**Technological Regimes in the Brazilian Manufacturing Industry: an Empirical Investigation**

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**Abstract**

The paper aims to assess technological regimes in the context of the Brazilian manufacturing industry over the 2000-2005 period. The industries were classified in terms of SM-I and SM-II technological regimes by means of multivariate statistical methods based on variable approximating technological opportunity, appropriability, cumulativeness and knowledge base. The evidence indicated some salient classification contrasts with respect to previous evidence for developed countries. In particular, the pharmaceuticals and paper and cellulose sectors in the Brazilian case have some expected specificities. The contrasts between SM-I and SM-II for the totality of firms, indicated discernible differences in the case of two hypotheses: the share of small firms is higher in SM-I industries than in SM-II industries and in SM-I industries profit rates are lower than in SM-II industries.

**Keywords:** technological regimes; manufacturing industry; Brazil;

**JEL classification:** L60; O30

1. **Introduction**

The role of innovation in stimulating economic growth has been increasingly recognised in the endogenous growth literature [see e.g. Romer (1990)]. In fact, abrupt changes following innovation have been recognised since Schumpeter (1912, 1942); that author who contended that innovation is responsible for incessantly destroying the old and creating the new. This notion of *creative destruction* innovation encompasses two major categories: the radical innovations that follow the precepts of creative destruction and so as to dramatically alter existing structures, and incremental innovations that follow an incremental process of *creative accumulation*.

Following that lead, Nelson and Winter (1982) and Kamien and Schwartz (1982) highlighted two salient innovative patterns: the first is characterised in terms of a *creative destruction*, with an easy entry for new innovators, who introduce new ideas, processes and products that have disruptive effects on the competitive environment. This pattern has been labelled as Schumpeter Mark I (SM-I), and is associated with a widening pattern, that allows an expansion of the knowledge-base.

The second pattern is related to the notion of *creative accumulation*.In this pattern,the innovation process is conducted by large established firms, that have institutionalised the innovation process and effectively create barriers to entry for new innovators. This pattern has been named Schumpeter Mark II (SM-II), and it can be associated with a “deepening” pattern, in which the innovation is dominated by a few firms that continuously accumulate technological and innovative capabilities over time.

The concept of technological regimes articulates technological opportunity, appropriability, cumulativeness and knowledge-base conditions to define de SM-I and SM-II[[1]](#footnote-1). Thus the use of this concepts allows advances in empirical frameworks, enabling a growing number of studies in the literature, such as those as Malerba and Orsenigo (1995, 1997), Mesa and Gayo (1999), Breschi et al. (2000) and Van Dijk (2000, 2002) for different European countries [France, Germany, Italy, Netherlands, Spain and United Kingdom].

The majority of these studies focused on advancing statistical approaches to classify the industries in terms of the two previously mentioned patterns by considering their conditions as the relevant underlying factors. Therefore, the emphasis has been placed on inter-sectoral heterogeneities associated with the structural and dynamic features in the populations of innovative firms. It is important to stress, however, that the studies by Van Dijk (2000, 2002) further explored contrasts between SM-I and SM-II industries in terms of statistical tests of specific hypotheses for firms in general.

The present paper aims to consider a similar analysis in the case of the Brazilian manufacturing industry using as a reference a rich survey data that gave become increasingly available. The study is motivated on different grounds:

1. The existing literature has concentrated on developed countries and it is relevant to investigate a large emerging economy such as Brazil where the coexistence of traditional sectors and more dynamic and innovative sectors can be observed. Nevertheless, it appears that the typical level of technological effort is still low as suggested by Gonçalves and Simões (2005), Kannebley Jr, et al. (2005) and Zucoloto and [Toneto Jr.](http://lattes.cnpq.br/6878697355639730) (2005);
2. The underlying structural factors that define the two regimes warrant further investigation. In fact, previous studies by Van Dijk (2000, 2002) relied on the prevailing classification used by Malerba and Orsenigo (1995) that referred to different countries. The consideration of tests comparing SM-I and SM-II industries that do not rely on classifications for other countries is warranted, and the consideration of an emerging economy can address a gap in the literature.

The remainder of the paper is organised as follows: the second section discusses the empirical characterisation of technological regimes. The third section discusses data sources, construction of the variables and the regimes´ classifications. The fourth section considers contrasting patterns in the two types of regimes in terms of different statistical tests. The fifth section provides some final comments.

1. **Technological Regimes: Empirical Characterisation**

A salient contrast can be made in terms of the SM-I (“widening”) and SM-II (“deepening”) regimes that would respectively be related to specific industrial dynamics features. Breschi et al (2000) characterised the SM-I as a sector with high technological opportunity associated with low appropriability, cumulativeness conditions and an applied knowledge-base conditions. The articulation of these conditions reflects is reflected in intense industry dynamics, a high entry of new innovators, low concentration and great instability in the innovators hierarchy. SM-II, on the other hand, is characterised as a sector with high technological opportunity, high appropriability and cumulativeness conditions and a knowledge-base closer to basic science. The combination of these conditions is reflected by sectors with reduced entry of new innovators, high concentration in innovative activities and an established hierarchy for the group of innovators.

