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Challenges for technological capacity building in latecomer firms: a study empirical in manufacturing firms in Brazil

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Abstract: This article aims to assess the technological capability of manufacturing companies in latecomer firms through analysis of the main technological functions presented in the literature. In addition to analysing the activities of the functions that make up the technological capability, highlighting the intensity in each of them, we seek to differentiate the firms in terms of technological competence levels acquired via calculation of a Technological Capability Index (TCI). To achieve these objectives, we conducted a study with 44 capital goods firms, located in south-eastern Brazil. The results show large variations between national and multinational firms, and between smaller and larger firms. These differences are highlighted in the assessments of capability functions and technological capability rates calculated.

Keywords: technological capability, manufacturing firms, technological capability index, latecomer firms.

Introduction

Recent decades have witnessed an intensification of the importance of technological innovation for the competitiveness of companies and economic progress of countries. Competitiveness in a global marketplace is increasingly dependent on creative and innovative technological capability. Technological capability is the foundation that allows companies to conduct their innovation activities and determine their degree of competitiveness in active markets.

Technological change is understood as a dynamic process and a cumulative nature. These characteristics have guided the study, especially in the evolutionary approach, of the understanding of regularities in sectoral determinants of innovation. According to Malerba (2006), innovation differs across sectors and firms in terms of different knowledge, skills, different learning process levels and organization of innovative activities, leading to configuration of different levels of technological capability. In this sense, it is important to emphasize, according to Figueiredo (2001), that the mastery of new technologies requires skills, efforts and investments, and may vary according to the company, as the skills considered, as well as the techniques, are developed differently in each company.

Technological capability accumulation, in turn, comprises aspects that are internal and external to the company (Khayyat e Lee, 2015; Sobanke et al., 2014; Berry et al., 2010). From an external standpoint, in addition to the market and technology, fluctuations in economic growth have a strong influence and interrupts the learning cycle, thereby contributing to the breakdown of the evolutionary and cumulative sequence of the technological capability accumulation process (Handoko et al., 2014). As for the internal elements, it is crucial for the survival and competitiveness in a globalized market that companies engage in continuous learning processes for building and accumulation of technological capability, institutional building, and political measures. In other words, according to the evolutionary theory of technical change, companies are assigned a key role when it comes to technological efforts performed to master new technologies, adapt them to local conditions, and improve them.

The several approaches considered for categorization of several types and levels of technological capacity have handled and explored matters in macro and micro levels. The review context has mainly looked for categorizing and distinguishing the technological capacities considering the industry as study subject. This paper focuses on the technological capacities under a micro level sight (technological capacities that use, handle, create and change technology), highlighting their differences regarding technological functions. The technological functions are the ones linked to the process technology and product technology, different kinds of engineering, or the management of technological linkages with other companies and organizations; and can be gathered concerning investment capacity, production capacities and capacities of external partnerships.

Therefore, in light of the evolutionary approach, this article's main goal is to assess the technological capability through an analysis of the main technological functions presented in the literature. In addition to analyzing the activities of the functions that make up technological capability, highlighting intensity in each of them, we seek to differentiate firms in terms of technological competence levels acquired by calculating a Technological Capability Index (TCI). The TCI is a useful tool to quantify differences in technological capability among firms and capture evidence of internal efforts of firms and limitations for technological capability accumulation.

After this introduction, Section 2 presents a theory of technological capability accumulation, highlighting main empirical studies in developing countries and the indicators for measuring technological capability. Section 3 presents the performance of the Brazilian capital goods sector. Section 4 shows the method used to analyze the technological capacity. Section 5 present the study results and the last section brings conclusions and recommendations for policies and future researches..

Literature review

Technological capability accumulation in developing countries

Since the 1970s, the literature on technology and development has emphasized the acquisition of technological capability in developing countries as a crucial determinant of successful industrialization (Romijn, 1997). Several detailed studies on the accumulation of technological capabilities at the company level in emerging countries in Asia (Bell et al., 1982; Lall, 1987) and Latin America (Katz, 1987) have revealed significant technological capabilities, which allowed companies undertake several innovative activities in different sectors. Technologies in use in these countries were not limited to those generated in advanced economies. As emphasized in Bell and Figueiredo (2012), companies in emerging countries may evolve from the simple use or imitation of technologies based on their limited innovation capabilities to deeper levels of technological involvement.

Simply, as showed by Yam et. (2011), the technological innovation capacity can be defined as a group of characteristics that ease and support the companies' technological innovation strategies. In a more comprehensive definition, technological capability, according to Bell and Pavitt (1993, 1995), consists of the necessary resources to generate and manage technical change and includes, in particular, skills, knowledge, experience, and an institutional structure. This assumption is supported by the evolutionary theory of technical change (Nelson and Winter, 1982), in which companies are assigned a key role with regard to technological efforts implemented to master new technologies, adapt them to local conditions, and improve them. Such features, according to Figueiredo (2004; 2014), are stored and retained in at least three components, namely:

- Human capital: refers to tacit knowledge, knowledge bases, experiences and skills/talents of specialized professionals, engineers and operators, which are acquired over time without neglecting their formal qualification;
- Organizational system: refers to the accumulated knowledge in organizational and managerial routines of businesses, procedures, instructions, documentation, and implementation of management techniques;
- Technical and physical systems: refer to the machinery and equipment, information technology-based systems, hardware, laboratories, equipment, software in general, and manufacturing plants.

