TOWARDS A NEW TAXONOMY OF TECHNOLOGICAL REGIMES IN DEVELOPING ECONOMIES: THE CASE OF BRAZILIAN MANUFACTURING*

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ABSTRACT
This paper explores the characteristics of innovative activities under different technological regimes in Brazilian industries. Using evidence from the Survey of Technological Innovation 2005 a new classification of technological regimes is proposed. Our results confirm the existence of significant differences in the innovation dynamics with respect to developed countries.

SUBTHEME: triple helix in developing countries

KEYWORDS: innovation; technological regimes; Brazilian industries; industrial policy

1. Introduction

Innovation is an important driving force behind the dynamics of firm competition in an industry. However, the ways in which innovation and technology occur in industries may be quite different amongst industries and countries. It is recognized that most of the knowledge applied by firms in innovation is appropriate for specific applications. So, the notion of *technological regimes* may be a useful concept for studying the differences in innovative activities.

The concept of technological regime has been introduced by Nelson and Winter (1982) and guides the actors involved in innovative activities towards developing heuristics, tactics, and objectives to solve a particular problem.

The literature about technological regimes considers only developed countries while grouping their industrial sectors within technological regimes. However, developing countries present a different dynamic in innovation and technological evolution so that the industrial sectors corresponding to the technological regimes may be different from the industrial sectors in developed countries' technological regimes.

The aim of this paper is to give insights into the characteristics of technological regimes in developing countries like Brazil, creating a new taxonomy. Using Survey of

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Technological Innovation 2005 (PINTEC in Portuguese) of Brazilian industrial firms, a multivariate analysis is performed in order to classify the industrial sectors into technological regimes. The results demonstrated that there are different technological regimes in Brazil, due to differences in industrial dynamics in this country, when compared to the dynamics of industries in developed countries.

This paper intends to contribute to a better understanding of the differences between developed and developing countries in the dynamic of industrial evolution and technological change and of the role of technological regimes in a developing country like Brazil; moreover, this work creates new groups of industrial sectors, analysed by the technological dependency/independency point of view, that suits better to the characteristics of a developing country. The main implication of grouping industrial sectors in technological regimes is that, by organizing inter-industry differences into a few invariant categories, it helps the government to elaborate an industrial policy aiming to improve industries and to foster innovative activities.

The paper is organized as follows. In section 2 theoretical and empirical studies of how industrial dynamics vary according to technological regimes are reviewed. Section 3 describes the data used in the empirical analysis and the structure of the test. Section 4 shows the empirical findings. Section 5 provides some concluding remarks.

2. Technological regimes

The industry evolution varies from industry to industry due to the innovative activity. It depends on the underlying knowledge conditions, defined by Nelson and Winter (1982) as *technological regimes*. They distinguished two technological regimes – the entrepreneurial regime and the routinized regime: ‘An entrepreneurial regime is one that is favourable to innovative entry and unfavourable to innovative activity by established firms; a routinized regime is one in which the conditions are the other way around’ (Winter, 1984, p. 297).

Malerba and Orsenigo (1997) define technological regime in terms of opportunity and appropriability conditions, degrees of cumulativeness of technological knowledge, and characteristics of the relevant knowledge base. Using the European Patent Office database of patent applications of six developed countries, they found that two distinct groups of technologies emerge, which were labelled as Schumpeter Mark I (creative destruction) and Schumpeter Mark II (creative accumulation). Both groups were found to be relatively invariant across the countries examined.

These two distinct regimes are derived from Schumpeter, who indicated that the character of innovation is related to the historical phases of economic development. Schumpeter Mark I is characterized by the technological ease of entry and where new firms are responsible for the innovative activities. This regime refers to *Theory of Economic Development* (1911). On the other hand, Schumpeter Mark II is characterized by the presence of barriers to entry for new innovators and by the dominance of a few large firms. This regime refers to *Capitalism, Socialism and Democracy* (1942).

Breschi, Malerba and Orsenigo (2000) proposed that the pattern of innovative activity is industry specific and is the outcome of the technological regimes. They estimated the relationships between Schumpeterian patterns of innovation – defined by concentration of innovative activities, stability in the hierarchy of innovators and technological entry and exit – and the variables defining technological regimes.

They define a technological regime as a combination of four factors: technological opportunities, appropriability of innovations, cumulativeness of technical advances, properties of knowledge base. Technological opportunities are defined as the likelihood of innovating given the investment in search. Appropriability of innovations indicates the level of difficulty in imitating innovations and the possibilities of profit from innovative activities. Cumulativeness of technical advances indicates that innovations are gradual improvements on the original one, based on past knowledge and innovative activities. The properties of the knowledge base are related to its degrees of specificity, tacitness, complexity and independence.

