# Technological cumulativeness and innovation in Brazilian Industry: evidences from Brazilian innovation surveys 2008, 2011 and 2014

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# Resumo

Este artigo tem como objetivo analisar as estratégias tecnológicas das empresas industriais no Brasil, incorporando a cumulatividade tecnológica intrafirma como um determinante das inovações, além das suas capacidades estruturais de realizar interação com agentes do Sistema de Inovação (SI). Os resultados apontam baixa cumulatividade nos esforços inovativos tanto para inovação de processo quanto para inovação de produto, com algum destaque para o treinamento de recursos humanos em períodos passados. Além disso, é identificado um limitado impacto da interação com agentes do SI através de arranjos cooperativos, e uma maior relevância de informações vindas de fornecedores (inovação de produto) e concorrentes (inovação de processo), o que indica uma estratégia inovativa de dependência e passividade das empresas brasileiras.

**Palavras-chave:** cumulatividade, estratégias de inovação, PINTEC, Brasil

# Abstract

The present paper aims to analyze the technological strategies of Brazilian industrial firm s. It incorporates both technological cumulativeness and the ability to interact with other National Innovation System’s (NSI) agents as innovative determinants. The results suggest low cumulativeness in innovative efforts for both product and process innovations, with emphasis to human resources training in past periods. Besides, it is verified only a limited impact from the interactions with other NSI’s agents through cooperative arrangements. Lastly, the knowledge that comes from suppliers (product innovation) and competitors (process innovation) is found to be of great importance, which indicates a dependent and passive innovative strategy prevails in the Brazilian industrial park.

**Key-words:** cumulativeness, innovative strategies, PINTEC, Brazil

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# Introduction

Enterprises are expected to follow well-stablished behaviors in order to remain competitive, especially in imperfect markets (PORTER, 1986, 1998). Adopting internal and routinized technological strategies would allow firms to experience cumulative patterns of technological learning and benefit from path dependency, increasing the possibilities for economies of scale and scope (ARTHUR, 1989). This would be particularly important, since in the new techno-economic paradigm, innovation refers to the main strategy to create and sustain dynamic competitive advantages based on internal technological and innovative capabilities (SILVERBERG; DOSI; ORSENIGO, 1988).

Still, adopting innovative strategies and creating technological advantages seem to be a particular challenge for firms in developing countries (MATHEWS, 2002; VIOTTI, 2002; XIAO; TYLECOTE; LIU, 2013). In Brazil, the National Innovation System (NSI) has been characterized as incipient (ALBUQUERQUE, 1999) and directed towards passive learning strategies focused on the absorption of foreign technology (VIOTTI, 2002). It follows that the national innovative efforts would be oriented towards internal adaptations and incremental innovations, lacking active learning strategies to the creation of technological capabilities and the cumulativeness of past innovative efforts.

Nonetheless, during the last decade Brazil faced a period of macroeconomic stability, which has enabled firms to perform long term investments and build innovation capabilities. The implementation of industrial, as well as science and technology policies have provided firms with a large set of instruments and mechanisms that reduced costs and technological uncertainty in the development of new processes and products. According to the Brazilian Innovation Survey (PINTEC), approximately one third of innovative firms received some sort of governmental support in the period. This is expected to have favored learning and competence building, avoided discontinuity and fostered cumulativeness.

In the light of this, the present work aims to analyze the technological strategies followed by Brazilian industrial firms, focusing on intrafirm technological cumulativeness as a determinant of innovation. The empirical investigation employs firm level data from the Brazilian Innovation Survey, years 2008, 2011 and 2014, revealing cumulativeness patterns in Brazilian industrial firms.

Besides this introduction, the remainder of the article is organized as follows. The second section reviews the concepts of technological strategies that may be followed by firms and their implications for cumulativeness. It also provides an overview of the recent efforts undertaken by Brazilian industrial firms. A third section presents the methodology employed in the empirical investigation. The forth section discuss the results and the fifth section present the concluding remarks.

# Strategies of firm growth, cumulativeness and innovation

To maintain competitive advantages, firms usually follow well-defined patterns of behavior (PORTER, 1986, 1998). On its hand, introducing internal and routinized innovation strategies would create cumulative patterns of technological knowledge (ARTHUR, 1989). This would intensify gains from economies of scale and scope, defining competitive advantages for first-movers (PORTER, 1986). Moreover, the chances of future success in competitive markets would increase based on a firm’s past experience in accumulating, managing and using knowledge (SILVERBERG; DOSI; ORSENIGO, 1988).

Latecomer firms, however, find difficulty in accessing both national and world markets. Since path-dependency assign a special role to cumulativeness, these firms find themselves lagging behind in terms of knowledge and the technological capabilities necessary to succeed. Hence, their main source of competitive advantages relies on the cost of the labor inputs (MATHEWS, 2002).

The creation and internalization of technological capabilities would mainly involve assimilating, using and adapting existing technologies (KIM, 1980; XIAO; TYLECOTE; LIU, 2013). During this process, technological cumulativeness could arise from intrafirm technological efforts, for instance, in stablishing internal structures for conducting R&D and further financing it with the firms’ own profits (MALERBA; ORSEGNO, 1993). Moreover, sectoral specificities would determine different degrees of opportunity and appropriability (PAVITT, 1984; DOSI; MALERBA, 1996; MALERBA, 2002), with important impact on cumulativeness.

Xiao, Tylecote & Liu (2013) present some possibilities and technological strategies for latecomer firms in developing countries, summed up in a ‘technology strategy and capability matrix’. In the authors’ framework, initially a latecomer firm chooses between a dependency strategy and an imitation strategy, which may both involve technological licensing from foreign frontier firms (FFF). However, the latter tends to minimize dependency over time with the internalization of technological capabilities, through technological diversification and reverse engineering, for example. Differently, the dependency strategy has a lower ability to accumulate knowledge.

In a second stage, the latecomer firms should choose between offensive and defensive strategies. Firms that initially chose an imitative strategy usually follow an offensive strategy in the next stage. While, in a defensive strategy prevails incremental innovations and process innovations, in an offensive strategy product innovations prevail.