As emphasized by Lall (1992) and outlined above, the focus of technological capability at the company level lies in the equipment, skills, attitudes and abilities and knowledge required to choose, install, operate, maintain, understand, adapt, improve and develop technology.

Nevertheless, it is also important to note that, for developing countries, the development of skills, experience and efforts that allow a country's companies to acquire, use and adapt, refine and create technologies efficiently is not a simple task. Machinery is equally available to all countries; however, the unincorporated components of technology may not be purchased or transferred as physical products. Technological knowledge is difficult to locate, and its transfer cannot be incorporated into the equipment, instructions, patents, designs, or layouts. Corporate knowledge can only be used in the best possible way if they are complemented by a number of tacit elements that need to be developed locally. In other words, there is a need to develop a local learning.

The various approaches used to classify several technological capability types and levels have addressed and exploited macro- and micro-level issues (Archibugi and Coco, 2005). At the macro level, several studies emerge, especially Ayyagari et al. (2012); Egbetokun et al. (2012); Barry et al. (2012); Khayyat e Lee (2015). The approaches at the micro level, in turn, focus on the technological capabilities at the level of companies that use, operate, create and modify the technology.

According to Sobanke et. al (2012; 2014), the focus of the technological capacity in micro level has to do with skills, equipments, knowledge, attitudes and competences, needed for technologies' selection, installation, operation, maintenance, adaptation, improvement and development. The technological capacity, in corporative level, eases the innovation, which leads to the productivity increase. As a result, in order to increase the competitiveness of a country, it`s needed to focus on the processes of technological capacity accumulation.

It is worth noting that the analysis of context predominantly emphasizes the industry as an object of study, seeking to classify and differentiate capabilities. A summary of the main empirical studies and their contributions on technological capability in developing countries is presented in the Table 1.

Table 1 - Main empirical studies on technological capability in developing countries

Empirical studies	Contributions
Hayami and Ruttan (1971)	Defined differences in capability levels and international technology transfer (ITT). Defined three phases of ITT: material transfer; project transfer; and capability transfer. Assumed a progress trajectory based on the use of imported technologies, enabling adaptations and improvement.
Katz (1987)	Studies have revealed that a number of companies went beyond the simple operation of the acquired technology, with progress in various adaptations and improvements. Highlighted (a) the importance of various key technological functions in companies; with (b) ideas on the sequences in which companies build up capabilities in these functional areas.

	Identified three main functions: (a) product design and specifications; (b) process engineering; and (c) industrial engineering/production planning.
Dahlman and Westphal (1982)	Defined a broader concept of capability that goes beyond use and production: innovation capability.
Dahlman, Ross-Larsen and Westphal (1987)	Built on the idea of different capability levels for different stages in the lifecycle of industrial projects.
Amsden (2001)	Made use of a structure similar to Dahlman and Westphal, focusing on different stages in the life cycle of industrial projects. Developed a capability building series ranging from production capability, through project execution capability (investment capability), to innovation capability.
Lall (1987; 1992)	Distinguished more clearly capability functions and levels. Classified technological capabilities into: (i) investment capability; (ii) production capability; (iii) capability to develop external links. Emphasizes the importance of distinguishing the capabilities of technological functions, such as process engineering, product engineering, and project execution. Developed a set of differences in the capabilities of each type of function.
Bell and Pavitt (1995)	Regarding Lall's work, considered important a greater distinction between the capability to imitate/use/operate the technology and the ability to change/create it. Maintained the distinction between investment and production phases in the project cycle and introduced the basic production capability.
Ariffin (2000), Dutrenit (2000), Figueiredo (2001)	Developed features based on the accumulated contributions of Lall and Bell-Pavitt: (i) distinction between the different capability dimensions, particularly across functions and levels; (Ii) greater differentiation between the levels of change/creation and technological innovation; and (iii) differentiation between the levels of (a) imitation/use/operation of the technology and (b) technology change/creation/innovation. Dutrenit focused on the learning process by highlighting individual knowledge conversion efforts at the organizational level. Figueiredo highlighted the influence of mezzo- and micro-level factors for understanding learning strategies underlying the companies' technological capability.
Bell (2007)	Simplified distinction between two kinds of capability: production and innovation Production capability: use and operation of process technologies in existing organizational settings; Innovation capability: creating new product and process technology configurations and implementing changes and improvements for existing technologies. Components that make up the capability: physical capital; knowledge capital; human capital; organizational capital, the latter includes not only the organizational structures and internal procedures of the companies, but also external links and relationships it may have with other companies and related organizations.

Table 1 shows that the different approaches presented, according to Bell (2007), aim to differentiate one or more than three capability dimensions as follows:

- Among different capability levels, reflecting an increase of degrees of creative engagement with the technology. Differentiation along this dimension is supported by the idea of some form of progress evolving from the execution capability to the ability to perform varying degrees of innovation;
- Among different technological functions, such as those related to process technology and product technology, with different types of engineering, or management of technological links with other companies and organizations;
- Among different phases of the project lifecycle in production activities (usually industrial). Here, the distinction is common among cycle investment and production stages; however, sometimes, more subtle differences are introduced within these phases (especially between the different steps in the investment phase).