The results showed a non-linear relationship between Schumpeterian patterns of innovation and the relevance of science for innovation. These results suggest that technological regimes have a more complex character than Nelson and Winter's model implied.

In this way, Pavitt's model (1984) classified firms into three categories: supplier dominated; production intensive and science based. This model focuses on the determinants and directions of technological trajectories and defines the taxonomy of the organizational and structural traits of innovative firms. This classification was tested by using data on innovation counts for Britain from the SPRU innovation database.

Marsili and Verspagen (2001) refine Pavitt's taxonomy, distinguishing five regimes: science-based regime; fundamental processes regime; complex systems regime; product-engineering regime and continuous processes regime, in order to test the robustness of the classification in the case of Dutch manufacturing. When grouping industrial sectors into technological regimes, they expressed the properties of innovative processes by the level of technological opportunity; the level of technological entry barriers as a function of the specificity of knowledge; and the degree of cumulativeness.

Even though there are a large number of empirical studies relating innovative activities to technological regimes, they treat only the cases of developed countries. When Marsili and Verspagen's exercise is replicated to Brazilian industrial sectors, the technological regimes found show no difference amongst each other with respect to the indicators built. Therefore, it is not possible to infer whether or not the relationship between innovative activity and technological regimes is the same to developing countries like Brazil.

Cimoli and Porcile (2007, 2010) argue that developing countries presents different economic trajectories with respect to the developed countries due to the existence of technological asymmetries. In their models, the technological policy affects dynamics of structural change and of technological learning, and those are the factors that influence economic growth. A long run growth is only guaranteed if the country presents technological capabilities to adjust to changing technologies and markets.

3. The data and the structure of the test

The Survey of Technological Innovation is conducted by the Brazilian Institute of Geography and Statistics with support of the Research and Projects Financing and of the Ministry of Science and Technology. The objective of the survey is to construct national and regional indicators of technological innovation activities of Brazilian industrial firms with 10 or more employees. These indicators are constructed following international methodological patterns, such as Oslo Manual and CIS III, making it possible to compare with data of other countries.

The survey does not provide access to variables of appropriability of innovations, cumulativeness of technical advances and technological opportunities, which were used in the empirical analysis of Malerba and Orsenigo (1997). Instead, it includes topics such as the efforts made to innovate; results of the innovative process; identification of the influence of the innovations in the performance of the enterprises; sources of information and relations of co-operation established with other organizations; support of the government to the innovative activities; and identification of the problems and obstacles for the implementation of innovations. These topics result in approximately 164 variables useful in the empirical analysis of this paper.

Unfortunately, it is not possible to assess data from the individual firms. Instead, the empirical test is carried out at the two-digit level, grouping industries in 27 sectors.

Given the number of variables considered, Factor Analysis of the Principal Components was used to reduce the dimension of the data matrix, which is achieved through linear combinations. This analysis allows us to model the relevant information as coming from a limited number of latent factors.

The factors found were used to group industrial sectors through the Cluster Analysis. The objective of this analysis is to build subgroups or clusters of individuals. These clusters should be as homogeneous as possible and the differences among the various groups as large as possible. In this empirical analysis, the clusters found help in the characterization of the technological regimes.

4. Empirical findings

As mentioned above, 164 variables were considered in the empirical analysis. Using the Principal Component extraction method, all the variables presented high communalities values.

In order to select the number of factors to retain in the analysis, the Kaiser criterion was used. According to this criterion, the factors selected have to present eigenvalues higher than 1, which resulted in 13 factors explaining 97% of total variance, as showed in Table 1.

Table 1 – Total variance explained and the number of factors to consider

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	101,585	61,942	61,942	101,585	61,942	61,942	73,042	44,538	44,538
2	24,013	14,642	76,584	24,013	14,642	76,584	43,341	26,428	70,965
3	7,748	4,725	81,309	7,748	4,725	81,309	13,020	7,939	78,904
4	4,667	2,846	84,154	4,667	2,846	84,154	4,991	3,043	81,948
5	3,770	2,299	86,453	3,770	2,299	86,453	4,798	2,926	84,874
6	3,524	2,149	88,602	3,524	2,149	88,602	3,078	1,877	86,750
7	3,071	1,872	90,474	3,071	1,872	90,474	3,019	1,841	88,591
8	2,387	1,455	91,930	2,387	1,455	91,930	3,003	1,831	90,422
9	2,176	1,327	93,256	2,176	1,327	93,256	2,915	1,777	92,200
10	2,083	1,270	94,527	2,083	1,270	94,527	2,461	1,501	93,700
11	1,798	1,097	95,623	1,798	1,097	95,623	2,149	1,310	95,010
12	1,398	,852	96,476	1,398	,852	96,476	1,954	1,192	96,202
13	1,264	,771	97,246	1,264	,771	97,246	1,712	1,044	97,246
14	,966	,589	97,835						
.	.	.	.						
.	.	.	.						
.	.	.	.						
164	-4,340E-15	-2,646E-15	100,000						