In these lines, Viotti (2002) suggests a classification to define the capabilities of the latecomer firms[[1]](#footnote-1). Three categories are used to define capabilities. First, ‘production capabilities’ refers to the knowledge, skills and other condictions required for the process of production. On its hand, ‘improvement capabilities’ is used to define the knowledge, skills and other conditions required for the continuous and incremental upgrading of product design, performance features and of process technology. Lastly, ‘innovation capabilities’ comprise the knowledge, skills and other conditions required for the creation of new technologies (i.e. major changes in the design and core features of produts and production processes) (VIOTTI, 2002, p.664).

Comparing both authors’ classifications, product capabilities would be linked to passive learning, while improvement capabilities would refer to active learning. In the first case, incremental innovations would be a result of learning-by-doing processes in which the incorporation of new techniques is accompanied with little or none absorptive efforts, presenting low adaptation costs. On the other hand, active incremental innovation would result from active efforts directed towards technological incorporation. Lastly, the offensive strategies would relate to innovation capacity. This scheme is outlined in Figure 1.

**Figure 1 – Technological capabilities in Viotti (2002) vs. Xiao, Tylecote & Liu (2013)**

Xiao, Tylecote & Liu (2013)

Dependency

Offensive

Defensive

Immitation

Passive (production capability)

Active (incremental capability)

Viotti (2002)

Innovative (innovation capability)

Notes: Thicker lines represent stronger connections.

Source: authors’ elaboration.

According to this framework, firms specialized in production capability would tend to maintain a dependency position, with little possibilities for technological change and little scope for learning-by-doing. Therefore, cumulativeness would be low. On the other hand, strategies directed towards incremental capabilities would relate to constant efforts to assimilate and create new technologies. This would be associated with an imitative strategy with strong potential for learning and cumulativeness, which could conduct to technological lead – either offensive or defensive – in the future. Lastly, innovation capability is related to advanced capacity to create innovations with high technological content, based on high R&D efforts and cooperation with different agents. These would be the firms able to achieve international competitive standards, mainly with offensive R&D strategies.

This characterization guide the following empirical investigation in an attempt to identify the technological strategies followed by Brazilian industrial firms. Based on it, firms are to be classified as passive-dependent or active-imitative, considering the degree of cumulativeness of their past technological efforts.

# Brazil: international comparison and firm capabilities evolution

Prior studies already suggested that Brazilian industrial firms do not follow advanced innovative strategies in the terms defined in the prior section (DE NEGRI; SALERNO, 2005; DE NEGRI et al, 2007; DE NEGRI; LEMOS, 2011). Using different measures and indicators, a number of works have provided evidence of the weaknesses of the Brazilian NSI (ALBUQUERQUE, 1999; VIOTTI, 2002; CALIARI; CHIARINI, 2016). In comparison with other economies, it is possible to note that overall, Brazilian performance is inferior than that observed in developed and late industrialization countries, being paralleled only to the BRIC economies. China, on its hand, have presented good indicators in both input and output indicators. These are a result of the Chinese industrial policy and Chinese firms positioning in active incremental innovation (HU; JEFFERSON, 2009; XIAO; TYLECOTE; LIU, 2013). Table 1 presents some innovation statistics (both input and output) from Brazil and selected countries for international comparison. According to the Global Innovation Index[[2]](#footnote-2) 2016 Brazil is ranked behind all the ten selected countries at the 69th position. The other countries are ranked as follows: United States (4th), Singapore (6th), Germany (10th), South Korea (11th), Japan (16th), China (25th), Russia (43th), South Africa (54th) and India (66th).

The last three editions of the Brazilian Innovation Survey (PINTEC) is analyzed to investigate the Brazilian case. The survey is conducted every three years by the Brazilian Institute of Geography and Statistics (IBGE), producing indicators on the firms’ technological activities at the industrial, regional and national levels. Data collection follows the Community Innovation Surveys methodologies, therefore being compatible with international recommendations. It is focused on the identification of the factors that influence the innovative behavior of firms, detecting and measuring the strategies, efforts and results achieved by them. The survey provides information on the number of innovative firms and on their innovative activities related to product innovation, process innovations or both. Moreover, innovations are classified in terms of their degree of novelty, being new to the firm, new to the country or new to the world. Data displayed in Table 2 (as well as in the econometric investigation presented in Section 3.2) refer to the years of 2008, 2011 and 2014[[3]](#footnote-3) and concerns exclusively the manufacturing sector[[4]](#footnote-4).

**Table 1 - Innovation indicators (input and output) for selected countries, 2013**

| **Classification** | **Country** | **Input** | | | **Output** | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **R&D Investment (% GDP)** | **Enrollment in Tertiary Education (% pop with 23 years old or more)** | **R&D Researchers (per million inhabitants)** | **Scientific Publications (per million inhabitants)** | **Patents by Residents (%)** | **High-Tech Exports (% manufactures)** |
| BRICS | Brazil | 1.24 | 46.4 | 698.1\* | 238.0 | 16.1 | 9.63 |
| China | 2.01 | 30.2 | 1089.2 | 295.7 | 85.4 | 26.97 |
| India | 0.82\*\* | 23.9 | 156.6\* | 73.0 | 24.8 | 8.07 |
| Russia | 1.13 | 78.0 | 3073.1 | 247.7 | 64.1 | 10.01 |
| South Africa | 0.73\*\*\* | 19.7 | 404.7\*\* | 181.6 | 8.7 | 5.47 |
| Late Industrialization | South Korea | 4.15 | 95.3 | 6456.6 | 1171.7 | 78.2 | 27.10 |
| Singapore | 2.00 | 69.8 | 6665.2 | 1974.1 | 11.8 | 46.99 |
| Developed Countries | Germany | 2.83 | 61.1 | 4399.7 | 1253.3 | 75.0 | 16.08 |
| Japan | 3.47 | 62.4 | 5201.3 | 811.8 | 82.7 | 16.78 |
| United States | 2.73 | 88.8 | 4018.6\*\* | 1303.7 | 50.4 | 17.82 |

Notes: \* year 2010; \*\* year 2011; \*\*\* year 2012.

Source: Author’s elaboration based on World Bank Data.