The related empirical literature can be schematically summarised in two threads:

1. Empirical classification of industries into SM-I and SM-II types

Using the structural and dynamic factors that characterise the industries, Breschi et al. (2000) proposed a synthetic characterisation of the different industries by means of a multivariate statistical method for their principal components (PC). The method attempts to describe variations in observed data by considering linear combinations (the PCs) of the representative variables such that successively orthogonal PCs explain a decreasing proportion of the data variance[[2]](#footnote-2). Thus, once a number of PCs that accounted for a significant proportion of the data variation were selected, the idea was to interpret the signs of the coefficients of that synthetic indicator with respect to different variables (by inspecting the *factor* *loadings*) and to classify each industry into one of the two categories of technological regimes. In previous applications, one could focus on the first (dominant) PC because it accounted for a significant proportion of the data variance ranging from 49% to 81% in the cases addressed by the authors. The empirical strategy advanced by that research essentially focused on the interpretation of the first PC (called SCHUMP) that was obtained upon the consideration of 3 variables:

1. ENTRY: percentage share of patent applications by firms applying in a given technological class for the first time;
2. STABILITY: the Spearman rank correlation coefficient between the hierarchies of firms patenting in two different periods;
3. C4: the concentration ratio of the top four patenting firms in a given technological class

The analysis relied on patent data from the EPO-CESPRI database and an industry was classified as SM-I in the case of a negative and lower value for SCHUMP**,** whereas a positive and higher value would favoured the SM-II classification. To gain further confidence on the classification, Breschi et al. (2000) conducted an econometric analysis to investigate the relationship between the synthetic indicator SCHUMP and variables that proxied technological opportunity, appropriability and cumulativeness and the knowledge-base. The results provided additional motivation for the adopted classification approach. Nevertheless, it is important to stress that the use of innovation criteria based on patents require some caution because often play a strategic role that not necessarily an accurate reflection of the relevant innovative results.

Contrasts between regimes for the full population of firms

The research line mentioned above in (a) relates to the population of innovating firms. Van Dijk (2000, 2002) suggested exploring contrasts between the SM-I and SM-II regimes using structural and dynamic aspects in the context of the full population of firms as the next natural step in the research of technological regimes, For that purpose, he considered tests for the differences in means for a set of hypotheses summarised in Table 1 for the industries in Netherlands, keeping in mind previously mentioned caveat regarding reliance on the classification of industries for another country.

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In the present paper, we intend to consider both lines of research for the case of the Brazilian manufacturing industry by exploring multiple data sources that have not previously been explored in this context. Therefore, we intend to conduct a data intensive study that can provide the first attempt to fill a gap in the literature for developing countries but that also course does not rule out less coarse characterisations of technological regimes. For example, Leiponen and Drejer (2007) suggested that intra-regimes heterogeneities might deserve further investigation.

1. **Technological Regimes in Brazil: Empirical Analysis**
   1. - Data construction

The main data source for the present study was provided by a comprehensive survey on technological innovation in the context of Brazilian industry [Pesquisa de Inovação Tecnológica-PINTEC, Instituto Brasileiro de Geografia e Estatística-IBGE], which is conducted on a bi-annual basis on active firms with 10 or more employees whose main revenues associated with an extractive or manufacturing industry. The database was built from microdata, for the years 2000, 2003 and 2005[[3]](#footnote-3). It is worth noting that the questionnaire closely follows that of the Community Innovation Survey (CIS 1) that focuses on European countries. However, we do not face a micro-aggregation limitation in the Brazilian database. A complementary source was the annual industrial survey [Pesquisa Industrial Anual-PIA, Instituto Brasileiro de Geografia e Estatística-IBGE] which was matched with the previous database to construct several indicators. The data description will consider two steps of the analysis.

1. The classification of industries in terms of technological regimes: In this case, we considered a principal components procedure inspired by Breschi et al. (2000). However, it is important to highlight differences that pertain to the definition of innovating firms and the level of aggregation. Our study contrasts with previous studies on the definition of innovating firms by not exclusively relying on patent data, which reflects a data availability issue in the present study. Accordingly, we did not work with technological classes and yet we were able to consider industrial sectors that are classified at the 3-digits level (CNAE3). The criterion adopted for defining an innovating firm was the implementation of some process or product innovation or yet if the use of some intellectual property instrument (such as patent, secrecy, a license or a trademarks, etc.) during the survey period[[4]](#footnote-4). Using the sample of selected innovating firms, 3 indicators were considered for implementing the principal components analysis (PCA):

.**ENT**: approximated the entry of new innovators, by comparing the PINTEC surveys for 2000, 2003 and 2005, and identified the firms that first appeared as innovators in 2005 for each 3-digits sector. The indicator was then defined as the proportion of innovating firms relative to the total number of firms in the particular sector in 2005;

