Sources of Technological Opportunity in Brazil

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Abstract

This paper aims to assess the relevance of different sources of TO for Brazilian industries and to compare the results with those obtained in science-frontier countries. The paper uses micro level data from PINTEC (2003). The paper covers two different sources of TO: extra-mural sources of knowledge and technological trajectories and compare them with sectoral R&D intensity, sectoral rate of innovation (innovative output) and a input-output measure of TO, that is, of the probability of an innovative effort transforming into an innovation. The paper concludes that: (i) the knowledge used by Brazilian industry is highly production intensive. Very few sectors give relevance to sources of knowledge outside industry. Technological trajectories patterns are also different from scientific frontier countries; (ii) the distinguishing factors in terms of innovative strategy and performance are different. They refer, on the supply side, to sources of information outside Brazil, that is, most innovative industries require international sources of information and do not use Brazilian scientific and technology institutions. On the demand side, behavior is framed by market regulation institutions that require the use of productive standards. Therefore, most innovative industries make use of certification agencies to attend to market regulation standards, that is, innovation in Brazil is not associated with technological breakthroughs but it is related to following quality patterns; (iii) this pattern of distinguishing sectors is quite different from leading countries' results whose distinguishing features are proximity to science and the use of higher education and research labs.

Keywords: technological opportunity; Brazilian industry; technological innovation
JEL: O31; O33; L11

Resumo

Este artigo visa à mensuração da relevância de diferentes fontes de oportunidade tecnológica (OT) na indústria brasileira comparando-as com os resultados obtidos para países situados na fronteira científica. O artigo usa micro-dados originários na PINTEC (2003). Ele cobre duas fontes diferentes de OT: fontes de conhecimento externas à firma e trajetórias tecnológicas, correlacionando-as com intensidade em P&D, taxa de empresas inovadoras e uma medida de OT obtida pela probabilidade de uma empresa ser inovadora dada a realização de P&D. O trabalho conclui que: (i) existem fortes diferenças entre as fontes de conhecimento no Brasil e em outros países. O conhecimento usado na indústria brasileira é altamente intensivo em fontes associadas à produção. As trajetórias tecnológicas também não aparentam ter o mesmo padrão; (ii) os fatores que distinguem os setores em termos de estratégia e desempenho inovadores estão associados, do lado da oferta, a fontes de conhecimento estrangeiras, seja no âmbito da firma, por intermédio de suas subsidiárias, seja pelo sistema de transferência de tecnologia. Pelo lado da demanda, a existência de regulação parece ser um fator que distingue os setores na indústria brasileira; e (iii) esses resultados são muito diferentes dos obtidos em outros países.

Palavras-chave: oportunidade tecnológica, indústria brasileira, inovação tecnológica

Introduction

Since the studies on the relationship between market structure and innovativeness, indicators associated with technological opportunity (TO) have appeared as important explanatory variables of rate and direction of industrial technical change. Though there is an explicit and clear definition of TO, associated with the easiness to innovate, the measurement of TO has followed a two-fold trajectory. On the one hand, there are those that measure it as a parameter that relates effort inputs to outputs (results), based on a hypothetical production function of knowledge

On the other hand, a second stream of the literature has developed a measurement of TO through the determinants of innovativeness. This has been mainly an approach at the sectoral level, where TO has been linked to the sources of the innovative process in each sector: relevance of science and technology, other extra-mural sources and of knowledge and natural technological trajectories. This approach allows classifying sectors according to the relevance of the source of knowledge through which TO emerges. This analysis implicitly assumes that TO will show low variation inside sectors and therefore that sectoral level analysis is sufficient to adequately assess TO.

The importance of externalities from science and other sources of knowledge to the innovative process may vary with the distance a country's productive structure keeps from scientific and technological frontiers. Learning routines are evaluated as being quite different in catching-up countries when compared with leaders. Therefore, other sources of TO either than science may and should play a more relevant role in catching-up countries. Furthermore, once the proximity to science is not as important as other issues to determine TO, one may argue for the inadequacy of the simple transposition of TO parameters from science-frontier to catching-up countries.

This paper aims to shed some light into this latter issues by measuring the importance of different sources of opportunity to sectors of the Brazilian economy and correlating their importance to different measures of input and output and comparing the results with the outcomes found in Klevorick et al. (1995). Therefore, it carries out three main tasks: (i) the identification of the most relevant TO sources in each Brazilian manufacturing sector; (ii) the detection of the way in which sources of TO are linked to levels of TO; and (iii) the comparison between the Brazilian results and Klevorick, et al (1995)'s findings for the US industry trying to capture differences between leaders and followers countries.

Apart this introduction, the paper has other three sections. In the first section, the paper develops the analytical framework that illuminates the empirical analysis. In the second section, the paper identifies the relevant sources of TO for each level and in comparison with the results obtained by Klevorick et al (1995). The third section describes de main conclusions for the paper.

1. Analytical framework

1.1. Sources of Knowledge, Innovation and TO

In the original version of technological opportunity (TO), the literature emphasized the technological imperatives of technical change and therefore TO was a purely technological concept. TO, appropriability, cumulativeness defined the sector's technological regime. These features were the main driving forces of the direction and rhythm of technical change. Appropriability conditions defined the incentives to innovate and imitate and therefore the rhythm of diffusion of technologies. The cumulativeness of technology defines the level of continuity in the innovative process and the TO defines the easiness to innovate. Demand through the use of market mechanisms conditions the level of acceptance of the technology in the market place.

(Malerba y Orsenigo, 1997; Marsilli, 2002).