A first glance at the PINTEC data reveals that throughout the years there was an increase in the number of innovating firms, although their participation decreased relative to the total number of manufacturing industries. This reduction is mainly due to the decreasing number of product innovating firms. Nonetheless, this change has been accompanied by changes in the degree of novelty introduced by the product innovating firms. Among them, the number of firms that develop innovative products beyond its own production limits (new to the country or new to the world) has increased. In other words, despite in small number relative to the overall amount of product innovating firms, a selected group of firms managed to increase the degree of novelty of product innovations. This suggests that potentially there are firms adopting defensive/offensive innovation strategies.

**Table 2 – Innovation indicators: PINTECs 2008, 2011 and 2014**

| **Indicators** | **2008** | | **2011** | | **2014** | | **∆ 2014/2008** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **N** | **%** | **N** | **%** | **N** | **%** |
| **Number of firms** | | | | | | | |
| Total | 98,420 |  | 114,212 |  | 115,268 |  | 117.1 |
| Innovating Firms | 37,808 | 38.4 | 41,012 | 35.9 | 41,850 | 36.3 | 110.7 |
| Product Innovators | 22,749 | 23.1 | 19,991 | 17.5 | 21,169 | 18.4 | 93.1 |
| Process Innovators | 31,793 | 32.3 | 36,497 | 32.0 | 37,410 | 32.5 | 117.7 |
| Product and Process Innovators | 16,734 | 17.0 | 15,475 | 13.5 | 16,730 | 14.5 | 100.0 |
| **Degree of innovation novelty** |  |  |  |  |  |  |  |
| Product Innovation |  |  |  |  |  |  |  |
| Firm | 19,266 | 84.7 | 16,406 | 82.1 | 16,634 | 78.6 | 86.3 |
| Country | 3,217 | 14.1 | 3,101 | 15.5 | 4,046 | 19.1 | 125.8 |
| World | 266 | 1.2 | 483 | 2.4 | 490 | 2.3 | 184.0 |
| Process Innovation |  |  |  |  |  |  |  |
| Firm | 29,942 | 94.2 | 34,096 | 93.4 | 34,033 | 91.0 | 113.7 |
| Country | 1,777 | 5.6 | 2,161 | 5.9 | 3,077 | 8.2 | 173.2 |
| World | 74 | 0.2 | 242 | 0.7 | 300 | 0.8 | 404.0 |
| **Responsible for the innovation** | | | | | | | |
| Product Innovation |  |  |  |  |  |  |  |
| Firm/group | 19,503 | 85.7 | 17,048 | 85.3 | 17,012 | 80.4 | 87.2 |
| Cooperation | 1,781 | 7.8 | 1,116 | 4.9 | 1,756 | 7.7 | 98.6 |
| Other agents/firms | 1,465 | 6.4 | 1,827 | 8.0 | 2,402 | 10.6 | 164.0 |
| Process Innovation |  |  |  |  |  |  |  |
| Firm/group | 4,183 | 13.2 | 6,262 | 17.2 | 10,157 | 27.1 | 242.8 |
| Cooperation | 1,040 | 3.3 | 2,236 | 6.1 | 2,245 | 6.0 | 215.9 |
| Other agents/firms | 26,570 | 83.6 | 28,001 | 76.7 | 25,008 | 66.8 | 94.1 |

Source: Authors’ elaboration based on data from the Brazilian Innovation Survey 2008, 2011 and 2014.

Additionally, the first analysis of the PINTEC data also reveals that only a small number of product innovations were developed in cooperation with other agents of the NSI. In most cases product innovation is developed by the own firm or some firm within the same group. Nonetheless, the latter has been losing participation relative to the former, indicating that other agents and other firms have increasing its participation in introducing innovations.

In what concerns process innovations, it is found an increase in the degree of novelty both to the country and to the world. However, this kind of innovation was mainly directed towards incremental improvements in firms’ technological capabilities. This observation goes in line with studies that emphasize the importance of the introduction of new productive technologies in the Brazilian industry as one of the main innovation determinants in the country (DE NEGRI; SALERNO, 2005). Besides, it is possible to observe an increment in the participation of the own firm in introducing process innovations. In 2014, process innovation introduced by the own firm added up to the innovation introduced in cooperation with other agents summed up to one third of the total process innovations, against a result of 16% in 2008.

**Table 3 – Innovation investments, 2008, 2011 and 2014**

|  | **2008** | **2011** | **2014** | **∆ 2014/2008** |
| --- | --- | --- | --- | --- |
| Sales revenue (R$ millions)1 | 2,332 | 2,401 | 2,587 | 110.9 |
| Total innovation (% of revenue) | 2.60 | 2.46 | 2.16 | 83.1 |
| Internal R&D (% of revenue) | 0.64 | 0.72 | 0.68 | 106.1 |
| External R&D (% of revenue) | 0.11 | 0.11 | 0.18 | 166.4 |
| Machinery and equipment acquisition (% of revenue) | 1.28 | 1.16 | 0.86 | 67.4 |
| Other investments (%of revenue)2 | 0.58 | 0.47 | 0.45 | 76.9 |

Notes: ¹ Monetary values in 2014 prices deflated using the IPCA (Broad National Consumer Price Index).

² “Other investments” comprises external knowledge acquisition, software acquisition, training, introduction of technological innovations in the market, industrial project and other technical preparations.

Source: Authors’ elaboration based on PINTEC data years 2008, 2011 and 2014.

The sample selection of PINTEC is biased towards innovative firms[[5]](#footnote-5), given that the amount invested in innovation as a proportion of revenue by the firms in the sample is higher than the national innovation investments relative to GDP in 2013. Despite that, the real value has fallen from 2008 to 2014 due to the reduction of the amount invested in the acquisition of machinery and equipment, as well as in “other investments”. This can be particularly a problem given the obsolescence of the machinery and equipment employed in the national industrial park[[6]](#footnote-6). On its hand, internal R&D investments remained relatively stable while external R&D slightly increased. The decrease in the invested real value could be associated with the decrease of the participation of other agents/firms in process innovation.

