The Relationship between Technological Capability and Firm Performance in an Emerging Economy

This research aims to investigate the relationship between investments in technological capability and economic performance in Brazilian firms. Based on the theory of economic development and on the history of developed countries, it is assumed that this relationship is positive. Through key indicators, 133 Brazilian firms have been analyzed. Given the economic circumstances of an emerging economy, which the majority of businesses are primarily based on low and medium-low-technology industries; it is not possible to affirm the existence of a positive relation between technological capability and firm performance. There are other elements that allow firms to achieve such results. Firms of lower technological intensity industries performed above average in the economic performance indicators; adversely, they invested below average in technological capability. These findings do not diminish the merit of firms' and country's success. They in fact confirm a historical tradition of a country that concentrates its efforts on basic industries.

Key-words: technological capability, firm economic performance, emerging economy

A Relação entre Capacidade Tecnológica e o Desempenho da Firma em uma Economia Emergente

Esta pesquisa objetivou investigar a relação entre os investimentos realizados em capacidade tecnológica e o desempenho de firmas brasileiras. Baseando-se na teoria do desenvolvimento econômico e no histórico de países desenvolvidos, pressupõe-se que a relação é positiva. Por meio de indicadores, analisou-se 133 firmas brasileiras. Dado o cenário de um país de economia emergente, cuja base empresarial é formada por setores primordialmente de baixa e média-baixa intensidade tecnológica, não foi possível confirmar esta relação. Existem outros fatores que levam as empresas a atingirem desempenho positivo. Firmas dos setores de intensidade tecnológica mais baixa apresentaram resultados superiores à média da amostra nos indicadores de desempenho econômico; complementarmente, elas investiram abaixo da média em capacidade tecnológica. Estes resultados não tiram o mérito de sucesso nem das firmas nem do país. Na verdade, eles confirmam a tradição histórica de um país que concentra seus esforços em setores industriais básicos.

Palavras-chave: capacidade tecnológica, desempenho econômico da firma, economia emergente

La relación entre capacidad tecnológica y el desempeño de la firma en una economía emergente

Este trabajo tiene por objetivo investigar la relación entre las inversiones realizados en capacidad tecnológica y el desempeño de firmas brasileñas. Basado en la teoría de desarrollo económico y en el histórico de países desarrollados, es de suponer que la relación es positiva. Por medio de indicadores, se analizó 133 firmas brasileñas. Dado el escenario de un país de economía emergente, cuya base empresarial es formada por sectores primordialmente de baja y media-baja intensidad tecnológica, esta relación no fue confirmada. Existen otros factores que llevan a las empresas a alcanzar desempeño positivo. Firmas de los sectores de intensidad tecnológica más baja presentan resultados superiores a la media de la muestra en los indicadores de desempeño económico;

complementariamente, ellas invirtieron debajo de la media en capacidad tecnológica. Estos resultados no retiran el mérito de éxito ni de la firmas ni del país. En verdad, ellos confirman la tradición histórica de un país que concentra sus esfuerzos en sectores industriales básicos.

Palabras clave: capacidad tecnológica, desempeño económico de la firma, economía emergente.

1. Introduction

Joseph Schumpeter, in 1911, has already recognized the relationship between economic development and technical progress. These concepts underpin the economic development based on innovation. In this sense, as the society develops, the firms face increasingly complex challenges and, to respond to them, complex knowledge is required. It is from the relationship between knowledge and development, based on many studies in developed economies, that we assume the existence of a positive relationship between technological capability and economic performance. Those studies often understand the technological capability as a base for innovation. Therefore, if we consider that to profit, a firm needs a capability to innovate, the more the firms invest in their technological capability, the greater its performance will be.

The years have shown that this relationship is often positive in developed countries. However, between 2000 and 2010 Brazilian GDP grew more than 200%, even though its economy is based on low and medium-low-technology industries (as OECD, 2011 classification). Industries such as these tend to invest less in their technological capability. Nevertheless, companies like Petrobras (petroleum product), Vale (basic metals) and Ambev (beverages), besides being industry and national leaders, represented the biggest revenues among Brazilian industrial firms, between 2008 and 2010. This picture indicates that, besides investing in technological capability, there are other means for lower technological intensity firms achieve positive economic performance. Given this context, the aim of this paper is to answer the following question: *what is the relationship between technological capability and firm performance in Brazilian firms*?

In answering that we may contribute to the understanding of this relationship in an emerging economy scenario, where most industrial companies are traditionally operational.

This paper is organized in a way as to give a background of technological capability and firm performance, as well as the relationship between them; and to present the indicators used to measure both constructs. Following that, we present the method used in this research; and then, we analyze the data and discuss the results of the study and, finally, we make our final remarks on the research.

2. Technological capability and firm performance

In the 1900s there were many researches focused on the technological capability of the firm. By mid-decade, the studies were mostly theoretical (Lall, 1992; Panda; Ramanathan, 1996; Kim, 1999). After that, empirical studies started to test these previous theories. From this, both theoretical and empirical studies deepened the research on the subject. Then, they started to address the relationship between technological capability and the firms' success (Hall; Bagchi-Sem, 2002; Garcia-Muiña; Navas-López, 2007); to conduct sector studies (Archibugi; Pianta, 1996; Jin; Von Zedtwitz, 2008); and to seek to identify how firms have distinctive performance in the market (Figueiredo, 2009).

In general, authors use certain terms associate to technological capability, such as internalization of functions, learning process, knowledge needed to create change, accumulation of knowledge, machinery and equipment, investments in research and development, value creation, production process, and new products.

Emphasis to technological change has been given as a component for the technological capability (Lall, 1992; Bell; Pavitt, 1995). Skills, knowledge and experience are required to operate existing systems and to generate technical change from the technological capability. Lall (1992) sees the technological capability as a continuous process to create or absorb technological knowledge from the interaction with the environment and the accumulation of skills and knowledge acquired by the firm. Still in relation to change, Bell and Pavitt (1995) understand that efficiency is not only affected by the acquisition of imported technology, but the ability to create and manage the changes in the technologies used in the production. The acquisition or transfer of technology is an element of the technological capability often cited by researchers. Technological capability may be acquired through a process of learning - absorptive capacity (Kim, 1999), where the transference of technology from developed countries is essential to accrue technological knowledge. However, the simple fact of buying technology does not mean that the firm is acquiring technological capability (Madanmohan; Kumar; Kumar, 2004).

