (ii) adjustment to the local environment and demand, and (iii) innovation beyond foreign technologies (Fessehaie and Rustomjee, 2018). Although the cases presented in this report are very diverse from institutional, historical, industrial, educational, and social points of view, common lessons can be learned by examining recurring patterns and common challenges that each of these experiences presents.

Mining is increasingly regarded as a sector that could foster development and sustained growth. As stated throughout this report, given mining's intrinsic characteristics, long-term commitments both from an institutional and policy point of view and from a business development perspective are crucial to its development. Foreign direct investments (FDIs) by large mining companies are crucial to attract mining activities to the country (unless there are efforts toward building a national champion, as Chile did with Codelco). Although FDIs are essential to building local capabilities and to developing a local supplier base, they are not sufficient. As shown by the experiences of Australia, Chile, and South Africa, investments in capabilities pass through complementary investments in education, R&D for local solutions, and a series of instruments that increasingly lead mining firms to supply goods and services locally.

With this in mind, we propose the following five lessons as a guide for mining sectoral policies in Latin America.

## Balance Supply and Demand Policy

The taxonomy proposed in this report aims to deepen the analysis of why certain types of policies are successful and foster a country's mining industry. While demand-side innovation opportunities provide little concrete support for innovation (Bravo-Ortega and Muñoz, 2015; Pietrobelli et al., 2018), they are important because they promote local suppliers and thus local development through different kinds of institutions, rules, and standards. Supply-side incentives have proven effective in the mining global value chain when they focus on innovation, such as in Australia. In this sense, suppliers managed to enter the global industry taking advantage of the new windows of opportunity opened by new technologies and new materials. Nonetheless, as shown in the Australian case, there are a whole set of policies on the demand side that provide a whole framework to take local suppliers on board for a new project, despite these policies not being strictly compulsory unless projects are more than AU$500 million (US$340 million).

Supply and demand policy equilibrium is crucial to create a local and regional ecosystem, especially in light of the fact Latin American countries are the only natural resource–rich countries that lack a regional mining service cluster (Korinek, 2018).[14] Within this framework, local content policies that in our analysis could clearly apply to South Africa and Australia, are a typical demand-side instrument (upper right quadrant in the taxonomy) and are considered critical because they are difficult to design and risky to adopt. A full range of failure experiences exist in which local content provisions were not matched by policies on the supply side. One common aspect related to this failure is related to the misalignment between local content provisions and the lack of investment in the process of capability-building and accumulation. Very often, this creates an environment where the ultimate choice is between complying with local content provisions and competitiveness. Local content provisions are just a first step toward the possibility to develop a local industry, which can be fully exploited only if other conditions are promptly met (Lebdioui, 2019a).

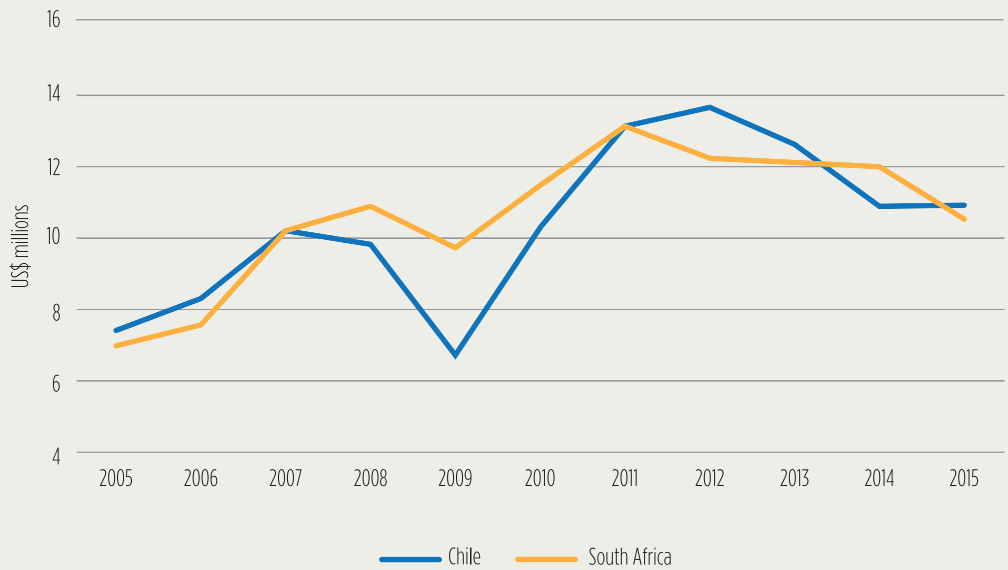
## Uncover Manufacturing Export Potential