. **CONC**: measured the concentration of innovating firms in terms of revenue that accrued from innovative activities (process or product). This indicator was built upon firm-level data for the 2005 PINTEC from which we obtained the share of revenue attributed to innovative activities, and that information was then matched with data on total revenue for the same firms from the 2005 PIA. The combination of these two variables allowed us to create of what we call the "innovation revenue" for each 3-digits sector. Thus, we were able to generate firm-level data on innovation revenue. The related shares (si) could then be readily used to calculate the Herfindahl concentration index defined as H = Σi si2;

.**STAB**: indicated the hierarchical stability of innovators that aimed to approximate the degree of technological dynamism in the sector. To construct this indicator, we first identified the innovating firms in 2000 based on the PINTEC and then we determined the innovation revenue based on the procedure described in the previous item for 2000 and 2005, In cases of non-innovating firms we assigned zero revenue. The stability indicator then compared the ranking of innovation revenue in each 3-digits sector between the two years in terms of Spearman correlation coefficients. Given the small number of firms in some sectors, we considered only those where a significant correlation coefficient was obtained. Thus, starting from an initial sample of 112 sectors at the 3-digits level (comprising extractive and manufacturing industries) we ended with a final sample comprised of 69 sectors. The corresponding summary statistics for those indicators are presented in Table 2.

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Following the classification of industries in accordance with the technological regimes, Breschi et al. (2000) further investigated the adherence to factors that were supposed to represent the SM-I and SM-II regimes. In the present paper, we considered such a complementary analysis in terms of discriminant analysis which we will discuss later. The following variables constructed based upon the PINTEC were considered:

.**TECOP**: an indicator for technological opportunity that assessed how easily the innovations were likely to emerge in a given sector. The indicator was based on adding the responses provided by firms on the importance of available external sources of innovation. A larger value indicated greater technological opportunities;

. **APROP**: an indicator of appropriability that identified the degree of protection derived from intellectual property. It was obtained by adding the responses provided by innovating firms on questions related to the importance of patents and other intellectual property mechanisms to protect the innovation activities. This indicator was an inverse proxy, such that a smaller value was expected to reflect a greater appropriability;

.**CUMUL**: an indicator intended to identify the degree of dependence between innovation and past technological knowledge. The indicator was constructed by adding responses provided by firms with respect to the prevailing constancy with which undertook research and development. A larger value denoted a higher cumulativeness;

. **KBASE**: this indicator referred to the knowledge base and attempted to identify the extent to which the technological knowledge had a more generic or more applied dimension. For the innovating firms, we considered the share of employees that possessed an educational background related to generic and applied knowledge. For this category, we constructed two indicators. First, the indicator **BASIC** highlighted how generic the knowledge base was and was obtained based on the share of employees related to basic/generic sciences (chemistry, physics, biology, and mathematics). Second, the indicator **APPL** considered the proportion of employees with an educational background related to applied sciences (engineers, physicians, architects among others), The interpretation of the indicators was direct: the larger the value of the basic science (applied science) indicator the more generic (applied) be the technological knowledge

b) Inter-industry contrasts

Following Van Dijk (2000, 2002) it is possible to produce tests that highlight the contrasts between SM-I and SM-II. The tests allow us to infer whether it is statistically relevant to classify industries according to this methodology and to implement these tests we considered the entire sample and not only the innovating firms. To construct the variables used to test the differences between SM-I and SM-II, we worked with the universe of all firms aggregated into 4-digits sectors (CNAE4)[[5]](#footnote-5) and instead of using the PINTEC database, we used the Relação Anual de Informações Sociais (RAIS, Ministry of Labour and Employment, Brazil), that is an annual census type survey over a 10 years period (1995-2005).The variables were used in the tests in Section 3 and are described next. The tests were implemented for the sectoral mean values across the 10 years span.

.**share of small firms**: measured in terms of the share of small firms of the total sector. It is important to emphasise two points for the construction of this variable, first, that we considered small firms as those that had more than 5 and less than 100 employees, second, when we calculated the share of small firms in a sector, we used the number of employees rather than the number of firms;

.**Industrial concentration**: measured by the Herfindahl index at the 4-digits level obtained through specially requested tabulation from the PIA-IBGE;

**.Suboptimal scale:** measured as the proportion of employment in firms that was below the minimum efficient scale (MES). This reference was approximated by the median size of firms as motivated, for example, by Sutton (1997). It was an inverse measure of barriers to entry and the necessary data was obtained from the RAIS;

**. Capital intensity:** measured by capital stock divided by revenue. The capital stock was obtained through the perpetual inventory method by relying on different years of the PIA survey whereas the sectoral data for revenues were readily available from the same source.[[6]](#footnote-6) Note that we were able to construct this variable at the 3-digits level;

**.Profit rate:** calculated by dividing the gross value of production (minus operating expenses) by the total revenue of the sector at the 4-digits level;

