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Innovative Technological Capabilities Accumulation in the Mining Industry in the context of Emerging Economies: Substantive and Methodological Aspects of an on-going Firm Level Empirical Research in Brazil

Janaina Piana
Getulio Vargas Foundation
Brazilian School of Public and Business Administration
janainapiana@gmail.com

Abstract

This paper realizes a substantive and methodological reflection about the innovative technological capabilities accumulation process, technological learning processes (source of innovation technological capabilities building) and the outcomes generated by them for the competitive performance of the firms. This reflection is conducted in the context of natural resources-based industries, specifically in the mining industry in emerging economies.

The commodity boom that started in the 2000s intensified the debate about the role of natural resources-based industries for economic and technological development of emerging economies. Especially in mining industry, many approaches describe this industry and firms in a negative way. They argue that the mining industry is "low-tech" and/or mere commodity producers, works as an enclave, contributes only to generate royalties for the government, offers little opportunity for technological innovation and provides weak contribution to industrial development and international competitiveness.

However, studies with a negative view on the mining industry have shown limitations by (i) addressing issues related to mining from highly aggregated secondary data; (ii) developing a common vision of the mining industry; and (iii) reducing innovation to spending on R&D and patent number. In addition, there is an absence of studies on the innovative technological capabilities process at the level of the firms in the mining industry in the emerging economies. The lack of studies at firm level, which captures the nuances and variability of the firms, generates concerns because the generalized interpretations (and negative) presented above are used as inputs for public policy and may not be reflecting the reality of the industry, which consequently can make potentially ineffective public policies. These issues stimulates the production of new analyzes that can complement the understanding about the reality of mining industry.

In this sense, studies on technological capabilities accumulation in emerging economies at the level firms have made little progress (i) to present studies in the context of natural resources-based industries, especially mining; (ii) to give explanations about the nature and the temporal dimension in which firms in emerging economies accumulate innovative technological capabilities; (iii) about the understanding of the relative importance of different processes of learning and

how this importance and characteristics of these processes are modified when the firms deepen their innovative technological capabilities; and (iv) about the understanding of the outcomes from innovative technological capabilities beyond the technological catch-up.

Technological capabilities refer to a stock of resources necessary to conduct production and innovation activities at different levels, including skills, knowledge and experience, institutional structures and interaction networks, which may be within the firm or distributed among other organizations linked to the firm (Bell and Pavitt, 1993; 1995; Bell and Figueiredo, 2012). For firms from emerging economies accumulate innovative technological capabilities, they need to realize technological learning efforts. Technological learning is understood here as the way in which the firm acquires and assimilates knowledge and skills needed to engage in innovation activities (Bell and Figueiredo, 2012). The outcomes from innovative technological capabilities accumulation refer to the degree of success achieved by firm´s technological activities in terms of catch-up, innovative performance (inventive and innovative activities) and business performance (operational and environmental performance).

The paper presents a methodology that is being applied in an on-going research in mining sector in Brazil. The methodology presents an inductive approach based on a single case study in VALE company. The study focus on four specific technology areas of the company: mineral exploration, mining, mineral processing and logistics. The study is based on a long-term coverage (1980-2013) with evidence collected through extensive fieldwork. Thirty-six semi-structured interviews with duration of 60-120 minutes were realized with mining professionals from VALE.

This paper contributes to a clearer notion of the innovative technological capabilities accumulation process in the emerging economies and presents a methodology for measurement and analysis of the variables involved in this process. This is particularly important for the mining industry in the context of emerging economies because helps to drive new innovative technological capabilities studies mainly based on fieldwork, not just in analysis of official statistics, that enable collect qualitative and quantitative evidences first-hand that grasp the reality of technological activities in the industry with the appropriate level of detail and depth. This help to broaden the debate beyond the common generalizations (and negative) on the role of mining industry for technological development in the context of emerging economies.

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1. INTRODUCTION

This paper realizes a substantive and methodological reflection about the innovative technological capabilities accumulation process, technological learning processes (source of innovation technological capabilities building) and the outcomes generated by them for the competitive performance of the firms. This reflection is conducted in the context of natural resources-based industries, specifically in the mining industry in Brazil.

The commodity boom that started in the 2000s intensified the debate about the role of natural resources-based industries for economic and technological development in emerging economies. On the one hand there are “optimistic” visions about the role of natural resources-based industries such as “Blessing of Resources”perspective and studies about low-medium-tech industries in Europe. On the other hand, there are “pessimistic”visions about these industries that has been prevalent such as "Resource Curse" and "Dutch Disease" perspectives and studies in Latin America that have related the poor economy performance of Latin American countries, after the reforms of the 1990s, to their dependence on natural resources-based industries.

The “Resource Curse” and “Dutch Disease” approaches, although with different emphasis among the authors, claim that the economies abundant in natural resources: (i) have reduced the size of the manufacturing sector (Papyrakis and Gerlagh, 2006); (ii) are vulnerable to corruption (Auty, 1997; Papyrakis and Gerlagh, 2006) and; (iii) provide economic stagnation (Sachs and Warner, 1999; Gylfason, 2001; Sachs and Warner, 2001). Even more, claim that natural resources-based industries (i) do not generate spillovers in the economy (Sachs and Warner, 2001; Papyrakis and Gerlagh, 2006); (ii) contribute only to generate royalties for the government (Postali, 2009); and (iii) have limited opportunities to technological development and low-knowledge involved in their activities (Sachs and Warner, 2001).

Studies in Latin America argue that, after the market opening and abandonment of import substitution policy, occurred a productive specialization for maquilaria and for natural resources-based industries has led Latin American countries to a "low development trap" (Katz, 2000; Ocampo, 2001; Castaldi, Cimoli, Correa and Dosi, 2009). Furthermore, these authors state that specialization in these industries generates limited opportunities for innovative technological capabilities accumulation and technological learning and consequently it reflects in the lack of positive outcomes from innovative activities and knowledge involved in these activities.

These interpretations, although providing significant understandings, have limitations by (i) addressing the issues related to natural resources-based industries from highly aggregated secondary data; (ii) developing a common vision of Latin America and of the natural resources-based industries; (iii) classifying the natural resources-based industries such as low intensity of knowledge, or, according to Ferraz, Kupfer and Iootty (2004), as industries that carrying incipient efforts to realize innovative activities. However, hidden behind low-tech industries characteristics, these sectors include companies with considerable innovation capabilities (von Tunzelmann and Acha, 2005).

Specifically in mining industry, the sector is traditionally seen as a declining industry with enclave operation, based on the exploitation rather than innovation. It is considered a type of industry based on low value aggregate resource, low technology and, therefore, countries should give up of mining industry (Scott-Kemmis, 2013). Barnett and Bell (2011) and Urzúa (2013) emphasize it in the mining industry in Chile, that persisted for a long time in the Chilean government the following idea: (i) the mining sector's activities concentrates only in extraction of mineral resources without generating industrial development; (ii) the sector works as an enclave; and (iii) the industrial activities contribute to the long-term development only with the generation of royalties to the government.