It should be noted that, in a few studies, only one of them is a subject; others contain two, often presented in some form of two-dimensional tabulation. In some cases, however, two different dimensions are combined together in a single one-dimensional list. Similarly, two-dimensional tabulations sometimes implicitly combine all these three dimensions.

Another key aspect of the approaches presented is the emphasis given to certain characteristics that are relevant to success in the technological capability accumulation process. According to Wignaraja (2002), four characteristics are crucial to building the technological capability, at the company level, in developing countries:

1. Uncertainty in the technological capability acquisition process. According to Lall (1992), investments in resources such as finance have considerable risk and the outcome is uncertain. In research activities, the technical and financial difficulties are inherent in the process;
2. Capability development is an incremental and cumulative process. According to Bell and Pavitt (1993), the development of capabilities aimed at addressing new technologies occurs incrementally, based on past investments and moving from simple activities to ones of greater complexity. One cannot make leaps in areas that are completely new in terms of competence;
3. Capability development involves cooperation among players. According to Bell (2007), initial approaches on the technological capability essentially focused on the companies' internal resources. Currently, there is a recognition that resources go beyond the internal focus of companies, encompassing knowledge focused on interactions between companies and between companies and other organizations. As per Lall et al. (1994) and Mytelka (2000), companies rarely acquire skills alone. When they absorb imported technology, they interact and exchange technical inputs with other companies (competitors and suppliers) and support institutions (research and educational institutions), thereby characterizing the collective learning – a key feature for the development of technological capabilities;
4. Capability development is affected by the policies of countries and institutional factors. According to Katz (1987) and Westphal (2001), learning at the company level can be stimulated mainly by the industrial policy, macroeconomic regime, and institutions that provide financial support, training, information, and technology support.

In addition to qualitative case studies, other quantitative studies on technological capability stand out. Costa and Robles Reis de Queiroz (2002) presented a quantitative method to calculate technological capability indicators focusing on the role of multinational companies in technology learning. Wignaraja (2002; 2008) created technological capability scores, converting them into indexes with the goal of identifying the companies' efforts to acquire, adapt and improve technology in a uniform, aggregated basis.

Studies on technological capability in developing countries, whether qualitative or quantitative, provide valuable information on the nature of technology activities, different learning mechanisms, and factors affecting capability development at the company level.

Nevertheless, it should be noted that one of the main challenges facing the work on technological capability is to measure the differences among companies in capabilities. A few studies seek to evaluate technological capabilities, bringing together objective and subjective information at the company level, to pursue a statistical analysis of its determinants. Some of the aspects of indicators used to measure inter-company technological capability differences are presented in the section below.

Indicators for measuring technological capability

One of the most elaborate taxonomies of technological capability, at the micro level, is the one developed by Lall (1992). According to Molina-Domene and Pietrobelli (2012), Lall's technological capability taxonomy has been successfully used in a case study to assess the

levels of technological development at the company level in developing countries (Lall, 1987; Lall et al, 1994; Romijn, 1997).
At the company level, the Lall's taxonomy (1992) captures a number of aspects of technological capability, encompassing the three main types.

Investment capability
This comprises the skills, knowledge and organization required to identify, develop and obtain technology to design, build and equip an expansion or a new facility (Lall, 1992; Pierre et al., 1992). They include the project's capital costs, chosen technology, equipment, product mix and operational knowledge of the technology involved. It should be noted that the economic and technical feasibility of the new project should be reviewed to determine the best combination of options for the project. Investment capability is crucial to ensure a successful commercial operation. According to Lall (1992), if a company is not able to make independent decisions on its investment plans or equipment selection processes alone, achieve minimum levels of operational efficiency, quality control, equipment maintenance or improvement costs, adapt its product designs to changing market conditions, or establish effective links with reputable suppliers, it is unlikely to be able to effectively compete in open markets.
Production capabilities
Production capabilities refer to the necessary skills and knowledge for the operation of production facilities. They range from basic technology skills such as quality and inventory control, operation and maintenance, to the more advanced, such as improvements or adjustments for research, design, and innovation (Egbetokun, 2009). In other terms, refer to the process engineering, product engineering and industrial engineering (Lall, 1992; Biggs e Srivastava, 1995).
This involves the mastery of technology and, among others, lesser or greater innovation. They cover both the process and product technologies, as well as the monitoring and control functions included in industrial engineering. The skills involved not only determine how technologies are explored and improved but also how the internal forces are used to absorb technologies purchased or imitated from other companies.
External link capabilities
The external links capabilities refer to the necessary skills for the transfer of information, skills and technology to receive knowledge from components or raw material suppliers, service companies, consultants, and technology institutes. It focuses on heterogeneous that develop marketing or non-marketing interactions for the generation, adoption and use of new (or already established) specific technologies and for the creation, production and use of new products relevant to the sector. It involves the analysis customers, suppliers, manufacturers, universities, financial institutions, government agencies, and others (Lall, 1992; Olamade, 2001). These links affect not only the company's production efficiency (allowing it to specializes more fully), but also the diffusion of technology. The importance of extra-market links for the promotion of increased productivity is recognized in the developed world literature.
Performance of the Brazilian capital goods sector
According to Nassif and Ferreira (2010), the capital goods sector represents roughly 15% of the value added by the Brazilian manufacturing industry, with several segments ready to compete internationally and others with high potential for future demand, induced, in turn, by major projected investments. In this sense, there are expressive possibilities of achieving technological mastery in segments in which Brazil does not yet have a comparative advantage, and significantly increasing the industry's participation in the global market, through either exports or direct foreign investment.