Firms need, in fact, to accumulate resources and competencies which allow them to have a more developed technological capability than their competitors. In that sense, the technological capability relates to the absorption and transformation of a technology as a way of reaching higher levels of technical-economic efficiency (Zawislak; Alves; Tello-Gamarra; Barbieux; Reichert, 2012; Trez; Steffanello; Reichert; De Rossi; Pufal, 2012).

Many authors link the technological capability to the knowledge of the firm (Panda; Ramanathan, 1996; Garcia-Muiña; Navas-López, 2007; Jin; Von Zedtwitz, 2008). For Pavitt (1998), firms develop their technological capability in an incremental way, and in doing that, they are limited to continue to do what they already know, which means there is a cognitive limit to what the firm is capable of doing. Jin e Von Zedtwitz (2008) however, say that firms from emerging countries, after they import technologies, go through a learning process which eventually enable them to develop their own technologies. So for them, the concept of technological capability embraces the generation of new knowledge.

In this study, we understand *technological capability as the firm's ability, based on its accrued knowledge, to perform a set of activities which results in new technological knowledge development*.

The aim of every firm is to achieve positive results. Hence, in order for a firm to keep operating in the market, it needs to differentiate itself from its competitors. The societies are constantly changing and requiring solutions for increasingly complex problems. Firms that follow or anticipate these changing trends are able to achieve positive economic performance.

What defines the firm's performance may vary and depends on what its goal is and the context in which it operates. For Taylor (1911), the emphasis was on the optimization of tasks' performance. The goal of the firms was to achieve greater labor productivity and therefore, maximum efficiency. From there, management structures which were able to plan and coordinate large-scale production and to apply scientific knowledge to industry have been developed. With the rise of information technology and the consequent globalization of markets, companies seek competitiveness through technological and organizational innovations (Tigre, 1998). Thus, evolutionary theories of the firm (Nelson; Winter, 1982) got stronger and therefore, technological changes have become a major concern within the firms. Moreover, firms were no longer focusing only on their internal performance; they started to pay attention on the market. Technical knowledge must be sold or somehow used in the market to generate higher profits (Teece, 1986). Dosi (1988) emphasizes the importance of economic returns arising from activities such as exploration and development of new products and new production techniques when the firm believes there is a market for its new products and processes. Calantone, Cavusgil and Zhao (2002), say that learning leads the firm to innovate, which affects its performance. Accordingly, they argue that firms need to focus on the learning process to obtain competitive advantage in the market. Sirmon, Hitt and Ireland (2007: 277) say that the firms' ability to leveraging relates to its “capability to create value for customers and wealth for owners”.

Just like Pavitt (1998), who expresses the importance of applying knowledge into commercially successful innovations, a firm with good performance is a firm that achieves competitive advantages. Tsai (2004) argues that a firm with a product development process faster than the competition can get first in the market and ensure good economic returns. Many authors believe that the economic gains arising from this development of society and firms are the result of innovations. Firms innovate because they expect to obtain economic benefits with it. Often this profit does not come from the launch of completely new products; it can actually come incrementally, from adjustments in the production process that consequently allow for higher margins.

Thus, the understanding of the firm performance evolves along with the society development. While the society was simpler, the performance was related to cost reductions and higher profits. As the society become more and more complex, firms as a way to keep their business up and running, must also evolve. As a way to be competitive, i.e., to achieve positive performance, firms start to pay attention to technological changes and to deliver according to market needs and expectations. Even if the means have changed, the objective of the firms remains to achieve positive results. So when they invest, they do it based on the expected returns.

By analyzing the relationship between R&D and productivity, Griliches (1998), in his book, considers the role of R&D as an input to the productivity growth process. His main research result indicates that research and development positively contribute to productivity growth. Authors studying the impact of technological innovation capability in Chinese firms' performance found that, although small, there is a significant relationship between R&D investments and performance indicators (Yam; Guan; Pun; Tang, 2004). Wang (2007: 356) states that "new knowledge and new technology generated from R&D activities increase productivity, not only at the firm level, but also at the industry and national levels." In studying relationship between R&D and market value in developed countries, Ehie e Olibe (2010) understood that successful investments in R&D result in innovative products and services that enable the company to improve its intangible assets. They concluded that investments in R&D positively affect the performance of firms.

Besides some specific findings, most of these studies indicate, in one way or another, that there is a positive relationship between technological capability and firm performance. These findings reinforce the assumption that the greater are the investments in technological capability, the better the economic performance of firms is. The question is whether this assumption is valid in an economy like Brazil, which is traditionally operational.

3. Measuring technological capability and firm performance

The studies that aim to measure the firm performance as a result of its technological capability often use R&D investments and the number of patents registered by the firm. The performance has been commonly assessed through traditional financial measures, internal efficiency, or market performance. The reviewed authors mentioned around 90 technological capability elements. The most frequent approach is in relation to research and development activities and to patent registration. The Table 1 sums up these works.

The firm performance may be measured by different indicators, such as internal measures of efficiency and productivity; outcome measures like profit; marketing measures such as market share. Despite the variety of indicators used by the authors to evaluate firm performance, we highlight two main groups of measures: results and market. For both, these elements can be measured through financial or other alternative indicators.

Some authors (Guan; Yam; Mok; Ma, 2006; Coombs; Bierly, 2006; Choi; Jong, 2010) indicate the importance of using multiple measures to assess the performance of the firm, as opposed to only financial indicators or only market indicators. Therefore, to evaluate the economic performance of Brazilian firms, we selected indicators that: covered the two major groups identified; could be measured financially; and were available in the companies' reports. The Table 2 sums up these measures.