This report touches on Latin America's as yet not fully realized export potential. Although international data are limited, we provide figures for the export of both mining support services and two categories of mining equipment. Korinek (2018) reported that Latin America is the only mining region that does not have a mining service cluster. Figure 3 compares the exports of mining support services for Chile and South Africa. The drop in 2009 could, for both countries, point to the financial crisis, with a stronger impact on Chile. From 2010 to 2015, both countries increased their mining support service activities, yet invested very little in absolute terms. If we consider the

14 "Imported services, although lower in all regions than domestically produced ones in terms of value added, differ in magnitude and in region of origin. Two regions, Europe and East Asia, show significant regional trade in mining services.... For all other regions, intra-regional trade in mining services accounts for less than 2% of the value added of the mining sector. In sub-Saharan Africa, MENA and Latin America, the share is less than 1% of the value added of the sector. In Latin America in particular, home to three of the top four global minerals exporters in value added terms, the existence of a regional mining services cluster is surprisingly absent. In Latin America, MENA and sub-Saharan Africa, the largest share of imported services for the mining sector comes from Europe" (Korinek, 2018).

42 percent of total Australian METS exported to South America, this means there is potential for Chile and other mining countries in Latin America to specialize in mining services.

**Figure 3.** Mining Support Service Exports, Chile and South Africa, 2005–15



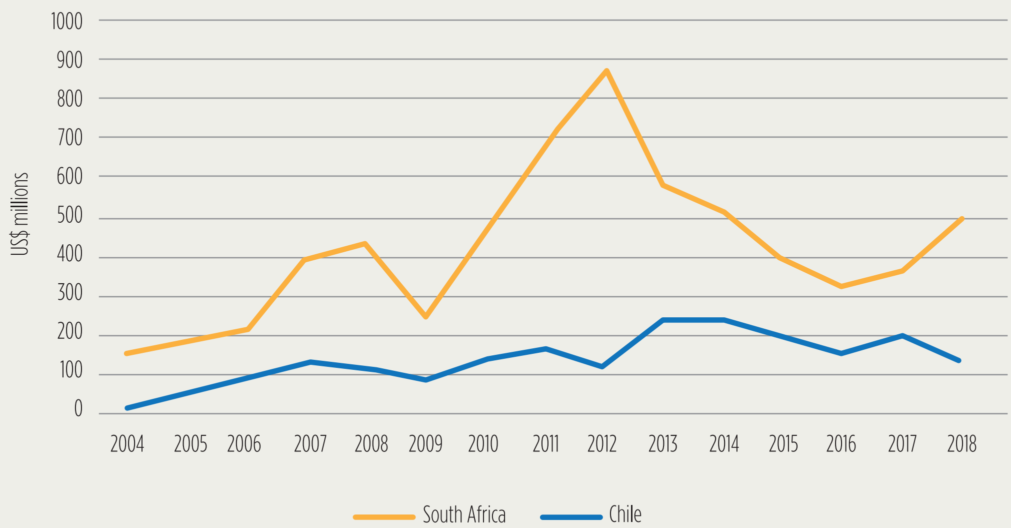

*Source:* Author's elaboration based on TiVa dataset.

As for the export of mining equipment, Figures 4 and 5 compare Chile's and South Africa's exports of two types of mining equipment, surface and underground mining equipment, and mineral processing equipment.[15] We compared South Africa and Chile, but not Australia because it is more useful to compare countries that are at a similar stage of development. The export gap between Chile and South Africa could have different causes, from historical legacy to policy focus. South Africa put a strong policy emphasis on manufacturing, especially machinery for underground mining, because of its particular narrow-vein deposits.

Considering Chile's potential in the export of mining products and the different measures the country has implemented to control its macroeconomic stability, there is room for export growth. This is especially true for the mining equipment sector because Chile is surrounded by mining countries that are potential importers of mineral goods and services.