The capital goods sector was introduced in Brazil in the 1950s and was consolidated in the second half of the 1970s, with a strong presence of transnational companies, which occupied an important place in the industry matrix, as highlighted by Resende (1994).
The capital goods industry in Brazil has followed an irregular growth trajectory, characterized by continual crises and recoveries. The 1950s and 1970s were key periods for the building and development of the capital goods industry in Brazil, marked by import replacement policies, greater investment in the industry, high growth rates, and certain technological maturity. There was expansion of the production capability and participation of local production in total supply. Although this was a period considered favorable to the capital goods industry, one should note different phases of contraction and expansion of the sector.
In the 1980s, the capital goods industry underwent a phase of instability that followed the behavior of the Brazilian economy. Economic instability reduced public investment and the process of industrialization through import replacement came to an end, as it was no longer seen as a source of growth for industrial production.
The 1990s were characterized by macroeconomic instability and trade liberalization in Brazil. There is a contraction in the domestic market, which combined with the overvaluation of the Brazilian currency, favored the expansion of the import coefficient, with replacement of domestic by foreign machines. There is an expansion of foreign products and components in the domestic market and participation of transnational companies leading the production of the various segments of the capital goods industry in Brazil.
In the 2000s, the performance of the capital goods industry is again associated with the economic investment cycle. The beginning of the decade marked a new recovery, driven by economic growth, followed by another contraction at the end of the decade, due to the international financial crisis. In general, there is a substantial growth of physical production, with minor fluctuations, interrupted in 2009 by the international crisis.
Throughout the 2000s, there was a broad shift in the origin of imports, with a strong and growing presence of China. The increase in imports, particularly from China, does not stem from a lack of physical capability, but rather from low the competitiveness of Brazilian companies, presented essentially the standard of competition via price.
The capital goods sector in Brazil has a good production capability, but presents a technological delay. On the other hand, the sector has a diversified and consolidated structure. Although it has limitations in terms of competitiveness, there is an accumulated experience in the sector and a large domestic market to enable economies of scale. Thus, we should note the importance of investing and encouraging the sector. Such actions are justified, as highlighted by Nassif and Ferreira (2010), since the Brazilian sector presents a huge potential for increased demand, and maintains, as already stressed, a high potential for generation and dissemination of innovation, being able to assist the productivity growth rate in the economy as a whole.

Methodological procedures

Measures

In order to evaluate the companies' technological capacity, this study has focused on their technological functions, described in the bibliography. Mainly it has been focused on the technical tasks dedicated to the production capacity and the capacity of external partnerships; the information about the investment capacity was not available and thus was not evaluated.
For the other goals of this study, we used a Technological Capability Index (TCI) based on Lall's taxonomy variants (1992). This index has been widely adopted to operationalize the technological capabilities at the company level (Westphal et al., 1990; Romijn, 1997; Wignaraja, 1998, 2002, 2008). The variables measured were grouped into process

engineering, product engineering, quality engineering, and external link development. We used categorical variables were used 0 (none), 1 (ad-hoc) and (systematic), capturing different competence levels (low, medium, and high), as shown in Appendix A.
Each company was assigned a score based on its competence level. The maximum score is 38 points for the capability, considering a total of 19 variables, and may be obtained by adding the maximum value of the degree of competence displayed in each function. The results were then normalized between 0 and 1 to provide the TCI.

Sample profile

The technological capability analysis of this study included a sample of 44 firms in the capital goods sector operating in Brazil, with 28 domestic companies and 16 multinationals, with at least 50 employees. Of this total, 90% have been in the market for over 20 years, and 40% have had a presence for over 50 years.
The main activities undertaken by surveyed companies include the manufacture of machinery and equipment. The destination of manufactured products covers a number of sectors and segments of the economy, such as pulp and paper, mining, oil and gas, food, and steel.
Sales are concentrated in the domestic market, with a total of 79.5% of companies selling more than 80% of their products in the country. Exports do not occur in 31.8% of companies and only 16% export 21-50% of their production. The volume of sales to the foreign market is considered very low, where approximately 84% of the companies export up to 20% of their production volume, and of this total, 56% do not exceed 5%.

The date

This study used various sources of evidence. Interviews and documents review were performed. We conducted personal interviews with directors, managers, and technicians of the respective areas of interest. The data collected were submitted to a reliability test (Cronbach's alpha), with results ranging between 0.679 and 0.795 (see Appendix B). According to Field (2013), the values are considered acceptable, as they are above 0.60. The documents review comprised reports and data stored in data basis.
As data collection tool, a two sections questionnaire was applied. The first section aimed to identify general aspects of the companies, distinguishing activity markets and main aspects of competitiveness. The second section comprised issues concerning the technological functions performed by the companies..

Results and discussion

Production capability

Depending on the goals of this work, the production capability was split into: (i) process engineering, (ii) product engineering; and (iii) engineering quality. These three different combined activities promote, more efficiently and effectively, operations, adaptation, improvement, quality, workflow and production planning, and monitoring.