In sum, the increase in the firm’s ability to internally create process innovations are inconclusive, since they can simply represent budget adjustments due to economic restrictions imposed by the 2008 financial crisis. Together with the information about product innovation, it is not suggestive of any significant evolution in the technological strategies adopted by firms between the years of 2008 and 2014. Still, the analysis endorse the frail condition of the Brazilian NSI, potentially associated with the notion of National Learning Systems, in Viotti’s (2002) terminology.

It follows that to identify the technological strategy consistent with the Brazilian context an econometric analysis is to be conducted in the next section.

# Hypothesis

It is acknowledged that a dependent-passive technological strategy (passive learning) is mainly associated with the purchase of foreign technology. In that case, the acquisition of equipment and machinery would play a central role in internalizing knowledge, although without incrementing firm’s absorptive capacity. On the other hand, an imitative-active strategy (active learning) would comprise an internal structure to support innovation (laboratories, human resources) related to internal R&D investments. External R&D would play an important role in both strategies, whether replacing or complementing internal R&D or operating as a facilitator in introducing techniques developed elsewhere.

Process and product innovations are made possible through various forms of financing, with prevalence of internal R&D in the former case and acquisition of machinery and equipment for the latter. In that case, to identify the type of technological strategy it would not suffice to regard the kind of investment employed. Most important to the Brazilian case would be the analysis of the cumulativeness of the technological efforts conducted by firms and their relationship with other actors in the NSI.

At firm level, cumulativeness requires that either investment in innovative activities present continuity. Moreover, constant cooperation with other agents of the NSI should also be relevant to indicate cumulativeness, mainly by fostering firms’ absorptive capacity.

The empirical analysis that follows emphasize cumulativeness and its interaction with important sources of innovation. It follows that in the empirical analysis, cumulativeness is defined in terms of the continuity of the investments in innovative activities as well as in the constant cooperation with other agents of the NSI. The main purpose of this investigation is to identify the determinants of the innovative process, for both product and process innovation.

# Method

# Data

The following empirical investigation is carried out using PINTEC microdata for the years of 2008, 2011 and 2014. To analyze cumulativeness, a firm panel was gathered comprising all surveyed firms that participated in all three consecutive applications. It should be stressed that the firm level disaggregation of PINTEC data allows verifying in further detail a series innovative features of Brazilian industries. PINTEC microdata are of restricted access and, therefore, the reported results constitute an important contribution to field.

The selected indicators to proceed the investigation are presented next, classified according to their purpose in the analysis:

**Chart 1 – Selected variables for the econometric investigation**

|  |  |  |
| --- | --- | --- |
| **Classification** | **Indicator** | **Description** |
| Financial variables | Expenditure in innovative activities | Innovative investment under each heading:   * Internal R&D * External R&D * Machinery and equipment acquisition * Knowledge acquisition * Software * Training |
| Cooperation variables | Cooperative setup | Indicates if the firm were involved in cooperative arrangements with the other agents of the NSI |
| Cooperation assessment | Indicates whether the interaction with the following agents were considered of high importance:   * Machinery and equipment suppliers * Clients and consumers * Competitors * Universities * Research institutes * Conferences and events * Business fairs |
| Scale Effects | Industrial Revenue | Net sales revenue of the firm in the respective year |
| Employed workers | Number of people employed in the company in December 31st |
| R&D efforts | Continuous R&D | Indicates if R&D activities were continuous or occasional in each three-year period |

Source: Authors’ elaboration.

To apprehend the cumulativeness of the innovation efforts carried out in the past periods, financial and cooperation variables entered the estimation using lags. Additionally, sectoral dummies (CNAE 2.0 at the 2-digit level of aggregation), regional dummies and year dummies where included in all estimations.

Lastly, it should be noted that the survey is conducted every three years and while qualitative information refers to all three years, information on expenditure values correspond only to the last year of the triennium. Annual discontinuity in spending would already suggests the prevalence of imitative and dependent strategies, separate from internal accumulation of knowledge and capability building.

# Logit model and panel data

The estimation strategy adopted next uses the logit model. To control for the unobserved characteristics due to the existence of organizational and productive routines coordinately adopted by firms, fixed effects are employed (GREENE, 2000; WOOLDRIGDGE, 2002). The PINTEC microdata indicates whether each firm have innovated in the surveyed year . The binary dependent variable attributes the value of one if the firm innovated at time and zero otherwise. The general regression to be estimated is defined as:

|  |  |  |
| --- | --- | --- |
|  |  | (1) |

where denotes a vector of non-observed fixed effects, denotes a vector of explanatory variables concerning the firms’ characteristics, is a vector of regional variables, are year dummies and is the idiosyncratic error, being , and the parameters to be estimated. The firm’s characteristics are expressed in the Chart 1. Regional variables comprise dummy variables for each of the five regions in Brazil.

To capture cumulativeness from the expenditure in innovative activities and the participation in cooperative arrangements, different regressions were estimated using the first and second lags of both variables. However, including lagged variables in the estimations reduce the number of observations, as well modify the group of firms included in each estimation, narrowing the number of firms that participated of the survey in two (or three) consecutive years.

The following analysis is based on the sign and significance of the estimated coefficients, indicating which characteristics are more likely to increase the chances of a firm to introduce an innovation.

# Results

Table 4 reports the results of the attempts to capture the impact of cumulativeness on the probability of creating innovations. Separate estimations were carried out for product innovation and for process innovation. Columns “Mod t” refer to the estimations using variables at time , while columns “Mod t-1” and “Mod t-2” include the firsts and the second lags of the variables respectively.

