3

Mining Foreign Direct Investments and Local Technological Spillovers

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Introduction: Motivation and Structure

The purpose of this chapter is to examine the book's main theme of innovation and intellectual property rights in the mining industry through the lens of foreign direct investment (FDI).[1] Specifically, it looks at the role of mining multinational enterprises (MNEs) as promoters of international mine production and as drivers of technological development in host countries. Indeed, the issue of FDI spillovers, both technological and of another nature, has a particularly critical development dimension in the mining industry where the bulk of investment takes place in developing countries, often LDCs (least developed countries).

The content of this chapter benefits from the expertise developed within UNCTAD Investment and Enterprise Division on the main trends and issues related to mining FDI (see e.g. *World Investment Report 2007*, chapters III to V: UNCTAD, 2007a) as well as on the link between FDI, technology and innovation (*World Investment Report 2005*, chapters III to VIII: UNCTAD, 2005c). The direct experience gained by UNCTAD through technical assistance to developing countries rich in mineral resources (see e.g. *Investment Advisory Series*: UNCTAD, 2011) also integrates the theoretical discussion with policy lessons learned 'in the field'.

Section 3.1 describes the broad context of mining FDI. Section 3.2 introduces the development dimension of mining FDI, and briefly discusses the different types of impacts that mining FDI have on host economies, with

[1] Foreign direct investment (FDI) is defined as an investment involving a long-term relationship, and reflecting a lasting interest and control, by a resident entity in one economy (foreign direct investor or parent enterprise) in an enterprise resident in an economy other than that of the foreign direct investor (FDI enterprise or affiliate enterprise or foreign affiliate) (UNCTAD, 2009a).

a focus on poor and vulnerable countries. Section 3.3 focuses on the innovation and technology dimension, the core theme of this chapter. It introduces a framework to analyze the role of mining MNEs as agents of innovation and triggers of technological spillovers in host countries. Section 3.4 presents an empirical assessment of how conducive the current context of mining FDI is to the transfer of technology and innovation to host countries. Finally, Section 3.5 provides policy insights and recommendations to host countries on how to leverage the technological and innovation potential of mining FDI for sustainable development.

3.1 Mining Foreign Direct Investment: An Overview

3.1.1 Multinational Enterprises (MNEs) in the Mining Industry

Investments in extractive industries have special features that make them very different from other kinds of productive investment. Long gestation periods and high capital expenditures are required to reach a minimum efficiency scale and this entails a significant degree of risk. They also have uncertain returns, due to the volatility of international commodity prices, as well as high sunk costs of project-specific assets that can hardly be transferred or sold.

Such kinds of investment, especially when taking place in developing countries, generally require the involvement of a large multinational enterprise (MNE) or a state-owned enterprise (SOE) that can rely on financial support from the government. As developing countries may lack the stock of knowledge and capital necessary to exploit their mineral endowments, a large number of investment projects is undertaken by foreign affiliates of MNEs. It follows that mining production is predominantly transnational: FDI plays a key role in enabling world mineral production, and MNEs in orchestrating it.

An analysis of the 100 largest (publicly listed) mining corporations confirms a prominent role of MNEs, at almost 70 percent of the sample, and a significant share of state-owned enterprises (17 percent) (Figure 3.1, left-hand side). In terms of geographic presence, a remarkable 60 percent of the subsidiaries of the largest 100 mining firms are located abroad (Figure 3.1, right-hand side). In other words, more than half of the operations of the largest mining MNEs are foreign owned. Also evident is that Chinese mining plays a major role in the domestic component of the statistics. Excluding Chinese firms from the sample leads to an increase in the share

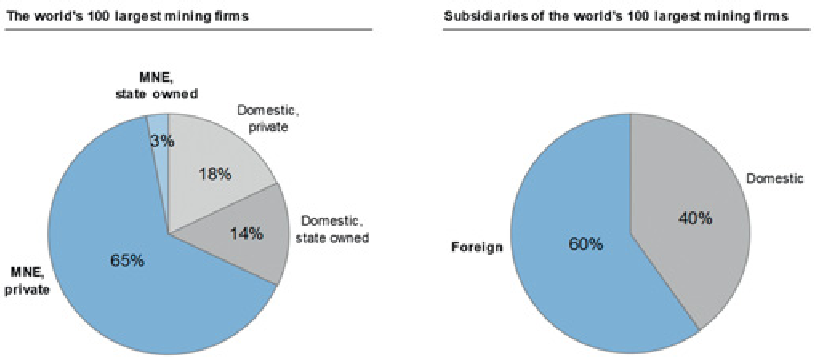

Figure 3.1 Ownership profile of (large) mining firms. Largest 100 mining companies based on operating revenues (distribution based on number of firms)
Note: Extraction from ORBIS Bureau Van Dijk, December 2018. Includes publicly listed firms operating in mining, based on US Standard Industrial Classification (SIC) (primary codes: 10 – Metal mining, 12 – Coal mining, 14 – Mining and quarrying of non-metallic minerals, except fuels). Relevance of each company for the purpose of the analysis was assessed against ORBIS trade description and, in some cases, company websites. Top 100 firms are ranked by operating revenues in the latest available year (2017 or 2018). For each company, ORBIS provides the list of *majority-owned subsidiaries* (direct or total ownership equal or above 50%). 'MNEs' are classified as companies with 10% or more of majority-owned subsidiaries located outside the home country. Companies with partial ownership information, dual-listed companies and entities part of the same corporate group were omitted.
Source: Author's calculations.

of MNEs to 76 percent and in the corresponding share of foreign subsidiaries to 64 percent.

Not only are large mining companies predominantly transnational, but mining multinationals also tend to have a more pronounced international footprint compared to other MNEs. This can be seen by comparing mining with non-mining multinationals in UNCTAD ranking of top 100 MNEs, including very large MNEs from different industries.[2] Mining MNEs (Glencore, BHP Billiton, Rio Tinto, Vale, Anglo-American) are the most internationalized in the sample according to the UNCTAD *transnationality*

[2] UNCTAD ranks the largest non-financial MNEs by their foreign assets and presents data on assets, sales and employment in two top 100 lists, respectively global and from developing and transition economies. The rankings are released on an annual basis as annex tables to the flagship *World Investment Report*. For analytical insight on the role and relevance of these MNEs in the global economy, see UNCTAD (2017).

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index or TNI (see the note to Table 3.1 for the TNI definition). Furthermore, they are relatively more present in developing countries. Some 35 percent of foreign affiliates of mining in UNCTAD ranking are located in developing economies, half of which are in Africa (17 percent), a share four times larger than manufacturing and services in the same group, at 5 percent and 4 percent respectively (Table 3.1).

3.1.2 Recent Trends in Mining FDI

Against the backdrop of an industry 'structurally' transnational, the level of cross-border mining investment has been dramatically falling in recent years. Since 2012, and partly due to declining commodity prices, global mining FDI has decreased by almost 90 percent, after having surged throughout the boom and hit a long-time high in 2011.[3] A pronounced downward trend has been involved in both FDI modes of entry, greenfield FDI and cross-border M&As. Such a drop reflects quite closely the decline in commodity prices and its impact on investment decisions (Figure 3.2). As of 2012, MNEs found themselves bearing the costs of a decade of large-scale, growth-led investments, without the support of the high operating margins blessing the industry during the 2000s commodity super-cycle. The fall in commodity prices and consequent erosion of operating margins have forced mining MNEs to rethink their international investment model, shifting the focus from growth and investment to efficiency and productivity. Between 2012 and 2016, the operating profits of the largest five mining MNEs declined by over 60 percent, with net income falling even more (–90 percent), squeezed by weak prices and high levels of debt. For three of the top five mining MNEs (Glencore, Vale and Anglo-American), cumulative net income was even negative in the period. These very challenging operating conditions are the root causes of the abrupt retreat in mining international investment in the most recent years.