Process engineering

Its goal is to analyse the performance of the companies' competences or production skills. It aims to differentiate process engineering and refers to the companies' production and innovation technological capabilities, i.e., the companies' capability to use/operate existing technology and production systems, as well as the ability to generate new technological solutions. Technological innovation capability involves the technological capability.
The process function analysis includes the acquisition of new equipment and certifications obtained for improvement of processes, such as ISO 9000; ISO 14000; ISO 18000, and others. The equipment purchase function was selected to refer to the incorporation of new technologies into physical equipment. The equipment constitutes a dimension directly related to process and product engineering. It is the company's physical capital. From the improvement of production methods to process and product innovations, the equipment plays

a key role, as it supports the implementation of such changes. Equipment upgrade has a direct positive effect in product quality, productivity, production flexibility, and an adequate supply of goods and services. The analysis considered new equipment with a high degree of international upgrade, purchased in the last five years. The quality certification implies carrying out processes according to formal quality control systems. In addition, we assess the levels of internal training and production and process techniques, activity and process standardization level, and degree of production monitoring.

In general, companies present average competence levels in this function. It is important to highlight the considerable difference between domestic and multinational companies. The absence of practices in various process engineering functions is mainly observed in domestic companies. Multinationals are noted for continuously developing activities that strengthen skills for use/operation of new technology and existing production systems. These skills generate higher production capabilities, which comprise a crucial requirement for the development of innovation capabilities.

Table 2 - Production capability: functions related process engineering

Process engineering		None	Ad-hoc	Systematic
Acquisition of new equipment	Total	8 (18.2)	15 (34.1)	21 (47.7)
	Domestic	6 (75.0)	12 (80.0)	10 (47.6)
	Multinational	2 (25.0)	3 (20.0)	11 (52.4)
Certifications for production improvement	Total	17 (38.6)	17 (38.6)	10 (22.7)
	Domestic	16 (94.1)	9 (52.9)	3 (30.0)
	Multinational	1 (5.9)	8 (47.1)	7 (70.0)
Internal training of production/process techniques	Total	7 (15.9)	20 (45.5)	17 (38.6)
	Domestic	6 (85.7)	15 (75.0)	7 (41.2)
	Multinational	1 (14.3)	5 (25.0)	10 (58.8)
Activity and process standardization	Total	1 (2.3)	14 (31.8)	29 (65.9)
	Domestic	1 (100.0)	14 (100.0)	13 (44.8)
	Multinational	0 (0.0)	0 (0.0)	16 (55.2)
Productivity monitoring	Total	10 (22.7)	18 (40.9)	16 (36.4)
	Domestic	8 (80.0)	12 (66.7)	8 (50.0)
	Multinational	2 (20.0)	6 (33.3)	8 (50.0)

Table 2 shows that only 18.2% of the sample companies did not acquire new equipment for their production process. The vast majority invested in the acquisition of at least one new piece of equipment in the previous five years. Nevertheless, it is important to highlight the main objectives relating to the purchase of new equipment. For about two thirds of the sample (67%), the purchase of new equipment aimed at reducing operating costs and for 56%, increasing production scale. For only 4% of the respondents, the goal of the acquisition was the simple replacement due to usage time. By analyzing the origin of companies, we notice that 75% of that companies that did not upgrade their production system equipment are domestic companies. Multinational companies, as shown in Table 2, upgrade their equipment with greater intensity.

We should note the technological efforts of companies that have invested in new machinery and equipment over the past 5 years. In most cases, the main motivation of these investments stemmed from the positive outlook of domestic economic growth, alongside a greater internal demand and consumption.

As for certifications for the production process improvement, 38% of the companies have no certificate. Of this total, 94.1% are domestic companies. With the exception of one, multinational companies have at least one certification – in this case, the ISO 9000 series, and 70% have other certifications, including ISO 14000, ISO 26000, and OHSAS 18000.

Activities related to the internal training of production techniques and productivity monitoring have similar characteristics. In general, companies develop practices to improve production. It is worth noting again that, regarding nonexistent practice, over 80% of the cases also occur in domestic companies. The best performance seen in the process engineering function is the standardization of activities. Both domestic and multinational companies have routine practices in this activity. Over 65% of the companies have systematic processes aimed at the standardization of their activities.

Product engineering

Product engineering aims to identify and differentiate the companies' technological efforts for technological capability accumulation. Technological efforts determine whether the activities are aimed at improving the technological content, for the development or improvement of new products and processes. We analyze the continuous entrepreneurial effort in terms of expenditure for research and development activities, as well as the degree of innovation assigned to the product from these activities.

The analysis of this function comprises the frequency of the companies' product development activities and reverse engineering activities. The intensity of investment in technology is also assessed, as well as the intensity of new product introduction in the domestic market.

Table 3 shows that approximately one quarter of the companies have low levels of technological efforts aimed at the development and improvement of new products and processes. In general, a low percentage of companies continuously develops practices aimed at product development (27.3%), which, in a way, justifies the lack of investment in technology at the same rate. According to Kim (2005), R&D activities are crucial, as they allow businesses to stay alert to the meaning of new external signs exploring the information available more efficiently.