In summary, the most of these studies have limitations because they use analyzes based on highly aggregated data that do not capture the variability of efforts in innovative technological capabilities accumulation at the firm level. The lack of studies at firm level, which captures the nuances and variability of the firms, generates concerns because the general interpretations (and negative) presented above are used as inputs for public policies and may not be reflecting the reality of the industry, which consequently can make potentially ineffective public policies. Therefore, it is important to bear in mind that instead of reproducing up perspectives and common generalizations that are derogatory and negative on the natural resources-based industries, it is better to understand the true nature of their innovation process. These issues stimulate the production of new analyzes that can complement the understanding about the reality of natural resources-based industry, particularly in the mining industry.

In this sense, studies on technological capabilities accumulation in emerging economies at the firm level have made considerable progress about (i) the description of trajectories of technological capabilities accumulation (e.g. Figueiredo, 2001; Dantas and Bell, 2011); (ii) the understanding that the technological learning is the most influential factor in the technological capabilities accumulation process (e.g. Bell and Figueiredo, 2012; Figueiredo, Cohen and Gomes, 2013); and (iii) the outcomes from technological capabilities accumulation in terms of catch-up (e.g. Figueiredo, 2001; Dantas and Bell, 2009).

However, the technological capabilities accumulation literature in emerging economies has been made little progress (i) in studies in the context of natural resources-based industries, especially mining; (ii) to give explanations about the nature and the temporal dimension in which firms in emerging economies accumulate innovative technological capabilities (Bell and Figueiredo, 2012); (iii) in the understanding of the relative importance of different processes of learning and how this importance and the characteristics of these processes are modified when the firms deepen their innovative technological capabilities (Bell and Figueiredo, 2012; Figueiredo et al, 2013); and (iv) in the understanding on outcomes beyond the technological catch-up (Figueiredo, 2014).

Thus, in order to contribute to filling this gap the on-going firm level empirical research will examine the following question: How did occur the technological capabilities accumulation process in mining industry in Brazil, specifically in Vale company? In this paper is presented substantive and methodological aspects of the on-going research in mining industry in Brazil.

The Section 2 presents substantive aspects about the technological capabilities process. Specifically, the next section discusses issues about latecomer firms, technological capabilities, learning processes and outcomes from innovative capabilities accumulation. The Section 3 presents the industry context and the Section 4 discusses methodological aspects of the on-going research in the mining industry in Brazil. Finally, the Section 5 presents the conclusions.

2. SUBSTANTIVE ASPECTS ABOUT THE INNOVATIVE TECHNOLOGICAL CAPABILITIES ACCUMULATION PROCESS

2.1 Latecomer firms and technological capabilities

Latecomer firms are typically characterized by a low level or absence of innovative technological capabilities and by being "initially imitative", regardless of how ill positioned they may be with respect to markets and technology sources (Mathews, 2002). However, they may move from merely using or imitating technology to deeper levels of technological engagement and technological capabilities that enable them to undertake different types of innovative activities (Bell and Figueiredo, 2012).

Therefore, this paper makes use of the term "technological capability" in the sense defined in Bell and Pavitt (1993; 1995). Technological capability is defined here as the resources needed to generate and manage technological change, including skills, knowledge and experience and organizational systems. In other words, Bell and Figueiredo (2012) claim that the technological capability of the firms refers a stock of accumulated knowledge in people (formal qualification, knowledge, experience and skills), organizational systems (knowledge accumulated in organizational routines, procedures, instructions, documentation, management techniques and processes), technical-physical systems (machinery, equipment, information systems) and goods and services (design, development, prototyping, testing, production and marketing of products). It should be noted that the resources can be accumulated in a distributed manner, ie , knowledge that is searched, accessed, coordinated, integrated and optimized can be hosted in other organizations as suppliers, users, competitors, suppliers, consultants, university, among others (Bell and Figueiredo, 2012; Dantas and Bell, 2011).
The reasons for using this definition are that its sense is embedded in the characteristics of the latecomer firm, thus is more adequate than the sense available in the literatures on firms in the context of advanced economies and its sense is broad enough to describing paths including both technical and organizational dimensions of technological capability.

The literature distinguishes between production and innovation capabilities (Bell and Pavitt, 1993; 1995). The formers refer to those capabilities to use or operate current technologies and production systems with given levels of efficiency, and latter refers to a firm´s abilities to assimilate, adapt, and change current technologies that enable firms to create new technologies and develop new products and process (Bell and Figueiredo, 2012). The analytical distinction is important because latecomer firms generally begin as technology users and or/ imitators, and the distinction helps determine whether their capabilities grow over time into more innovative levels.

2.2 The role of learning in building innovation capability in latecomer firms

The learning is the variable more closely and with higher degree of influence in the innovation technological capabilities accumulation trajectory (Lall, 1992; Bell and Pavitt, 1993; Bell and Figueiredo, 2012). Technological learning processes are concerned with the specifics efforts firms make to create innovative capabilities – i.e. they are about the intensity, persistence, and effectiveness with which firms specifically manage and invest in acquiring and creating the human resources, knowledge bases and organizational capabilities that they need to conceive and implement innovation (Bell and Figueiredo, 2012).

According to Bell and Figueiredo (2012), it is possible to identify different approaches to learning. The first approach considers learning as a specific type of innovation (e.g. Scott-Kemmis and Bell, 2010). The second approach considers learning as a particular type of knowledge (Viotti, 2002). The third approach considers learning as knowledge acquisition from sources outside the firm (e.g. Cohen and Levinthal, 1989). These approaches have limitations for this research. So, here learning is understood from conscious, intentional, costly, not automatic, active and deliberate processes, in which technical skills and knowledge are acquired by individuals and the organization (Bell and Figueiredo, 2012). Moreover, these acquisitions are cumulative and increase the stock of knowledge or the technological capabilities of the firm (Malerba, 1992). This approach is consistent with that used in the technological capabilities accumulation in emerging economies literature (e.g. Lall, 1992; Bell and Pavitt 1993; 1995; Figueiredo, 2001; Figueiredo et al, 2013).

Several authors have developed various types of learning activities. Arrow (1962) identified the learning by doing, Rosenberg (1982) spread the learning process learning by using, in this case the technological capabilities accumulation is related to the use of the product and not the process by which it is produced, as in learning by doing. Lundvall (1988) highlights the learning by interaction where the learning process is characterized by a joint learning from cooperation ties. Bell (1984) has developed a set of types: learning by doing, operating, changing, searching, hiring, training and system performance feedback. Malerba (1992) and others argue over other types of activity: learning by searching, from inter-industry spillovers and from advances in science and technology.

Therefore, technological learning is described as a continuous and iterative process involving external and internal learning processes. The change in the characteristics of these processes explains the accumulation of technological capabilities trajectory in firms from emerging economies (Figueiredo et al, 2013).