The idea that TO was solely defined in the technological environment and the limited availability of sources of information on innovative behavior made economists approach TO based on a model restricted to input-output relations associated with an hypothetical knowledge production function. This trend was followed by two important analytical procedures.

On the one hand, during the 80's, the study of the rhythm and direction of technical change was mainly oriented to the industrial analysis. The main purpose of these studies was to understand inter-sectoral and intra-sectoral differences in the patterns undertaken by technical change and innovative activity. Technology trajectories and sources and origins of technical progress were studied (frequently) referred at the sectoral level.[1]

On the other hand, measures of TO based in the production function implicitly held a diminishing returns hypothesis. This hypothesis was derived from the perception that the once R&D projects are completed the pool of available knowledge diminishes. This hypothesis has a theoretical inconsistency due to the fact that R&D projects and other sources of knowledge may increase the pool of available knowledge and therefore hypotheses that involve increasing returns to R&D projects may be true. This perception had an important repercussion on empirical investigation that showed that the types of returns to R&D projects varied across sectors (Archibugi et al. 1993, Klevorick et al. 1995).

Furthermore, the traditional association of technological opportunity with scientific and technological paradigms was increasingly seen as restricted, once it was recognized that the proximity to science was only one of the sources of knowledge at the sectoral level. A non-depreciable part of knowledge is produced through research and learning processes inside companies as well as the interaction with other companies and institutions. The easiness to innovate is strongly associated with knowledge spillovers from sources outside companies' boundaries and that also provides an important source of knowledge. Therefore, intra-industrial relations and the proximity of firms of its clients and suppliers may be a source of TO as well, once it provides important knowledge spillovers that increase firms' probability to innovate (Klevorick et al, 1995).

It is therefore natural to conclude that these works elaborated a new vision of TO with a strong sectoral component, that considers sources of technological knowledge (intra-industrial relationships, closeness to other sectors, type of knowledge production) and the proximity to science as the main drivers of the technology trajectories undertaken in each sector. TO therefore apart from being associated with technological imperatives became also referred to market procedures, selection mechanisms. Therefore, it is also fueled by economic imperatives.

These are the main reasons for the sources of TO to differ not only across technologies but also across sectors. The perception that closeness to different sources of knowledge affects TO opened a new line of investigation that attempts to account for the complexity of technological and market environments and their interactions. Therefore, this line of work approaches TO with reference to the scientific and technological fields that prevailed in each sector, their speed of change, the closeness of the linkages between firms, technology and science (Jaffe 1989) and their pervasiveness (Marsilli 2002).

Klevorick et al. (1995) systematizes a methodology of analysis at the sectoral level through the application of surveys to sectoral specialists that identify as sources of innovation the proximity to science, the rate of use of intra-industrial knowledge and the level of industrial maturity through the interaction with technological trajectories. Their effort aims to answer two different questions. First, to what extent and how do sectors differ in their level of TO? Second, how does TO influence

[1] This feature may be illustrated by the great number of Works on the relationship between market structure and innovative behavior that included pectoral measures of TO (Cohen and Levin 1989).

levels of expenditure in innovative efforts?

Klevorick et al. (1995) determine that electronic components, aircraft and drugs are the manufacturing three-digit sectors with greater level of opportunity while non-metalic minerals, metallic products and mechanical industrials present the lowest levels of opportunity. However, they also claim that one cannot rank with absolutely certainty sectors' TO based in their use of certain sources of knowledge. For instance, though non-metallic minerals present a low level of opportunity, advances in science seem to be important in that sector. On the other hand, electronic components have high level of opportunity and rely on their input suppliers to display innovations.

They also find that R&D intensity is not a perfect match with TO, though it shows a positive correlation, mainly when sources of knowledge are associated with science developments in universities and public laboratories. In some cases, R&D intensity may have a negative correlation with TO such as those industries where clients and equipment suppliers are the main sources of external knowledge. Therefore, other modes of efforts and expenditures that account for acquisition of embodied knowledge and the interaction across firms' boundaries should be viewed as relevant. This fact marks a disruption in the traditional association between R&D intensity and level of TO. Not necessarily sectors with highest R&D expenditures have the highest level of TO. However, the innovative performance is still associated with the level of TO.

Palmberg (2004) associates sources of innovation to TO. He finds that different levels of TO are linked to different sources of innovation, such as demand, market niches, cooperation and standards and regulation. Palmerg (2004) confirms the result obtained by Klevorick et al. (1995) that the coexistence of different sources of innovation may cast doubt on the traditional industrial classifications according to R&D intensity and the identification of sectors with higher R&D expenditures as sectors of higher TO. Others, like Fung (2002, 2004) already introduce indicators of internal, intra-industrial and extra-industrial knowledge flows as a measure of TO, due to the existence of spillovers, to verify the existence of scale economies and level of productivity of R&D expenditures between industries..

The assessment of TO through the examination of the sources of knowledge may show some shortcomings. Scherer (1965) stresses that TO does not solely depend on demand forces, but it also relies on forces that come from the supply side, associated with the advancements in scientific and technological knowledge. The relevance of the sectoral closeness to scientific knowledge has also been emphasized in later studies, such as Rosenberg (1974), Nelson (1982) and Dosi (1988). Dosi (1988) specifically highlights the role played by technological paradigms arguing that TO should be greater the more recent the technological paradigms.

1.2. Sources of technological opportunity among countries

In the original version of TO, where it was solely defined in reference with technological imperatives, the existence of cross-country differences in technological regimes was not predictable. Patterns of innovative activity could vary across technologies, but not across countries, where they should display a high level of similarity (Malerba and Orsenigo 1997). However, the sectoral dimension of TO may predict that the way sectors work is highly dependent on sectoral balances and knowledge flows that depend on specificities of national systems of innovation.