Table 3 - Production capability: activities related to the product engineering function

Product engineering		None	Ad-hoc	Systematic
Product development activities	Total	7 (15.9)	25 (56.8)	12 (27.3)
	Domestic	4 (57.1)	19 (76.0)	5 (41.7)
	Multinational	3 (42.9)	6 (24.0)	7 (58.3)
Reverse engineering execution	Total	14 (31.8)	19 (43.2)	11 (25.0)
	Domestic	8 (57.1)	12 (63.2)	8 (72.7)
	Multinational	6 (42.9)	7 (36.8)	3 (27.3)
Investment in technology	Total	10 (22.7)	23 (52.3)	11 (25.0)
	Domestic	7 (70.0)	17 (73.9)	4 (36.4)
	Multinational	3 (30.0)	6 (26.1)	7 (63.6)
Development of new products in the domestic market	Total	9 (20.5)	22 (50.0)	13 (29.5)
	Domestic	6 (66.7)	13 (59.1)	9 (69.2)
	Multinational	3 (33.3)	9 (40.9)	4 (30.8)

Note: results in brackets refer to percentages

The same low rate is repeated in all other activities of the product engineering function. Although the competence results are not good, there is a greater effort among domestic companies to improve the technological content of its products, reflected in the ad-hoc standards.

A key thing to note is that, as regards products developed and released in the Brazilian market, domestic enterprises have superior results. Approximately 70% of the domestic companies continually introduce some kind of incremental innovation developed internally. New product launches from the multinationals, also including incremental innovations, are usually developed by headquarters. The subsidiaries operating in Brazil are responsible for little introduction of innovations developed internally; most of the times, only adaptations are made for the local market, not constituting a degree of innovation in the product. Superior reverse engineering practices reflect this greater effort.

Quality engineering

The quality engineering function analyzes companies' engagement in activities aimed at the area of quality. It aims to differentiate companies in terms of the intensity and practices adopted for quality management. To measure this function, we chose implementation and intensity in training in quality systems; absence, presence and degree of intensity of treating abnormalities; conducting quality audits; establishment of Quality Control Circle (QCC) groups; and finally insertion of improvement suggestion systems.

Table 4 - Production capability: activities related to the quality engineering function

Quality engineering		None	Ad-hoc	Systematic
Quality system training	Total	10 (22.7)	17 (38.6)	17 (38.6)
	Domestic	8 (80.0)	13 (76.5)	7 (41.2)
	Multinational	2 (20.0)	4 (23.5)	10 (58.8)
Anomaly treatment	Total	9 (20.5)	17 (38.6)	18 (40.9)
	Domestic	7 (77.8)	12 (70.6)	9 (50.0)
	Multinational	2 (22.2)	5 (29.4)	9 (50.0)
Internal process and product auditing	Total	12 (27.3)	9 (20.5)	23 (52.3)
	Domestic	12 (100.0)	4 (44.4)	12 (52.2)
	Multinational	0 (0.0)	5 (55.6)	11 (47.8)
QCC group formation	Total	18 (40.9)	15 (34.1)	11 (25.0)
	Domestic	14 (77.8)	10 (66.7)	4 (36.4)
	Multinational	4 (22.2)	5 (33.3)	7 (63.6)
Improvement suggestion system	Total	6 (13.6)	27 (61.4)	11 (25.0)
	Domestic	4 (66.7)	17 (63.0)	7 (63.6)
	Multinational	2 (33.3)	10 (37.0)	4 (36.4)

Note: results in brackets refer to percentages

According to Table 4, companies have an average performance in relation to activities related to the engineering quality function. In other words, there is a key engagement of companies in activities related to the area of quality. Some points, however, are worth mentioning. Anomaly treatment and internal process and product auditing are those with the best competence results. We should note that, in these activities, the performance of domestic and multinational companies is similar. As for quality system training (61.4%), QCC group formation (75%) and improvement suggestion systems (75%), companies have low competence, with no or possible practices. Nevertheless, in these activities, differences between domestic and multinational companies are representative. Domestic companies account for over 75% of cases where there is the absence of such practices. The absence of practices that strengthen these activities entails major consequences for the process of accumulation of technological competences. QCC group formation, quality system training and suggestion improvement systems are directly related to the process of socialization of knowledge, i.e., these activities allow individuals to share tacit knowledge, enabling the development of increasing skills in the production and process of product development.

External link capabilities

For the purposes of this study, we chose to analyse the companies' external relations, with an emphasis on joint actions for the product development process. Relations with universities were also considered in order to identify the acquisition of external scientific knowledge. Work with customers aim at the operation and development of new concepts. Cooperation with educational institutes and development of external contact networks complete the group of activities analysed.