**Table 4 – Logit estimations for product and process innovations**

| **Variables** | **Product Innovation** | | | **Process Innovation** | | |
| --- | --- | --- | --- | --- | --- | --- |
| **Mod t** | **Mod t-1** | **Mod t-2** | **Mod t** | **Mod t-1** | **Mod T-2** |
| Exp. Internal R&D t | 0,110\*\*\* | 0,107\*\*\* | 0,141\*\*\* | -0,037\*\* | -0,005 | -0,071\*\* |
| (0,016) | (0,019) | (0,028) | (0,019) | (0,022) | (0,035) |
| Exp. External R&D t | 0,003 | -0,014 | 0,001 | 0,026 | 0,013 | 0,072 |
| (0,021) | (0,024) | (0,035) | (0,023) | (0,028) | (0,048) |
| Exp. Machinery & Equipment t | -0,014 | -0,002 | -0,004 | 0,235\*\*\* | 0,223\*\*\* | 0,192\*\*\* |
| (0,010) | (0,012) | (0,017) | (0,013) | (0,016) | (0,024) |
| Exp. Knowledge Acquisition t | 0,092\*\*\* | 0,063\*\* | 0,030 | -0,035 | -0,032 | 0,008 |
| (0,020) | (0,025) | (0,035) | (0,023) | (0,030) | (0,046) |
| Exp. Software t | -0,054\*\*\* | -0,061\*\*\* | -0,054\*\* | 0,148\*\*\* | 0,215\*\*\* | 0,274\*\*\* |
| (0,014) | (0,018) | (0,026) | (0,022) | (0,032) | (0,053) |
| Exp. Training t | 0,083\*\*\* | 0,089\*\*\* | 0,057\* | 0,057\*\* | 0,054\* | 0,064 |
| (0,018) | (0,023) | (0,033) | (0,022) | (0,029) | (0,045) |
| Cooperative Arrangement | 0,565\*\*\* | 0,541\*\*\* | 0,690\*\*\* | 0,323\*\*\* | 0,282\*\* | 0,223 |
| (0,077) | (0,090) | (0,141) | (0,094) | (0,111) | (0,169) |
| Exp. Internal R&D t-1 |  | 0,059\*\*\* | 0,051\*\* |  | -0,025 | -0,011 |
|  | (0,016) | (0,024) |  | (0,019) | (0,028) |
| Exp. External R&D t-1 |  | 0,001 | 0,033 |  | -0,019 | -0,076\* |
|  | (0,029) | (0,042) |  | (0,029) | (0,042) |
| Exp. Knowledge Acquisition t-1 |  | -0,011 | -0,002 |  | 0,039\*\* | 0,031 |
|  | (0,013) | (0,019) |  | (0,015) | (0,023) |
| Exp. Knowledge Acquisition t -1 |  | 0,024 | 0,019 |  | -0,055\* | -0,010 |
|  | (0,028) | (0,041) |  | (0,029) | (0,048) |
| Exp. Software t-1 |  | -0,020 | -0,038 |  | 0,003 | 0,015 |
|  | (0,021) | (0,031) |  | (0,025) | (0,040) |
| Exp. Training t-1 |  | 0,036 | 0,038 |  | 0,003 | 0,045 |
|  | (0,025) | (0,038) |  | (0,028) | (0,047) |
| Cooperative Arrangement t-1 |  | -0,013 | 0,121 |  | 0,174 | 0,180 |
|  | (0,109) | (0,148) |  | (0,126) | (0,175) |
| Exp. Internal R&D t-2 |  |  | 0,025 |  |  | -0,019 |
|  |  | (0,026) |  |  | (0,028) |
| Exp. External R&D t-2 |  |  | -0,061 |  |  | 0,009 |
|  |  | (0,042) |  |  | (0,047) |
| Exp. Machinery & Equipment t-2 |  |  | -0,018 |  |  | -0,040\* |
|  |  | (0,019) |  |  | (0,023) |
| Exp. Knowledge Acquisition t-2 |  |  | -0,006 |  |  | -0,038 |
|  |  | (0,038) |  |  | (0,044) |
| Exp. Software t-2 |  |  | -0,022 |  |  | 0,012 |
|  |  | (0,031) |  |  | (0,035) |
| Exp. Training t-2 |  |  | 0,070\* |  |  | 0,082\* |
|  |  | (0,038) |  |  | (0,046) |
| Cooperative Arrangement t-2 |  |  | -0,420\*\* |  |  | 0,145 |
|  |  | (0,173) |  |  | (0,204) |
| Industrial Revenue | 0,117\*\*\* | 0,161\*\*\* | 0,207\*\*\* | -0,042 | 0,021 | 0,081 |
| (0,037) | (0,046) | (0,067) | (0,041) | (0,050) | (0,072) |
| Employed Workers | -0,017 | -0,129\*\* | -0,150\* | 0,155\*\*\* | 0,053\*\*\* | 0,119\*\*\* |
| (0,048) | (0,061) | (0,088) | (0,055) | (0,056) | (0,058) |
| Continuous R&D Dept. | 0,564\*\*\* | 0,629\*\*\* | 0,348\*\* | 0,371\*\*\* | 0,457\*\*\* | 0,697\*\*\* |
| (0,107) | (0,117) | (0,177) | (0,119) | (0,135) | (0,201) |
| Cooperation assessment t: |  |  |  |  |  |  |
| Machinery & Equip. Suppliers | 0,183\*\*\* | 0,143\*\*\* | 0,119\*\* | -0,325\*\*\* | -0,306\*\*\* | -0,304\*\*\* |
| (0,031) | (0,039) | (0,057) | (0,035) | (0,045) | (0,069) |
| Clients & consumers | -0,354\*\*\* | -0,287\*\*\* | -0,307\*\*\* | 0,093\*\* | 0,048 | 0,053 |
| (0,029) | (0,039) | (0,056) | (0,037) | (0,047) | (0,070) |
| Competitors | -0,019 | -0,024 | -0,035 | 0,132\*\*\* | 0,149\*\*\* | 0,147\*\* |
| (0,029) | (0,037) | (0,055) | (0,035) | (0,045) | (0,068) |
| Universities | 0,048 | 0,089 | 0,058 | -0,029 | 0,004 | -0,027 |
| (0,042) | (0,054) | (0,080) | (0,049) | (0,062) | (0,089) |
| Research Institutes | 0,011 | -0,006 | 0,079 | 0,019 | -0,030 | -0,064 |
| (0,041) | (0,0530) | (0,076) | (0,048) | (0,062) | (0,092) |
| Conferences and events | -0,059\* | -0,052 | -0,076 | 0,014 | 0,024 | 0,072 |
| (0,034) | (0,044) | (0,068) | (0,039) | (0,051) | (0,074) |
| Fairs | -0,059\* | -0,057 | -0,107\* | -0,088\*\* | -0,057 | -0,0410 |
| (0,032) | (0,042) | (0,062) | (0,038) | (0,049) | (0,074) |
| Year dummy 2011 | -0,383\*\*\* |  |  | 0,102 |  |  |
| (0,0734) |  |  | (0,0874) |  |  |
| Year dummy 2014 | -0,0958 | 0,258\*\*\* |  | 0,484\*\*\* | 0,231\*\*\* |  |
| (0,0748) | (0,0750) |  | (0,0917) | (0,069) |  |
| Sectoral Dummy | Omitted | | | | | |
|
| Regional Dummy | Omitted | | | | | |
|
| Constant | -0,384 | -0,895\*\* | -0,842 | 0,279 | 0,278 | -0,493 |
| (0,309) | (0,389) | (0,558) | (0,367) | (0,461) | (0,722) |
| Number of observations | 6776 | 4504 | 2288 | 6776 | 4504 | 2288 |

Notes: Robust standard errors in parenthesis. Significance levels: \*\*\* p<1%, \*\* p<5%, \* p<10%.