Source: Author's estimation based on PINTEC 2005

After using the varimax rotation method and considering loadings higher than 0.5 as significant (see Appendix), the latent dimensions found can be described as:

- Factor 1: *Innovation Index*
- Factor 2: *Cooperation* – composed by cooperation with Brazilian users, competitors, organizations and universities; and cooperation with international suppliers. In this latent variable, cooperation leads to new products and new processes to the firm and to new products to the domestic market.
- Factor 3: *International Sources of Information* – composed by information from international universities, consultancy, competitors and organizations of professional training, leading to new products and to new processes in terms of international market.
- Factor 4: *R&D Cooperation* – cooperation with international universities and Brazilian organizations of professional training and technical support. In this factor, the object of cooperation is R&D and tests on new products.

- Factor 5: *International Professional Training and Technical Support* – cooperation with international organizations of professional training and technical support.
- Factor 6: *Internal R&D* – composed by the number of people employed in the R&D department.
- Factor 7: *Public Financing to R&D* – the main source on R&D financing is the public sector.
- Factor 8: *Internal Financing* – to R&D and other innovative activities
- Factor 9: *Product Innovation* – incremental innovation in new products to the international market
- Factor 10: *Public Financing to Innovative Activities* – financing of innovative activities except R&D from public banks.
- Factor 11: *Consultancy on R&D* – cooperation with consultancy firms on R&D
- Factor 12: *Information on International Professional Training and Technical Support* – information from international organizations of professional training and technical support.
- Factor 13: *Information from Users in International Market*.

Factor 11 did not present loadings higher than 0.5.

These latent variables can be first divided in two main groups: one composed by factor 1 and one group composed by the other factors. Factor 1 might contain variables which indicates the existence of more autonomy from technology and financing relatively to the other factors, since it is significant only to the most autonomous clusters created, as showed in the following steps of this analysis. These latent variables indicates the existence of a strong relation with the international market, showing that the Brazilian industrial sectors are dependent on technology developed in other countries.

However, it is difficult to characterize factor 1, since it is composed by 101 distinct variables. So, we performed another factor analysis, in order to better characterize factor 1, using the same variables that constitute this factor.

Again, following Kaiser criterion, 6 factors were found (see Table 2). After using the varimax rotation method and considering as significant loadings higher than 0.5, we have:

- *Impact of Innovative Activities and Importance of the Sources of Information*: composed by the high degree of impact of innovative activities reducing the use of resources and reducing production costs; and by the high degree of importance of the sources of information used.
- *Cooperation with Brazilian Organizations*: composed by relations of cooperation with Brazilian suppliers, organizations of professional training and technical support, and users.

- *International Sources of Information*: composed by information from international suppliers, fairs, conferences and specialized publications.
- *Obstacles to Innovate*: composed by the high degree of importance of lack of information on technology and markets and of firm's difficulties in adequate to regulation.
- *Private Financing on R&D*: use of resources from private organization to perform R&D activities.
- *Reduction of Water Consume*: high impact of the innovative activity through reduction of water consume.

Table 2 – Total variance explained and the number of factors to consider

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	81,076	81,076	81,076	81,076	81,076	81,076	40,174	40,174	40,174
2	6,726	6,726	87,802	6,726	6,726	87,802	21,401	21,401	61,576
3	2,363	2,363	90,164	2,363	2,363	90,164	15,384	15,384	76,960
4	2,310	2,310	92,474	2,310	2,310	92,474	15,274	15,274	92,234
5	1,420	1,420	93,895	1,420	1,420	93,895	1,555	1,555	93,789
6	1,053	1,053	94,948	1,053	1,053	94,948	1,159	1,159	94,948
7	,983	,983	95,931						
.	.	.	.						
.	.	.	.						
.	.	.	.						
100	-3,74E-015	-3,74E-015	100,000						

Source: Author's estimation based on PINTEC 2005

From these latent variables it is possible to conclude that the taxonomy of technological regimes cited above is not adequate to Brazilian industry. Instead, it needs a deeper analysis of the characteristics of the industrial sectors in order to create a new taxonomy.