[3] Based on the sum of the value of FDI greenfield investment from the Financial Times Ltd, FDI markets and cross-border M&As from Thomson Reuters. Greenfield FDI relates to 'investment projects that entail the establishment of new entities and the setting up of offices, buildings, plants and factories from scratch,' while cross-border M&As involve 'the taking over or merging of capital, assets and liabilities of existing enterprises' (UNCTAD, 2009a). The use of project data on FDI greenfields and of data on cross-border M&A deals is well-established in the analysis of FDI (see UNCTAD *World Investment Report,* various editions). In particular, these two sources usefully integrate and complement Balance of Payments (BoP) FDI data in sectoral analysis as official BoP statistics are generally poor, especially for developing economies, and only available with a lag of two years.

Table 3.1 *Mining MNEs in UNCTAD Top 100 ranking of the largest global MNEs*

	TNI index						**Ownership structure**					
	Domestic vs foreign affiliates						Geographic breakdown of foreign affiliates					
Sector	# of MNEs	Avg share of foreign assets	Avg share of foreign sales	TNI index	Share domestic subsidiaries	Share foreign subsidiaries	Share developed	Share developing	Africa	Asia	LAC	Share transition
Primary, mining	5	73%	79%	0.76	14%	86%	64%	35%	17%	8%	9%	1%
Primary, oil & gas	6	82%	66%	074	13%	87%	74%	24%	5%	13%	8%	2%
Manufacturing	64	57%	72%	065	20%	80%	66%	30%	5%	18%	9%	4%
Services	25	62%	47%	0.55	29%	71%	70%	28%	4%	14%	10%	1%

Source: Author's calculations.
Note: The list of top 100 MNEs is based on UNCTAD ranking of 2016 (UNCTAD, 2017). For each MNE, the share of foreign asset and the share of foreign sales were derived from financial reports. The transnationality index (TNI) is calculated as the arithmetic mean of the share of foreign assets and the share of foreign sales. TNI is a firm-level measure of international exposure, e.g. the degree to which a MNE's interests and operations are embedded within the home country or retained abroad. It ranges from 0 (no transnationality) to 100 (full transnationality). Note that this is a simplified version of the full UNCTAD TNI that includes also the share of foreign employees in the average. The ownership structure of UNCTAD top 100 MNEs was extracted using ORBIS Bureau Van Dijk's ownership information. Subsidiaries included in the analysis are majority-owned (directly or in total) by the corporate parent.

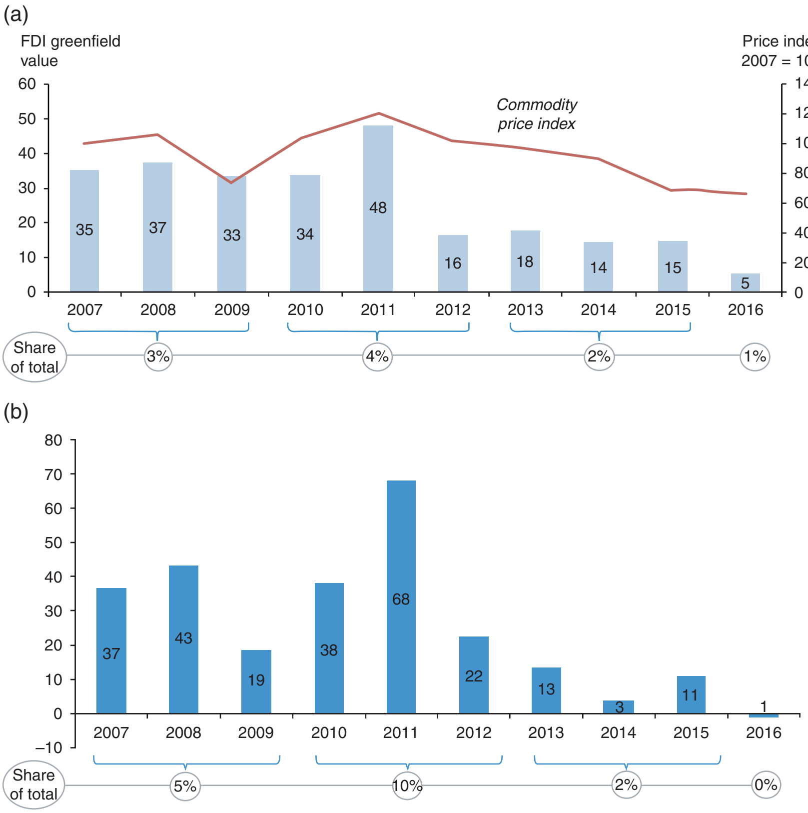

Figure 3.2 Recent trends in mining FDI
Note: Greenfield FDI and cross-border M&As are from UNCTAD FDI/MNE database, based on original data from Financial Times Ltd, fDI Markets and Thomson Reuters respectively. The same analysis based on number of projects and deals (instead of values) produces similar results.
Source: Author's calculations.

A long period of falling investment has led the global weight of mining FDI to become increasingly marginal (see shares in Figure 3.2). Yet, some developing, particularly low-income, countries still heavily rely on mining FDI. In the period 2012 – 2016, mining investment still represents 10 percent of greenfield FDI flowing to developing countries, relative to 4 percent for developed economies. This share surges to 18 percent for the groups of least developed countries (LDCs) and, in many of those economies, it exceeds 30 percent. These figures expose the development dimension of mining FDI, whereby a sizable part of fresh foreign investment flowing into some of the most vulnerable countries is tied to the exploitation of mining resources. These countries so far have been unable to diversify and attract other types of FDI.

With the bulk of economies untouched by mining FDI and few, mainly low-income countries heavily dependent on it, major developments are instead taking place on the investor side. The most visible effect is the growth of some developing country investors, such as China, India and Brazil, replacing most traditional investor countries from the developed world, particularly Canada and Australia (Figure 3.3). The most prominent case is China. Greenfield FDI investment from China between 2012 and 2016 have doubled relative to the comparable period 2002–6, positioning China as the third largest investor in cross-border greenfield projects after Canada and the United Kingdom. Chinese growth in cross-border M&As is even more impressive. In a decade, the total value of cross-border acquisitions by Chinese MNEs has increased by almost thirty times, from a cumulative 200 million US$ in the period 2002–6 to almost 6 billion US$ in 2012–16. During this period, Chinese companies have been by far the most active in acquiring foreign mining companies, with the share of China in (outward) cross-border M&As jumping from 1 percent (in 2002–6) to 25 percent. One out of four dollars spent in M&A of foreign mining companies has come from China. Around 60 percent of the value of cross-border M&As concluded by Chinese investors have targeted local companies, while 40 percent involved the acquisition of foreign affiliates of non-Chinese MNEs. The expansion of Chinese MNEs has been particularly pronounced in Africa where, between 2012 and 2016, around 20 percent of the value of FDI greenfield projects and more than 40 percent of cross-border M&As was financed by Chinese capital.

3.2 Mining FDI and Development

At the core of the critical link between mining FDI and sustainable development is the objective evidence that foreign affiliates of mining MNEs operate in some of the poorest and most depressed areas of the world. According to our preliminary analysis, more than half of the large mining exporters (with a share of mining exports in total exports above 10 percent) lie in the bottom quartile of the Human Development Index (HDI), a composite measure of achievement in key human development