2.3 Outcomes from innovative capabilities accumulation

One of the implications of the technological capabilities accumulation most studied is the catch-up, which can be technological catch-up and production catch-up. The first happens when latecomer firms achieve the global innovation leader in terms of capacity to generate and manage change in their technologies. The second happens when latecomer narrow the gap between the technology they use in production and technology that global leaders in international technological frontier use in production (Bell and Figueiredo, 2012).

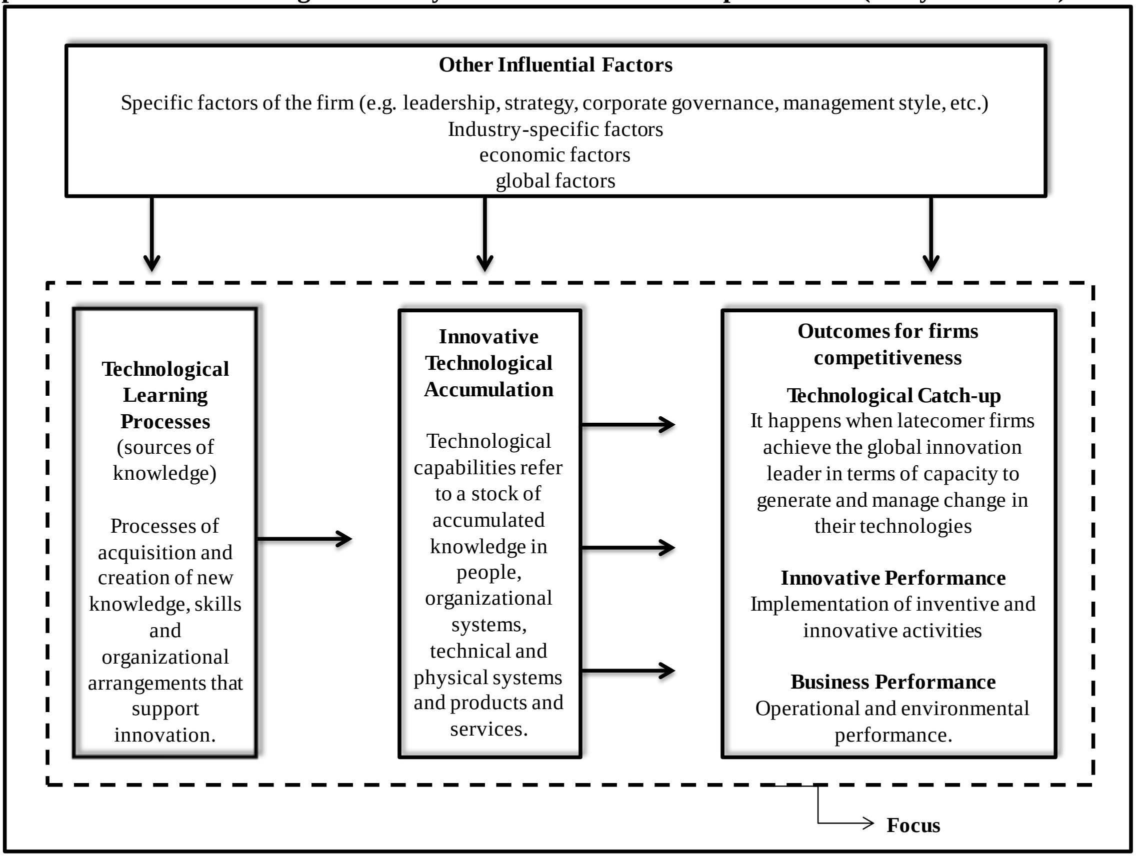
Others studies about the outcomes from technological capabilities has been concerned with the implications in terms of operational performance (e.g. Figueiredo, 2001; Figueiredo, 2014), innovative performance (e.g. Yam et al, 2010; Shan and Jolly, 2012; Figueiredo, 2014), the company's growth (e.g. Penrose, 1959; Chandler, 1962; Figueiredo, 2014) and sales performance (e.g. Shiang, 2008; Yam et al, 2010; Shan and Jolly, 2012).

When latecomer firms attain the capability level of undertaking world-leading innovative activities, that is, when they catch up technologically with global leaders, their technological behavior becomes similar to global innovative firms from advanced economies (Figueiredo, 2014). The latecomers become concerned with how to use, sustain, and expand their innovative capabilities to re-build and re-create new and distinctive positions of strategic competitive advantage, perhaps even by changing, or at least adding to, the areas of technology within which they innovate, which is an issue of concern in the strategic management literature (e.g. Teece, 2007). Thus, the bodies of literature of capabilities building and of strategic management seem to converge on a common concern, i.e., the outcomes that firms achieve from their innovative capabilities (Figueiredo, 2014).

Therefore, it has been argued in the latecomer literature that the ability of firms to implement innovative activities and achieve distinctive performances reflects the nature and depth of their technological capabilities (e.g. Lall, 1992; Bell and Pavitt, 1993). In addition, several studies in the strategic management literature have assumed that innovative capabilities operate as a source of competitive performance (e.g. Penrose, 1959; Chandler, 1962). However, there has been a steadily growing debate over the past decades on innovative capabilities as the fundamental source of a firm’s sustainable competitive advantage and superior performance. Among the reasons for this debate, it has been argued, is the fact that most studies in that branch of the literature have been dominated by theoretical discussions, relatively weak empirical support (Newbert, 2007) and by a multiplicity of metrics for both innovative capability and performance (Coombs and Bierly, 2006).

The above perspectives (Section 2) constitute an important conceptual basis that helped to form a research design and show the importance to increase the understanding about innovative technological capabilities accumulation process, technological learning and the outcomes generated from them to firm competitiveness. The Figure 1 shows the relationship among innovative technological capabilities process, technological learning process and the outcomes generated by them for the firm’s competitiveness.

Figure 1. Relationship among innovative technological capabilities process, technological learning process and the outcomes generated by them for the firm´s competitiveness (analytical model)



Source: Adaptated from Bell and Figueiredo (2012) e Figueiredo (2014)

Therefore, the next section presents the methodology that is been applied in an on-going research in mining industry in Brazil and the context of this industry.

3. INDUSTRY CONTEXT

The mining industry in Brazil represents 3% to 4% of GDP and 20% of total exports, generating 175,000 direct jobs in mining and 2.2 million in the mineral manufacturing industry, equivalent to 8% of jobs in the industrial sector, in 2010 (IBRAM, 2012). About ten firms, both national and international origin, dominate the Brazilian mining market. Brazil is the second largest producer of iron ore in the world, with 17% of total world production. After oil, iron ore is the second largest export product of the country, which has China (45.78%), Japan (9.71%) and South Korea (4.97%) as the main buyers (IBRAM, 2012).