Table 1 – Basis for technological capability indicators

Element	Basis for technological capability indicators
R&D	•Resources allocation to R&D (ARCHIBUGI; PIANTA, 1996; KIM, 1999; TSAI, 2004; FIGUEIREDO, 2009) •Average R&D investment as % of sales (MADANMOHAN; KUMAR, KUMAR, 2004) •R&D intensity (the ratio of R&D expenditure and sales) (COOMBS; BIERLY, 2006; HALL; BAGCHI-SEN, 2002) •R&D for product specification (BELL; PAVITT, 1995) •Cooperative R&D (LALL, 1992; JIN; VON ZEDTWITZ, 2008) •Basic research (LALL, 1992) •Development of new technologies through partnerships (BELL; PAVITT, 1995) •Projects of R&D (PANDA; RAMANATHAN, 1996) •Conduction of R&D activities (ARCHIBUGI; PIANTA, 1996; JIN; VON ZEDTWITZ, 2008) •Existence of an R&D department (KIM, 1999) •R&D capability (YAM et al., 2004) •Efforts in R&D (internal R&D, cooperative R&D and technology import) (TSAI, 2004) •Existence of R&D centers which have a partnership with research institutes (FIGUEIREDO, 2009)

Element	Basis for technological capability indicators
Patent	•Number of patents (ARCHIBUGI; PIANTA, 1996; TSAI, 2004; COOMBS; BIERLY, 2006; FIGUEIREDO, 2009) •Patent applications (domestic and international) (HALL; BAGCHI-SEN, 2002) •Patent approval (domestic and international) (HALL; BAGCHI-SEN, 2002) •Patent impact (measured by average citations that patents received) (COOMBS; BIERLY, 2006) •Technology cycle time (average number of years that the patent was prominently cited) (COOMBS; BIERLY, 2006) •Scientific relationship (patent citation in scientific articles) (COOMBS; BIERLY, 2006) •Relationship between patent indicator and its impact (COOMBS; BIERLY, 2006) •Total scientific relationships of the firm's patents (COOMBS; BIERLY, 2006) •Local property right of a product (JIN; VON ZEDTWITZ, 2008)

Table 2 – Basis for firm performance indicators

Element	Basis for firm performance indicators
Sales	•ROS (Return on Sales) (CALANTONE; CAVUSGIL; ZHAO, 2002; COOMBS; BIERLY, 2006; DEHNING; RICHARDSON; ZMUD, 2007) •Sales growth (SCHOENECKER; SWANSON, 2002; YAM et al., 2004; COOMBS; BIERLY, 2006; GUAN et al., 2006; ARTZ et al., 2010) •Total revenue (HALL; BAGCHI-SEN, 2002)
Profit	•Overall profitability (CALANTONE; CAVUSGIL; ZHAO, 2002) •Growth rate of profitability (CHOI, JONG, 2010) •Greater profitability than competitors (ISOBE; MAKINO; MONTGOMERY, 2008) •EBITDA (Earnings Before Interest, Taxes, Depreciation and Amortization) (BELLINGHINI; FIGUEIREDO, 2006) •Percentage of profit growth (GUAN et al., 2006) •EVA (Economic Value Added) (COOMBS; BIERLY, 2006)
Market	•IPO (Initial Public Offering) (DE CAROLIS, DEEDS, 1999) •MV (Market Value) (COOMBS; BIERLY, 2006) •MVA (Market Value Added) (COOMBS; BIERLY, 2006)

3.1. Technological Capability and Firm Performance Indicators

It is assumed that the effective use of resources reflects in good results for the firm. In this sense, investments in technological capability allow the firm to obtain positive economic performance. From this, we sought to identify which are the most significant indicators of technological capability and firm performance that are able to be identified through the reports released by companies. Tables 3 and 4 show the indicators used in this research.

Table 3 – Technological capability indicators

Technological capability elements	Technological capability indicators
R&D	•Existence of R&D activities •R&D Investment per year
Patent	•Number of patents registered per year

Table 4 – Firm performance indicators

Firm performance elements	Firm performance indicators
Sales	Net Sales per year and Net Sales Growth
Profit	EBITDA per year and EBITDA Growth
Market	Stock Price (in the last sale of each year), measured by the price percentage variation and Stock Price Growth

4. Method

To understand the relationship between technological capability and firm performance in and emerging economy, we analyzed 133 Brazilian industrial firms which are listed in the major national stock market (BM&FBovespa) in the years 2008 to 2010. The choice for listed firms was due to the fact that they are required to inform their results, they must follow the same data presentation standard, and they have a market indicator which can be measured (stock price).

In 2011, 518 companies were listed in BM&FBovespa (2011), however, because we limited our research to industrial firms, we had 169 firms. We have also excluded companies that, besides being industrial, are focused in services, for example, transportations services, sales of machinery and equipment, and telecoms. In addition, there has been exclusions of companies, such as: they are foreign companies that have consolidated data in their country of origin; they had no operations or had their operations halted in one or more years of the analyzed period, or the capital was closed until a closing date of that period; there has been a merger between companies in situations where the data were computed by another company, or when data from groups of companies are presented only consolidated; and they are no longer listed in BM&FBovespa and for this reason its historical data are no longer available. After all exclusions, our final sample was 133 industrial firms. Appendix 1 shows how these companies are classified by BM&FBovespa according to their industrial sector.

We collected secondary data through the companies' annual reports and profit and loss statements, the companies' websites, and through data released by the BM&FBovespa. Data was analyzed for the years 2008, 2009 and 2010. The data collection procedure at this stage was documentary research. Information on the number of patents was collected on the website of the INPI - National Institute of Intellectual Property (INPI, 2011). Data on R&D investment is not always available, as its report is not a requirement. When we decided to carry out this research, we expected that the economic information and technological capability were available in the documents provided by the companies. However, unlike developed countries such as the United States, the disclosure of the investments made in research and development by the public companies is not mandatory in Brazil. Thus, a very small number of companies spontaneously detailed that data in their reports. Many companies have merged these data with other investments, for example, the expansion of productive capacity. For those companies which did not release that information, we contacted them by telephone. Since it was difficult to get information on R&D investments, differently from all other indicators used (n=133), the sample was smaller (n=38). Even though the response rate was low, we used this indicator in our analysis. Hair et al. (2005), say the sample is considered small if it is equal or less than 30. Hall and Bagchi-Sen (2002) considered the cutoff even lower. For them, the significance test is invalidated for 'n' smaller than five. These authors have also analyzed their results using different 'n' values, such as here, where we work with values of 38 and 133.