Sources of TO at the sectoral level may be grouped in three classes: (i) those related to the proximity to certain science fields, (ii) internal and external sources of knowledge and (iii) natural trajectories of the technical change in each sector (Klevorick et al. 1995). The closeness to scientific fields measures the sensibility of the sectoral technical progress to the scientific progress and, as a consequence, which possibilities may be derived from new technological opportunities. The closeness to science is strongly linked to the technological dimension of TO. In this sense, one should not find great differences across countries due to this dimension or source of TO, if there are no changes in technological and scientific paradigms and if the exploitation of paradigms has the same rhythm across countries.

If countries explore the possibilities form the paradigms in different rhythms, some differences may be found as long as there are different levels of industrial and technological development across countries. Therefore, the benefits one would obtain from scientific paradigms would differ according to specific characteristics of the national systems of innovations, which define the relevance of different sources of knowledge, cooperative agreements, acquisition of knowledge form third parties, patenting systems and the rhythm of transference of technology from foreign companies.

Natural trajectories may also define TO. They determine the focus of the technological activity in each sector and they are determined by market and production imperatives (Pavitt 1984). In this sense, cross-country differences will be related to differences in patterns of productive specialization, differences in market structural characteristics, such as the relative prices of factors of production, the price and income-elasticity of demand, market concentration level among other things.

In this sense, some works have already shown that patterns of innovation and the classification of sectors into innovation taxonomies may vary across countries due to productive specialization (Archibugi et al. 1991). Developing countries have a further reason to display different opportunity levels and modes across sectors: they are not in the technology frontier. Therefore, spillovers from science and intra-industrial sources should not play the same role as they do in technology frontier countries. Although the literature has stressed the importance of non-R&D efforts to determine technological opportunities, the way to deal with these contributions and the way they capture spillovers from intra-industrial sources of knowledge is far from consolidated.

Finally, on the third source of TO, it is expected that countries should differ on extraindustrial source of knowledge (suppliers, users, independent R&D labs, universities) due to differences in the relationships established by firms and the way they interact and organize knowledge flows in specific systems of innovation. In this sense, countries have different incentives to cooperate in the industrial environment and with other institutions, such as universities. Different roles are played by technology transference and certification and regulatory agencies. Fiscal incentives are also different and, therefore, levels of expenditure on innovative activities may differ due to differences in institutional arrangements.

All this shows that there are important signs that indicate the existence of different patterns of TO across countries. This maintains the hypothesis that developed countries rely more on opportunities that rise from scientific advances that are obtained in their national systems of innovation, while followers or less developed countries that have a catching-up strategy may rely more on intra-industrial sources of knowledge.

2. SOURCES OF TECHNOLOGICAL OPPORTUNITY IN THE BRAZILIAN INDUSTRY

2.1. Database.

The paper uses the Brazilian Technological Innovative Industrial Survey (PINTEC) applied by the Instituto Brasileiro de Geografia e Estatística (IBGE) for 2003. The PINTEC (2003) database contemplates to about 11,000 manufacturing and mining industrial companies. It includes all companies that have records on official Brazilian innovative databases, such as financial institutions, registration of technology transfers and all companies over 500 employees. It covers a random representative sample for companies over 10 employees. The sample is representative for companies in 10 to 29, 30 to 99, 100 to 499 employees' size cohorts. The survey uses a questionnaire based on the Oslo manual.[2]

Companies are classified in four-digit sectors according to Classificação Nacional das Atividades Econômicas (CNAE). CNAE is based on ISIC. The paper aggregates companies in an adaptation of the three-digit CNAE-ISIC classification. CNAE has 104 three-digit sectors in the mining and manufacturing industries and the aggregation here used has 65 sectors (see annex 1 for a description of the sectors).

2.2. Sources of "TO" in Brazilian industry

The purpose in this section is to present an analysis of TO in Brazil following Klevorick et al (1995) methodology and as a consequence to compare the results obtained for Brazil in 2003 with those obtained by Klevorick et al (1995). We are conscious about the different periods that are in comparison, however, we are here more interested in capturing differences between technological follower and leader.

PINTEC (2003) has two sets of questions that may help in the reproduction of Klevorick et al. (1995)'s analysis. The importance of the sources of information is covered by questions 108 to 120 where it is asked what is the importance of each source of information to the development of technologically new products and processes. The importance of technological trajectory is covered by questions 93 to 107 where it is asked what is the importance of the impact of product and process innovations to each technological trajectory.[3] Firms are asked to state if the importance of each source of knowledge or technological trajectory to the sector is high (3), medium (2), low (1) or none. Whenever the mean answer was between greater than 2, we rated the factor as highly important, whenever, mean average was greater than 1, but lower than 2, we rated it as of medium importance and whenever it was less than 1, we rated it as of low importance. Only firms that have declared themselves as innovative answer these questions. Therefore, the rate of answers given should be valued as indicating the direction, not the intensity of a source or as a rate of change in a trajectory.

"Natural trajectories of technological advance" measure "the extent to which technological opportunities feedback on themselves and are enhanced by the presence of natural trajectories" (Klevorick et al, 1995:200). Nelson and Winter (1982)'s natural trajectories focused on mechanization, product differentiation and diversification. They state that these trajectories should be pervasive across sectors.