Source: Authors’ elaboration based on PINTEC 2008, 2011 and 2014.

First of all, when analyzing the determinants of product innovation without employing lags (Mod t), it is verified positive and significant coefficients for ‘Expenditures in Internal R&D’, ‘Expenditures in Knowledge Acquisition’ and ‘Expenditures in Training’, whereas ‘Expenditures in Software’ enters with a negative sign in what concerns product innovation. In what concerns process innovation, the negative and significant coefficient for ‘Expenditures in Internal R&D’ stands out, as well as the positive and significant impact for the ‘Expenditures in the Acquisition of Machinery & Equipment’, ‘Expenditures in Software’ and ‘Expenditures in Training’. Such results endorse prior findings, specifically that from De Negri & Salermo (2005) when analyzing the Brazilian case.

It is also important to mention the importance of the cooperation with other agents of the NSI, as reflected by the large magnitude and significance of the coefficient of the participation in some sort of Cooperative Arrangement. This result is compatible with those previously reported in both the national and international literature (LUNDAVALL, 1992; HAGEDOORN & SCHANKENRAAD, 1994; BRITOO & DEL-VECCHHIO, 2014). In addition, the large and significant coefficients for the existence of a “Continuous R&D Department” suggest the importance that innovative firms attribute to a persistent innovation strategy. This result is aligned with the notion of cumulativeness within the technological strategies. It is also in accordance with the results reported by De Negri & Lemos (2011).

Regarding the scale effects on product innovation, results drew attention to the fact that while industrial revenue revealed to be relevant, the number of employed workers was not. On the contrary, in process innovation, the latter is found to be relevant while the former was not.

Although there is a high correlation between employed workers and industrial revenue in productive firms, this result provide evidence of the different competitive dynamics in both types of innovation. In product innovation it is usual that competitiveness gains arise from acquiring larger portions of demand with more inelastic products. This type of innovation is related to novelties in production, the creation of new markets and higher mark-ups. On its hand, process innovation is related to competitive gains through cost reduction in mature markets. Therefore, this type of innovation should depend more on economies of scale, or putting in other words, the size of the firm – number of workers employed – than on the industrial revenue.

In what concern the firms’ assessment to cooperation[[7]](#footnote-7) in developing product innovations, a positive and significant coefficient was found relative to ‘machinery and equipment suppliers’. On the other hand a negative and significant coefficient was found relative to ‘clients and consumers’ and to the ‘participation in conferences, events and fairs’. The interactions between firms and universities or research institutes was not significant, although positive. These results are in line with other studies that stress the importance of cooperation with universities to reduce the technological risks in developing new products (BAKER, 2013), as well as corroborate the results from PAPPE Program in Brazil (TORRES & BOTELHO, 2018).

In the estimations including time lags (Mod t-1and Mod t-2) results contradict common sense in terms of cumulativeness in innovation activities expenditure. For product innovations, only ‘internal R&D’ spending was found to be positive and significant when including the first lag. In other words, expenditures carried out in the first three months of the prior year positively affected the likelihood of a firm innovating, although in smaller magnitude than the expenditure carried out in the current period. When adding the second lag (meaning the innovative efforts conducted 6-8 ago), only expenditures on ‘training’ where found to increase the likelihood of innovating.

The participation in a cooperative arrangement in t-1 didn’t affect the probability of introducing an innovation, whereas in t-2 it decreases the likelihood of creating innovations. These results highlight the frailty of the innovative process in Brazil in terms of persistent efforts. Interaction variables preserved the results from the former estimation in t.

The lack of cumulativeness is also observed in process innovation. Differently from product innovation though, the introduction of lagged variables for the interaction with other agents modified the estimated signs found in t. The estimation of Mod t-1, revealed ‘employed workers’ and ‘internal R&D’ spending not to be significant. Moreover, only ‘machinery and equipment’ spending in t-1 positively affected the likelihood of introducing a process innovation, although in smaller magnitude than in the current period. In turn, ‘Knowledge Acquisition’ spending affected negatively the likelihood of innovating. When including both lags (t-1 and t-2) only ‘training’ expenditures were found to be positive and significant in t-2. The estimated coefficients of ‘Employed workers’ and ‘cooperative arrangements’ no longer remained significant after the inclusion of the two period lags.

These results suggest that a technological strategy centered on the acquisition of machinery and equipment is not related to intra-firm learning process. It also suggests that this strategy is not connected to the other agents of the NSI that could potentially contribute to technological absorption, notably those along the productive chain.

Although investments in innovative activities and cooperation are found to be important in innovating, their impacts are not persistent through time. The estimations revealed that current efforts to innovate are more important than past efforts, indicating the prevalence of a short-term dynamics of the innovation process.

Table 5 report the results of panel estimations[[8]](#footnote-8), following the former specifications. Regarding the first model that comprise the innovative efforts in the current period for both product and process innovation, it is verified that scale effects are no longer important in determining the likelihood of innovating. This suggests that after controlling for the firms non-observed characteristics – notably the firms’ routines – the prior estimations where biased by omitted variables. In that sense, the innovative performance relies more on the non-observed routines than on scale effects.