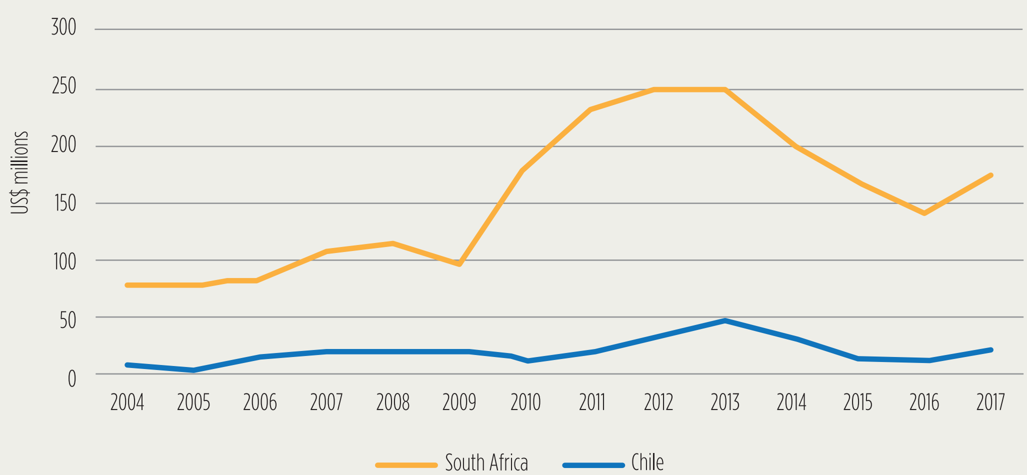
15 The HS class references for the two categories are based on the work on Peruvian mining equipment by Bamber, Fernandez-Stark, and Gereffi (2016).

**Figure 4.** Surface and Underground Mining Equipment Exports, South Africa and Chile, 2004–18




*Source:* Author's elaboration based on UN Comtrade data.

**Figure 5.** Mineral Processing Equipment Exports, South Africa and Chile, 2004–17




*Source:* Author's elaboration based on UN Comtrade data.

## Industry and Environmental Changes Could Trigger Technological Change…

Changes in the mining industry have been driven by both external (environmental and natural conditions) and internal (industry-related) dynamics. Some of the internal dynamics were explored in the analysis of the deverticalization that occurred in the past three to four decades with a series of mergers and acquisitions that left the industry dominated by a few giants.

As for external dynamics, the mining sector is having an increasing impact on the environment and the sector faces a series of challenges related to climate change and the speed at which the soil is transforming. A number of factors are affecting the industry from a purely environmental point of view. Decreasing ore grade, changes in environmental conditions, steadily decreasing productivity, and increasing costs are some of the challenges that Pietrobelli et al. (2018) and Stubrin (2017) highlighted with reference to Chile and may be extended to countries such as Brazil (especially with reference to iron ore deposits) and Peru. This is confirmed by Molina, Olivari, and Pietrobelli (2016): Peruvian companies already suffer from dealing with "dirty" minerals because of the depletion of high-quality ore. Moreover, mining activities demand huge amounts of water, and this in itself poses remarkable environmental challenges. These obstacles challenge the mining industry but, at the same time, could act as a trigger to learn and to develop new solutions. For instance, in Peru, a publicly funded R&D effort to develop tailor-made solutions for dirty materials could improve the quality of the extracted ore. Therefore, natural resource scarcities and environmental or material-related bottlenecks in production could be overcome through a dynamic process of capability development (Pietrobelli et al., 2018).

The need to search for local solutions to local problems triggers the adoption of new sophisticated technologies; nonetheless, the adoption of new technologies requires huge investments by countries that may not be in a position to acquire or invent new technological applications. Hence, state interventions play a pivotal role in this area. Australia and Norway demonstrated how solutions for in situ applications were the first step toward building up technological capacity, also showing how sustained growth was established through incremental improvements around daily problem-solving activities (Ville and Wicken, 2013).

As discussed, South Africa and Chile embarked on a similar path, albeit on a much smaller scale (Ebert and La Menza, 2015; Kaplan, 2012). Investing in knowledge and the ability to tap into new technology niches, as shown by the attention that mining countries pay to high-technology services, is the key not only to linking up with the global demand of multinational companies but also to ensuring a successful path toward export. Kaplan (2012) showed a clear link between technological development and exports. In Latin America, the commodity boom coincided with a gradual change in the orientation of PDPs, which started to focus more on science, technology, and innovation to achieve long-term economic growth (Crespi and Dutrenit, 2014; Crespi et al., 2014), cognizant of the idea that policy interventions for knowledge investments are necessary because market forces would only allow suboptimal investments in this area (Mazzucato, 2016).