Data was analyzed through SPSS – Statistical Package for the Social Sciences software. Statistical tests were performed with 133 companies, respecting, for each indicator, the total valid responses. For data analysis we performed the following statistical tests: frequency tests, descriptive statistics (minimum, maximum, mean and standard deviation), mean comparison t test, analysis of variance ANOVA and Pearson bivariate correlation. As the t-test "can be used to test a hypothesis that states that the means for the variables associated with two independent samples or two groups are equal" (Hair; Babin; Money; Samouel, 2005: 297), it was applied to verify the difference between the means of firms that have R&D activities and those that do not, according to information collected through their annual reports, websites, or phone calls. The ANOVA "is used to assess statistical differences between the means of two or more groups" (Hair et al., 2005: 297). This analysis was applied to determine the mean differences between industrial sectors in the sample. From correlation tests (Pearson), which is an associative technique that determines whether there is a consistent and systematic relationship between two variables (Hair et al., 2005), we attempted to observe the existence of relationship between technological capability and firm performance. The correlation coefficient measures the strength of the relationship between variables (Pestana; Gageiro, 2003). For Hair et al. (2005) this strength of correlation is divided into five levels: mild, almost imperceptible (0.01 to 0.20); small (0.21 to 0.40); moderate (.41 to .70); strong (0.71 to 0.09) and; very strong (0.91 to 1).

5. Results analysis

For this research we analyzed 133 Brazilian industrial firms listed in the stock market. Among the companies that made their information about investment in research and development available (n=38), the average investment in R&D represented 2.44% of net sales from 2008 to 2010. Ehie and Olibe (2010), in researching the relationship between R&D investment and market value of U.S. industrial firms, found that the percentage invested in R&D compared to net sales was 3.24%. The patent registration was low (average of patents registered from 2008 to 2010 was 3.8 per company), and decreased during the period. Of the 133 firms, 81 did not registered any patent in the period observed. The small number of patents reflects how little this practice is encouraged in the country. Some companies, however, stand out compared to the others, such as Petrobras, which recorded 360% more patents in relation to second place in this ranking. In relation to the firm performance indicators, between 2008 and 2010, the 133 firms presented an average growth of 17.5% in net sales.

The Bovespa Index is the most important indicator of share prices of the Brazilian stock market (BM&FBovespa, 2012). For this reason, we used it to compare the performance of individual shares of the firms in the sample. The 133 firms analyzed are classified into seven major sectors, according to BM&FBovespa (2011): Industrial Goods; Construction and Transportation; Cyclical Goods; Non-Cyclical Goods; Basic Materials; Oil, Gas and Biofuel; and Information Technology (IT). In order to contextualize the complexity with which these sectors deal in their daily production, and thereby understand their results, we used the technological intensity classification, according to the Organization for Economic Cooperation and Development - OECD (2011). Firms in the sample are predominantly (68%) of low and medium-low-technology, which is a representation of a country which is historically operational. Table 5 shows how the firms of the sample are classified according to OECD (2011) classification.

Table 5 – Technology intensity for the firms of the sample

Technological intensity/Industrial sector	High	Medium-high	Medium-low	Low	Total
Industrial Goods	2	24	0	0	**26**
Construction and Transport	0	0	5	0	**5**
Cyclical Goods	0	2	0	27	**29**
Non-Cyclical Goods	2	0	0	24	**26**
Basic Materials	0	10	15	15	**40**
Oil, Gas and Biofuel	0	0	4	0	**4**
IT	3	0	0	0	**3**
Total	**7**	**36**	**24**	**66**	**133**

The industries of cyclical and non-cyclical goods stand out as the sectors which best represent the national economy. They are large sectors formed by intensive labor manufacturing companies such as footwear; and by companies of agricultural sectors, like food and tobacco production. Moreover, the minority of the companies of the sample are classified as high-tech, represented here by computers and equipment, aviation, hospital equipment and medicines industries. It is noteworthy, however, that the highest operating profit (EBITDA in relation to net sales) and the highest net sales growth between 2008 and 2010 came from industries of medium-low and low-technology. Results like these suggest that, not necessarily, companies need to be high-tech to obtain good results, at least in an emerging country context. Table 6 brings the results of the indicators, by technological intensity classification.

Table 6 – Technological capability and firm performance indicators, by technological intensity and industry

		Technological intensity		Industry						
Indicators	Sample (133)	High (7) Medium-high (36)	Medium-low (24) Low (66)	Industrial Goods (26)	Construction and Transport (5)	Cyclical Goods (29)	Non-Cyclical Goods (26)	Basic Materials (40)	Oil, Gas and Biofuel (4)	IT (3)
There are R&D activities	74%	93%[1]	66%	92%[1]	40%	55%	77%[1]	75%[1]	100%[1]	100%[1]
R&D investment/Net sales (3 years average)	2.44%	3.76%[1]	1.25%	2.22%	1.25%	2.05%	5.96%[1]	0.62%	0.63%	3.80%[1]
Patents	3.8	4.49[1]	3.47	5.46[1]	0.6	1.62	0.62	2.73	45[1]	2.67
EBITDA/ Net sales (3 years average)	10.50%	6.44%	12.45%[1]	11.82%[1]	22.47%[1]	5.49%	0.28%	17.74%[1]	17.71%[1]	10.25%
Δ% Net sales (2008 to 2010)	17.50%	-0.54%	26.18%[1]	5.60%	26.88%[1]	3.85%	60.68%[1]	3.26%	56.47%[1]	2.51%
Δ% Stock price (2008 to 2010)	84.6%*	517.18%[1]	3,413%**[1]	231.10%[1]	65.89%	9,415%**[1]	141.41%[1]	587.56%[1]	70.73%	65.12%