VALE company dominates the sector, accounting for 80% of total Brazilian iron ore production, followed by CSN, Anglo American, MMX and Samarco (Global Business Report, 2012). Currently VALE is a mining company operating principally in the production of iron, manganese, copper, cobalt, coal and some fertilizers such as phosphate and nitrogen (urea and ammonia) (VALE, 2013). The company operates in 13 Brazilian states and in 37 countries and employs more than 195,000 employees (including employees and contractors). VALE is the largest producer the world of iron ore and pellets, and the second largest in nickel (VALE, 2013).

VALE´s exports overcome the soybean, sugar, meat, automobiles, coffee and airplanes exports. Table 1 shows the growth of exports in the 2001-2010.

Table 1. VALE´s exports compared with other products (US$ million)

Year	VALE´s exports	Soybean *	Sugar*	Meat*	Automobiles *	Coffee	Airplanes
2001	3,297	5,206	2,279	2,629	4,239	1,393	2,839
2002	3,173	5,906	2,094	2,879	4,510	1,362	2,335
2003	4,229	7,935	2,140	3,729	5,827	1,516	1,939
2004	5,534	9,822	2,640	5,648	7,307	2,025	3,269
2005	7,021	9,232	3,919	7,391	9,189	2,879	3,168
2006	9,656	8,911	6,167	7,701	10,366	3,311	3,241
2007	12,492	10,888	5,100	9,559	10,396	3,829	4,719
2008	17,606	17,300	5,483	12,046	11,109	4,697	5,495
2009	13,719	17,058	8,378	9,602	7,122	4,222	3,860
2010	29,090	16,953	12,762	11,375	10,348	5,717	3,972

* Soy includes beans, crushed, bran, oil and waste oil extraction; sugar includes sugar cane, raw and refined; meat includes the various forms of processing of different meats of chicken, pork and beef; automobiles includes passenger cars, tractors, parts and engines; and coffee includes raw grain and soluble.

Source: VALE (2012)

4. METHODOLOGICAL ASPECTS ABOUT THE INNOVATIVE TECHNOLOGICAL CAPABILITIES ACCUMULATION PROCESS

4.1 Research Design

The on-going research focuses on the innovative technological capabilities accumulation paths, learning processes and the outcomes from them to competitive performance of the firms and aim to examine the following question: How did occur the technological capabilities accumulation process in mining industry in Brazil, specifically in Vale company? To answer this question is being applied a research strategy based on an inductive and qualitative approach. The research design is based on a single in-depth case study and on empirical evidence with long-term coverage that is being obtained through extensive fieldwork.

This research strategy is appropriate because facilitates a better understanding of what is behind a little studied phenomenon, showing details and nuances that could not be captured by other methods, including in especially aggregated analysis derived purely from quantitative methods (Yin, 2001). In addition, the research strategy is adequate because has been widely used in recent studies examining research questions with similar nature. These studies have shown convincing and conclusive results on issues related to technological capabilities accumulation in emerging economies (e.g. Dantas and Bell, 2011; Figueiredo, 2014).

4.2 Operationalization the research constructs

<u>Innovative technological capabilities accumulation</u>

The conventional indicators to measurement innovative technological capabilities are related to research and development (R&D) and patents. For example, number of people allocated in the R&D laboratories, number of formal qualifications of these individuals, expenses involved in R&D, patenting intensity, expenses on education, and engineering personnel statistics (Figueiredo, 2001).

These indicators are useful because they (i) are presented as a model with generic characteristic, allowing it to be applied in different contexts; (ii) enable periodic and continuous application of questionnaires, often with faster data surveys that other forms of measurement; and (iii) are a model replicated and popularized among different countries, allowing comparisons about innovation in different countries (Figueiredo, 2001).

However, there are situations where these indicators have limitations. These limitations are justified by the fact that these indicators (i) do not describe in detail the innovative technological capabilities accumulation process; (ii) do not capture specific and intraorganizational nuances, neglecting performance heterogeneities in different technological activities; (iii) have a static approach (snap-shot) and usually focused on short periods; (iv) use a logical that neglects activities such as imitation, copy, adaptation, experimentation, adoption of new products, processes and organizational arrangements (Lall, 1992; Bell & Pavitt, 1993; 1995; Figueiredo, 2001).

Indicators based on R&D and patent activities are only sufficient in some industrial sectors from advanced countries. In advanced countries, the firms usually have deepened levels of innovative technological capabilities. So, the exclusive application of these indicators for firms in emerging economies is irrelevant because the firms often lack sophisticated levels of innovative technological capabilities to conduct R&D and patents (Lall, 1992; Bell & Pavitt, 1993, 1995; Figueiredo, 2001). In mining industry, for example, much of the product and process development expenditure is not classified as R&D. According to Kaplan (2012), the R&D measure when applied to the mining industry in aggregate also ignores the more technology intensive activities within mining such as exploration mineral.

Therefore, this article proposes an analytical framework that captures the different degrees of innovative activities, and use of R&D and patents indicators to understand the innovative technological capabilities accumulation path. This framework is viable because other researchers have used it successfully to trace technological capabilities accumulation paths (Ariffin, 2000; Dantas & Bell, 2009; 2011; Figueiredo, 2014), however, has not been developed and applied in the mining industry.

The framework to measuring technological capabilities in the mining industry uses a structure inspired by Lall (1992), Figueiredo (2001) and Urzúa (2013). Lall (1992) created a model in which the technological capabilities of a firm are categorized by function and suggests that the accumulation proceeds from the simplest to the most complex categories. After, Figueiredo (2001) empirically adapted the model proposed by Lall and others to better explain the differences between two steel firms in Brazil, in terms of the way and rate (time) of the technological capabilities accumulation. Urzúa (2013) created a specific taxonomy for knowledge-intensive industry in mining services (KIMS) that due to the proximity with the mining industry, it was used to inspire the framework developed here. In addition, the framework here presented, was adapted from the original models to the mining industry through evidence provided by specialists in the mining industry in Brazil and technical materials about mining.

Box 1 shows the framework to measuring technological capabilities in the mining industry with illustrative examples of activities that express the functions (technological areas) levels and types of technological capability, the latter differentiated in production capabilities and innovative capabilities. The first refers to the ability to use and operate existing technologies, the latter refers to the ability to generate and manage technical change (Ariffin, 2000).

The functions or technological areas of mining proposed in the framework are (i) mineral exploration, which includes all the activities leading to the discovery of resources; (ii) mining, this stage starts with the commercial exploitation of the mine and consists in the removal of the mineral value in ore from the host rock or matrix.; (iii) mineral processing, which involves the activities to separate the mineral from waste material, remove impurities, or prepare the ores for further refinement and; (iv) logistics.