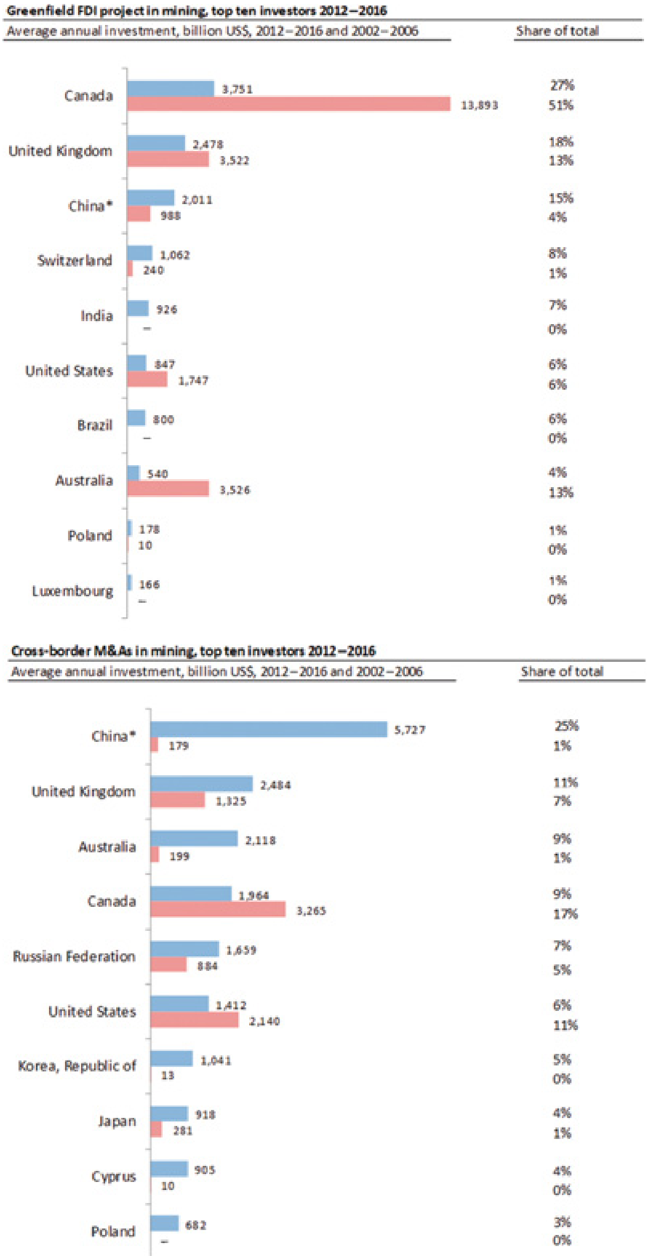

Figure 3.3 Largest investors in mining FDI

Note: Greenfield FDI and cross-border M&As are from UNCTAD FDI/MNE database, based on original data from Financial Times Ltd, fDI Markets and Thomson Reuters respectively. The same analysis based on number of projects and deals rather than values produces similar results.

Source: Author's calculations.

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dimensions. Importantly, in the group of mining exporters, better HDI performance is observed in countries with lower shares of mining FDI relative to total FDI. On the other hand, countries highly dependent on mining FDI exhibit, on average, a lower level of development, substantially comparable to that of countries with negligible or no foreign investment at all.[4] In other words, while extractive FDI is crucial for mining-oriented economies, in that it represents the springboard for economic growth, countries that manage to diversify their FDI footprint across sectors tend to achieve (relatively) better development outcomes.

The impact of mining FDI on development is complex, as it spans multiple dimensions, and has historically produced controversial outcomes (UNU-WIDER, 2018). In principle, FDI can work as boosters to mineral production in countries where enabling conditions are weak. MNE entry can help overcome key constraints, such as the lack of investment financing, limited capabilities and poor access to markets. By generating tax revenues and export earnings, MNEs can also contribute to higher national income, as well as creating business and employment opportunities (UNCTAD, 2007a). However, the potential impact of mining operations, including FDI, goes well beyond the financing dimension, involving at least four different areas: i. economic impacts; ii. environmental impacts; iii. social and political impacts; and iv. technological impacts (Figure 3.4).

The rest of this section will briefly discuss the first three dimensions (economic, environmental and social and political impacts), before tackling the technological dimension, the main focus of this chapter, in Sections 3.3 and 3.4.

Economic impact. Mining FDI do not automatically generate economic gains in host countries. Research has historically pointed at an

[4] More specifically, the analysis of trade data for the 10 years period 2007–16 revealed 46 developing countries with an average share of exports in mining above 10% of total exports. The median HDI ranking for this group was 148 against 122 for the overall group of developing economies (based on 2015 HDI ranking). After further segmenting the group of 46 mining exporters in three sub-groups according to their FDI footprint – 22 countries with relatively low mining FDI (less than 20%), 18 countries with relatively high mining FDI (above or equal 20%) and 6 countries with negligible total FDI (at less than US$1 billion in the ten years) – the median HDI ranking for the group with relatively low mining FDI was higher than in the other two groups, at 138 against respectively 157 and 164. While merely descriptive and not implying any causal relationship, this analysis hints at a separate role of FDI in the complex and controversial link between commodity dependence and development. We believe that such dimension warrants further attention in future research work.

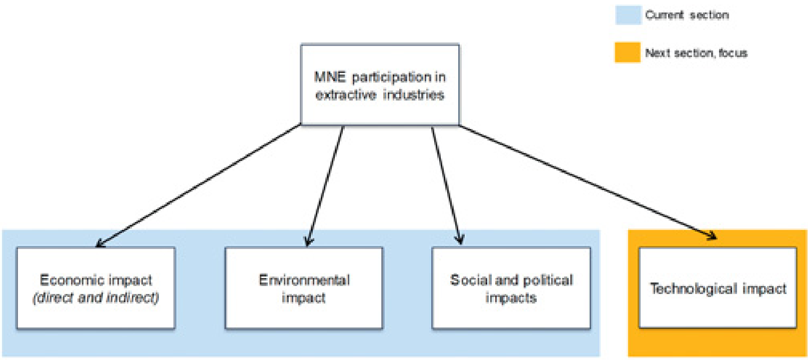

Figure 3.4 Development impact of mining FDI, multiple dimensions
Note: Based on UNCTAD (2007a).

ambiguous relationship between natural resources and economic growth. Prebisch (1950) and Singer (1950) were first to observe a long-term decline in the relative price of commodities, causing the terms of trade of commodity exporters to deteriorate. Since then, many have pointed to a negative relationship between resource abundance and economic development. Corden and Neary (1982) shed light on the recurrent link between an expanding commodity sector and de-industrialization within countries, commonly known as the 'Dutch disease'. Similarly Auty (1993) and Sachs and Warner (2001) have advanced the 'resource curse' concept, demonstrating how resource-rich countries tend to grow slower than their resource-poor peers. Others, such as Cavalcanti et al. (2011), argued that price volatility, rather than abundance per se, would be the main force behind the curse.

Most recently, the emergence of global value chains and major changes happening in the industry have led some scholars to reexamine natural-resources-based development through the lens of modern globalization. Some, including Farinelli (2012), Kaplinsky (2011), Morris et al. (2012), Ramdoo (2013), Ramdoo and Bilal (2014) and UNECA (2013), have provided new arguments for commodity-based development, emphasizing the cross-border nature of modern industrialization and the potential it entails for the extractive sector. Still, evidence at the country level is controversial, as 'blesses' and 'curses' cohabit the same regions. In sub-Saharan Africa, for instance, the breadth and depth of linkages in the extractive sector differ widely (Farooki et al., 2016; Morris et al., 2012).

Downstream activities in diamond processing have developed in Botswana, prompted by joint support of the government and foreign investor De Beers (Mbayi, 2011; UNCTAD, 2016). Spurred by FDI, a mining equipment cluster has developed in South Africa, making it a regional hub that has become, in some areas, globally competitive (Fessehaie et al., 2016). In some cases, however, potential remained untapped. In industries such as oil drilling in Angola (Teka, 2011) and gold mining in Tanzania (Mjimba, 2011), linkages of foreign affiliates with local firms are weak, limited to the sourcing of low-value services; and value addition is limited to the labor content.

Environmental impact. Environmental degradation and pollution of mine-surrounding areas are also major concerns related to mineral investment. The net environmental impact of mining FDI is the result of an interplay of factors, including project features (commodity, technology, scale and location), the quality and enforcement of regulation in the host country, and the MNE attitude towards environmental responsibility (UNCTAD, 2007a). Environmental degradation linked to mining operations is a well-documented phenomenon, particularly in countries that lack well-developed institutional ecosystems. In line with the 'race to the bottom' argument, some (e.g. Doytch and Uctum, 2016) have found mining FDI having worse environmental effects in low-income countries. Weak framework conditions, such as institutional capacity and law enforcement, but also aggressive investor lobbying, have historically been major bottlenecks to effective environmental safeguards in host countries (Appiah and Osman, 2014; Boocock, 2002; UNCTAD, 2005b). However, research also pointed at FDI as conducive to better environmental practices. In some cases, MNE entry has facilitated the inflow of environmentally sound technology (Borregaard and Dufey, 2002) and led to improved environmental standards (Mwaanga, 2017). Recently, some top MNEs have also started improving their environmental conduct as part of their commitment to advance the sustainable development agenda (UNDP/WEF/Columbia/SDSN, 2016).