* Average of Bovespa Index performance.
** The use of the Bovespa Index as an average was due to the fact that the prices of some shares vary greatly and deviate from the sample mean. This occurs because there are shares that have very little trade and that for some reason, when the transactions are made, they do not follow any pattern.
[1] Values above sample average

Although smaller, the oil, gas and biofuel and information technology are the only industries which all companies carry out R&D activities. Also, the sectors of industrial goods, non-cyclical goods and basic materials have, by percentage, more companies with R&D in comparison with the sample. This finding is consistent with the classification of technological intensity, because these are the only sectors with firms of high and medium-high-technology intensity. The exception of this information is the oil, gas and biofuel, which due to Petrobras' large size, causes a bias in the results. Although OECD (2011) classifies petroleum products as medium-low-technology, to Brazil, this is one of the industries that leads the economy.

In observing the results of Table 6 we see that sectors that have excelled in their economic performance are mainly medium-low and low-technology. These industries did not invest above average in R&D. In addition, the primarily high-tech sector, information technology, invested above average in R&D but have, in general, underperformed. We have also observed that although all industries have increased their share prices between 2008 and 2010, the high-technology was the only one which had a growth smaller than Bovespa Index average. Data like these, once again, provide evidence of the Brazilian economic profile.

In relation to the number of patents registered between 2008 and 2010, the only sectors that have above average records were the industrial goods and oil, gas and biofuel. The same reasoning done about Petrobras in relation to R&D investment can be done in relation to the patents registration. In the period analyzed, Petrobras have registered almost five times more patents than the second firm with the largest number of registrations, raising the average for the entire industry. Through ANOVA it was observed, with 95% confidence interval, a significant difference between the means of the industries regarding patent registration. The oil, gas and biofuel has significant difference with each of the other sectors. In other words, worldwide it can be a medium-low-tech industry, but in Brazil, due to the complexity of its operation and technological requirements, it is a "cutting edge" industry.

Considering the net sales in the last year analyzed, we highlight the performance of firms of non-cyclical goods, basic materials and oil, gas and biofuel industries. Included in this list are companies such as Petrobras, Vale, Siderurgica Nacional, Usiminas, Marfrig, JBS, Gerdau, Cosan, Braskem, Arcelor and Ambev. This means that, besides Braskem (medium-high-technology), the highest revenues in Brazil come from low and medium-low-technology industries. Regarding the operating profit, EBITDA, industries of lower technological intensity have superior results, once again supporting the reality of an economy driven by its operational capability. Of the 133 firms in the sample, 83 (62%) had an EBITDA margin (EBITDA/net sales) above average. Of these, 66% are of industries of low and medium-low-technology.

In relation to the recognition of these companies by the market, we found that five low-tech industries had the price of their shares increased above Bovespa Index average: fabrics; agriculture; beverage, tobacco and other non-cyclical goods; personal products; and miscellaneous basic materials. Besides them, two medium-high-technology industries also grew more than average: road materials; and chemicals.

In short, the higher revenues in Brazil come from low and medium-low-technology companies and, once again, it highlights the fact that the country is focused on its operational capability. Itautec, for example, a high-tech company, which despite having invested above average in R&D (4.13%) and having registered more patents than average, had, in general, a below average economic performance.

These data, and the finding that sometimes those industries that have invested in their technological capabilities did not have superior economic performance; and that those industries with superior performance did not invested above average in technological capability; strengthen the characteristic of the national economy. It leads to questioning the reasoning that to grow, firms must invest in technological capability.

5.1.Descriptive Analysis

When we look into the raw data (nominal figures, in dollars) for R&D investment of the Brazilian companies, from the Pearson correlation, we found positive correlation (significant at 99%) between R&D investment and patents registered. For example, correlating investments made in 2008 and patents registered in 2010, the correlation coefficient was 0.513 ($p = 0{,}01$). From previous works on this field, it is assumed that the more is invested in R&D, more patents are registered. That is the case of Artz et al. (2010), who tested nominal figures, found significant and positive relationship between R&D investments and the number of patents registered.

However, the results of the correlation become completely different when we adjusted this indicator after controlling for firm size. For that, we measured R&D investment as the ratio of R&D expenditure to total net sales of the firm, as it has been previously used by technological capability authors (Hall; Bagchi-Sen, 2002; Madanmohan; Kumar; Kumar, 2004; Coombs; Bierly, 2006; Ehie; Olibe, 2010). Ehie and Olibe (2010) said that it is preferable to use this measure instead of the nominal one. They claim that the latter is related to firm size and can confuse the relationship between R&D and performance. Making the analysis of the weighted data, the relationship is not significant between R&D investment and the number of patents registered during the period ($n = 38$). In this sense, in the analyzed sample, the larger the company, the greater its investments in research and development were. And the more these companies invested in R&D, the more patents they registered in the period. *However, this relationship was not sustained when controlled for the size data is analyzed*. If on one hand the theory shows that investment in technological capability can be translated by investments in R&D and that, in turn, these may reflect the number of patents registered; on the other hand, the analysis showed that this relationship is not true for Brazilian firms.

Of the sample, 99 (74.4%) firms perform R&D activities. From this observation, we chose to use the t test to detect differences between the means of firms that have R&D and the ones that do not. It is statistically significant (< 0.05) the difference between the means of the two groups in relation to the number of patents for each year and also for total patents registered in the period. Firms with R&D registered, on average of the period 4.97 patents, while those that do not perform these activities, registered only 0.38. This result confirms that companies that have research and development activities register more patents than those who do not. This difference also occurred with respect to two indicators of economic performance, EBITDA and net sales. There was significant difference to the value of EBITDA in 2008, 2010 and the total period. The average EBITDA for the three years, for the companies that have R&D was more than 2,000% higher than the ones without R&D. The difference of means in relation to net sales occurred in all years of the period as well as in total period. The average net sales was 864% higher for companies carrying out R&D activities.

