

Capabilities, sustainability, and innovation in mining value chains

Carlo Pietrobelli ^{1,2,*} Gabriel Casaburi³ and Michiko Iizuka⁴

¹UNESCO Chair at the United Nations University UNU-MERIT, Boschstraat 24, Maastricht 6211 AX, The Netherlands. e-mail: carlo.pietrobelli@uniroma3.it, ²Department of Economics, Roma Tre University, Via Silvio d'Amico 77, Rome 00145, Italy. e-mail: carlo.pietrobelli@uniroma3.it, ³Inter-American Development Bank, Esmeralda 130, Buenos Aires, Argentina. e-mail: GABRIELCA@iadb.org and ⁴National Graduate Institute for Policy Studies (GRIPS), 7-22-1 Roppongi, Minato-ku, Tokyo 106-8677, Japan. e-mail: mi-iizuka@grips.ac.jp

*Main author for correspondence.

Abstract

The original research presented in this Special Section analyzes different aspects of the potential offered to mining firms in developing countries by new demands for solutions to face environmental, social and technological challenges. The evidence is drawn from extensive fieldworks and comparative econometric research on Latin America, and suggests that the existing opportunities will need to be pursued with firm-level efforts and active regulatory and innovation policies.

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The mining industry is at the crossroads. The mining value chains span globally and enable to trace mineral products back to their origin of production, mainly in developing countries, and make the global issues of climate change and human rights increasingly relevant to local production sites and communities. The demand for sustainable practices in production influences the behavior and strategy of multinational corporations and their suppliers. In parallel, the local communities are increasingly aware of the environmental and social impacts of mining activity and take powerful local initiatives (Tetreault, 2020; Haslam, 2021). The growing pressures from both ends of global value chains are transforming the mining industry and opening new spaces for product and producer upgrading in the value chain.

Many diverse actors are being incorporated into the sector consequently. It is not anymore mainly multinational mining corporations but also many different actors that play a central role in the industry. These include local communities demanding fairer and more sustainable activities; local suppliers offering local and context-specific solutions; regulatory institutions governing the exploration and exploitation of resources, their production and trade, and the ensuing practices; and innovation and technology agencies supporting the increasingly technology-intensive stages of the value chain.

The global-value chain framework, by focusing on the global–local production and trade linkages, facilitates detecting these emerging signals and processes of transformation in the mining sector and illustrates new development routes for resource-rich developing countries.

This Special Section presents original research that analyzes different aspects of the potential offered to firms in developing countries by new demands for mining solutions to face environmental, social, and technological challenges. These developments are especially relevant also because the mining sector contributes greatly to the economies of many developing and emerging countries. This is especially true for the Latin-American region, where mining represents a high share of gross domestic product (GDP) and exports. Chile and Peru are major players in copper mining—first and fourth world producers—while Brazil is the third producer of iron in the world. Moreover, Latin America has been the recipient of an important portion of global investment flows, both for exploration and for exploitation of mineral resources. In addition, the requirement of low-carbon technologies, such as for example those employed in electric vehicles and telecommunications, generates new demands for metals such as copper, lithium, nickel, and aluminum among others (Hund *et al.*, 2020).

Still, the mining industry has had limited success in sparking processes of economic transformation and diversification spreading to other activities, and in some instances, it has been considered a “curse” for economic development. This has been the object of a traditional debate in development economics: are natural resource endowments a curse or a blessing for a developing economy (Sachs and Warner, 2001)? As the experience of fast industrializers shows, economic transformation and development are intrinsically related to the process of innovation and spillovers leading to the creation of value in existing sectors, as well as to the emergence of new sectors in the economy. Unlike what happened in the mining sector in advanced countries, in Latin America the local provision of intermediate inputs and services is still limited and confined to the second and third lower value-added tiers of the mining value chains.

Moreover, also the mining industry has been transforming its organization in the direction of global value chains (Korinek, 2020). A tendency toward vertical disintegration and local outsourcing has been growing since the 1970s, with opportunities for local outsourcing and learning increased. Indeed, large mining houses began to concentrate on their core capabilities and outsource the rest of the activities (Fessehaie, 2012), opening new opportunities for intermediate goods and services suppliers. However, in mining Global Value Chains (GVCs) hierarchical forms of governance tend to prevail (Morris *et al.*, 2012), due to the complexity of information involved in the transactions between the lead firms and their suppliers, the often tacit local knowledge involved, and the huge size and related economies of scale enjoyed by the lead mining firms, which often produce asymmetric power relations in the chain. Such hierarchical governance prevailing in most mining GVCs appears to seriously limit suppliers’ learning opportunities (Pietrobelli *et al.*, 2018), and the provision of intermediate inputs is often dominated by first-tier providers that follow mining companies in their activities overseas, and that tightly control access to these niches.

However, new interesting opportunities appear to be emerging for local suppliers, and are related to: (i) the continued need that mining companies face to outsource and make production more efficient; (ii) the emergence of new solutions to extracting and manufacturing activities derived from advances in relevant branches of science and technology, such as biotechnology and Information and Communication Technologies; (iii) the search for local solutions required to address technological, environmental, and social challenges that are increasingly local; (iv) the rising demands for environmentally and socially sustainable arrangements and practices. Still, these opportunities for domestic suppliers and local content can only be exploited provided that some underlying conditions are fulfilled. These conditions are related, for example, to the development of local technological competences, and the availability of an institutional setting that allows encompassing the social, environmental, and production-related demands within a coherent framework.