0 lists some impacts of innovation that may be related to these technological trajectories. Product quality and product diversification seem to be the most important technological trajectories followed by the Brazilian industry, confirming Nelson and Winter (1982)'s hypothesis. Seventeen out of the 65 analyzed sectors have declared the improvement of product quality as a highly relevant trajectory, while 48 declared it to be of medium importance. No sector declared it to be of low importance. The sectors that have taken it in a higher account are Repairs of motors (345), Manufacture of other instruments (330 – which is dominated by equipment of automation), Engines, pumps, compressors, taps and turbines (291), and Basic iron and steel (278) and Other transportation equipment (359 – which is dominated by the production of motorcycles). With the exception of Repairs of motors and Other transportation equipment, the other sectors are important intermediary suppliers to the economy. Product diversification is also highly rated across sectors. Computers (300), Motor vehicles (340) and telecommunication equipment (332) are the sectors that most valued this characteristic. It is important to say that they are among the most fast

[2] A detailed description of the database may be found in IBGE, *Pesquisa Industrial de Inovação Tecnológica.* http://www.ibge.gov.br.

[3] We do not tackle directly proximity to science. The only comparable information to Klevorick et al. (1995)'s analysis is the number of employees in R&D in each field of science. However, the exploration of the data revealed values that seemed to express a lack of understanding of the question.

changing sectors in international economy. These sectors have grown internationally through modifications that required a strong focus on product diversification.

The "natural trajectories" classes closest to mechanization are those relative to reduction of labor costs and production costs. As can be seen, these trajectories are not as pervasive as the hypothesis of Nelson and Winter (1982) and the results for USA of Klevorick et al. (1995). They only appear to assume relevance in very few sectors such as those belonging to the motor vehicle production chain (340 and 344), Other transportation equipment (359), Forging, pressing, stamping and roll-forming of metal; powder metallurgy (283), Manufacture of ceramic products (269), and Grain mill products (155).

On the other side, changes in the scale of production and changes in product dimensions is less pervasive in the USA case, being the former relevant to aluminium smelting, wet corn milling and in product dimension semiconductors and computers. For Brazil, increases in plant capacity are rated as of medium important in 53 industries over a total of 65. The Manufacture of other electrical equipment, the motor vehicle production chain, Mining and quarrying, Other transportation equipment and Structural metal products lead the statistics in importance of this trajectory.

Table 1. Natural Technological Trajectories

	High	Medium	Low	None	Total	Relevant sectors
1. Product quality	17	48	0	0	65	345, 330, 291, 359, 278
2. Product diversification	3	31	31	0	65	300, 340, 322
3. Increase in plant capacity	0	53	9	0	65	310, 344, 340, 998, 359, 280
4. Production flexibility	0	43	22	0	65	340, 152, 344, 359
5. Reduction of production costs	0	23	42	0	65	359, 340, 344, 269
6. Reduction of labor costs	0	14	51	0	65	359, 283, 344, 155
7. Reduction of material consumption	0	1	64	0	65	359, 340, 211, 278
8. Reduction of energy consumption	0	0	64	1	65	----------------
9. Reduction of water consumption	0	0	64	1	65	----------------
10. Reduction of environmental impact	0	35	30	0	65	248, 155, 998, 359, 997
11. Domestic regulation requirements	0	20	45	0	65	340, 245, 155, 153
12. Foreign regulation requirements	0	3	62	0	65	340, 997, 211

Source: Own elaboration and PINTEC-2003

Finally, PINTEC covers other "natural trajectories" not considered in Klevorick et al (1995). Reduction of energy, water and material consumption and regulation requirements are not covered in Klevorick et al (1995). Nonetheless, they do not seem to be of great relevance. Almost all industries rate them as of null or low importance. Environmental impact takes some relevance in some sectors such as Paints and varnishes (248), Grain mill products (155), Mining and quarrying (998), Other transportation equipment (359), Sugar and alcohol mills (997). Domestic regulation assumes some importance in food processing (155 and 153), pharmaceuticals and motor vehicle sectors, while foreign regulation is relevant only in sectors that export a substantial part of their production, such as pulp and paper (211), motor vehicles (340) and Sugar and alcohol mills (997).

Some regularities may be found in these results. First, motor vehicles and other transportation equipment (dominated by motorcycles) have been highly rated in many trajectories. They seem to have very pervasive strategies of innovation that require advances in both process and product. Second, there is a set of very process intensive sectors that have focused on cost reduction innovations. Finally, regulation seems to tackle very specific sectors due to their production and innovative characteristics.

Knowledge sources originated outside companies are considered as "external sources". As Klevorick's methodology, this study includes intra-industrial sources (other firms in the group, suppliers, clients, and competitors) and extra-industry sources (Consultancy, Higher Education and

Research Institutions, Training Centers, Certification Institutions and Patent Disclosures, Licensing and Know-how).

0 shows that the findings for Brazil are quite similar to the general finding of Klevorick et al. (1995) for the American industry. Intra-industry sources seem to be much more relevant that extra-industry sources. More than half of the industries rate other firms within the group suppliers and users as high or medium importance sources of innovation. In the US industry, Klevorick et al. (1995) found suppliers important in Pavitt (1984)'s supply dominated sectors such as food products, lumber/wood products, radio/TV sets and metal working. In Brazil, food processing industries such as manufacture of coffee (157), Grain mill products (157), Vegetables and animal oil and fats (153) and Tobacco (160) follow into this category. In the Brazilian case an additional type of users rely on information from suppliers. These are assemblers of complex products that require the supply of reliable inputs have also rated suppliers as an important source of information. Motor vehicles (340), Electricity distribution and control apparatus (312), and Machinery for mining, quarrying and construction (295) are among these sectors.