Following the theory; based on Schumpeter (1942), with regard to the role of R&D departments as promoters of extraordinary profits; in this study we could say that the fact that companies execute R&D activities led them to the superior performance. However, when we test this same relationship, but with values weighted to company size (% growth of EBITDA and net sales), these correlations are no longer significant. The relationship tested with nominal figures (dollars) only shows that the larger companies (higher values of EBITDA and net sales) are those which perform R&D activities. This finding is actually stating that among the factors that influence Brazilian firms to carry out, or not, R&D activities, is their size, because once data are controlled for the companies' size, the statistical relationship is not significant.

Among the sample, we identified that firms with R&D have recorded more patents than the ones without. They also have higher EBITDA and net sales in dollars. Since this relationship was not true to the values weighted to the size of firms in the Brazilian reality, is not the fact that companies having R&D activities lead to higher net sales and EBITDA, but rather the opposite. Large *companies are those that are able to afford a R&D department*.

Similar to what happened with the correlations of EBITDA and net sales in relation to the existence of R&D activities of the firm, happened with the other technological capability indicators: R&D investment and patent registration. When nominal figures were analyzed, the correlations were significant and strong; however, when we attempted to control for the size of the firm, the results were rather different. We calculated, the percentage of net sales invested in R&D, that is, the ratio of the average over the three years of investments in R&D to the average net sales over the same period. When testing this new indicator to net sales growth of companies between 2008 and 2010, there was no significant correlation. We have also tested it with two new EBITDA indicators, to consider the size of the firms: EBITDA growth from 2008 to 2010; and EBITDA margin (EBITDA as a percentage of net sales) of each year. While the correlations between the nominal figures of investments in R&D and EBITDA were from strong to very strong, and more than 99% significant; the data considering the firm size show only one significant correlation, small (0,328), and 95% significance (% variation of EBITDA from 2008 to 2010 with R&D investment/net sales). Another performance indicator analyzed was the growth of the stock prices. There is no significant relationship between it and R&D investments. With this finding, we note that the market is not 'recognizing' nor 'valuing' the investments in R&D activities.

Taking into account only the indicators of nominal figures (in dollars), we could conclude that the more a firm invests in R&D, the more patents it registers, and the better is its economic performance. If we take Petrobras as an example of the Brazilian scenario, we have the company with the largest revenue in dollars, the company that invests in R&D in dollars the most, and the company that have registered the largest number of patents between 2008 and 2010. However, all these correlations lost strength when values are controlled for the size of the firms. In this sense, confirming the findings of Griliches (1998), we understand that the true relationship should be: the larger the company, the more it is able to invest in technological capability. We have also found that, unlike the assumption that the relationship between investments in technological capability and firm performance is positive; companies with superior economic performance invested less in R&D than the average of the firms analyzed.

6. Final remarks

Through the study of Brazilian firms, grouped into seven different industrial sectors, we analyzed the relationship between technological capability and firm performance. By correlating the indicators of both constructs, we observed that when treating data in dollars as opposed to weighted to the firm size, several relationships are significant. The main ones are the investments in R&D with patent registration, and each one of them with EBITDA and net sales. These last two were also positive related with the existence of a R&D area at the company. These findings could agree with the common sense that the companies which have an R&D department have higher revenue and profit; or even, the more the firms invest in R&D, the more they generate patents and the greater their revenue and profit are. This reasoning is plausible for complex societies of developed economy. The emerging economies do not present the same characteristics, so their results are also different. Brazil is an example of this situation, a country where the industrial base consists primarily of low and medium-low-technology firms.

If there is no correlation between technological capability and firm performance once we control for the firm size; we then have the largest companies (higher net revenue) investing more (in dollars) in R&D and registering more patents. These results are consistent with the ideas of Griliches (1998), who said the rich companies can spend more of their money on 'luxuries' such as R&D. We not only found that larger companies invest more in technological capability; but we have also found that when we test the correlation between technological capability and firm performance weighted to the firm size data, the results show that the investments in technological capability are not responsible for leading Brazilian firms to achieve positive performance. Besides, as it is a fact that even not investing in R&D some companies have positive performance, there are other factors that are leading the companies to achieve such results.

On average, low and medium-low-technology companies had superior results than the sample average in the performance indicators: EBITDA margin, net sales growth and growth of share price. In addition, these industries invested below average in R&D and registered fewer patents than the sample average. On the other hand, while high and medium-high-technology companies invested more in R&D and registered more patents than average, that is, they invested more in technological capability; their performance was not as remarkable as that of other sectors.

These results reflect the traditional national economic structure, which is not yet focused on technological development, but on operational capability. The results show that there are industries, of fundamentally lower technology intensity, which do not require investments in technological capability to achieve superior economic performance. They belong to more stable industries, focused on operational efficiency, on providing products of good quality, and on seeking the lowest possible cost. Furthermore, the operational focus stands out once again when we realized that the higher revenues come from low and medium-low-technology firms, such as Petrobras, Vale and Ambev.

Having these finding been set, we raised a few concerns on the future of the Brazilian economy. As societies became more complex over time, emerging countries are also developing. The theory states that positive economic results are the result of investments in knowledge, in this case, technological capability. Thus, we need to discuss where, how and why to invest in research and development. There are industries that do not depend primarily on technological development to survive, such as low-tech. The majority of investment these firms make is not on R&D activities, but on guaranteeing that their process is in order to maintain their operational levels better than the competition's. Besides, if in Brazil there are 5.1 million firms, and of that total, 98% are micro and small companies (SEBRAE, 2012), how can we promote national technological development?

Even if the majority of the analyzed firms are of lower technology intensity, in one way or another, they maintain some kind of technological activity. Moreover, Brazil stands out worldwide in low-tech industries, such as agribusiness. Having that said, how would the relationship between technological capability and firm performance be if we observe the same industries internationally? That is, how much do the same size and sectors firms of other countries spend? If Brazil invests more in these industries than other countries, then yes, the technological capability can influence development in emerging economies.