The next step of the empirical procedure is to group the industrial sectors into clusters according to those latent variables, using the hierarchical method and the ward's linkage. Six clusters were found, as showed in Table 3.

Table 3 – Clusters

Cluster	Industry
1	Manufacture of machinery and equipment NEC
2	Manufacture of other non-metallic mineral products
3	Manufacture of chemicals and chemical products Manufacture of rubber and plastic products Manufacture of office, accounting and computing machinery Manufacture of electrical machinery and apparatus NEC Manufacture of communication equipment and apparatus Manufacture of medical, precision and optical instruments, watches and clocks
4	Food products, beverages, tobacco and textiles Tanning and dressing of leather; manufacture of luggage, handbags, saddler, harness and footwear Manufacture of wood and furniture Manufacture of paper and paper products Publishing, printing and reproduction of recorded media Manufacture of basic metals Extraction of crude petroleum and natural gas Manufacture of coke, refined petroleum products, nuclear fuel and alcohol fuel Manufacture of motor vehicles, trailers and semi-trailers Manufacture of other transport equipment
5	Recycling
6	Manufacture of fabricated metal products

Source: Author's estimation based on PINTEC 2005

In order to assess the most relevant factors to each cluster, the Discriminant Analysis was used. Table 4 shows the Classification Function Coefficients from Fisher's linear discriminant functions. According to this criterion, the highest coefficients defines the most important factors to each cluster.

The clusters can be classified in two main groups: *Dependent* or *Autonomous* on international technology. The *Dependent* group includes clusters 1, 3 and 5; whereas the *Autonomous* group includes clusters 2, 4 and 6.

Cluster 1: *Part of a Global Chain* – The most relevant factors to cluster 1 are the international sources of information, public financing to innovative activities other than R&D and cooperation. Despite being classified as dependent, this cluster also presents R&D activities, as it uses both consultancy and cooperation on R&D; moreover, this is an exporter, as it presents information from users in international markets as relevant. This cluster is probably inside a global productive chain. This cluster presents the highest average values of international sources of information and R&D cooperation (see Table 5). In terms of the defining factors of technological regimes proposed by Breschi, Malerba and Orsenigo (2000), this cluster presents high levels of appropriability of innovations and cumulativeness of technical advances. However, it is dependent on technology from other countries, so that it is impossible to achieve satisfactory levels of technological opportunities. Considering Marsili and Verspagen's (2001) taxonomy, the industrial sector in this cluster would be classified in the product engineering regime.

Table 4 – Classification Function Coefficients – Fisher's linear discriminant functions

Variables	Cluster Number of Case					
	1	2	3	4	5	6
Innovation Index	-19,9	35,4	-17,1	6,1	-48	38,6
Cooperation	121,9	-116,1	53	-13,5	53,1	-40,3
International Sources of Information	360,6	-220,8	69,6	-19,7	92,3	-85,5
R&D Cooperation	24,4	-10,4	0,04	-0,01	11,3	-25,5
International Professional Training and Technical Support	25,8	-17,7	10,4	-11,2	141,3	-13,03
Internal R&D	-193,6	223,3	-71,7	17,1	-77,2	62,2
Public Financing of R&D	-148,3	122	-48,9	10,7	-81,6	79,7
Internal Financing	-68,7	56,7	-19,3	5,8	-69,1	92,4
Product Innovation	-0,1	2,1	1,7	0,04	9,1	-20,8
Public Financing to Innovative Activities	174,9	-181,2	80,2	-21,2	102,3	-72,6
Consultancy on R&D	56,6	-33,9	9,5	-1,2	15,7	-29,5
Information on International Professional Training and Technical Support	-32,8	22,1	-8,9	3,6	-10,9	-19,3
Information from Users in International Market	69,9	-75,1	33,7	-8,9	47,7	-49,6
(Constant)	-1092	-720,8	-104,5	-10,7	-525,4	-336,6

Source: Author's estimation based on PINTEC 2005

Cluster 2: *Autonomous in R&D* – This group develops R&D activities, which are financed by public institutions. It presents use of information from organizations of professional training and technical support and high level of innovation index. This cluster presents the highest average values of internal R&D and product innovation. The industrial sector in this cluster is characterized by low levels of appropriability and cumulativeness; and it would be classified in the continuous processes regime.