Klevorick et al. (1995) have related the relevance of clients and users as source of information to Pavitt's specialized suppliers sectors. They state their findings to be consistent with von Hippel's analysis over semiconductors-process equipment and scientific instruments. For the American industry, this represents machinery, electrical equipment, surgical/medial instrument. This matches the findings for the Brazilian industry that shows the producers of Bodies for motor vehicles (343), Machinery for mining, quarrying and construction (295), Manufacture of other instruments (330 – which is dominated by equipment of automation), Telecommunication equipment producers (322) follow into this category. An important exception is Motor vehicles (340), but final consumers may play a relevant role, in this case.

Table 2. External sources

	High	Medium	Low	None	Total	Relevant sectors
1. Other firms within the group	25	33	7	0	65	294, 157, 359, 311, 248, 283, 345
2. Suppliers	10	52	3	0	65	340, 157, 155, 153, 312, 295, 160
3. Clients / Users	14	48	3	0	65	343, 295, 330, 340, 322
4. Competitors	1	48	16	0	65	160, 322, 330, 247, 312
5. Consultancy	0	1	64	0	65	997, 153, 249, 312, 151
6. Higher education and research institutions	0	3	62	0	65	322, 300, 155, 211, 245, 278, 295
7. Training centers	0	1	64	0	65	340, 261, 300, 153, 343, 155
8. Certification institutions	0	4	61	0	65	261, 298, 340, 240, 322
9. Patent disclosures, licensing and know-how	0	0	64	1	65	340, 322, 211, 160, 300

Source: Own elaboration and PINTEC, 2003.

There are two important sources of TO in Brazil that do not appear in Klevorick study: 'Other firms within the group' and 'Competitors'. The former is, in fact, the most important source of TO for Brazilian industry. Forty percent of industries have rated other company within the group as highly important and only 10 per cent have given it low importance. Foreign capital plays a very important role in the Brazilian economy. The sectors that have rated this source of information as most important are dominated by multinational companies. Machine tools (294), 157, Other transportation equipment (359), Electric motors, generators and transformers (311), Paints and varnishes (248), Forging, pressing, stamping and roll-forming of metal; powder metallurgy (283) are sectors with a very high participation of multinational companies.

'Competitors' is a source less relevant than the other ones, but it still has relative importance. The only sector that finds it highly important is the Tobacco industry. However, some other sectors give some importance to it such as), Telecommunication equipment producers (322), Manufacture of other instruments (330), Soap and detergents (247), and Manufacture of electricity distribution and control apparatus (312).

Extra-industrial sources of knowledge are almost irrelevant. This reveals a very important feature of the Brazilian industry: its feeble interaction with non-industrial science and technology institutions. This gap is very important due to the low level of R&D disbursements of the industry and the high scientific level of some institutes and Universities. Klevorick et al. (1995)'s results for American industry are quite different. They show evidence of close linkages between extra-industrial science and technology institutions and industry. Research institutions, universities and government play a very important role in support of industrial innovation in at least six US industries (for example: fertilizers, logging and sawmills and optical instruments).

In the Brazilian case, only three sectors find higher education and research institutions intermediately important as a source of information. These sectors are Telecommunication equipments, Computers and Grain mill products. In our study, all the sources considered are related to the government and public institutions articulations to enforce national technological advance. Another important observation is the lack of importance given to patent disclosures and licensing. This feature may indicate a low level of use of technology transfer agreements.

2.3. "TO" values.

This section measures TO from an input output perspective. The paper uses two alternative measures of innovative effort (input): R&D. The dependent variable (output) is obtained from two questions of PINTEC referring to the introduction of process and product innovation. The first question is: Did your company introduce a new or significantly technologically improved process that constituted a novelty to the sector in Brazil during the 2001-2003 period? The second question is: Did your company introduce a new or significantly technologically improved product that constituted a novelty to the market in Brazil during the 2001-2003 period? If the answer to at least one of these questions is yes, the dependent variable assumes 1 and 0, otherwise.

The relation between these input and output measures is obtained through a probit model run at the firm level data for each of 65 sectors. The model has two independent variables: the level of innovative effort and its quadratic form, as it is represented in equation (1), where RD stands for the firm's total expenditures in R&D. The dependent variable assumes value 1 whenever the firm has introduced a product innovation that constitutes a novelty to the Brazilian market or a process innovation that is new to the Brazilian productive sector.4 The use of R&D expenditures instead of the ratio of R&D expenditures to sales (R&D intensity) is due to the definition of R&D, that is, the increase in the probability to innovate when you increase a unit of the input. The sectoral level of TO is represented by the level of expenditure (innovative effort) that maximizes the firms probability to innovate, represented by $\left|\frac{\beta_1}{2\beta_2}\right|$.

$$P(y=1|x)=\alpha+\beta_1 RD+\beta_2(RD)^2+\varepsilon \qquad (1)$$

One important characteristic of the measure proposed is that there is got to be a maximum, that is, in order for the $\left|\frac{\beta_1}{2\beta_2}\right|$, obtained from equation (1), to make sense, the sign for β_1 has to be positive and significant and the sign for β_2 has to be positive and significant. Model (1) was tested

[4] It is important to note that it is a quite narrow definition of innovation when compared to the usual definition present in Oslo Manual surveys.

for both variables in 65 sectors. The results are shown in annex 2. Only 5 out of 65 sectors present negative value of the coefficient of the R&D variable; but in all five cases the sign is non-significant. Only 6 out of the 57 sectors that have positive sign for the coefficient of the R&D variable, are non-significant. In only 8 cases the square of R&D had positive sign. However, in no case it was statistically significant. In 18 out of the 57 cases where the coefficient for the square of R&D was negative, the coefficient was not statistically significant.