Social and political impact. Finally, mining FDI have profound social and political implications in host countries, particularly for local communities residing in the vicinity of mines. Adverse social impacts affecting communities include the use and management of land in areas used for other activities, the displacement of indigenous populations, and accordingly, the loss of land and livelihoods (UNCTAD, 2012). Weak institutional capacity (ACET, 2014; Adu, 2018) and investor focus on host governments over local stakeholders (Greenovation Hub, 2014) have been major determinants behind deteriorating social conditions at mines. In addition, concerns have been raised on MNEs contributing to adverse political developments, often related to the distribution of rents. These include the perpetuation of, or the provision of incentive for, conflict (UNCTAD, 2007a) and adding to illegal practices, such as corruption (OECD, 2016a). In Africa, MNE activity in exploitative sectors has been found having a positive impact on the likelihood of conflict, particularly via large-scale land acquisitions (Sonno, 2018). In response to an increased scrutiny by the international community, however, top MNEs have been multiplying their efforts to gain a ‘social licence to operate’. Global partnerships and corporate social responsibility (CSR) initiatives have been proliferating in recent years, defining new models of FDI-led community development (Gifford et al., 2010; IFC, 2014).

3.3 Mining FDI as a Vehicle of Technological Development

3.3.1 Theoretical Background

The issue of technology spillovers of FDI (i.e. the diffusion and appropriation of foreign technology, know-how or skills that may not be available locally), has been extensively studied. Literature usually links technology spillovers to productivity enhancements (or ‘premia’) experienced by local firms, as their most immediate and measurable effects. In general, research has found a positive relationship between inflows of FDI and the performance of domestic firms (Blomström and Kokko, 1998; Haskel et al., 2007; Keller and Yeaple, 2009). Receiving firm characteristics are important determinants of technology spillovers. Many pointed at the role of *absorptive capacity*, the stock of technology and know-how embedded in the local firm base, in ultimately determining their readiness to ‘absorb’ foreign assets (Fu and Gong, 2011; Kinoshita, 2000). Yet, benefits from FDI are sector-specific and increase with absorptive capacity only up to some threshold levels (Girma, 2005). The position in the supply chain and the size of receiving firms are also important factors at play. Suppliers in upstream industries enjoy productivity gains, while downstream customers tend to incur losses (Jude, 2016). Irrespective of productivity levels and technology gaps, spillovers most frequently appear in small and medium-sized firms (Damijan et al., 2013). Spillover effects also depend to some extent on foreign-investor characteristics, such as ownership and nationality. Wholly owned foreign operations are found to have more moderate (Farole and Winkler, 2014) or no productivity spillovers (Smarzynska-Javorcik, 2004) on domestic firms compared to projects involving shared domestic and foreign ownership. Industries that are more diverse in terms of FDI origin, for example, those attracting foreign investors from a larger number of nationalities, tend to have more productive domestic firms (Zhang et al., 2010). In the case of R&D investment, FDI-led productivity growth is larger when MNEs from OECD countries invest in emerging economies than in the case of R&D investments carried out by emerging country MNEs in OECD countries (Amann and Virmani, 2015).

Literature on drivers and determinants of technology spillovers is largely composed of country-level or multi-country empirical studies lacking a clear sector focus. Only some, such as Kokko et al. (1996) and Globerman (1979), have focused on the manufacturing sector of distinct countries. Spillovers in the mining sector have been only partially addressed. Discussion has been centred on the potential of MNE-SME linkages for local value addition, with the technology dimension treated as tangential to the match-making issue (OECD, 2016b; CCSI, 2016; Kaplinsky, 2011, among others). Most of these contributions take a purely qualitative approach. To our knowledge, only two studies have looked at the R&D and technology angle empirically (Farole and Winkler, 2014; Ghebrihiwet, 2019). Both of them provide statistical insight using country-level survey data, with no global assessments available to date.

In a multi-country survey, Farole and Winkler (2014) have identified two channels of technology spillovers: licensing of patented technology and R&D collaboration. On average, licensing of patented technology was listed by respondents (domestic suppliers) among the top five forms of assistance provided by foreign customers, while R&D collaboration involved up to 65 percent of respondents. In this context, joint product development has reportedly resulted in upgrading of equipment and improved quality of inputs for 'a significant number of companies'. However, there is strong variability across countries. The use of licensing and R&D collaboration is much more frequent in countries with relatively developed mining industries (and a minimum sufficient stock of absorptive know-how). Ghebrihiwet (2019) found R&D collaboration with foreign clients or suppliers having a positive and significant effect on the likelihood that firms introduce new product and process innovations. In line with the spillover literature, the likelihood and ultimate impact of collaboration on indigenous innovations differs based on the role of firms in the value chain. Suppliers are 0.5 times more likely to introduce product innovations compared to mining companies and downstream firms. In addition, continuous in-house R&D efforts (e.g. local firms' absorptive capacity), has a highly significant effect on the probability of introducing new methods of production.

3.3.2 A Framework for the Analysis of Innovation and Technological Spillovers in Mining FDI

The spectrum of mining innovations is relatively wide and varied. It not only includes frontier technology solutions developed within and for the mining industry – such as new exploration, extraction or processing techniques – but also widely applicable technologies that, despite originating in other industries, are largely used in mining supply chains (Chapter 2). These include, for instance, special transport systems connecting mines to ports, or data centres for remote operations management. Depending on intellectual property rights and contractual arrangements, technologies may, at least theoretically, transcend firms' boundaries and 'spill over' into the rest of the economy.

In the absence of a comprehensive and established approach, we introduce here a framework for the analysis of the technological impact of mining FDI (Figure 3.5). The purpose of this framework is to identify the main channels through which mining FDI can help move the technological frontier in host countries. We have identified three main channels and assessed them based on the impact on the host country's technological development (from low/indirect to high/direct).

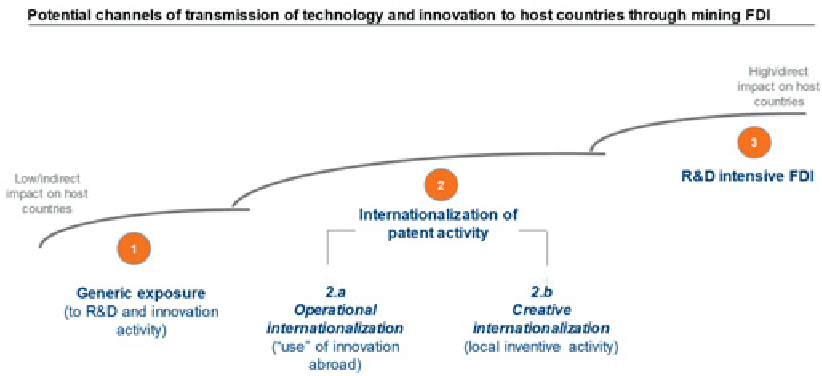

Figure 3.5 An analytical framework
Source: Author's calculations.

First, and most obviously, R&D and innovation activity performed by mining MNEs, even in remote locations, and often in the home country, may generically contribute to technological development across all MNEs' international operations and therefore create spillovers in the host country. This type of channel qualifies nothing more than a 'generic exposure' of host countries to R&D and innovation activity taking place at the corporate level. The impact of this channel is unclear and indirect. In fact, on the one side, FDI do establish a preferential and stable link ('ownership-based') between the local economies and MNEs' technological and innovation capital. On the other, however, no necessary transfer mechanism ensures inclusive access to such intangible assets from the operational peripheries of the multinational group.