Technological capabilities levels are associated with the novelty and complexity degree of the technological activities carried out by firms. Based on Figueiredo (2001), Bell and Figueiredo (2012) and Urzúa (2013) the levels used are:
Level 1 - Basic Production: Capability to use existing technologies with local efficiency and quality degree.
Level 2 - Advanced Production: Capability to use existing technologies based on overall (global) efficiency and quality degree.
Level 3 - Basic Innovation: Capability to develop small adjustments and improvements in existing technologies.
Level 4 - Intermediate Innovation: Capability to implement innovative activities of incremental nature and follower of technology strategy.
Level 5 - Advanced Innovation: Capability to implement innovative activities near the international technological frontier within an existing technological trajectory.
Level 6 - Innovation global leadership: Capability to implement innovative activities based on world-class R&D to push or open new segments in the international technological frontier of innovation.

Box 1. Framework to measuring technological capabilities

Types and Levels of Technological Capabilities		Technological areas and related activities: Mineral Exploration	Mining	Mineral Processing	Logistics
Innovative Capabilities Capability to generate and manage technical change	**Level 6 - Innovation Global Leadership**	Implementing innovations that are new to the world and deepen the existing technological frontier and/or open new segments in the international technological frontier, such as: R&D geological prospecting models; R&D in equipments to from mineral exploration.	Implementing innovations that are new to the world and deepen the existing technological frontier and/or open new segments in the international technological frontier, such as: R&D in extration and transport equipments; R&D in mines planning (mining and closing) and better use of resources.	Implementing innovations that are new to the world and deepen the existing technological frontier and/or open new segments in the international technological frontier, such as: R&D in biotechnology; R&D in chemistry and production; R&D in mechanical engineering to optimize the treatment and processing of minerals.	Implementing innovations that are new to the world and deepen the existing technological frontier and/or open new segments in the international technological frontier, such as: R&D in marine engineering; R&D in automation.
	Level 5 - Advanced Innovation	Implementing innovations that are new to the continent/country and/or are close to existing international technological frontier, such as: development of specialized software and methods of research and exploration; development of project management on a global scale.	Implementing innovations that are new to the continent/country and/or are close to existing international technological frontier, such as: development of sophisticated on-line production control and monitoring system; development of new dismantling process; development of autonomous equipment.	Implementing innovations that are new to the continent/country and/or are close to existing international technological frontier, such as: development of new methods with generating higher mineral recovery; development of mineral processing increasingly automated, secure and environmentally responsible; new process development (patent).	Implementing innovations that are new to the continent/country and/or are close to existing international technological frontier, such as: development of sophisticated systems of control and monitoring near of the international technological frontier.
	Level 4 - Intermediate Innovation	Implementing innovations that are new to the regional context based on relatively complex improvements and modifications such as: metalogenetic development (for the definition of extended mineral) and structural studies; development of feasibility studies technically targeted for large expansions.	Implementing innovations that are new to the regional context based on relatively complex improvements and modifications such as: process modifications associated with the new characteristics of the mine.	Implementing innovations that are new to the regional context based on relatively complex improvements and modifications such as: engineering efforts to reduce the variability of the product characteristics (concentrates), and improve specifications.	Implementing innovations that are new to the regional context based on relatively complex improvements and modifications such as: development of techniques and methods to improve logistics processes; customising logistics softwares solutions
	Level 3 - Basic Innovation	Implementing innovations that are new to the business context and are based on small adjustments and adoption of copied improvements, for example: copy of new types of equipment and tools; repairing and troubleshooting of equipments problems; small adjustments to geological models.	Implementing innovations that are new to the business context and are based on small adjustments and adoption of copied improvements, for example: efficiency improvements from experience; troubleshooting of extraction processes; adaptations in terms of increasing production capacity and elimination of bottlenecks.	Implementing innovations that are new to the business context and are based on small adjustments and adoption of copied improvements, for example: mineral processing adaptation according to the specific demands of the steel plants; adjustments and improvements in equipment; troubleshooting of mineral processing; elimination of bottlenecks.	Implementing innovations that are new to the business context and are based on small adjustments and adoption of copied improvements, for example: maintenance and small adaptations of railcars and locomotives; process optimization based on operational research and intelligent systems.
Production Capabilities Capabilities to use and operate existing technologies	**Level 2 - Advanced Production**	Execution of more complex activities of planning, organization and implementation in existing technologies, such as: implementation of geophysical and geochemical surveys; use of petrographic and chemical analysis for evaluation of ore; 3D modeling implementation of the ore body for evaluation and implementation of probe programs.	Execution of more complex activities of planning, organization and implementation in existing technologies, such as: standard equipment procurement (search, evaluation and selection of technology supplier); standardization of extraction processes.	Execution of more complex activities of planning, organization and implementation in existing technologies, such as: international quality control systems and standard (certification); standard equipment procurement (search, evaluation and selection of technology supplier); basic services of chemical engineering and production; standardization of mineral processing.	Execution of more complex activities of planning, organization and implementation in existing technologies, such as: use of international standards of logistics planning; use of logistics softwares solutions with international standards.
	Level 1 - Basic Production	Use and operation of existing technologies, such as: quantification of volume of mineral resources from direct observations in the field; routinaly physical and chemical analysis of samples.	Use and operation of existing technologies, such as: routinely quality control; maintenance of the equipment components; construction of basic works; routine operation of the mineral extraction process.	Use and operation of existing technologies, such as: routinely quality control; routinely production process operation; basic production planning and control and line balancing; maintenance of the equipment components.	Use and operation of existing technologies, such as: routine maintenance of locomotives and wagons; use of logistics softwares solutions.

Source: Adapted from Figueiredo (2001) and Urzúa (2013). Own elaboration based on research data.

The development of this framework to this study was achieved after approximately three months' work and involved several consultations with experts in the mining industry. These interactive and iterative consultations were used to adapt the taxonomy to the technological specifics of this industry.

Technological learning

The technological learning is being operationalized through a characterization of knowledge flows involved in the learning processes used by firms to acquire, assimilate, combine, create and transfer knowledge that contribute to the innovative technological capabilities accumulation.

According to Kim (1998), technological learning involves a four-step cycle: (i) internal preparation for the acquisition of external knowledge; (ii) the acquisition of knowledge, (iii) effective assimilation of knowledge; and (iv) improvement, ie, creating a broader knowledge base for the preparatory phase of another cycle of learning. The cycle demonstrates the importance of integration of internal and external processes of learning because the cycle is only completed with steps involving internal learning processes such as assimilation, improvement and / or creation of knowledge by the firm, and other steps involve external learning processes as for example, knowledge acquisition from external sources (Bell and Figueiredo, 2012).

According to Iansiti and Clark (1994) the integration of internal and external processes refers to capability to connect information and evolutions of knowledge (from inside and outside of the firm) for the capabilities technological creation and building.

So, in order to build a framework to examine technological learning processes, this study draws on the literatures addressing this issue in industrialized and latecomer firms and also on insights from the fieldwork. The dimensions of analysis are: (i) variety; (ii) direction and origin; (iii) content; (iv) intensity; and (v) effectiveness. Box 2 presents the framework for technological learning.