Table 3. Distribution of Sectors per Quintile According to Level of TO, R&D and Total Cost of Innovation Measures

Very High	High	Medium	Low	Very Low
Refined petroleum products	Tobacco products	Television and radio receivers, sound or video recording	Basic precious non-ferrous metals and casting of metals	Other manufacturing n.e.c.
Motor vehicles	Parts and accessories for motor vehicles and their engines	Other chemical products n.e.c.	Other fabricated metal products n.e.c.	Dairy products
Telecommunication equipment	Soap and detergents	Transport equipment n.e.c.	Ceramic products	Glass and glass products
Rubber products	Pharmaceuticals	Vegetable and animal oils and fats	Machinery for mining, quarrying and construction	Publishing, printing and reproduction of recorded media
Basic Petrochemicals	Pulp, paper and paperboard	Production, processing and preservation of meat and fish	Medical and surgical equipment	Furniture; manufacturing n.e.c.
Other electrical equipment n.e.c.	Other food products	Other non-metallic mineral products n.e.c.	Tanning and dressing of leather	Forging, pressing, stamping and roll-forming of metal; powder metallurgy
Domestic appliances n.e.c.	Engines, pumps, compressors, taps and turbines	Cutlery, hand tools and general hardware	Inorganic Chemicals	Weapons and ammunition
Mining and quarrying	Electric motors, generators and transformers	Electronic valves and tubes and other electronic components	Wearing apparel; dressing and dyeing of fur	Wood and of products of wood and cork, except furniture
Basic iron and steel	Agricultural and forestry machinery	Grain mill products, starches and starch products, and prepared animal feeds	Spinning, weaving and finishing of textiles	Structural metal products, tanks, reservoirs and steam generators
Instruments and appliances for measuring	Bodies (coachwork) for motor vehicles	Other machinery of general purpose	Knitted and crocheted fabrics and articles	Building and repairing of ships, boats and trains
Paints and varnishes	Paper and paper products	Electricity distribution and control apparatus	Other instruments nec	Processing and preserving of fruit and vegetables
		Other special-purpose machinery		
		Plastics products		

Source: Own elaboration from micro-data from IBGE – Pesquisa Industrial de Inovação Tecnológica, 2003.

The results obtained in annex 2 are summarized in 0 for every sector that has maintained positive sign for the R&D variable and negative sign for the square of R&D. 5 Sectors are ranked in five categories according to the level of TO. 0 shows that our measure finds quite different TO rankings for Brazilian industry than those catalogued for techno-scientific frontier countries (see Klevorick et al. 1995). In the first column that lists very high TO sectors, there are sectors that are not expected to show very high TO levels, such as Refined petroleum, Mining and quarrying, Basic iron and steel, Rubber products, Basic petrochemicals, Domestic appliances and Paints and varnishes.

These differences may have two different explanations. First, the method used to obtain TO ordering has R&D expenditures as independent variable, not R&D intensity (the ratio of R&D expenditure to sales). In this case, it may have biased the results towards industries with large firms. However, there are other sectors dominated by large firms where TO levels are not high, such as Television and radio receivers, sound or video recording and Electric motors, generators and turbines.

Second, the list in the first column, as well as other columns, seems to be coherent with Brazilian productive specialization. Refined petroleum, and Mining and quarrying are among the most successful sectors of the recent evolution of Brazilian industry that seems to become more internationally specialized in resource-based, scale and production intensive sectors. These sectors are characterized by medium level of R&D expenditure and a reliance on a network of equipment suppliers as a source of technology. This pattern may be confirmed by the absence from the first column of some sectors that are expected to have very high TO, such as pharmaceuticals and Medical and surgical instruments, where Brazil does not show a great level of specialization. Furthermore, in the second column there is a set of sectors that stand as important equipment suppliers for these leading Brazilian sectors, such as Engines, pumps, compressors, taps and turbines and Electric motors, generators and transformers. The presence of Paper and pulp as a high TO sector may also be explained by its importance as an exporter sector.

One may find a set of sectors linked to the Motor vehicles industry, such as Motor vehicles, Parts and accessories for motor vehicles, Bodies for motor vehicles and Rubber products (tires), in the first and second columns of 0. The Motor vehicle industry has international specialization of assembly and the production of bodies and parts. Intra-industry trade seems to be an important feature.

2.4. TO vs Technological trajectories and Information Sources

This subsection is dedicated to the exposition of the relationship between TO levels as measured in subsection 2.2 and the sources of TO, as expressed in subsection 2.3. The aim is to answer the question: are TO sources correlated to input-output approach? Does a pattern of innovation (sources and trajectories) indicate a level of TO. In order to do this, 0 uses two distinct indicators: (i) the TO indicator derived in subsection 2.2, (ii) R&D intensity and (iii) the ratio of innovative to total number of firms. The use of the R&D and innovativeness indicators allows comparisons with Klevorick et al. (1995)'s results.

Klevorick et al. (1995) hypothesize and confirm that TO sources should be correlated with innovation output, but not necessarily with innovation input. Our results do not reproduce theirs. The rate of innovation is not positively correlated with all the indicators in the sample. Actually, it is correlated with few of the TO sources. Nonetheless, R&D intensity follows a similar pattern to the ones established by Klevorick et al. (1995). It is positively correlated to clients and some non-industrial sources of innovation. Product diversification trajectories are also positively correlated to R&D intensity as it was in Klevorick et al. (1995). Furthermore, some indicators not covered by

[5] A thorough analysis of these results is made in Rocha and Urraca (2006).

Klevorick et al. (1995) also have positive correlation with R&D indicator. Mainly, they are associated with foreign sources of knowledge, such the transference of knowledge through patent disclosure and licensing and some non-market selection mechanisms such as domestic and foreign regulation.