All these findings do not diminish the merit of the firms' and the country's success. They in fact confirm a historical tradition of a country that concentrates its efforts on basic industries. Since this is a country of companies focused on operational efficiency, how can they invest in R&D without impairing their performance? What types of projects can they develop?

Regardless of which is the 'source' of the positive performance of the Brazilian firms, technological or operational, any firm, to be a leader, needs to be ahead of the others. That is, it must constantly change its technological content and thus, add value to the shareholders.

Acknowledgements

The present study was carried out with the financial support of the Brazilian Government research funding agencies Research Foundation of the State of Rio Grande do Sul (FAPERGS) and the Brazilian National Council for Scientific and Technological Development (CNPq).

References

ARCHIBUGI, D.; PIANTA, M. Measuring technological change though patents and innovation surveys, **Technovation**, v. 16, n. 9, p. 451-468, 1996.

ARTZ, K.; NORMAN, P.; HATFIELD, D; CARDINAL, L. A longitudinal study of the impact of R&D, patents, and product innovation on firm performance. **Journal of Product Innovation Management**, v. 27, n. 5, p. 725-740, 2010.

BELL, M.; PAVITT, K. The development of technological capabilities. **Trade, Technology and International Competitiveness.** Economic Development Institute of the World Bank: p. 69-100, 1995.

BELLINGHINI, M. F.; FIGUEIREDO, P. N. Capacidades tecnológicas e estratégia empresarial: Evidências em nível de empresa da indústria de telefonia no Brasil, **Revista de Administração Mackenzie**, v. 7, n. 2, p. 39-60, 2006.

BM&FBOVESPA. Setor de Atuação, **Empresas Listadas**. Accessed in: 15 apr. 2011. Available in: <http://www.bmfbovespa.com.br/Cias-Listadas/Empresas-Listadas/BuscaEmpresaListada.aspx?idioma=pt-br>, 2010.

BM&FBOVESPA. Índice Bovespa, **Estatísticas históricas**. Accessed in: 24 apr. 2012. Available in: <http://www.bmfbovespa.com.br/indices/EvolucaoMensal.aspx?Indice=Ibovespa&idioma=pt-br>, 2012.

CALANTONE, R.; CAVUSGIL, S.; ZHAO, Y. Learning orientation, form innovation capability, and firm performance. **Industrial Marketing Management**, v. 31, p. 515-524, 2002.

CHOI, B.; JONG, A. Assessing the impact of knowledge management strategies announcements on the market value of firms**. Information and Management**, v. 47, p. 42-52, 2010.

COOMBS, J. E.; BIERLY, P. E. Measuring technological capability and performance. **R&D Management**, v. 36, n. 4, p. 421-438, 2006.

DECAROLIS, D.; DEEDS, D. The impact of stocks and flows of organizational knowledge on firm performance: An empirical investigation of the biotechnology industry. **Strategic Management Journal**, v. 20, p. 953-968, 1999.

DEHNING, B.; RICHARDSON, V. J.; ZMUD, R. W. The financial performance effects of IT-based supply chain management systems in manufacturing firms, **Journal of Operations Management**, v. 25, p. 806-824, 2007.

DOSI, G. Sources, procedures, and microeconomic effects of innovation. **Journal of Economic Literature**, v. XXVI, p. 1120-1171, 1988.

EHIE, I.; OLIBE, K. The effect of R&D investment on firm value: An examination of US manufacturing and service industries. **International Journal Production Economics**, v. 128, p. 127-135, 2010.

FIGUEIREDO, P. **Gestão da Inovação: conceitos, métricas e experiências de empresas no Brasil**. Rio de Janeiro: LTC, 2009.

GARCÍA-MUIÑA, F.; NAVAS-LÓPEZ, J. Explaining and measuring success in new business: the effect of technological capabilities on firm results. **Technovation,** v. 27, p. 30-46, 2007.

GRILICHES, Z. **R&D Productivity: the econometric evidence**. Chicago: The University of Chicago Press, 1998.

GUAN, J.; YAM, R.; MOK, C.; MA, N. A study of the relationship between competitiveness and technological innovation capability based on DEA models. **European Journal of Operational Research**, v. 170, p. 971-986, 2006.

HAIR, J.; BABIN, B.; MONEY, A.; SAMOUEL, P. **Fundamentos de métodos de pesquisa em administração**. Porto Alegre: Bookman, 2005.

HALL, L.; BAGCHI-SEN, S. A study of R&D, innovation, and business performance in the Canadian biotechnology industry. **Technovation**, v. 22, p. 231-244, 2002.

IBGE. **Pesquisa industrial de inovação tecnológica** (PINTEC), Rio de Janeiro, 2010. Accessed in: feb. 2011. Available in:
<http://www.ibge.gov.br/home/estatistica/economia/industria/pintec/2008/default.shtm>, 2008.

INPI – Instituto Nacional da Propriedade Intelectual. **Consulta à Base de Patentes do INPI**. Accessed in: nov. and dec. 2011. Available in:
<http://pesquisa.inpi.gov.br/MarcaPatente/jsp/servimg/validamagic.jsp?BasePesquisa=Patentes>, 2011.

ISOBE, T.; MAKINO, S.; MONTGOMERY, D. Technological capabilities, and firm performance: The case of small manufacturing firms in Japan. **Asia Pacific Journal of Management**, v. 25, p. 413-428, 2008.

JIN, J.; VON ZEDTWITZ, M. Technological capability development in China's mobile phone industry. **Technovation**, v. 28, p. 327-334, 2008.

KIM, L. Building technological capability for industrialization: analytical frameworks and Korea's experience. **Industrial and Corporate Change**, v. 8, n. 1, p. 11-136, 1999.

LALL, S. Technological capabilities and industrialization. **World Development**, v. 20, n. 2, p. 165-186, 1992.

MADANMOHAN, T.; KUMAR, U.; KUMAR, V. Import-led technological capability: a comparative analysis of Indian and Indonesian manufacturing firms. **Technovation**, v. 24, p. 979-993, 2004.

NELSON, R.; WINTER, S. Uma teoria evolucionária da mudança econômica. Campinas, UNICAMP, 2005 (orig. 1982).