Table 5 - Production capability: activities related to the external link function

Link development		None	Ad-hoc	Systematic
Joint PDP actions	Total	10 (22.7)	20 (45.5)	14 (31.8)
	Domestic	7 (70.0)	12 (60.0)	9 (64.3)
	Multinational	3 (30.0)	8 (40.0)	5 (35.7)
Relations with Universities	Total	18 (40.9)	24 (54.5)	2 (4.5)
	Domestic	15 (83.3)	12 (50.0)	1 (50.0)
	Multinational	3 (16.7)	12 (50.0)	1 (50.0)
Relations with customers in the exploration and development of new concepts	Total	6 (13.6)	17(38.6)	21 (47.7)
	Domestic	4 (66.7)	13 (76.5)	11 (52.4)
	Multinational	2 (33.3)	4 (23.5)	10 (47.6)
Development of external contact networks	Total	9 (20.5)	23 (52.3)	12 (27.3)
	Domestic	7 (77.8)	14 (60.9)	7 (58.3)
	Multinational	2 (22.2)	9 (39.1)	5 (41.7)
Cooperation with regional educational institutes	Total	11 (25.0)	20 (45.5)	13 (29.5)
	Domestic	9 (81.8)	13 (65.0)	6 (46.2)
	Multinational	2 (18.2)	7 (35.0)	7 (53.8)

Note: results in brackets refer to percentages

The interaction with the various players represents one of the most important learning and innovation efforts for companies' development and competitiveness. Table 5, however, shows a weak link development capability between companies and other stakeholders, occurring most often sporadically (ad-hoc basis), with the exception of the relationship with customers in the exploration and development of new concepts, where about half of the companies (47.7%) showed a high level of relationship. Only 13.6% of the companies do not have any kind of relationship with customers for this purpose. The systematic relationship with universities is virtually nonexistent. Nevertheless, we should highlight that there is an effort to approach and intensify links, reflected in the considerable participation of the companies (54.5%) in the ad-hoc category. Companies, in particular domestic ones, have an interest in exploring the university as a source of information and knowledge, but have difficulty in accessing and converging of interests. Regarding transnational companies, the university in many cases cannot meet its needs. There are also reports of differences over intellectual property.

The same pattern is observed in the development of external contact networks, with 52.3% of the companies developing medium links. As for cooperation with regional educational institutes, we also note a considerable effort in national companies, accounting for about 65% ad-hoc.

In summary, the low intensity of links between companies and the various types of stakeholders shows us that, in general, the development of new products essentially takes place at the company level, with few partnerships. According to Kim (2005), the absence of joint projects with the various types of stakeholders prevents companies from achieving new sources of scientific and technical information, which are crucial, as they can significantly increase the technological capability of the company. In the competition for product innovation, as highlighted by Ferraz et al. (1997), relations with the scientific and technological infrastructure are a vital resource for the company's competitiveness.

The relationship of interaction and cooperation with other stakeholders are still too weak, either by a discreet understanding of innovation as a phenomenon that is systemic, interactive and with multiple sources, or by lack of entrepreneurial culture or legal barriers. Regardless, the low rate of links displayed may represent a barrier to increased technological capability.

Technological Capability Index (TCI)

The Technological Capability Index (TCI) calculated for each company was assessed based on qualitative information obtained from interviews, at the company level, focusing on production and external link development capabilities. Information on investment capability were not available and were not considered in the analysis. Activities related to the production and external link function are presented in Appendix A. The activities of each function selected for this study differ a little from that of other studies, such as the Wignaraja (2002) and Sobanke et al. (2012). Because it is a cross-sectional analysis, we considered the most suitable variables chosen to transcribe the moment and compose the TCI.

Table 6 shows the distribution of Technological Capability Index score frequencies for the 44 companies investigated. Considering the TCI of the companies, we can see that 15.9% have low scores, between 0.00 and 0.30; 38.6% had scores between 0.31 and 0.60; and 45.5% had scores between 0.61 and 1.00. By dividing the TCI scores into two groups, we have approximately half of all companies (55.5%) with scores between 0.00 and 0.60, and the other approximate half (45.5) between 0.60 and 1 00.

Table 6 – Technological Capability Index versus company type (Domestic/Multinational)

TCI class	TCI total companies	Domestic	Multinational
0.00-0.10	4.5%	7.1%	6.3%
0.11-0.20	2.3%	3.6%	6.3%
0.21-0.30	9.1%	10.7%	6.3%
0.31-0.40	.8%	10.7%	6.3%
0.41-0.50	15.9%	17.9%	6.3%
0.51-0.60	15.9%	17.9%	6.3%
0.61-0.70	6.8%	7.1%	18.8%
0.71-0.80	15.9%	14.3%	6.3%
0.81-0.90	6.8%	3.6%	6.3%
0.91-1.00	15.9%	7.1%	31.3%
Overall Total	**100%**	**100%**	**100%**

Source: field survey-based own work

Nevertheless, when we look at the distribution of scores between domestic and multinational companies, the data show a significant variation in TCI scores. Regarding domestic companies, the highest concentration (67.9%) is located in TCI up to 0.60, while, in the case of multinational companies, the highest concentration is noted in TCI scores over 0.60. It should be noted that only 10.7% of domestic companies present TCI above 0.80. In contrast, in multinational companies, the concentration of companies is 37.6%. By analyzing the highest TCI (above 0.90), the variation between domestic and multinational companies is much higher. In this case, only 7.1% of domestic companies present TCI above 0.90, while, for multinational companies, the concentration reaches 31.3%.

The data reveal that, in general, the TCI reported is considered low for most of the investigated companies operating in the capital goods sector in Brazil. A technological capability index considered high (above 0.80), determining companies with relevant technology skills, concentrates only 22.7% of the total number of companies, i.e., less than a quarter of the sample. Taking into account domestic companies, the results are more worrying because only 6.8% of the total sample has TCI above 0.80.