0 presents also Pearson correlation of sources of information and technological trajectories to the TO indicator. As it may be seen, the TO indicator behaves in a similar way to R&D intensity with some exception. The TO indicator is positively correlated to other firm within the group as source of knowledge and, in the case of trajectories, it is also positively correlated to reduction of environment impact, again a consequence of regulation, and reduction of water consumption.

The results presented here suggest that TO sources guide in some way innovative effort and action. Mostly, the proximity to non-industrial sources of innovation seems to increase the incentives to perform R&D and the strictness of the selection mechanisms may increase the returns to R&D as well. Furthermore, the analysis shows that there is some evidence that shows that Brazilian industry is technologically dependent on foreign resources and demands and that they serve as a selection mechanism and a source of knowledge that distinguish the behavior of firms in selected sectors.

Table 4. Relevant sources of TO by level of TO. Pearson Correlations Indexes, Sources of Information and Technological Trajectories

	TO Indicator		R&D Intensity		Rate of Innovation	
R&D Intensity	0.3473	+++				
Rate of Innovation	0.1696		0.502	+++		
Sources of Information						
Other firm within the group	0.2692	++	0.1211		0.3846	+++
Suppliers	0.0309		-0.0542		-0.1193	
Clients	0.124		0.3964	+++	0.2047	
Competitors	-0.0328		-0.115		0.1083	
Consultants	0.0196		0.027		-0.08	
Higher Education and Research Institutions	0.0628		0.0913		0.2056	
Training Centers	0.1528		0.3078	++	0.1831	
Certification Institutions	0.2205	+	0.453	+++	0.2253	+
Patent disclosures, licensing and know-how	0.3706	+++	0.373	+++	0.1783	
Technological trajectory						
Product quality	-0.0065		0.1614		0.1585	
Product diversification	0.3544	+++	0.5112	+++	0.3851	+++
Increase in plant capacity	0.117		-0.0264		0.0455	
Production flexibility	0.16		-0.0157		0.0091	
Reduction of production costs	0.0511		0.0276		-0.0671	
Reduction of labor costs	-0.0132		-0.1294		-0.0003	
Reduction of material consumption	0.1747		-0.0938		-0.1503	
Reduction of energy consumption	0.1479		-0.0049		-0.0204	
Reduction of water consumption	0.3679	+++	0.0792		0.157	
Reduction of environmental impact	0.2648	++	-0.1329		-0.0356	
Domestic regulation requirements	0.349	+++	0.4549	+++	0.2944	++
Foreign regulation requirements	0.4756	+++	0.4507	+++	0.2327	+

Source: Own elaboration and PINTEC, 2003.

3. Conclusions

This paper aimed to measure the relevance of different sources of TO for Brazilian industries and to compare the results with those obtained in other countries. The paper dealt with two different sources of TO: extra-mural sources of knowledge and technological trajectories. Furthermore, the paper compared the sectoral results of these sources of TO with sectoral R&D intensity (innovative effort) sectoral rate of innovation (innovative output) and a input-output measure of TO, that is, of the probability of an innovative effort transforming into an innovation.

With respect to the relevance of different sources of knowledge and technological trajectories, the main results are:

other companies in the same business group appears to be the most important source of knowledge for the Brazilian industry. We associate this happening to the important role played by multinational corporations in the Brazilian economy as a diffuser of technologies through its Brazilian affiliates. In fact, sectors that declare other companies in the same business group as important sources of knowledge are dominated by multinational corporations. However, this result cannot be compared with Klevorick et al. (1995) due to the inexistence of this item in their survey;

intra-industrial sources of knowledge, such as suppliers and clients, follow in importance as a source of knowledge. The importance of suppliers tend to be greatest in Pavitt's supply dominated sectors and in complex assembly industries that coordinate supplier networks, which are mostly classified as scale intensive (assembly) industries. Clients tend to be important to specialized suppliers industries. This result is quite similar to the evidence collected by Klevorick et al. (2005);

non-industrial sources of knowledge tend to be unimportant. This is a striking contrast with the findings in Klevorick et al (2005) where Universities and R&D labs play a dominant role, mostly in science-based sectors; and,

the most important technological trajectory in the Brazilian industry is product quality improvement, followed by product diversification. There seems to be little search for cost reductions trajectories. This again shows an important contrast to Klevorick's findings.

When TO is measured by an input-output measure, the results show that there are great differences in high opportunity sectors in Brazil when compared to leader countries' experiences. Brazil`s highest TO sectors are associated with its productive specialization. Therefore, commodity industries seem to be amongst the most highly rated industries according to a TO categorization.

When sources of knowledge and technological trajectories are correlated to R&D intensity, innovation ratio and an input-output TO measure, results are quite different to those obtained in scientific frontier countries. First, factors that are associated as highly important sources of knowledge or technological trajectories are not necessarily correlated to innovation outputs, as it is hypothesized and confirmed for the US by Klevorick et al. (1995). On the contrary, some low rated knowledge sources and technological trajectories are amongst factors with highest correlation to innovation output.

These conclusions give some input to draw a picture on TO for the Brazilian industry quite different to that drawn for industries in leading countries. First, sources of knowledge in the Brazilian industry are highly production intensive. Industries understand that intra-industry sources of knowledge are very relevant and this is widely spread across sectors. However, the distinguishing factors in terms of innovative strategy and performance are different. They refer, on the supply side, to sources of knowledge outside Brazil, that is, most innovative industries require international sources of knowledge and do not use Brazilian scientific and technology institutions. On the demand side, behavior is framed by market regulation institutions that require the use of productive standards. Therefore, most innovative industries make use of certification agencies to attend to market regulation standards, that is, innovation in Brazil is not associated with technological breakthroughs but it is related to following quality patterns. This is quite different from leading countries.