Box 2. Framework for technological learning

<table>
<tr><th rowspan="4">External and internal integration</th><th rowspan="2">Types of links</th><th colspan="5">Dimensions of analysis</th></tr>
<tr><th>Variety</th><th>Direction and Origin</th><th>Content</th><th>Intensity</th><th>Effectiveness</th></tr>
<tr><td>External knowledge flows
Refers to knowledge flows involving the firm and other organizations</td><td>Refers to external learning processes used for the acquisition, transfer and combination of knowledge.
For example:
• Hiring;
• Tacit know-how acquisition;
• Learning through interaction;
• Codified knowledge acquisition;
• Organizational arrangements for the acquisition of external knowledge.</td><td rowspan="2">The knowledge flows direction involves the central firm and its partners and can be one-way, two-way and one-sided reverse.

The origin refers to the identification of the knowledge flow source. For example, universities, competitors, the company itself, etc.</td><td rowspan="2">Refers to the complexity level involved in the content flow. For example, less complex contents are concerned with operational knowledge, while content-based S&T are considered more complex.</td><td rowspan="2">Refers to the frequency with which learning processes are created, used and improved over time. For example, sporadically, concomitantly, etc.</td><td rowspan="2">Refers to new technological activities that the firm began to realize originated from the learning processes. For example, activities associated with R&D, activities associated with production, etc.</td></tr>
<tr><td>Internal knowledge flows
Refers to knowledge flows between areas of the firm</td><td>Refers to the internal learning processes used for the assimilation and knowledge generation.
For example:
• Internal training;
• Articulation of knowledge;
• Sharing of knowledge;
• Codification of knowledge and related organizational arrangements.</td></tr>
</table>

Source: Adapted from Iansiti & Clark (1994), Ariffin (2000), Figueiredo (2001), Dantas & Bell (2011), Figueiredo et al, (2013) Outcomes from technological capabilities accumulation

The outcomes from technological capabilities accumulation are being operationalized by: (i) innovative performance, which includes inventive and innovative activities; and (ii) business performance, which refers to the benefits generated by the inventive and innovative activities. Innovative and inventive activity can vary in the technological novelty degree: on one side are innovations that are next to be purely imitations and the other are fundamentally different from anything innovations currently existing (OECD, 2005). Box 3 shows the operationalization of innovative performance.

Box 3. Operationalization of innovative performance

Innovative performance	**Indicators**
Implementation of inventive activities	Analysis of quantity and nature of patents in Brazil (INPI), in United States (USPTO) and Europe (EPO) during the study period. Some examples of patents classes based on (i) USPC (United States Patent Classification): 075 (specialized metallurgical processes), 299 (disintegration of hard material), 023 (Chemistry: physical processes), 037 (excavation); (ii) CIP (International Classification of Patents): F42 (ammunition and blasting), B01 (physical or chemical apparatus and processes in general), C02 (water treatment).
Implementation of innovative activities	Analysis of the innovative activities of the firm or in partnership with suppliers, customers, research institutes and universities.

Source: Adapted from Figueiredo (2014)

The business performance means the benefits generated by inventive and innovative activities in terms of operational and environmental performance. Operational performance refers to the measurement of specific technical parameters, such as productivity, process quality, product quality, etc. (Figueiredo, 2014). The environmental performance is being based on the technologies type "win-win" that reduce costs and environmental damage, such as energy saving, pollutant emission reduction, etc. (Figueiredo, 2014). The indicators that will be used to evaluate the operational and environmental performance are based on the study of Nader, Tomi and Passos (2012) that identifies key performance indicators used in the mining industry (Box 4).

Box 4. Examples of operational and environmental performance indicators

Technological Areas	Examples of Operational Indicators	Examples of Environmental Indicators
Mineral Exploration	• Increase ratio of reserve adequacy and the quantity of released ore (production), this ratio indicates the time required for the reserves are exhausted (time); • Increase the percentage of attendance of the annual plan of exploration (%); • Increase the total labor productivity (production / hour); • Increase in reserves values (proven and probable) (tonnes).	• Decrease in the number of non-compliance environment; • Decreased energy costs ($).
Mining	• Decrease failure rate (production / failure); • Reduction of forced shutdown rate (probability); • Increase physical availability of equipment (%); • Decreased overtime maintenance index (maintenance / total hours of maintenance).	• Reduction in CO2 emissions (metric tons); • Decrease in the number of non-compliance environment.
Mineral Processing	• Increase of recovery mass (%); • Increase metallurgical recovery (%); • Increase the total labor productivity (production / hour).	• Reduction of the unit cost of the environment ($); • Reduction of energy consumption (kWh).
Logistics	• Decrease overtime maintenance index (maintenance / total hours of maintenance).	• Reduction of fuel consumption.

* The indicators are presented from positive effects for the competitiveness of the firm.

Source: Adapted from Nader *et al* (2012)

4.3 Case Selection

The choice for an individual case study and the selection of the mining industry and VALE company started from a deliberate and intentional guidance. First, it was necessary to select a case study with long-term coverage because there is a lack of studies on the role of natural resources-based industries with a longitudinal perspective at firm level. Second, the mining industry and VALE company were chosen because of the importance that they have for Brazil. The mining industry (excluded oil and gas) represents 4% of Brazil's GDP and about 20% of exports. VALE company represents 50% of the mining sector in Brazil (excluded oil and gas) in terms of production. VALE is considered the world's third largest mining company by market capitalization and the largest producer of iron ore[1].

4.4 Data Collection Process

The on-going research is being based mainly on empirical evidence collected in the VALE company and in related organizations, as such suppliers, customers, research institutes and universities. The instruments for the collection of data are interviews, direct observation, informal meetings and document analysis. The selection of these instruments are justified by the fact that the case studies should be supported by multiple sources of secondary and primary evidence to enable triangulation of data and avoiding distortions, producing more stable and reliable results (Yin, 2001).

[1] www.vale.com

4.5 Data analysis

The process of analyzing the collected data began during fieldwork and includes, according to Miles and Huberman (1994), different activities such as: (i) data cleaning, data and information obtained from extensive fieldwork are transcribed, coded and prepared in a common format; (ii) data reduction, continuous process of selection, simplification, abstraction and transformation of the original data from fieldwork; (iii) data presentation, organization of the data for the researcher make decisions and draw conclusions from the data (narrative texts, matrices, charts, diagrams etc.); and (iv) design and verification of conclusions, identifying patterns, possible explanations, cause and effect flow, with check, returning to the field notes and literature.

5. CONCLUSIONS

This paper realized a substantive and methodological reflection about the innovative technological capabilities accumulation process, technological learning processes (source of innovation technological capabilities building) and the outcomes generated by them for the competitive performance of the firms. This reflection was conducted in the context of natural resources-based industries, specifically in the mining industry.

This initiative can be interpreted by some as "extremely theoretical". However, it should reiterate that there has been indiscriminate use of (i) negative generalizations about the role of natural resources-based industries, especially in mining industry for the technological development frequently, without adequate analytical and empirical foundation. This practice can distort and interfere negatively in the design process and implementation of government and business strategies of technological innovation. So, the paper contribute to a clearer notion of the innovative technological capabilities accumulation process in the emerging economies and presents a methodology for measurement and analysis of the variables involved in this process.