Continuous R&D and the participation in cooperative arrangements remained positive and significant in determining product innovation, however the former lost significance in determining process innovations. In what concerns the expenditures on ‘Internal R&D’, ‘Knowledge Acquisition’ and ‘Training’, all remained positive and significant, nonetheless they now present a lower impact on innovation. Moreover, ‘Software’ expenditure no longer remained significant while ‘Expenditure on Machinery and Equipment’ began to positively affect product innovation. Lastly, in what concerns the cooperation variables, the importance attributed to participation in ‘Conferences and Events’ and ‘Business Fairs’ no longer remained significant.

On its hand, fixed effects estimations concerning process innovation revealed that ‘Expenditure on Internal R&D’ was no longer important, while ‘Expenditure on Machinery and Equipment’ and ‘Software’ acquisition remained positive and significant.

Turning to the effects of cumulativeness, the same strategy adopted in the prior estimation is followed next. However, using the panel estimator does not allow for the implementation of two time lags, since the information on the year of 2008 would be lost. Hence, only the first lag is analyzed. Regarding product innovation, the importance of scaled effects, measured through ‘Industrial Revenue’, should be noted. It was formerly not significant, however, when excluding the year of 2008 it became positive, suggesting that the scale effects could be related to changes between the considered years.

In what concerns process innovation, prior results are overall maintained, except for the number of ‘Employed Workers’, which was found to negatively affect the introduction of an innovation. The other variables maintained the sign and significance observed in the prior model (Mod t). It should be noted that expenditures in ‘Internal R&D’ and in ‘Machinery and Equipment’, as well as ‘participation in a cooperative arrangement’ were found to be significant in determining the likelihood of introducing an innovation only in the current period, once again shedding light to the lack of cumulativeness of the innovative efforts in the Brazilian industry.

**Table 5 – Panel Logit for product and process innovations**

| **Variables** | **Product innovation** | | **Process innovation** | |
| --- | --- | --- | --- | --- |
| **Mod. t** | **Mod. t-1** | **Mod. t** | **Mod. t-1** |
| Industrial Revenue | -0,098 | 0,492\* | 0,191 | 0,397 |
| (0,127) | (0,281) | (0,207) | (0,413) |
| Employed Workers | 0,158 | 0,140 | -0,035 | -0,558\* |
| (0,165) | (0,240) | (0,192) | (0,334) |
| Continuous R&D Dept. | 0,446\*\*\* | 0,829\*\*\* | 0,299 | 0,119 |
| (0,170) | (0,259) | (0,214) | (0,332) |
| Cooperative arrangement t | 0,634\*\*\* | 0,784\*\*\* | 0,326\*\* | 0,534\* |
| (0,124) | (0,248) | (0,155) | (0,300) |
| Exp. Internal R&D t | 0,069\*\* | 0,085\* | -0,019 | 0,072 |
| (0,028) | (0,045) | (0,034) | (0,058) |
| Exp. External R&D t | 0,007 | -0,012 | 0,048 | 0,031 |
| (0,033) | (0,059) | (0,035) | (0,068) |
| Exp. Machinery & Equipment t | 0,033\*\* | 0,061\*\* | 0,254\*\*\* | 0,285\*\*\* |
| (0,016) | (0,030) | (0,022) | (0,042) |
| Knowledge Acquisition t | 0,079\*\* | 0,048 | 0,033 | -0,028 |
| (0,031) | (0,063) | (0,038) | (0,073) |
| Exp. Software t | -0,017 | -0,022 | 0,131\*\*\* | 0,133\* |
| (0,023) | (0,046) | (0,033) | (0,073) |
| Exp. Training t | 0,055\*\* | 0,073 | -0,005 | 0,055 |
| (0,028) | (0,054) | (0,036) | (0,069) |
| Cooperative arrangement t-1 |  | 0,075 |  | 0,162 |
|  | (0,236) |  | (0,308) |
| Exp. Internal R&D t-1 |  | 0,024 |  | 0,033 |
|  | (0,037) |  | (0,046) |
| Exp. External R&D t-1 |  | 0,096 |  | -0,045 |
|  | (0,069) |  | (0,070) |
| Exp. Machinery & Equipment-1 t-1 |  | 0,017 |  | 0,093\*\* |
|  | (0,032) |  | (0,040) |
| Knowledge Acquisition t-1 |  | -0,014 |  | -0,073 |
|  | (0,058) |  | (0,068) |
| Exp. Software t-1 |  | -0,041 |  | -0,030 |
|  | (0,047) |  | (0,062) |
| Exp. Training t-1 |  | 0,026 |  | 0,000 |
|  | (0,055) |  | (0,069) |
| Cooperative Assessment: |  |  |  |  |
| Machinery & Equip. Suppliers | 0,112\*\* | 0,099 | -0,299\*\*\* | -0,330\*\*\* |
| (0,049) | (0,084) | (0,057) | (0,096) |
| Clients & Consumers | -0,328\*\*\* | -0,198\*\* | 0,108\* | 0,013 |
| (0,050) | (0,089) | (0,063) | (0,112) |
| Competitors | 0,009 | 0,086 | 0,064 | 0,012 |
| (0,049) | (0,088) | (0,061) | (0,104) |
| Universities | 0,052 | 0,218\* | -0,089 | 0,074 |
| (0,068) | (0,120) | (0,085) | (0,154) |
| Research Institutes | -0,010 | -0,192\* | 0,047 | -0,030 |
| (0,064) | (0,112) | (0,083) | (0,151) |
| Conferences & Events | -0,064 | -0,057 | 0,014 | 0,020 |
| (0,055) | (0,096) | (0,068) | (0,122) |
| Fairs | 0,008 | 0,039 | -0,162\*\* | -0,130 |
| (0,054) | (0,096) | (0,069) | (0,124) |
| Constant | -0,834\*\* | -1,282\*\*\* | 0,508 | 0,399 |
| (0,332) | (0,427) | (0,351) | (0,456) |
| Year dummies | Omitted | | | |
|
| Number of Observations | 6776 | 4504 | 6776 | 4504 |

Notes: Robust standard errors in parenthesis. Significance levels: \*\*\* p<1%, \*\* p<5%, \* p<10%.

Source: Authors’ elaboration based on PINTEC 2008, 2011 and 2014.