The second channel entails a more proactive role of MNEs in technology diffusion. This occurs when inventive activity explicitly spans beyond national borders and internationalizes as MNEs demand IP protection outside the home country. MNEs protect intellectual property abroad where they retain strategic business interests. This may be done to prevent competitors from accessing and using fundamental know-how, or to ensure protection of ground-level incremental innovations. In practical terms, internationalization happens at two levels. On the one hand, in field operations, foreign affiliates can make use of innovation generated elsewhere – most likely at headquarters (operational internationalization) – and indirectly contribute to its diffusion via licensing or other non-contractual forms of third-party relationship. More impactfully, they can trigger local inventive activity, by hiring locals in key R&D functions or via collaborative R&D with local firms (creative internationalization).

Finally, the 'frontier' of technological impact lies with R&D-intensive FDI, where the core motivation and value proposition of an FDI is to gain competitive advantage in innovation and technology development. Companies establish R&D activities in strategic locations where they have better access to knowledge-based assets that may not be easily available elsewhere. Situations of this type involve, at least theoretically, the most direct and stronger form of local impact. Indeed, not only do knowledge-intensive FDI add to the domestic stock of knowledge and call into play local economic actors, but (likely) imply frontier innovation and technology creation. If scaled, they may be at the foundation of new clusters of economic activities and ultimately shape domestic patterns of innovation.

3.4 Empirical Assessment of the Main Channels of Technological Development

The framework and channels' classification of Figure 3.5 is valid in principle and can be applied to FDI in all industries. However, when it comes to R&D and innovation, the mining industry is quite peculiar. Despite signs of change, it has historically been less oriented to transformative innovation than other industries, as largely centred on cost-cutting incremental innovations (Bryant, 2015; Deloitte, 2016 and 2017).

Compared to other industries, mining MNEs' contribution to global R&D is limited and sensitive to external shocks, such as commodity price cycles (Figure 3.6). In 2016, top mining companies invested only 0.4 percent of their sales in R&D activities, compared to 5 percent for MNEs in other, non-extractive sectors.[5] Furthermore, R&D expenditure by mining MNEs has witnessed a declining trend since 2012, as opposed to investment by other MNEs, including in oil and gas. In less than ten years, from 2008 to 2016, following a very challenging industry conjuncture since 2012, the R&D expenditure of large mining MNEs in UNCTAD ranking has decreased by 70 percent. This suggests that R&D investment in mining may not only be relatively limited compared to other sectors, but also sensitive to endogenous shocks, such as commodity price movements (see Chapter 7).

In this context, it is therefore particularly important to assess how feasible and/or realistic each channel is *in the mining context*. In the next sections, we attempt such an assessment by undertaking an empirical investigation of the current status and dynamics of R&D and innovation activity within mining MNEs. We focus on three key questions, each providing empirical background to one of the identified channels in Figure 3.5: (i) To what extent is innovation activity taking place within mining MNEs? *(channel 1)*; (ii) Does such innovation activity cross the frontier of the home country and spreads throughout the MNEs transnational borders? *(channel 2)*: (iii) Are mining MNEs directly investing in R&D projects abroad or seeking for knowledge intensive FDI? *(channel 3).*

[5] It must be noted that the analysis may underestimate the overall contribution of the industry to global R&D, as figures only account for the R&D expenditure of top mining MNEs. Indeed, an important portion of mining R&D is conducted by mining equipment, technology and services (METS) companies (Daly et al., 2019; Steen et al., 2018). In addition, mine exploration can also be deemed a form of R&D. The matter is discussed in more detail in Chapter 2.

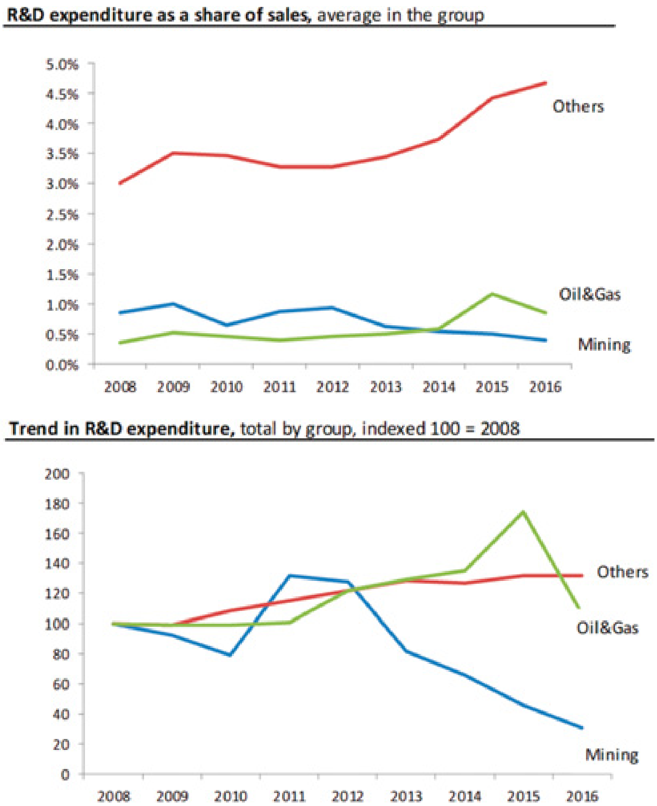

Figure 3.6 R&D expenditure of MNEs in UNCTAD top 100 ranking
Note: The sample of top 100 MNEs is based UNCTAD ranking of 2016 (UNCTAD, 2017). It includes five mining MNEs, six oil and gas MNEs, and eighty-nine other MNEs (operating in manufacturing and services, excluding financial services). Historic information on R&D expenditures and sales were extracted by ORBIS or derived from companies' financial reporting.
Source: Author's calculations.

3.4.1 *R&D and Innovation Activity within Mining MNEs* (channel 1)

One of the main features generally ascribed to multinational enterprises is superior technological standards. The better innovative performance of MNEs is documented by several studies. In 2002, 98 percent of the 700 largest R&D-spending firms were MNEs, accounting for more than two-thirds (69 percent) of the world's business R&D (UNCTAD, 2005c). At the country level, foreign-owned companies are found to be more innovative than domestic firms, with difference in size largely explaining the gap (Falk, 2008). Foreign affiliates also innovate more indirectly, by acquiring the most innovative domestic firms (Guadalupe et al., 2012).

In the mining industry, much innovation originates in the METS sector, with miners being largely consumers of it (Steen et al.,2018). While mining supply and service providers, particularly junior companies, tend to be more innovative than majors, frontier practices in technological, environmental, business model, and social innovation are pioneered by few top MNEs (IGF, 2018).

WIPO assembled a database containing patents for the mining sector from 1900 to 2015[6] (Daly et. al., 2019). According to the database, in the period 1990–2015, more than 600,000 patents[7] were filed in mining. Applicants were corporations in 64 percent of the patents, while in the other cases they were individuals (23 percent) or research institutions and universities (13 percent). We focus on the corporate applicants to analyze to what extent innovation is driven by MNEs. More specifically, we've compiled a global ranking of the top 100 corporate applicants of mining patents and cross-referenced it with ownership and location information to derive information on their ownership profile and locations (Figure 3.7). The analysis reveals that MNEs are the main source of innovation in the industry, with privately owned entities being the most active IP applicants. Around 60 percent of the applications in the twenty-five-year period covered by the database were filed by MNEs, mostly private owned (55 percent) (Figure 3.7, left-hand side). Interestingly, large multinational innovators (sixty MNEs), are equally split between developed economies (thirty) and developing and transition economies (thirty) (Figure 3.7, right-hand side). The latter are relatively more 'productive', as they make up 57 percent of MNE-filed applications.

3.4.2 Internationalization of MNEs Patent Activity (channel 2)

To what extent is the MNEs innovation activity reflected by the almost 300 thousand patent applications of Figure 3.7 (right-hand side; see note to the figure) really 'transnational'? (i.e. involving to some degree MNE host countries). Building on the classification introduced in Section 3.2 (Figure 3.5), we explore two types of internationalization of the patent

[6] For further details on how WIPO database has been assembled, please refer to Box 1.
[7] The numbers refer to first families' unique applications.