**. Labour productivity:** calculated as the gross production value divided by the total number of employees as obtained from the PIA at the 4-digits level;

**. Entry rate:** measured as the number of new firms relative to the previously prevailing stock. This variable was calculated at the 4-digits level upon data from the RAIS;[[7]](#footnote-7)

**. Exit rate:** measured as an analogous calculation for exiting firms;

**. Turbulence:** calculated as the average of the annual changes in the proportion of employees (relative to total employment in the sector) for the firms that were active throughout the sample period (1995 - 2005);

* 1. – Classification of technological regimes: empirical results

Initially, we focus on the principal components analysis (PCA) based on the ENT, CONC and STAB indicators. As indicated by Table 3, we can justify the sole retention of the first principal component (henceforth named SCHUMP) which accounts for 53,3% of the data variance. The relevant factor loadings are presented in Table 4.

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The factor loadings for the first principal component appear to be consistent with the theoretical foundations because ENT had a negative sign, whereas the loadings for CONC and STAB were positive. The inspection of the signs of the factor score coefficients for SCHUMP for each particular sector allows us to classify the sectors according to the technological regimes. A negative sign indicated a SM-I regime and a positive sign indicated an SM-II regime. Thus, we were able to classify 69 3-digits sectors in terms of SM-I and SM-II regimes as shown in Appendix 2.

However, it is important to provide additional confidence in the classification system by considering the role of the variables related to technological opportunity (**TECOP),** appropriability (**APROP),** cumulativeness **(CUMUL)** andknowledge base (either BASIC or APPL) as previously discussed. Breschi et al. (2000) undertook a regression analysis with their analogous explanatory variables. In the present paper, we considered the multivariate statistical technique of linear discriminant analysis (LDA). Given a sample divided into groups (SM-I and SM-II in the present application), we could obtain discriminant functions in accordance with the criteria of maximising the discrimination between groups and minimizing the heterogeneity within the groups. [See Manly (1994) for an overview]. Discriminant functions are sensitive to the scale of the considered variables. Thus, we considered standardised variables in terms of subtraction by the mean and division by the standard deviation.

In the present application, the LDA approach can be useful as a type of validation of the adopted classification, with 2 groups and 3 indicators we had a single discriminant function. The discriminating effects of the aforementioned indicators on the innovation patterns (as summarised by the technological regimes) were considered in terms of the procedures outlined by Morrison (1969). In that sense, if, (where is the coefficient of the discriminant function associated with indicator *j* andto the innovation pattern i)the indicator favored an SM-I regime. Conversely, if , the indicator favored an SM-II regime. Next, Table 5 presents the relevant results.

Inspection of the table reveals some inconsistencies with the theory because the discriminant coefficient associated with CUMUL in the SM-I sectors indicates that a higher value for that indicator would favor the probability of classification as SM-I when one would expect the opposite result. Therefore, there was some evidence of classification errors. To further assess such errors, we calculated discriminating scores for each 3-digits sector and based on a criterion motivated by Morrison (1969), we adopted the classification rule that , would suggest classification as SM-I.

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In fact, misclassifications appeared to be non-negligible. It was possible to identify 3 out of 14 SM-I sectors that were misclassified. Similarly, 7 out of the 55 SM-II sectors appeared to involve misclassifications. After adjusting the classifications as outlined, we obtained the discriminant function, and the related results are presented in Table 6:

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The results show consistency with the expected economic fundamentals discussed by Breschi et al. (2000). In particular, sectors with greater technological opportunities are classified as SM-I whereas sectors with greater appropriability and cumulativeness were be classified as SM-II. A final verification of the separation power associated with the discriminant function is warranted. We calculated the eigenvalue and the canonical correlation, which is a synthetic measure of association between groups of variables considering linear combinations of indicators in each group to maximize the related correlation. The evidence is summarised next in Table 7.

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The results show that the SM-I and SM-II patterns were well discriminated by the corresponding function given the observed high values for the eigenvalue and the canonical correlation and the high significance indicated by the obtained p-value. Moreover, the Mahalanobis distance had a value of 12.238 with a corresponding statistic F(5,63) = 30.620 [p-value: 0.000] which therefore provided evidence of a significant distance (difference) between the mean vectors of the SM-I and SM-II patterns.

Finally, to further confirm such differences in means, we calculated the Wilks' lambda test, which yield a statistic of 0.2824, with a p-value of 0.000. This result showed that the previous evidence based on the different tests favoured the rejection of the null hypothesis and thus delineated the significant mean discrepancies between the SM-I and SM-II sectors.