Innovation is also central in this approach, but it also faces important constraints (Marin *et al.*, 2015; Pietrobelli *et al.*, 2018). Commodity prices are volatile and determined exogenously, leaving no scope for differentiation; mining firms have low incentive to invest in knowledge due to low appropriability and risk aversion; mining firms tend to operate in enclaves, with limited backward and forward linkages (Calzada Olvera and Izuka, 2020). However, at the same time, new solutions of local environmental and technological problems are also called for, requiring

original adaptive and multidisciplinary responses, with the combined use of various technologies (e.g., chemical, digital, biotechnology).

In the first paper, [Pietrobelli *et al.* \(2024\)](#) study whether the mining sector can represent a true engine of growth for selected Latin American countries through the suppliers' entry and upgrading within mining value chains. The participation of Latin American countries in copper value chains, while highly relevant worldwide, is still confined to the upstream segment. Their share of innovation relevant for the sector remains very limited, although new data on patenting and publications show that the sector is becoming increasingly innovative worldwide. The authors exploit new microeconomic evidence from case studies in Latin America to analyze the specific opportunities and obstacles faced by mining suppliers in entering the value chain and upgrading within it, and how the regulatory and innovation systems have influenced this process. The main barriers appear to be related to the contractual practices, lead firms' attitudes, and the hierarchical industrial organization of the sector, coupled with the countries' weaknesses in local innovation and regulatory systems. This has often hampered suppliers' entry into mining value chains and upgrading.

Although Peru is one of the main producers of copper worldwide, the domestic industry has not yet fully taken advantage of this potential. [Bamber *et al.* \(2024\)](#) adopt a mixed-methods approach, combining quantitative and qualitative primary and secondary sources, including semi-structured interviews with key actors in the Peruvian mining sector. Their findings suggest that the weak presence of Peruvian suppliers in a sector dominated by few foreign firms is due to global industry dynamics as well as the underdeveloped capabilities of local firms operating in a fragile local institutional setting. However, the few integration opportunities open primarily in areas where new solutions are required, which places a demand on the suppliers' innovative capacity.

The paper on Argentina focuses on the opportunities for innovation in the mining sector that are leveraged by local knowledge-intensive mining suppliers (KIMS) in mineral-rich developing countries ([Stubrin *et al.*, 2024](#)). Argentina has a relatively small mining sector but an outstanding mineral potential with substantial unexplored and unexploited geological resources, and local communities very vocal in favor of sustainability and human rights. Therefore, supplier development faces challenges and opportunities that differ from those identified in the existing studies conducted in more advanced mining countries. This paper highlights these differences, and focuses on metal mining, including the stages of exploration, construction, and operation. The authors identify three types of innovation approaches that local KIMS can pursue, each associated with the main sources of innovation opportunities, the type of inputs supplied, and the prevailing market structures and entry barriers. The empirical analysis is based on the novel data collected in 2019 and 2022, with in-depth field research on a selection of local strategic mining suppliers. The authors conclude with several considerations on industrial and innovation policies for this sector in Argentina in the current technological and market context.

All the papers in this Special Section acknowledge that innovation in the mining sector plays a crucial role. The paper by [Calzada Olvera and Iizuka \(2024\)](#) contributes to better understand the factors that stimulate innovation to upgrade productivity and growth in the mining sector, where innovation is driven by profits, which in turn depend strongly on commodity prices. In their theoretical model and subsequent empirical analysis, they find two different innovation responses to prices: exploration and in-house research and development (R&D) investments by mining companies increase as commodity prices rise, while the use of suppliers' innovation intensifies when prices decrease. They conclude that policies should provide long-term support for the Mining Equipment, Technology and Services (METS) sector so that they can continuously invest in R&D and offer innovative solutions for mining firms, often applying digital and low-carbon solutions.

Although evolutionary economics has extensively analyzed the evolution of industries in relation to innovation and technology lifecycles, the interplay between industry lifecycles and evolutionary patterns of knowledge networks has not been fully explored yet. [Fusillo *et al.* \(2024\)](#) aim to bridge this gap by analyzing the coevolutionary patterns of knowledge and trade flows in the mining industry, using social network tools in combination with the Schumpeterian tradition

of analysis. The study focuses on Brazil, Chile, and Peru and suggests that the innovation network and the global value chain–trade network display divergent coevolutionary patterns; while the former tends to be stable and concentrated, the latter shows increasing fragmentation and turbulence. The analysis also shows remarkable evolutionary evidence at the country level.

All the papers in this Special Section argue that innovation and sustainability are bound to play a central role in the development of the mining industry. The emerging demands for solutions to face new mining environmental and technological challenges represent a powerful inducement for innovation in firms in developing countries. The evidence presented is original after long fieldworks and comparative econometric research, and it has been analyzed within a consistent and structured framework. The results on the various countries collectively contribute to further research in this area, and they are accompanied by studies that intentionally take a more global perspective to offer a comprehensive and comparative reading of the evidence.

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