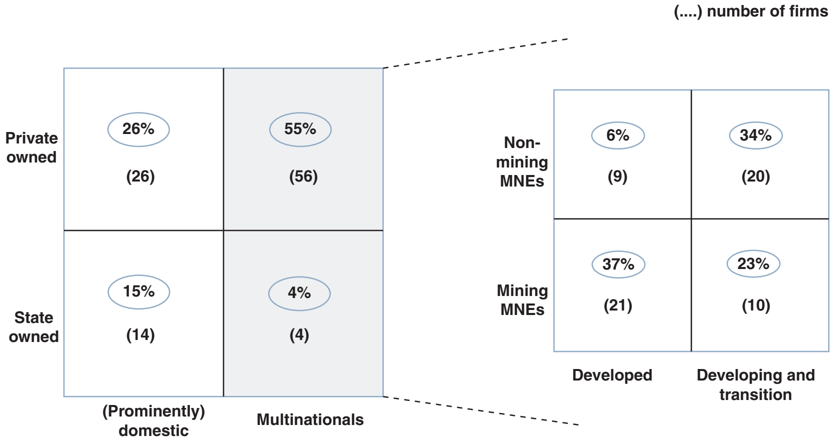

Figure 3.7 The ownership profile of the top 100 applicants of mining patents Number of applications in the period 1990–2015, share to total

Note: Patent data from EPO PatStat database. Total number of patent applications filed by top 100 corporate applicants in the period 1990–2015: 472,692 (left-hand side matrix). Total number of patent applications filed by (sixty) MNEs in the top 100 selection of corporate applicants: 277,978 (right-hand side matrix). 'MNEs' are companies with 10% or more of majority-owned subsidiaries located outside the home country. Companies with partial ownership information were omitted. The distinction between 'mining MNEs' and 'non-mining MNEs' is based on a qualitative assessment of company trade descriptions in ORBIS Bureau Van Dijk.

Source: Author's calculations.

activity: the operational internationalization and the creative internationalization.

The first and most simple channel takes place through the plain 'use' of MNE foreign-licensed technology by its foreign affiliates. We call it *operational internationalization.* Operational internationalization may occur via a number of channels, the most prominent being technology licensing within buyer–supplier relationships (UNCTAD, 2005a). Other less direct, but equally important forces, such as imitation, competition and demonstration effects, may be at play. In this context, MNEs bring the industry's more advanced technologies into developing countries and contribute to diffusion via the operations of foreign affiliates.

Recent research found that mining MNEs rely to a larger extent on local rather than central decision-making in procurement (Farole and Winkler, 2014). This attitude results both from MNEs strategic decisions and CSR mandate, where developing a local supply base has become critical to not only maximize operational efficiency, but also obtain a *social licence* to operate. In this way, local firms may end up successfully adopting superior technology when entering into contractual relationships with foreign affiliates. While operational spillovers seem to be quite indirect and uncertain, they are the most common type of technological spillovers in mining. Under the right circumstances (i.e. when a conducive policy mix is in place), they can effectively spur indigenous technological upgrades. Hence, they are a key motivation why many countries seek to attract FDI into their extractive industries (UNCTAD 2007a, 2011).

Mining FDI not only provides fertile ground for foreign-licensed technology spillovers, but also boosts local inventive activity (*creative internationalization*). Local firms may absorb foreign-licensed technology, and even develop it in-house. The increase in local inventive activity may happen at the level of foreign affiliates, when locals are hired in key R&D functions and contribute to product and process development; or when local firms end up producing new in-house innovations, as suppliers/contractors of foreign affiliates or within joint R&D ventures.

To empirically assess these two channels, we further examine the information provided by the EPO PatStat database, reporting for each patent not only the name of the applicant (i.e. the information used to perform the analysis in Figure 3.7), but also the country where the application is filed and the name and country of residence of the inventor. Such detailed information allows us to map patterns of MNE cross-border innovation, along the two main channels defined by our framework: the operational and the creative ones.

As for the operational channel, out of 277,978 mining patent applications filed by top applicant MNEs in the period 1990–2015, some 18 percent are registered in countries other than the parent's (Figure 3.8, blue shade). While MNE demand for IP protection abroad is not directly attributable to cross-border R&D (perhaps very limited in the mining industry) and may be done for purely competitive purposes, yet these data reveal the existence of some degree of internationalization in the 'use' of innovation. This is a necessary condition for the development of technological spillovers in the local economy.

It is important to notice that this type of transmission mechanism is enabled by the transnational nature of MNE activity. Not only MNEs do tend to be more proactive in developing innovations (Figure 3.7) but their transnational operating model favours innovation access and

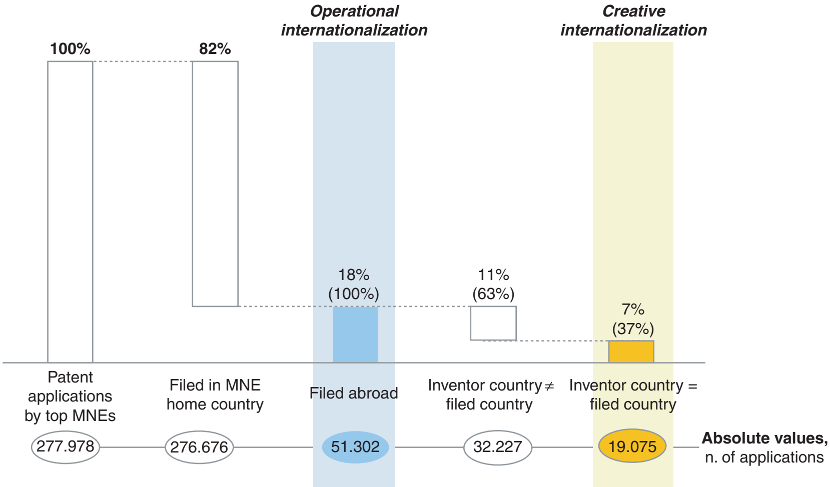

Figure 3.8 Internationalization of patent activity: evidence from WIPO patent statistics
Note: See Box 3.1.
Source: Author's calculations.

sharing across countries. Not surprisingly, the share of foreign-filed patents in the set of non-MNE top patent applicants is very limited, at 0.4 percent of the total number of patent applications.

Moving from the operational to the creative stage of patenting internationalization, one third of foreign fillings (37 percent) – corresponding to 7 percent of the total number of patent applications – reports inventor(s) whose nationality coincides with the country of filing (Figure 3.8, orange shade). While not automatic (inventor nationality may match with the country of filing for reasons other than direct involvement of local actors in the innovation process), such correspondence is interpreted as a strong hint to some kind of MNE-led local inventive activity, as implied by our definition of creative internationalization. This figure suggests that the applicant MNE may not only retain some lasting business interest in filing countries, but also conduct inventive activity involving country nationals; for example, MNE-led local innovation.

This analysis (methodological details are reported in Box 3.1) adds an important element to the discussion of technological impact of FDI in host countries. On the one hand, it confirms that innovation activity mostly takes place at the level of the parent company; however, and more

BOX 3.1 TRACKING R&D INTERNATIONALIZATION IN MINING FDI USING PATENT STATISTICS

WIPO mining databases extract patent data from the European Patent Office's PATSTAT database. Patents belonging to the mining sector were identified through a triangulation approach which combines industry classification (two-digit ISIC Rev. 4 codes), list of mining companies provided by partner IP offices (Australia, Canada, Chile, Brazil and the US), and a combination of patent classification (IPC codes) and keywords.* The year of first filing of each patent is taken into consideration. For each patent, it identifies: the country where the patent is filed (filing country), the home country of the firm which files it (applicant country), and the residence country of the inventor/s of that patent (inventor country).**

The sample of top 100 patent applicants used in the analysis is derived from a ranking based on total mining patent applications from 2006 to 2015. The ranking only considers the last ten years of the sample because it aims at identifying top innovators based on recent performance. Additionally, singletons have not been taken into consideration for elaboration. Singletons, as highlighted in Chapter 2, are often considered innovation of lower value given that their invention is protected in a unique jurisdiction and not in multiple ones. Only entities that could be matched with Bureau Van Dijk's ORBIS were selected. The selection includes private and state-owned enterprises according to the type of global ultimate owner (GUO). For the purpose of this work, companies were classified in two homogeneous groups – multinational enterprises (MNEs) and (prominently) domestic – based on insight into their international activity. If at least one of the following criteria is satisfied, the company is labelled as MNE:

I. *Country of incorporation of entity and GUO:* entity home country ≠ GUO home country
II. *Ownership structure of entity*: entity home country ≠ home country of at least 10 percent of affiliates
III. *Ownership structure of GUO:* GUO home country ≠ home country of at least 10 percent of affiliates
IV. *Desk research:* In cases where ownership analysis produced ambiguous results, information published on company reports, websites and the press was used to validate selection.