## ... And Sustainability

Environmental changes raise awareness of, and the quest for, sustainable production and growth. The imperatives of green growth generate pressure on mining firms that translate into changes in the patterns of demand toward more environmentally friendly technologies for suppliers (Bamber et al., 2016).

Mining is generally regarded as a non-green industry that negatively affects the environment and displaces people. This is confirmed by the constant emergence of social issues in communities where mines are located, which are quite often remote communities far from major cities. For instance, in Peru, social conflicts increased by 300 percent from 2009 to 2014, with 149 recent disputes involving extractive industries (International Monetary Fund, 2014). Two elements are important in this regard.

First, rising concerns about the necessity of respecting both the environment and the people living around mines will increasingly tighten the access and licensing process, as well as monitoring systems, to ensure that operations are in line with regulations. This increased monitoring will increase pressure on both mining firms and suppliers. The rising number of tripartite agreements between government, multinational companies, and Indigenous people is a sign of these changes. Examples from Australia, Canada, and to a lesser extent Brazil confirm this trend.

Second, the mounting pressure for green growth is likely to have a twofold effect. On one hand, consumers will be more and more conscious of and interested in sustainable products that comply with high standards. On the other hand, these standards are likely to act as a trigger for local suppliers that would have to, for instance, be able to collect data on the mining process so that the final product can be traced back to the extraction point. Hence, developing capabilities in the use of big data and blockchain technologies and honing the use of sensors are rapidly becoming fundamental needs for mining industries.

It is worth recalling that the latest mining policy documents in Chile—Valor Minero and Alta Ley—give special attention to sustainability. Valor Minero is a public–private initiative that has promoted productive, collaborative, and benefit-sharing development in mining areas. Alta Ley is an initiative designed to coordinate the building and development capabilities of public and private organizations and agencies with a specific focus on the challenges the mining sector faces. As part of this new role, the organization developed *From Copper to Innovation: Mining Technology Roadmap 2035*, which not only focuses on specific measures such as focused R&D, but also provides a more general message on attention to sustainable production processes and product design (Fundacion Chile, 2016). The design of such innovative Chilean programs could serve as a model for sustainable development policies for other countries in the region.

## Ensure Government Stability: Stable Institutions Matter

Specific features characterize the mining sector that require consistency and long-term public policies. From initial licensing to the closing of the mine, mining projects last decades. This means that undertaking this type of investment requires huge sunk costs and long-term prospects and thus the stability of the country is essential. Economic, institutional, and political stability demands stable taxation and regulatory systems and consistent policies for incentives and/or duties that affect mining companies.

The three countries studied in this report, Australia, South Africa, and Chile, present different degrees of political stability. Stability likely affected the rate of investment, which is also crucial in other parts of the world, notably Southeast Asia. Thus, in Latin America, maintaining high investment performance is not an easy task because of the typical problems of governments' "dynamic inconsistency" (Pietrobelli and Puppato, 2016). Within the institutional framework, it is worth considering the dynamic role played by public and public–private agencies in the process of PDP design, monitoring, and implementation.

Such agencies need to be insulated from the political cycle with "a steady flow of resources yet with flexibility to 'auto'-adjust to suit changing policy contexts. Such mechanisms are the missing linchpin for Latin American countries characterised by their 'policy volatility'" (Murillo, Scartascini, and Tommasi, 2008). Chile serves as an interesting example in this sense: support for copper-related programs seems to have continued despite changes in leadership, in contrast to programs directed at other sectors. Finally, public institutions also matter when it comes to the creation of natural resource funds, which can be considered as a sort of sovereign wealth fund in charge of managing revenue from the natural resource sector. Latin American natural resource funds are relatively small compared to those of OECD countries or oil-rich countries in the Middle East and, as shown by the Chilean experience, they are not characterized by adequate transparency within the decision-making and implementing process (Iizuka, Vargas, and Baumann, 2017).

# CONCLUSION

This report states the importance of systemic, coherent, and comprehensive policies. The equilibrium of supply and demand policies is essential to foster the creation of a regional ecosystem in Latin America, especially considering that the region is the only natural resources–rich area that lacks a regional mining service cluster. There is no one-size-fits-all argument, and it could be argued that the need for policies on the different quadrants of our taxonomy may differ according to a country's stage of development, sectoral power distribution, and institutions. What we observed as critical is the importance of balancing demand- and supply-side policies, which also involves consideration of the feasibility of policy design and implementation processes. We argue that countries that intend to foster their mining sectors through the adoption of PDPs are more likely to succeed if they consider demand and supply mechanisms.

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