It is worth considering an initial comparison with the classifications obtained by Breschi et al. (2000) for Italy, Germany and the United Kingdom and by Mesa and Gayo (1999) for Spain[[8]](#footnote-8). For example, it is possible to observe that the sectors related to textiles, electrical equipment, machines and equipment’s in general appeared to follow an SM-I pattern, and in the other hand, sectors related to chemicals, pharmaceuticals, oil and gas, and vehicle manufacturing appear to conform to a SM-II pattern. In the Brazilian case, similar patterns emerged in those sectors, however, a salient contrast was provided in the case of pharmaceuticals that were classified as SM-I. That result could reflect the dominance of subsidiaries of multinational firms as the important R&D efforts are likely to take place in their headquarters facilities abroad. The importance of Brazilian firms in that industry only started increasing in the 2000s with the dissemination of generic drugs, and in any case it refers to established active principles and therefore does not involve important innovative efforts.

Additionally, sectors that involve products derived from pulp and paper that were classified as SM-I in previous studies are classified as SM-II in the Brazilian case. A distinguishing characteristic in the case of pulp and paper is that Brazil has a significant competitive advantage, because it has soil conditions, climate and insolation levels that favour the growth of natural and planted forests.

Brazilian pulp and paper companies are characterised as being integrated from the beginning of the chain, because as the companies they control have both planted forests that supply the pulp for paper production, and produce the paper to be sold. More specifically, the pulp sector is, as presented by Dores et al. (2007, p.122), highly capital-intensive, with high efficiency and minimal scales, and displaying a cyclical pricing behaviour. Another relevant characteristic of this sector is that it is highly concentrated, with the 7 largest companies, in 2005, accounting for over 90% of the production, according to data from Dores et al. (2007). Thus, we can summarise the characteristics of this sector as capital-intensive, with high minimal scale, and with production concentrated in a few large companies which are much more SM-II characteristics than SM-I, so the change proposed by the LDA seems to be appropriate.

Following the classifications of sectors according to technological regimes, the next natural step is to explore structural contrasts between the sectors operating under the SM-I and SM-II regimes. For that purpose, the next section considers tests of different hypotheses that were advanced by Van Dijk (2000, 2002) for the totality of firms and not only the innovating firms.

**4. Technological Regimes and Inter-Industry Heterogeneity**

4.1 – Relevant statistical tests: a brief digression

Van Dijk (2000, 2002) explored inter-industry contrasts for industrial sectors classified in terms of technological regimes. This analysis considers the totality of the population as a reference and not only a sample of innovating firms. The related hypotheses were been summarised in table 1 and will be considered in the next sub-section.

The referred empirical approach made use of tests for difference in means of the form[[9]](#footnote-9):



The null hypothesis of the test was the equality of means across the different groups and the statistic is distributed as a Student t with (nx+ny – 2) degrees of freedom. However, this version for unequal sample sizes assumes equal variances. If such requirement is not tenable, we must rely on expression (2) of the test, known as Welch´s t test:



Under the null hypothesis the relevant degrees of freedom are obtained in accordance with the Satterthwaite formula[[10]](#footnote-10). Therefore, it is important to assess the constancy of the variances prior to the application of the test for the difference in means to determine the appropriate version. For that purpose, we considered Lavene´s test as properly outlined by Forsythe (1974). All of the tests were implemented with Stata 11.0.

4.2 – Empirical results

The one-tailed tests for the difference in means related to the different hypotheses listed in Table 1 are presented in Table 8. Due to data availability restrictions we were not able to test the previously mentioned hypotheses 6 and 9.

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Previous analogous tests, implemented by Van Dijk (2000, 2002) for the Netherlands, provided strong support for the various hypotheses. However, we must be cautions given that the classifications used in those studies were based on evidence obtained by Malerba et al. (1995) for a different country. Thus, the tests presented in this sub-section attempt to partially fill a gap in the literature in the context of an emerging economy, and to advance the works of Van Dijk *op. cit.*, by attempting to implement a proper methodology to classify the industrial sectors, while respecting the characteristics of the Brazilian industry.

The test results showed that in the present study, the contrasts between SM-I and SM-II were not overly sharp. In fact, significant differences could be observed for only two hypotheses. The share of small firms was higher in SM-I industries than in SM-II industries (hip. 1) and profit rates were lower in SM-I industries than in SM-II industries.

The somewhat weak results pertaining to differences between SM-I and SM-II sectors can be analysed from two perspectives. On the empirical front, beyond improving the measurement of some variables it would be worth exploring the relationship between technological classes and industrial sectors. On the other hand, we cannot rule out important specificities in the Brazilian industry that could lead to sectoral patterns of innovation that do not reflect the same standards of developed countries.

Guidolin (2007) sought to classify Brazilian industry into technological regimes as proposed by Marsali (2002). In that study the author showed that the technological regimes observed in Brazilian industry differed from those observed for developed countries mainly because of the characteristics of Brazilian innovative process, which are different from those prevailing for developed countries.

These results demonstrate significant differences between the types of analysis developed for the Brazilian industry and those for developed countries, because of the characteristics of the industry and more specifically to the Brazilian industrialisation process. Viotti (2002) highlighted that for the typical Brazilian industries there has been a strategic focus on the acquisition of technology via foreign direct investment, which may have inhibited the development of technology internally. These specific characteristics make most attempts to classify the Brazilian industry according to pre-established standards for developed countries questionable.