Information attached to patent applications of top applicant MNEs has been used to build proxy measures of two types of technology spillovers that may originate from MNE activity. The interpretation of each involves specific assumptions:

- Foreign filing (filing country ≠ applicant country) as a proxy of *operational internationalization*. Typically, the main reason for a firm to file for a patent in a country different from the home one is strategic. The company may or may not sell its product there but, in any case, it wants to exclude its competitors from the appropriation of the knowledge embedded in the patented

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BOX 3.1 (Continued)

innovation. After the innovation is patented, this knowledge, which cannot be appropriated from entities other than the applicant, is disclosed.

- Coincidence between filing country and inventor country as a proxy of *creative internationalization*. This is a subset of the operational spillovers. In this case not only is the invention protected in a country different from the home country of the firm, but also at least one of its inventors resides in that country.*** This is a stronger form of spillover as not only the knowledge is disclosed through the patents but there is also at least one physical person residing in that country with the know-how necessary to develop such technology.

* For a detailed description of the methods used to assemble the database, please see Daly et al. (2019).

** Home country is defined as the country where the filing entity is incorporated.

*** While inventors are usually employees of the filing company, they could also be contractors temporarily working for the firm with the only purpose of developing the innovation.

notably, it also reveals a non-negligible flow of innovation from the centre to the periphery, not only at the operational level but also at the creative level. Albeit limited, such diffusion of innovation and technology is highly critical in developing countries, where economic resources other than mineral endowments are few.

3.4.3 R&D-Intensive FDI (channel 3)

FDI in mining are traditionally natural-resource seeking, driven by the availability, price and quality of natural resources, infrastructure-enabling resources to be exploited and investment incentives. In this context, there is little scope for technology or innovation-driven FDI ('strategic asset-seeking' FDI). As confirmed by the analysis of FDI greenfield projects from 2007 to 2016, mining FDI are mostly concentrated in the activity of material extraction (68 percent), while a residual portion (32 percent) involves other types of activity such as sales (14 percent) and manufacturing (12 percent). R&D-oriented FDI are very limited, at 1.5 percent of the total number of projects (Figure 3.9, left-hand side). Noticeably, low development of R&D-intensive FDI is not an issue of mining FDI strictly speaking, but also for oil and gas and manufacturing industries close to mining, such as mineral and metal

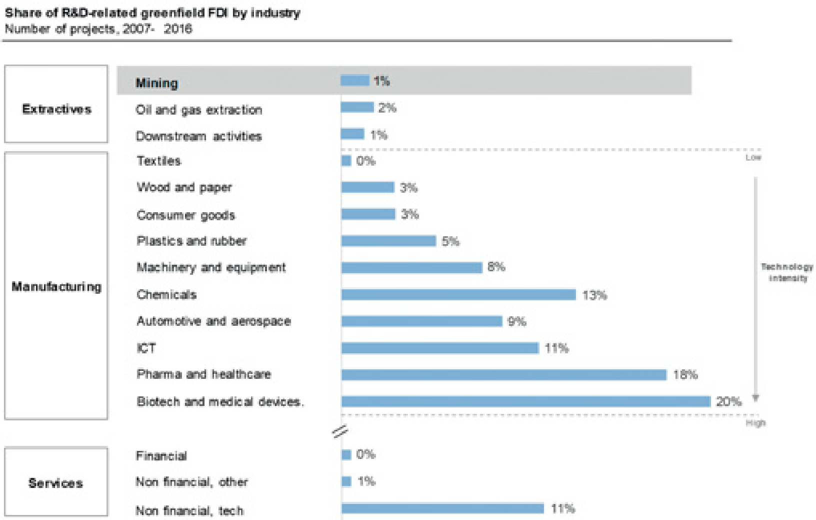

Figure 3.9 Greenfield FDI by type of activity
Note: Greenfield project data from Financial Times fDi Markets Project Database (Jan 2007–Dec 2016), December 2018. 'R&D-oriented' greenfield is any greenfield investment project conducted in 'Research and development', 'Design, development and testing' and 'Education and training' as defined by the publisher. Product groups are aggregates of fDi Markets sectors or subsectors. Ranking of technology intensity for manufacturing industries is adapted from the OECD ISIC Rev. 3 Technology Intensity Definition. *Downstream activities* include petroleum refining, iron and steel mills, ferroalloy and steel production. *Mining* includes coal mining; gold ore and silver mining; copper, nickel, lead and zinc mining: iron ore mining: non-metallic mineral mining; other metal ore mining; and support activities for mining.
Source: Author's calculations.

processing (Figure 3.9, right-hand side). More generally R&D intensive FDI are concentrated in selected industries characterized by high technological intensity, such as ICT, automotive and pharma, or high-tech services.

3.5 Concluding Remarks and Policy Implications

Despite the recent fall in mining FDI (Figure 3.2), the role of MNEs and cross-border investment in mining remains crucial. On the one side, a significant portion of global mining production is performed by MNEs through their foreign operations (Figure 3.1). On the other side, a number of countries, especially low income, heavily rely on mining FDI as a major source of foreign earnings and possible pathways to economic diversification. In a moment when the geography of investment in mining FDI is rapidly changing, particularly with the rise of Chinese MNEs (Figure 3.3), the discussion of the development implications of mining FDI becomes crucial. The impact of mining FDI on host countries is multiple, involving primarily the economic dimension, the social dimension, the environmental dimension and the technological dimension (Figure 3.4).

Focusing on the last mentioned, compared to other industries, the technological or innovation dimension of mining FDI is less visible and recognized. This is due to the fact that the mining industry is perceived as having rather poor technological content and carrying out limited innovation (Figure 3.6). In addition, a major driver for undertaking cross-border investment in mining is the access to mineral endowments, with no immediate connection to local technological development. However, insights from our analysis of the different channels of transmission of innovation and technology though FDI (Figure 3.5) suggest the existence of a link between mining FDI and technological development in host countries, which holds true across three different dimensions: (a) Given MNEs are the major source of innovation in the mining industry, FDI creates a preferential channel to their technological assets (Figure 3.7); (b) As MNE-owned patents are used and enforced by foreign affiliates in host countries, conditions are created for operational spillovers (Figure 3.8); (c) Under certain conditions, the availability, use or development of MNE technology can stimulate local inventive activity (Figure 3.8). Yet, a realistic assessment of the current FDI landscape in mining and other low-tech industries suggests that R&D-oriented FDI are still very limited and that traditional motivations (natural resource-seeking, efficiency seeking and market seeking) remain the dominant drivers of MNE foreign investment decisions (Figure 3.9).

Thus, policymakers in mining-rich countries, particularly those poor countries that heavily rely on mining, should not overlook the technology and innovation dimension when designing investment policy frameworks. At the same time, they should be aware of some intrinsic limitations of mining FDI in driving technological development and thus they should also pursue investment strategy oriented to the diversification of industries characterized by higher R&D and technological content.