Another important analysis to be highlighted is also a significant variation found in relation to the size of the companies, as shown in Table 7.

Table 7 – Technological Capability Index versus company size

TCI class	Firm size		
	Small	**Medium**	**Large**
0.00-0.10	11.1%	-	-
0.11-0.20	5.6%	-	-
0.21-0.30	22.2%	-	-
0.31-0.40	5.6%	11.8%	-
0.41-0.50	27.8%	11.8%	-
0.51-0.60	16.7%	17.6%	11.1%
0.61-0.70	-	23.5%	11.1%
0.71-0.80	5.6%	17.6%	11.1%
0.81-0.90	5.6%	0.0%	22.2%
0.91-1.00	-	17.6%	44.4%
Total	**100.0%**	**100.0%**	**100.0%**

Source: field survey-based own work

Table 7 shows that the TCI scores increase according to the size of the companies. Small companies present, for the most part (88.8%), low levels of technological competence, with TCI scores below 0.61, with approximately 40% with TCI scores between 0.00 and 0.30. Therefore, it could be argued that small companies still have limited technological skills and resources. The achieved capability levels are restricted to the production capability. With regard to medium-sized companies, scores are better but still considered low. Only 35.2% of the companies have a TCI above 0.70. Large companies are those with the highest TCI scores. No scores lower than 0.51 are reported for companies of this size, and for one third of them, TCI scores are considered average, ranging between 0.50 and 0.80. Another key point is the fact that the TCI exceeds 0.80 for two thirds of the companies (66.7%), denoting a technological capability that is compared with that of developed countries. It is important, however, to emphasize that the global technological capability of the companies in the sample is considered well below the average obtained in the international industry.

Conclusions and recommendations

This article aimed to evaluate the technological capability of capital goods companies in Brazil through an analysis of the main technological functions presented in the literature.

Even though its method limitations, it was possible qualify the companies' commitment in different activities that set the technological functions studied.

In addition to analysing the activities of the functions that make up the technological capability, highlighting the intensity in each of them, we sought to differentiate the companies in terms of technological competence levels acquired by calculating a technological capability index.

The results showed that, in general, companies have low to medium competence levels in the evaluated functions. We note that, for activities related to process engineering and product engineering functions, a large portion of the companies has developed practices to improve production; however, we still notice considerable absences in a considerable portion of the sample. With regard to activities related to the quality function, we note a major engagement of companies in the activities for this area; however, practices that seek the socialization of knowledge occur sporadically.

The development of external links has a worse evaluation. Interaction and cooperation relations with other stakeholders are still very weak, limiting the acquisition of external knowledge, tacit knowledge, considered essential for the creation and accumulation of technological competence.

The results of this study show different levels of technological capacity among local and multinational companies, and among small and large ones. These differences are highlighted in the evaluations of the capability functions and technological capability rates calculated. A significant portion of domestic companies has low levels of production capability, with few skills developed for use/operation existing technology and production systems. The same situation happens when the companies' size is evaluated. Large companies have higher technological capacity rates than the small companies' ones. In this way, it's important emphasizing how a greater intervention of support public policies for promotion and development is needed, especially for small and medium size companies.

Finally it`s important to highlight that these technological functions groups can be compared among themselves when the companies studied belong to the same segment. However this study is subjected to some limitations which can be study subject of further researches. A priori the present analysis didn't allow to evaluate whether a certain technological function is simple or complex for a company regarding its segment. For it, more detailed cases studies that take into account information in the complexity level of the technological functions seen are needed.

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Appendix A - Questions for technological capability measurement

PRODUCTION CAPABILITY
Functions related to process engineering
Acquisition of new equipment
Certifications for production improvement
Internal training of production/process techniques
Activity and process standardization
Productivity monitoring
Functions related to product engineering
Product development activities
Reverse engineering execution
Investment in technology
Introduction of new products in the domestic market
Functions related to quality engineering

Quality system training
Anomaly treatment
Internal auditing
QCC group formation
Improvement suggestion system
LINK CAPABILITY
Functions related to link development
i. Joint PDP actions
ii. Relations with Universities
iii. Relations with customers in the exploration and development of new concepts
iv. Development of external contact networks
v. Cooperation with regional educational institutes

Appendix B - Collected data reliability test: Cronbach's Alpha

	Cronbach's Alpha	Corrected Item-Total Correlation
PROCESS ENGINEERING		
Acquisition of new equipment	0.739	0.408
Certifications for production improvement		0.542
Internal training of production and process techniques		0.621
Activity and process standardization		0.566
Productivity monitoring		0.424
PRODUCT ENGINEERING		
Product development activities	0.749	0.722
Reverse engineering execution		0.428
Investment in technology		0.557
Introduction of new products in the domestic market		0.499
QUALITY ENGINEERING		
Quality system training	0.795	0.757
Anomaly treatment		0.675
Internal auditing		0.517
QCC group formation		0.651
Improvement suggestion system		0.299
LINK DEVELOPMENT		
Joint PDP actions	0.679	0.425
Relations with Universities		0.396
Relations with customers in the exploration and development of new concepts		0.455
Development of external contact networks		0.646
Cooperation with regional educational institutes		0.279