OECD. Directorate for Science, Technology and Industry. **Stan Indicators** (2005 edition), 2005.

OECD. **Technology intensity definition**. ISIC rev. 3. Accessed in: abr 2012. Available in:
< http://www.oecd.org/dataoecd/43/41/48350231.pdf>, 2011.

PANDA, H.; RAMANATHAN, K. Technological capability assessment of a firm in the electricity sector. **Technovation**, v. 16, n. 10, p. 561-588, 1996.

PAVITT, K. Technologies, products and organization in the innovating firm: what Adam Smith tells us and Joseph Schumpeter doesn't. **Industrial and Corporate Change**, v. 7, n. 3, p. 433-452, 1998.

PESTANA, M.; GAGEIRO, J. **Análise de dados para ciências sociais**: a complementaridade do SPSS. 3. ed., Lisboa: Sílabo, 2003.

SCHUMPETER, J. **The Theory of Economic Development**. 14. ed. New Jersey: Transaction, 2008a (orig. 1911).

SCHUMPETER, J. **Capitalism, Socialism and Democracy**. New York: Harper Perennial Modern Thought, 2008b (orig. 1942).

SEBRAE. Accessed in: mai. 2012. Available in:
<ttp://www.sebraesp.com.br/TenhoUmaEmpresa/Biblioteca/OutrosConteudos/EstudosEPesquisas/MPEsEmNumeros/Paginas/MPEsEmNumeros.aspx>, 2012.

SIRMON, D.; HITT, M.; IRELAND, R. Managing firm resources in dynamic environments to create value: looking inside the black box. **Academy of Management Review**, v. 32, n. 1, p. 273-292, 2007.

TEECE, D. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. **Research Policy**, v. 15, p. 285-305, 1986.

TIGRE, P. A. Inovação e teorias da firma em três paradigmas. **Revista de Economia Contemporânea**, v. 3, p. 67-111, 1998.

TREZ, J.; STEFFANELLO, M.; REICHERT, F.; DE ROSSI, G.; PUFAL, N. Footwear industry innovation capability: Southern Brazilian evidence. **2012 Academy of Management Annual Meeting**, Boston: p. 1-32, 2012.

TSAI, K. The impact of technological capability on firm performance in Taiwan's electronics industry. **Journal of High Technology Management Research**, v. 15, p. 183-195, 2004.

WANG, E. R&D efficiency and economic performance: A cross-country analysis using the stochastic frontier approach. **Journal of Policy Modeling**, v. 29, p. 345-360, 2007.

YAM, R.; GUAN, J.; PUN, K.; TANG, E. An audit of technological innovation capabilities in Chinese firms: some empirical findings in Beijing, China. **Research Policy**, v. 33, p. 1123-1140, 2004.

ZAWISLAK, P.; ALVES, A.; TELLO-GAMARRA, J.; BARBIEUX, D.; REICHERT, F. Innovation capability: from technology development to transaction capability. **Journal of Technology Management and Innovation**, v. 7, n. 2, p. 14-27, 2012.

Appendix 1 – Industrial sector classification

Classification	Detailed classification	Number
Industrial Goods	Industrial Goods / Electrical equipment / Electrical equipment	1
	Goods / Ind. machinery and equip/ Machinery and equip, constr. and agricultural	1
	Goods / Industrial machinery and equipment / Motors, compressors and other	3
	Goods / Industrial machinery and equipment / Weapons and ammunition	1
	Goods / Industrial machinery and equipment / Machinery and hospital equipment	1
	Goods / Industrial machinery and equipment / Industrial equipment and supplies	4
	Industrial Goods / Vehicles / Aircraft material	1
	Industrial Goods / Vehicles / Material road	13
Constr. and Transp.	Construction and transportation / Engineering and construction / Building materials	5
Cyclical Goods	Cyclical goods / Leisure / Bicycles	2
	Cyclical goods / Leisure / Toys and games	2
	Cyclical goods / Textiles, apparel and footwear / Accessories	1
	Cyclical goods / Textiles, apparel and footwear /Footwear	4
	Cyclical goods / Textiles, apparel and footwear /Fabric	15
	Cyclical goods / Textiles, apparel and footwear /Apparel	2
	Cyclical goods / Housewares / Appliances	2
	Cyclical goods / Housewares /Housewares	1
Non-Cyclical Goods	Non-cyclical goods / Farming / Agriculture	3
	Non-cyclical goods / Processed foods / Sugar and alcohol	3
	Non-cyclical goods / Processed foods /Various food	4
	Non-cyclical goods / Processed foods /Coffee	3
	Non-cyclical goods / Processed foods / Meat and meat products	5
	Non-cyclical goods / Processed foods / Grains and grain products	1
	Non-cyclical goods / Beverages / Beer and soft drinks	1
	Non-cyclical goods / Miscellaneous / Miscellaneous Products	1
	Non-cyclical goods / Tobacco / Cigarettes and tobacco	1
	Non-cyclical goods / Personal care products / Cleaning	1
	Non-cyclical goods / Personal care products /Personal care	1
	Non-cyclical goods / Health / Medicines and other products	2
Basic Materials	Basic materials / Packaging / Packaging	4
	Basic materials / Wood and paper / Wood	2
	Basic materials / Wood and paper / Pulp and paper	6
	Basic materials / Miscellaneous / Miscellaneous	3
	Basic Materials / Mining / Minerals metal	2
	Basic Materials / Chemicals / Fertilizers and pesticides	4
	Basic Materials / Chemicals / Petrochemicals	5
	Basic Materials / Chemicals / Chemical diverse	1
	Basic materials / Metallurgy and steel / Copper artifacts	1
	Basic materials / Metallurgy and steel / Iron and steel artifacts	7
	Basic materials / Metallurgy and steel / Steel	5
Oil, Gas and Biofuel	Oil, gas and biofuel / Oil, gas and biofuel / Exploration or refining	4
IT	Information technology / Computers and equipment / Computers and equipment	3

Source: BM&FBovespa (2011)