**5. Final Comments**

This paper aimed to assess technological regimes in the context of the Brazilian manufacturing industry. The classification procedure for identifying SM-I and SM-II technological regimes followed the lead of Brescia et al. (2000) though with different criteria for defining innovating firms. The obtained results were somewhat intuitive in the majority of cases and some salient classification discrepancies with developed countries emerged in the cases of pharmaceuticals and the paper and cellulose sectors. However, specific attributes of those sectors in the Brazilian case made those contrasts as not surprising. The validation of the classification by means of discriminant analysis provided additional confidence in the obtained results.

Finally, a set of hypotheses advanced by Van Dijk (2000, 2002) were made to contrast SM-I and SM-II sectors for the totality of firms. The results obtained were weaker than those obtained for the Netherlands. Specifically, the share of small firms was higher in SM-I industries than in SM-II industries and in SM-I industries, and in SM-I industries, profit rates were lower than in SM-II industries. Altogether, the evidence seemed to indicate less clear-cut contrasts between sectors under the two technological regimes which in part reflect the low technological efforts undertaken in a large number of industrial sectors in Brazil.

Possible avenues for future research involve a fine tuning within technological regimes along the lines of Leiponen and Drejer (2007) and such a study should be considered if the necessary data is available.

Future research could also involve measurements for some of the variables, for example in the case of productivity.

**Appendix 1: Perpetual Inventory Method**

The stock of the capital variable, used as a component of the capital intensity variable, was built using the perpetual inventory method. This method allows us to estimate the capital stock, starting from an initial depreciated capital stock and then summing the acquisitions (investments) in machinery and equipment and subtracting the losses of fixed assets. This method can be summarised in terms of the following expression:



where and , denote, the capital stock of sector *j*  in the *t+1* and *t* periods respectively; is the investment of sector *j* in period *t*; Sj,t represents the scrapping of capital stock, and is the average rate of depreciation, which we assumed to be equal to 9%. , based on studies of Alves and Silva (2008) and Ferreira & Guillién (2004).

As shown by the above equation it was necessary to define an initial stock of capital to enable us to estimate the remaining periods in the sample. The 1995 stock of capital was set as the initial point because that year was the last in which the IBGE disclosed an estimated stock of capital as measured by total fixed assets. Consequently, after 1995 the capital stock data were obtained recursively by adding the net investments made in the current year (investments in machinery and equipment less scrapping of fixed assets) to the previous year´s deflated capital stock, year. The application of this method allowed to estimate the stock of capital for the period from 1995 to 2005, enabling us to build the capital intensity variable.