This is particularly important for the mining industry in the context of emerging economies because helps to drive new industrial innovation studies mainly based on fieldwork - not just in analysis of official statistics - that enable collect qualitative and quantitative evidences first-hand that grasp the reality of technological activities in the industry with the appropriate level of detail and depth. This would contribute to broaden the debate beyond the common generalizations - or even negative - on the rule of mining industry for technological development in the context of emerging economies.

More specifically, studies based on samples with use of conventional indicators captured at a point in time can generate a mere "photography" of a situation, without details about the innovative technological capabilities accumulation process that does not always reflect the industrial reality. That is, such studies contribute little to the understanding of the real dynamics industrial - so necessary for the design and redesign government and business strategies.

With the complete realization of the on-going research is expected:
(i) generates new evidence, analyzes and explanations to provide an additional perspective on the role of industries related to natural resources for industrial and competitive development, particularly in the mining industry in Brazil;
(ii) generates new evidence, analyzes and explanations for the literature about innovative technological capabilities accumulation, technological learning processes and the outcomes generated by them; and
(iv) generates potential insights for the design, modification and implementation of corporate strategies for mining firms to improve innovative technological capabilities and generate potential inputs to design and / or redesign of public policies aiming to strengthen the innovative technological capabilities and the competitiveness of Brazilian mining industry.

REFERENCES

Ariffin, N. (2000). The Internationalisation of Innovative Capabilities: The Malaysian Electronics Industry. Tese de Doutorado, Science and Technology Policy Research (SPRU), University of Sussex, Brighton, England.

Auty, R. M. (1997). Natural resource endowment, the state and development strategy. Journal of International Development, 9 (4), 651-663.

Barnett, A.; Bell, M. (2011). Is BHP Billiton's Cluster-Programme in Chile relevant for Africa's mining industry? Policy Practice Brief, 7 August 2011.

Bartos, P. Is mining a high-tech industry?: Investigations into innovation and productivity advance. Resources Policy. Volume 32, Issue 4, December 2007, Pages 149–158

Bell, M.; Figueiredo, P. N. (2012). Building Innovative Capabilities in Latecomer Emerging Market Firms: Some Key Issues. In: E. Amann, J. Cantwell (Eds.). *Innovative Firms in Emerging Market Countries* (pp. 24-109), Oxford: Oxford University Press

Bell, M and Pavitt, K. (1993): 'Technological Accumulation and Industrial Growth: Contrasts Between Developed and Developing Countries', Industrial and Corporate Change, Vol. 2, No. 2, pp. 157-211.

Bell, M.; Pavitt, K. (1995). The development of technological capabilities. In: Ul Haque, I.; Bell, M., Dahlman, C., Lall, S., & Pavitt, K. *Trade, technology and international competitiveness*. Washington, DC: The World Bank.

Cantwell, J. (1995). "The globalisation of technology: what remains of the product cycle model?". *Cambridge Journal of Economics*, Vol. 19, No. 1, pp. 155-174

Castillo, J. et al. Chile: size does matter. In: Large mines and the community: socioeconomic and environmental effects in Latin America, Canada, and Spain. Washington (D.C.): The World bank/IDRC, 2001.

Castaldi, C.; Cimoli, M.; Correa, N.; Dosi, G. (2009). Technological learning, policy regimes, and growth: The long-term patterns and some specificities of a globalized economy. In: Cimoli, M., Dosi, G. & Stiglitz, J. E. (Eds). Industrial Policy and Development: the Political Economy of Capabilities Accumulation. Oxford: Oxford University Press.

Cimoli, M.; Correa, N. (2005). Trade openness and technological gaps in Latin America: a 'low growth' trap. In: Ocampo, J. A. (comp.). Beyond reforms: structural dynamics and macroeconomic vulnerability. Stanford: Stanford University Press.

Coombs, J. E.; Bierly, P. E. (2006). Measuring technological capability and performance. *R&D Management*, 36 (4), 421-438.

Dantas, E.; Bell, M. (2009). Latecomer firms and the emergence and development of knowledge networks: The case of Petrobras in Brazil. *Research Policy*, 38 (5), 829-844.

Dantas, E.; Bell, M. (2011). The Co-Evolution of Firm-Centered Knowledge networks and Capabilities in Late Industrializing Countries: The Case of Petrobras in the Offshore Oil Innovation System in Brazil. *World Development*, 39 (9), 1570–1591

De Ferranti, D., Perry, G., Lederman, D. and Maloney, W.F. (2002): From Natural Resources to the Knowledge Economy, Washington, DC, World Bank.

Dodgson, M.; Vandermark, S. (2000). The challenges and opportunities of globalization and innovation in the minerals industry. *Innovation: Management, Policy & Practice*, 3 (4), 3-15.

Ferraz, J. C.; Kupfer, D.; Iootty, M. (2004). Competitividad industrial en Brasil: 10 años después de la liberalización. Revista CEPAL, 82 (2), 91-119.

Figueiredo, P. N. (2001). *Technological learning and competitive performance*. Cheltenham, K; Northampton, MA, USA: Edward Elgar Publishing.

Figueiredo, P.N.; Cohen, M.; Gomes, S. (2013). Firms´ innovation capability-building paths and the nature of changes in learning mechanisms: Multiple case-study from an emerging economy. UNU-MERIT Working Paper Series, 2013-007.

Figueiredo, P. N. (2014). Beyond technological catch-up: An empirical investigation of further innovative capability accumulation outcomes in latecomer firms with evidence from Brazil. *Journal of Engineering and Technology Management*, 31, 73-102.

Freeman, C.; Clark, J. and Soete, L. (1982): Unemployment and Technical Innovation: A Study of Long Waves and Economic Development, London, Pinter.

Furtado, J.; Urias, E. (2013). Recursos Naturais e Desenvolvimento: estudos sobre o potencial dinamizador da mineração na economia brasileira. São Paulo, IBRAM.

Granville, A. (2001): Baseline Survey of the Mining and Minerals Sector, Mining, Minerals and Sustainable Development, MMSD Southern Africa, Research Topic N° 6.

Gylfason, T. (2001). Natural Resources, Education and Economic Development. European Economic Review, 45 (4-6), 847-859.

Hatzichronoglou, T. (1997). Revision of the High-Technology Sector and Product Classification, OECD Science. Technology and Industry Working Papers, 1997/02, OECD Publishing. Disponível em: http://dx.doi.org/10.1787/134337307632

Hirsch-Kreinsen, H. (2008). Low-tech Innovations. Industry & Innovation, 15, 19–43.

Hirsch-Kreinsen, H. (2013). ?Low-Tech? Research – Revisited. In: DRUID Celebration Conference, Barcelona.