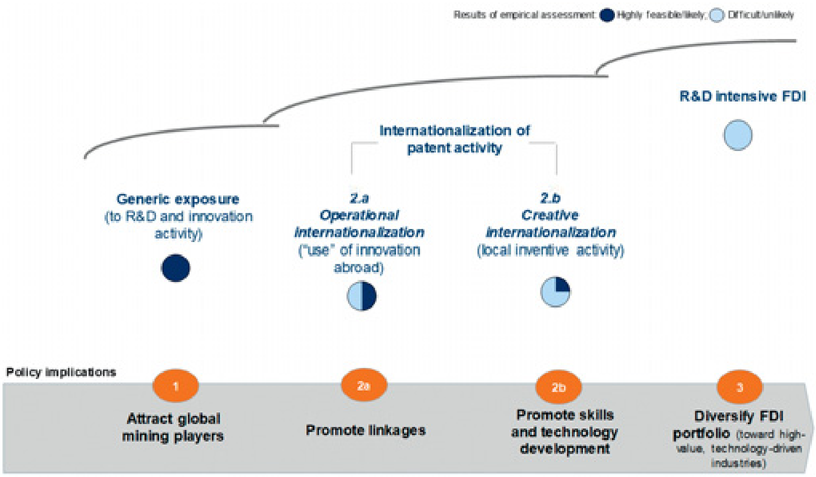

Figure 3.10 Policy recommendations: linking analysis and practice for impact
Source: Author's calculations.

Figure 3.10 relies on our framework (Figure 3.5) and the empirical assessment conducted in Section 4 to derive high-level policy options and recommendations for each channel. Policy options are briefly discussed in the following.

3.5.1 Attract Global Mining Players

Global mineral production and, ultimately, innovation, is largely undertaken by a number of global players. Not only do MNEs orchestrate most large-scale mining projects, they also lead global inventive activity (Figure 3.7). Possessing frontier technology, skills and know-how give MNEs a comparative advantage in mine construction, production and processing, which makes them desirable, if not essential partners for developing-country governments. In many cases, attracting foreign investment has not only helped host governments to secure investment financing, but has also enabled domestic exploration and extraction activities otherwise technologically unfeasible. Absent a strong comparative advantage, government efforts in this realm may be prohibitively costly and end up hindering investment, resulting in reduced production and tax revenues (UNCTAD, 2011). Following a wave of nationalizations in the 60s and 70s, attracting FDI has been instrumental in rehabilitating the declining copper industry of Zambia, initially through MNE takeovers of State-owned mines, and later through new greenfield investments (UNCTAD, 2007b).

Yet, the extra costs that governments bear in terms of resource rent sharing may be important (UNCTAD 2007a). In addition, as investment may be motivated by the need to supply foreign refineries and smelters, the flipside of relying on MNEs for mineral extraction is that refining and processing activities will often take place abroad. For these reasons, investment policy shall not work in isolation, but rather be coupled with policy instruments that seek to maximize local content and encourage the development of downstream activities.

3.5.2a Promote Linkages

Local procurement opportunities vary widely along the life cycle of a mining project. It is estimated that procurement opportunities range between 0 and 3 percent of total spend at exploration, and up to 75 to 90 percent at production (OECD, 2016b). In order to maximize *upstream linkages*, a number of governments have imposed import restrictions or other purchase requirements on MNE affiliates. In some cases, minimum levels of local purchase are specified in contracts; in other cases, affiliates are required to state how they plan to increase local content, or submit local procurement plans (UNCTAD 2007a).

Policies to promote upstream linkages increasingly go beyond local content requirements and involve nurturing the local firm base through supplier development programs implemented jointly with foreign affiliates. Support usually includes matchmaking, as well as technology and capacity development services (UNCTAD 2005a). Analysis in Figure 3.8 points to a substantive degree of internationalization in the 'use' of mining innovation. Some 18 percent of MNE patent applications are filed in countries other than the parent, roughly a quarter of them in developing economies. Through foreign affiliate operations, MNEs bring the industry's most advanced technologies to host countries. Thus, entering into contracts or other forms of partnership with foreign affiliates can be conducive to 'operational' spillovers.

As MNEs increasingly source 'local' and corporate responsibility levels – the playing field of global business – host country governments shall look beyond pure local content requirements and set up partnership-driven platforms that enable local firms to grasp the technology benefits of buyer–supplier relationships. Success stories in this realm have been multiplying in recent years. While most remain business cases, some have spread across firm boundaries. Working closely with MNEs as contractors of exploration services, for instance, some junior domestic firms in Canada have upgraded and become world leaders in mine exploration (UNCTAD, 2011).

3.5.2b Promote Skills and Technology Development

Our findings (Figure 3.8) suggest that interfirm relationships not only provide a preferential channel for technology transfer and appropriation, but may also spur local inventive activity (e.g. 'creative' spillovers). As literature shows, addressing weak absorptive capacity (i.e. the lack of a sufficient stock of skills, productive and technological capabilities of receiving firms), is crucial for enabling technology spillovers. While holding true for operational spillovers, this assumption is fundamental in the case of creative spillovers that involve indigenous R&D and technology development.

When designing mineral investment policies, governments should not only attract the right foreign partners, but also invest in upgrading local productive capabilities that are necessary for matchmaking. While sound innovation policies, coupled with the availability of well-developed business ecosystems play an important role, learning may also result from locally rooted MNE activity. In Chile, foreign investors have traditionally employed Chilean workers in their mine operations, including senior managers and engineers. Over time, this helped develop a local knowledge and skills base that would become important to the broader industry. At the same time, not only did government support focus on providing skills development, innovation and R&D support services, but a part of mineral revenues were earmarked to finance indigenous innovation and R&D activities. This, coupled with the availability of an extensive network of universities specialized in mining-related education and research, have contributed to the upgrading of domestic firms to global standards (UNCTAD, 2011).

UNCTAD field practice shows that a mix of policy tools is possible. These include, for instance, matchmaking services for MNEs and suppliers, or public funds for skill development and R&D. Yet, the industry's success stories remain limited to a small number of countries, such as Canada and Chile. Specific examples of policy tools employed in these countries, with varying degrees of success, include:

- Creating public–private networks for knowledge sharing and policy formulation;
- Setting up specialized training and research institutions (joint actions by the government and industry);
- Public financing of mining R&D, including investment funds financed with mineral tax revenues.

3.5.3 Diversify FDI Portfolio (towards High-Value, Technology-Driven Industries)

While research shows potential for and, to some extent, evidence of technology spillovers in some host countries, policymakers should maintain realistic expectations in mining FDI-led technological growth. This is due to some intrinsic characteristics of mining investment. Indeed, the industry has historically been resistant to groundbreaking innovation. Cross-border investment in the sector has traditionally been 'resource-seeking', with few technology-driven investments and those only rarely transnational (Figure 3.9).

For mineral-rich countries, diversification towards non-extractive value-added activities remains crucial. While resource extraction should be at the core of their industrial development strategies, it should be intended as a pathway to economic prosperity rather than a primary source of comparative advantage. Depending on context, local content policies should aim at nurturing infant downstream activities, beyond purely encouraging local firms and individuals to link up to upstream extractives. In the long term, mineral rents shall be reinvested in the development of economic and social infrastructure, rather than be channelled into more productive activities.

Attracting (the right!) global players and establishing sound public-private partnerships may well serve to this purpose. The diamond sector of Botswana is an exceptional case in point. Against the fashion at the time of discovery (1970s), the government did not nationalize the mines, but entered into a joint venture agreement with foreign investor De Beers. The government managed to negotiate favourable rent-sharing agreements and appropriate some 80 percent of the industry profits in the form of royalties, taxes and dividends. Much of these served to finance spending in infrastructure projects, education and health (Jefferis, 2014). As a result, 'policy-driven' linkages with downstream activities, such as diamond processing and polishing, have developed over time (Mbayi, 2011). As of 2016, cutting and polishing activities count twenty active firms generating some 2,270 local jobs (UNCTAD, 2016). DeBeers has lately moved its stone-sorting operations and international sales department from London to Gaborone.

Mineral wealth can also be used to boost domestic R&D and upgrade the local skills base. While success requires some minimum absorptive capacity, the experience of Chile shows that this is actually doable. Foreign companies have traditionally employed Chilean managers and engineers in their operations, developing a local knowledge base that has become important to the broader industry. Starting from the 1980s, government support has been centred on providing services related to skills development, innovation and R&D, with revenues of the 'mining tax' being specifically earmarked to these purposes. These initiatives, coupled with the availability of an extensive network of universities specialized in mining-related education, have encouraged inter-firm collaboration and contributed to the upgrading of domestic firms to global standards (UNCTAD, 2011).

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