The following chart sums up the results of the innovative efforts, comparing all the estimated coefficients for financial and cooperation variables that positively and significantly affected innovation. While results indicate cumulativeness in some innovative efforts, although results can be ambiguous considering the different specifications. The logit estimation indicates that current internal R&D spending is important for product innovation, however this is not confirmed in the panel estimations. Training expenditure in t-2 was also relevant in the logit estimation, but this was not corroborated by the panel estimations. Similar results were found for process innovations, although higher importance is attributed to expenditures on machinery and equipment, as well as its cumulativeness was verified in both logit and panel estimations.

**Chart 2 – Comparative of statistical significance and impact of the variables capturing innovative efforts**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Determinants | Innovation type | | | |
| Product Innovation | | Process innovation | |
| Logit | FE Panel | Logit | FE Panel |
| Innovative effort in t | Internal R&D and training | Internal R&D an Machinery & Equipment | Machinery & Equipment, software and training | Machinery & Equipment and software |
| Innovative effort in t-1 | Internal R&D (smaller magnitude) | - | Machinery & Equipment (smaller magnitude) | Machinery & Equipment (smaller magnitude) |
| Innovative effort in t-2 | Training (maintained magnitude) | Does not apply | Training (larger magnitude) | Does not apply |
| Cooperative arrangements in t | Yes | Yes | Yes | Yes |
| Cooperative arrangements in t-1 and t-2 | No | No | No | No |
| Cooperation assessment | Machinery & Equipment Suppliers | - | Competitors | - |

Source: Authors’ elaboration.

Overall, firms carried efforts in capacitating its human resources in previous periods, which have increased its capacity to absorb technologies as well as to create new ones (ZAHARA; GEORGE, 2002), positively affecting product and process innovations. However, this result does not suffice to affirm that the Brazilian industry adopts an imitative-active strategy (or even defensive/ offense).

# Concluding remarks

The present empirical investigation aimed to capture the effect past innovative efforts’ cumulativeness on current innovations. Technological strategies based on well-established behaviors and cumulative innovation efforts are found to concern Brazilian industrial firms. This is reflected in the significance of the estimated coefficient for continuous R&D. Also interesting to note that firms that have innovated in more than one period consider continuous R&D more important that the average of firms (coefficients are higher in t-2 than in t-1). However, this is not sustained by the information on innovative expenditures and by the assessment to cooperation with other agents.

When investigating the cumulativeness effects on present innovation, results indicated that neither the expenditures on innovative activities nor the cooperation with other agents in past periods were relevant to create innovations. Hence, it is assumed that Brazilian industrial firms experience low cumulativeness for the success of the innovative activities.

In sum, Brazilian firms are found to have developed the ability to absorb technologies and create new ones, what positively affects product and process innovation. However, the results reported in this article do not suggest that their technological strategies could be classified as active-imitative. It rather suggests a passive-dependent behavior regarding each of the two types of innovation:

**Product innovation:** overall, the information combined in the present article point to the importance of internal R&D structures and past efforts in the capacitation of human resources. Combined with the fact that greater importance is attributed to cooperation with machinery and equipment suppliers, as well as that the developed innovations are generally new to the firm, it is suggested that firms are mainly focused on the incorporation of technology embedded in capital assets.

**Process innovation:** machinery and equipment acquisition is of prime importance for innovation, being software and training expenditures, at some extent, also important. Nonetheless, resorting to Table 2, in 2014 over 90% of process innovations were only new to the firm, being innovations mainly created by other agents/firms. Still, past cooperative arrangements were not relevant for current innovations, being only cooperation with other competitors found to be relevant. Hence, capital investments play an important role in internalizing knowledge, however without incrementing firm’s absorptive capacity. It is suggested that firms are rather concerned with accompanying market strategies and imitating the best current technologies.

Lastly, for both types of innovation the lack of significance (or even negative coefficients) estimated for the cooperation with Universities and Research Institutes indicate that in Brazil, one of the most important relationships within the NSI is relatively ignored by industrial firms. In sum, results indicate that Brazilian industrial firms are still incipient in what concerns innovative capabilities.

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1. Viotti (2002) refers to the backwards firms as those that operate in the National Learning Systems (NLS), a concept used to describe the developing countries’ innovation systems. [↑](#footnote-ref-1)
2. The index is published by SC Johnson College of Business (Cornell University), Insitut Eropéen d’Administration des Affaires (INSEAD) and World Intectual Poperty Organization (WIPO). All anual reports are available at <<https://www.globalinnovationindex.org/home>>. Accesssed 25th May 2017. [↑](#footnote-ref-2)
3. It should be noted that the analysis reflects the effects of the 2008 economic crisis, especially when comparing the years of 2008 and 2011. [↑](#footnote-ref-3)
4. The first PINTECs were mainly focused on the manufacturing industry. In the more recent years (including 2011 and 2014), there has been significant efforts to include the services sector in the survey. Still, its inclusion has gone under several modifications, making it unsuitable for comparisons along the three years considered. Therefore, the present work attains exclusively to the manufacturing sector, which present consistent data for the entire period. [↑](#footnote-ref-4)
5. PINTEC is constituted of two groups of firms. The first one comprises all firms with more than 500 employees, whereas the second comprises firms with less than 500 employees. The sample is biased towards potential innovative firms comprising firms: (i) that innovated in the previous survey; (ii) with patent applications; (iii) that received some sort of governmental support to innovate (fiscal incentives and credit from FINEP or BNDES). [↑](#footnote-ref-5)
6. According to the information conveyed by the Brazilian Machinery Builders’ Association (ABIMAQ), the machinery employed in the Brazilian manufacturing industry is on average 17 years-old, four years older than that of Germany and seven years older that of the United States. Available at <<http://www.abimaq.org.br/site.aspx/Abimaq-Informativo-Mensal-Infomaq?SumarioClipping=47>>. Access in 26th May 2017. [↑](#footnote-ref-6)
7. Whether firms considered the interaction with other agents of the NSI to be of high importance to innovate. [↑](#footnote-ref-7)
8. Estimations were conducted employing both fixed and random effects. The Hausman’s teste indicated that the fixed effect estimation was preferable over random effects. Therefore, the reported results concern only fixed effects estimations. Random effects estimations are available [↑](#footnote-ref-8)