**Appendix 2**

INSERT APPENDIX 2 ABOUT HERE

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**Appendix 2**

Industrial sectors classified according to their technological regimes

|  |  |  |
| --- | --- | --- |
| **CNAE** | **Sectors** | **SCHUMP** |
| ***Schumpeter Mark I*** | | |
| **152** | PROCESSING, PRESERVATION AND PRODUCTION OF CANNED FRUITS, VEGETABLES AND OTHER VEGETABLES | -0,113 |
| **154** | DAIRY \* | -0,114 |
| **155** | GRIND, starch products MANUFACTURING AND BALANCED DIETS FOR ANIMALS | -0,123 |
| **158** | MANUFACTURE OF OTHER FOOD PRODUCTS \* | -0,047 |
| **176** | MANUFACTURE OF ARTIFACTS FROM TEXTILE FABRIC - EXCEPT APPAREL - TEXTILE AND OTHER ITEMS | -0,043 |
| **212** | MANUFACTURE OF PAPER, PLAIN CARDBOARD, CARDBOARD AND CARD | -0,031 |
| **222** | PRINTING AND RELATED SERVICES FOR THIRD | -0,066 |
| **242** | ORGANIC CHEMICALS MANUFACTURING \* | -0,018 |
| **245** | MANUFACTURE OF PHARMACEUTICAL PRODUCTS | -0,16 |
| **246** | MANUFACTURE OF AGRICULTURAL DEFENSIVE | -0,007 |
| **247** | MANUFACTURE OF SOAPS, DETERGENT, CLEANING PRODUCTS AND ARTICLES OF PERFUME \* | -0,042 |
| **248** | MANUFACTURE OF PAINTS, VARNISH, ENAMELS, LAKES AND RELATED PRODUCTS | -0,072 |
| **249** | MANUFACTURE OF CHEMICALS AND PREPARATIONS MISCELLANEOUS | -0,166 |
| **251** | MANUFACTURE OF RUBBER | -0,04 |
| **264** | MANUFACTURE OF CERAMIC \* | -0,01 |
| **271** | PRODUCTION OF PIG IRON and ferroalloy \* | -0,056 |
| **275** | FOUNDRY | -0,118 |
| **282** | FABRICATION OF TANKS, BOILERS AND METAL RESERVOIRS | -0,143 |
| **283** | Forging, STAMPING, POWDER METALLURGY AND METAL PROCESSING SERVICES \* | -0,105 |
| **289** | MANUFACTURE OF MISCELLANEOUS METAL | -0,096 |
| **291** | MANUFACTURE OF ENGINES, PUMPS, COMPRESSORS AND TRANSMISSION EQUIPMENT | -0,103 |
| **292** | MANUFACTURE OF MACHINERY AND EQUIPMENT FOR GENERAL USE | -0,147 |
| **293** | MANUFACTURE OF TRACTOR AND MACHINERY AND EQUIPMENT FOR AGRICULTURE, AND POULTRY PRODUCTS PROCUREMENT OF ANIMALS \* | -0,128 |
| **296** | MANUFACTURE OF MACHINERY AND EQUIPMENT OTHER SPECIFIC USE | -0,086 |
| **302** | MANUFACTURE OF MACHINERY AND EQUIPMENT FOR ELECTRONIC SYSTEMS DATA PROCESSING | -0,062 |
| **313** | MANUFACTURE OF WIRES, CABLES AND ELECTRIC LEADS ISOLATED | -0,08 |
| **315** | MANUFACTURE OF LAMPS AND LIGHTING EQUIPMENT | -0,092 |
| **316** | MANUFACTURE OF ELECTRICAL EQUIPMENT FOR VEHICLES - EXCEPT BATTERIES | -0,036 |
| **321** | MANUFACTURE OF BASIC ELECTRONIC MATERIAL \* | -0,005 |
| **323** | MANUFACTURE OF RADIO AND TELEVISION RECEIVERS AND PLAYBACK, RECORDING OR AMPLIFICATION OF SOUND AND VIDEO \* | -0,095 |
| **331** | MANUFACTURING EQUIPMENT AND TOOLS FOR MEDICAL USES-HOSPITAL, AND DENTAL LABORATORIES AND APPARATUS ORTHOPEDIC | -0,131 |
| **332** | MANUFACTURING EQUIPMENT AND MEASURING INSTRUMENTS, AND CONTROL TEST - CONTROL EQUIPMENT EXCEPT INDUSTRIAL PROCESSES | -0,109 |
| **333** | MANUFACTURE OF MACHINERY AND EQUIPMENT ELECTRONIC SYSTEMS INDUSTRIAL AUTOMATION AND DEDICATED TO CONTROL THE PRODUCTION PROCESS | -0,117 |
| **334** | MANUFACTURING EQUIPMENT, MATERIALS AND OPTICAL INSTRUMENTS, PHOTOGRAPHIC AND FILM | -0,054 |
| **343** | MANUFACTURE OF CABINS, CARTS AND TRAILERS | -0,060 |
| **344** | MANUFACTURE OF PARTS AND ACCESSORIES FOR AUTOMOTIVE VEHICLES | -0,111 |
|  | | |
|  | | |

Table 1

|  |  |
| --- | --- |
| Technological regimes: general contrasts - hypotheses | |
| **1** | The share of small firms is higher in SM-I industries than in SM-II industries |
| **2** | Concentration levels are lower SM-I industries than in SM-II industries |
| **3** | Entry barriers are lower in SM-I industries than in SM-II industries |
| **4** | Capital intensity is lower in SM-I industries than in SM-II industries |
| **5** | In SM-I industries, profit rates are lower than in SM-II industries |
| **6** | In SM-I industries, entrants are more productive than incumbents, whereas in SM-II industries incumbents are more productive than entrants |
| **7** | In SM-I industries, the amount of turnover due to entry and exit is higher than in SM-II industries |
| **8** | The turbulence within the group of incumbent firms is higher in SM-I industries than in SM-II industries |
| **9** | The contribution of the entry and exit process to productivity growth is higher in SM-I industries than in SM-II industries, and vice versa for incumbents’ contributions |

Source: Van Dijk (2002)

Table 2

Summary statistics – indicators for regime classification

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable** | **Obs** | **Mean** | **Std. Dev.** | **Min** | **Max** |
| **stab** | 69 | 0,225 | 0,143 | 0,016 | 0,775 |
| **entry** | 69 | 0,278 | 0,077 | 0,091 | 0,435 |
| **conc** | 69 | 0,337 | 0,250 | 0,062 | 1,000 |
| **schmp** | 69 | 0,042 | 0,189 | 0,168 | 0,933 |

Table 3

Principal components - communalities (no. of obs: 69)

|  |  |  |  |
| --- | --- | --- | --- |
| **Components** | **Eigenvalue** | **Proportion of variance** | **Cummulative proportion of variance** |
| **1** | 1.597 | 0.533 | 0.533 |
| **2** | 0.707 | 0.236 | 0.768 |
| **3** | 0.695 | 0.232 | 1.000 |

Table 4

Principal components - factor loadings (no. of obs: 69)