Hirsch-Kreinsen, H., Jacobson, D., & Robertson, P. L. (2006). Innovativeness and Development Perspectives – A Summary of a European Research Project. Prometheus, 24, 3-21.

Hirschman, Albert O. 1958. The Strategy of Economic Development. New Haven, CT: Yale University Press.

Huang, C. A.; Arundel, A.; Hollanders, H. (2010). How firms innovate: R&D, non-R&D, and technology adaption. The UNU-Merit Working papers series, 27.

Kaplan, D. (2012). <u>South African mining equipment and specialist services: Technological capacity, export performance and policy</u>. Resources Policy 37 (4) pp. 425-433.

Katz, J. (2000). Structural change and labor productivity growth in Latin American manufacturing industries. World Development, 28 (9), 1583-1596.

KOGUT, B. (2002). “International Management and Strategy”. In: A. Pettigrew, H. Thomas, R. Whittington (eds.). *Handbook of Strategy and Management*. London: Sage Publications, pp. 261-278.

Lall, S. (1993). Understanding technological development. Development and Change, Vol. 24, No. 4, pp. 719-753.

Lall, S. (1992). Technological Capabilities and Industrialisation. *World Development*, 20 (2), 165-186.

Larsen, E. R. (2006). Escaping the resource curse and the dutch disease? When and why Norway caught up with and forged ahead of its neighbors. American journal of economics and sociology, 65 (3), 605-640.

Maloney, W. F. (2001). Missed Opportunities: Innovation and Resource-Based Growth in Latin America, *Economía*, 3, (1), 111-167.

MARIN, A. and ARZA, V. (2009). "From Technology Diffusion to International Involvement: Re-Thinking the Role of MNCs in Innovation Systems of Developing Countries". In: B. A. Lundvall, K. Joseph, C. Chaminade and J. Van (eds.), *Handbook of Innovation Systems and Developing Countries - Building Domestic Capabilities in a Global Setting,* Edward Elgar.

Marin The possible dynamic role of natural resource-based networks in Latin American development strategies Anabel Marin,1 Lizbeth Navas-Aleman2 and Carlota Perez3 Prepared for the CEPAL-SEGIB Project July 2009

Miles, M. B.; Huberman, A. M. (1994). *Qualitative data analysis*. London: Sage Publication.

Mining Association of Canada (2001): *Presentation to the Society for Mining, Metallurgy and Exploration*, Denver, Colorado, 27 February.

MME (2009). Análise comparativa da competitividade do setor mineral nacional. Ministério de Minas e Energia. Disponível em: http://www.mme.gov.br/sgm/galerias/arquivos/plano_duo_decenal/estudos_economia_setor_mineral/P02_RT06_Anxlise_Comparativa_da_Competitividade_do_Setor_Mineral_Nacional.pdf

Ocampo, J. A. (2001). Structural dynamics and economic development. Santiago: United Nations Economic Comission for Latin America and the Caribbean, CEPAL/ECLAC. Mimeo.

Papyrakis, E.; Gerlagh, R. (2006). Resource windfalls, investment, and long-term income. Resources policy, 31, 117-128.

Pérez, C. (2001). Technological Revolutions and Opportunities for Development as a Moving Target. Cepal Review, 75, December 2001, pp. 109-130.

Pérez, C. (2010). Dinamismo tecnológico e inclusión social en América Latina: una estrategia de desarrollo productivo basada en los recursos naturales. Revista CEPAL, Santiago, 100, (2), 123-145.

Pérez, C. and Soete, L. (1988). Catching up in Technology: Entry Barriers and Windows of Opportunities, in Dosi et al. (Eds): Technical Change and Economic Theory, Pinter, London, pp. 459-479.

Peterson, D.J., La Tourrette, T. and Bartis, J.T. (2001): New Forces at Work in Mining: Industry Views of Critical Technologies, RAND Science and Technology Policy Institute. Available at http://www.rand.org/publications/MR/MR1324/.

Postali, F. A. S. (2009). Petroleum royalties and regional development in Brazil: the economic growth of recipient towns. Resources policy, 34, 205-213.

Power, T.M. (2002): *Digging to Development? – A Historical Look at Mining and Economic Development*, A report prepared for Oxfam America, September.
Ocampo, J. A. (2001). Structural dynamics and economic development. Santiago: United Nations Economic Comission for Latin America and the Caribbean, CEPAL/ECLAC. Mimeo.
Sachs, J. D.; Warner, A. M. (1999). The big push, natural resource booms and growth. Journal of Development Economics, 59, 43-76.

Sachs, J.; Warner, A. (2001). Natural resources and economic development: the curse of natural resources. European Economic Review, 45, 827-838.

Scott-Kemmis, D. (2004): Innovation Systems in Australia, ISRN 6th Annual Conference Working Paper, 13-14 May, Morris J. Wosk Centre for Dialogue – Simon Frase University, Vancouver, Canada.

Scott-Kemmis, D. (2013). How about METS? Levaring Australia´s mining equipment, technology and services sector. Mineral Council of Australia.

Segal, N. (2000): *The South African mining industry in the 21st century*, Chamber of Mines of South Africa. Available at: http://www.bullion.org.za/Level3/Publications/ Segal.pdf.

Stilwel, L.C. et al. An input-output analysis of the impact of mining on the South African economy. In: Resources Policy, 26. Amsterdam: Elsevier, 2000.

Urzúa, O. (2013). The emergence and development of knowledge intensive mining service suppliers in the late 20th century. PhD thesis, Science and Technology Policy Research (SPRU), University of Sussex, Brighton, England.

von Tunzelmann, N.; Acha, V. (2005). Innovation in Low-Tech Industries. In: J.Fagerberg, D. Mowery & R.R. Nelson (Eds.). The Oxford Handbook of Innovation (pp. 407-432). New York: Oxford University Press.

Walker, M. & Jourdan, P. (2003). Resource-based sustainable development: an alternative approach to industrialisation in South Africa. In: Minerals & Energy – Raw Materials Report, 18. new York: Taylor & Francis.

Walker, M. & Minnitt, R.C.A. (2006). Understanding the dynamics and competitiveness of the South African minerals inputs cluster. Resources Policy, 31. Amsterdam: Elsevier.

Wright, G. (2001). Resource-based growth then and now. Stanford University. Available at: <www-siepr.stanford.edu/conferences/HSTeachers_2001/resource-based-growth.pdf>.

Wright, G.; Czelusta, J. (2002). Exorcizing the Resource Curse: Minerals as a Knowledge Industry, Past and Present, Stanford University. Available at: http://www-siepr.stanford.edu/workp/swp02008.pdf.

Yin, R.K. (2001). Estudo de caso: planejamento e métodos. 2. ed. Porto Alegre: Bookman.

Fonte: McKinsey Global Institute, "Urban world: cities and the use of the consuming class" , 2012. Available at: http://www.mckinsey.com/insights/urbanization/urban_world_cities_and_the_rise_of_the_consuming_class