Cluster 3: *Dependent on Information and Cooperation* - The cluster is characterized by the use of international sources of information and public financing to innovative activities. It presents the highest average values of cooperation, public financing to innovative activities and information from users in international market. Although it presents high levels of appropriability and cumulativeness, it cannot achieve high levels of technological opportunity, as it is dependent on other countries. The industrial sectors in this clusters would be classified in the product engineering regime and in the science based regime.

Cluster 4: *Autonomous in R&D with use of International Information*: presents internal R&D activities, and these activities are financed by public institutions. This cluster presents the highest average values of consultancy on R&D and information on international professional training and technical support. It is characterized by high levels of opportunity and appropriability; however, presents low level of cumulativeness. These factors leads the industrial sectors in the cluster to be independent on technology from other countries. The industrial sectors would be classified in the continuous processes, fundamental processes and complex systems regimes.

Table 5 – Descriptive Statistics – Mean

Variables	Cluster Number of Case					
	1	2	3	4	5	6
Innovation Index	0.578	0.169	-0.239	0.425	-0.802	1.594
Cooperation	0.444	0.420	0.888	-0.304	-0.454	-0.215
International Sources of Information	5.954	-0.419	-0.079	-0.158	-0.066	-0.199
R&D Cooperation	0.422	-0.101	-0.309	-0.116	0.034	-0.985
International Professional Training and Technical Support	-0.134	0.321	-0.263	-0.295	5.293	1.333
Internal R&D	0.178	5.912	-0.189	-0.096	-0.385	-0.484
Public Financing of R&D	0.039	-0.032	-0.042	-0.238	-0.984	0.955
Internal Financing	-0.292	0.270	0.259	-0.184	-1.474	4.857
Product Innovation	-0.393	0.556	-0.015	-0.201	0.028	-0.981
Public Financing to Innovative Activities	0.009	-0.342	1.621	-0.329	0.631	-0.463
Consultancy on R&D	0.117	-0.204	-0.224	0.258	-0.602	-0.336
Information on International Professional Training and Technical Support	-0.436	-0.179	0.107	0.125	-1.153	-1.534
Information from Users in International Market	-0.268	0.680	0.744	-0.324	0.209	-1.102

Source: Author’s estimation based on PINTEC 2005

Cluster 5: *Dependent on Human Capital* – This group depends on international professional training and technical support, on public financing to innovative activities other than R&D and on international sources of information. It presents a lower level of cooperation, implying that this group is highly dependent on technology and professional training from other countries, in a continuous base. It also presents the highest average value of international professional training and technical support. The industrial sector in this cluster is characterized by high levels of cumulativeness and low levels of appropriability and opportunity. This industrial sector would be classified in the continuous processes regime.

Cluster 6: *Autonomous in Financial Resources* – This cluster is characterized by the presence of internal financing to innovative activities, public financing of R&D and by the development of internal R&D activities. This cluster also presents the highest level of innovation index, as well as the highest average value of the innovation index, public financing to R&D and internal financing. However, it presents low levels of opportunity, cumulativeness and appropriability. The industrial sector in this cluster would be classified in the continuous processes regime.

These empirical results reflect a North-South model, in which the dependent clusters are the ones presenting higher levels of appropriability and cumulativeness and the independent cluster are the ones presenting lower levels of cumulativeness. Furthermore, the comparison with the technological regimes created by Marsili and Verspagen indicates that the most innovative sectors are part of the dependent clusters whereas the independent clusters contain the less innovative sectors.

5. Concluding Remarks

In this paper, we performed a multivariate analysis to classify the Brazilian industrial sectors into technological regimes, using Survey of Technological Innovation 2005. The model grouped the industrial sectors in six clusters. These clusters were classified in two main groups: the group of industrial sectors dependent on technology from other countries and the group technologically autonomous.

As we are analysing a developing country, the industrial dynamics is different from that of the developed countries, and the technological dependency/independency suits better in this analysis.

The dependent industrial sectors showed to be more influenced by international R&D as well as the public financing. They also presented higher levels of appropriability and cumulativeness, making it difficult to achieve technological independency and satisfactory levels of innovation in the country.

On the other hand, the autonomous industrial sectors use internal R&D and their innovative activities are financed by public institutions and by the firms' own resources altogether. However, this group is composed by the low-tech sectors, characterized by lower levels of cumulativeness.

Grouping industrial sectors in technological regimes implies in organizing inter-industry differences into a few invariant categories. This classification would be helpful in the elaboration of an industrial policy aiming to improve industries and to foster innovative activities.

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