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Comp1** | **Comp2** | **Comp3** |
| **ENT** | -0.576 | 0.683 | 0.450 |
| **CONC** | 0.575 | 0.729 | -0.371 |
| **STAB** | 0.581 | -0.045 | 0.813 |

Table 5

Discriminant coefficients - initial analysis

|  |  |  |  |
| --- | --- | --- | --- |
| **Indicators** |  |  |  |
| **TECOP** | 4.140 | 1.999 | 2.141 |
| **APROP** | -1.153 | -0.418 | -0.735 |
| **CUMUL** | 2.316 | 2.279 | 0.037 |
| **BASIC** | -0.148 | -0.496 | 0.348 |
| **APPL** | 0.760 | -0.034 | 0.794 |
| **CONSTANT** | -5.857 | -2.543 | -3.314 |

Table 6

Discriminant coefficients – adjusted sectors

|  |  |  |  |
| --- | --- | --- | --- |
| **Indicators** |  |  |  |
| **TECOP** | 9.618 | 3.092 | 6.526 |
| **APROP** | -2.036 | -0.623 | -1.413 |
| **CUMUL** | 0.984 | 2.055 | -1.070 |
| **BASIC** | 3.109 | 0.085 | 3.024 |
| **APPL** | 2.756 | 0.366 | 2.390 |
| **CONSTANT** | -13.788 | -2.804 | -10.983 |

Table 7

Canonical correlation and eigenvalues associated to the discriminant function

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Canonical correlation** | **Eigenvalue** | **Likelihood ratio** | **F (5,63) statistic** | **p-value** |
| 0.847 | 2.541 | 0.282 | 32.02 | 0.000 |

Note: the null hypothesis assumes that the canonical correlation is zero

Table 8

One-tailed tests for difference in means

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Hypotheses** | | **Test statistic** | **Mean (std. error) SM-I** | **Mean (std. error) SM-II** | **p-value  (diff. > 0)** | **p-value  (diff. < 0)** |
| **1** | The share of small firms is higher in SM-I industries than in SM-II industries | 3,235 | 0.576 (0.015) | 0.502 ( 0,017) | 0.001 | - |
| **2** | Concentration levels are lower SM-I industries than in SM-II industries | -1.493 (\*) | 0.169 (0.181) | 0.208 (0.174) | - | 0.069 |
| **3** | Entry barriers are lower in SM-I industries than in SM-II industries | -1.125 (\*) | 0.086 (0.004) | 0.094 (0.006) | 0.869 | - |
| **4** | Capital intensity is lower in SM-I industries than in SM-II industries | -1.078 (\*) | 0.156 (0.035) | 0,218 (0.178) | - | 0.144 |
| **5** | In SM-I industries, profit rates are lower than in SM-II industries | -2.776 | 0.352 (0.012) | 0.423 (0.250) | - | 0.003 |
| **7** | Entry rate is larger in SM-I industries than in SM-II industries | 0.232 (\*) | 0.051 (0;002) | 0.050 (0.002) | 0.408 | - |
| Exit rate is larger in SM-I industries than in SM-II industries | -1.102 | 0.054 (0.002) | 0.571 (0.003) | 0.864 | - |
| **8** | The turbulence within the group of incumbent firms is higher in SM-I industries than in SM-II industries | 0.258 (\*) | 0.147 (0.007) | 0.145 (0.006) | 0.398 | - |
|  | | | | | | |

(\*) indicates acceptance of the equality of variances in accordance to Lavene´s test considered at the 5 % significance level. In those cases one considered the t test for differences in means in the version indicated in expression (1) whereas in other cases in the version from expression (2).

1. See Malerba & Orsenigo (1995) for an overview. [↑](#footnote-ref-1)
2. See Manly (1994) for an overview. [↑](#footnote-ref-2)
3. The authors are grateful to the IBGE for access to the microdata of PINTEC, which are subject to confidentiality and are provided solely for the purpose of this academic research. [↑](#footnote-ref-3)
4. It is important to note that even though PINTEC does not provide any information about the number or classification of a firm´s patent, it does answer whether the firm used any type of intellectual property, such as patents. [↑](#footnote-ref-4)
5. We assumed that the classification of the 4-digits industries into SM-I or SM-II followed the broader related 3-digits classifications [↑](#footnote-ref-5)
6. Additional details on the construction of the capital stock data are discussed in Appendix 2. [↑](#footnote-ref-6)
7. The identification of entering and exiting firms required identification codes for comparison across successive years and once again we had special access to the restricted microdata. [↑](#footnote-ref-7)
8. These authors focused on patent indicators to define innovating firms and thus worked with technological classes. Therefore, a straightforward comparison with the Brazilian case was not readily available but some salient results can be noted. [↑](#footnote-ref-8)
9. See Dixon and Massey (1983) for an introduction to those tests. [↑](#footnote-ref-9)
10. Where v = []2/[ ()2/(nx-1)+ ()2/(ny-1)] [↑](#footnote-ref-10)