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Annex 1 – Sectoral Classification

ISIC two digit	ISIC Compatible	CODE USED	SECTOR DESCRIPTION	Number of Observations	Expanded Sample
15	1511 + 1512	151	Production, processing and preservation of meat and fish	244	941
	1513	152	Processing and preserving of fruit and vegetables	88	520
	1514	153	Manufacture of vegetable and animal oils and fats	42	114
	152	154	Manufacture of dairy products	151	1040
	153	155	Manufacture of grain mill products, starches and starch products, and prepared animal feeds	173	1191
	1542	997	Manufacture of sugar and alcohol	208	373
	Part of 154	157	Manufacture of Coffee	47	221
	154-1542-coffee	158	Manufacture of other food products	445	5560
	159	159	Manufacture of beverages	157	764
16	160	160	Manufacture of tobacco products	39	63
17	171	170	Spinning, weaving and finishing of textiles	195	950
	173	179	Manufacture of knitted and crocheted fabrics and articles	296	2223
18	180	180	Manufacture of wearing apparel; dressing and dyeing of fur	947	11726
19	190	190	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	580	3843
20	200	200	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	493	5102
21	210 - 2101	210	Manufacture of paper and paper products	274	1573
	2101	211	Manufacture of pulp, paper and paperboard	23	20
22	220	220	Publishing, printing and reproduction of recorded media	356	3733
23	232	232	Manufacture of coke, refined petroleum products	47	63
24	2411	241	Manufacture of Inorganic Chemicals	80	391
	2412.2413	240	Basic Petrochemicals	91	526
	2423	245	Manufacture of pharmaceuticals, medicinal chemicals and botanical products	165	622
	2424	247	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations	128	920
	2422	248	Manufacture of paints, varnishes and similar coatings, printing ink and mastics	72	391
	249	249	Manufacture of other chemical products n.e.c.	109	659
25	251	251	Manufacture of rubber products	149	1230
	252	252	Manufacture of plastics products	515	3819
26	261	261	Manufacture of glass and glass products	48	285
	2694.2695	260	Manufacture of cement, lime and plaster	153	1680
	2691, 2692, 2693	264	Manufacture of ceramic products	303	3290
	2696, 2699	269	Manufacture of other non-metallic mineral products n.e.c.	120	1430
27	271	278	Manufacture of basic iron and steel	135	422
	272, 273	279	Manufacture of basic precious non-ferrous metals and casting of metals	142	977
	281	280	Manufacture of structural metal products, tanks, reservoirs and steam generators	190	2029

	2891.2892	283	Forging, pressing, stamping and roll-forming of metal; powder metallurgy	181	2086
	2893	284	Manufacture of cutlery, hand tools and general hardware	98	731
	2899	289	Manufacture of other fabricated metal products n.e.c.	282	2580
29	2911, 2912	291	Manufacture of engines, pumps, compressors, taps and turbines, except aircraft, vehicle and cycle engines	122	539
	2913, 2914, 2915, 2919	292	Manifacture of other machinery of general purpose	165	1406
	2921	293	Manufacture of agricultural and forestry machinery	91	584
	2922	294	Manufacture of machine tools	46	317
	2924	295	Manufacture of machinery for mining, quarrying and construction	44	289
	2923, 2925, 2926, 2929	290	Manufacture of other special-purpose machinery	197	1590
	2927	299	Manufacture of weapons and ammunition	40	436
	293	298	Manufacture of domestic appliances n.e.c.	48	250
30	300	300	Manufacture of office, accounting and computing machinery	72	201
31	311	311	Manufacture of electric motors, generators and transformers	50	255
	312	312	Manufacture of electricity distribution and control apparatus	61	346
	313, 314, 315, 319	310	Manufacture of other electrical equipment n.e.c.	185	1090
32	322	322	Manufacture of radio transmitters and apparatus for line telephony and line telegraphy	59	145
	323	323	Manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods	43	143
	321	321	Manufacture of electronic valves and tubes and other electronic components	59	308
33	3311	331	Manufacture of medical and surgical equipment and orthopaedic appliances	61	402
	3312	332	Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment	34	99
	3313, 332, 333	330	Manufacture of other instruments nec	57	340
34	341	340	Manufacture of motor vehicles	31	40
	342	343	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	49	393
	343	344	Manufacture of parts and accessories for motor vehicles and their engines	224	1012
	345	345	Repairs of Motors	33	502
35	351, 352	350	Building and repairing of ships, boats and trains	38	233
	353	353	Manufacture of aircraft and spacecraft	51	75
	359	359	Manufacture of transport equipment n.e.c.	43	220
36	361	361	Manufacture of furniture; manufacturing n.e.c.	474	4642
C,	999	998	Mining and quarrying	247	1888
Other manufacturing	233, 369, 371, 372	999	Other manufacturing n.e.c.	234	2428
				10624	84261.9989

Annex 2 - Regressions

CODE USED	Intercept	ChiSq	RD	ChiSq	RD2	ChiSq
151	-2.0E+00	485.979	3.3E-03	20.492	-3.2E-07	17.759
152	-1.7E+00	274.787	3.1E-02	40.798	-1.2E-04	26.074
153	-2.2E+00	44.409	1.8E-03	1.610	-1.3E-07	0.585
154	-3.0E+00	126.981	8.8E-03	16.607	-4.3E-06	4.947
155	-2.2E+00	500.953	2.5E-03	27.539	-3.5E-07	12.388
157	-1.9E+00	118.431	4.3E-04	0.017	7.2E-07	0.137
158	-1.9E+00	3045.106	7.8E-03	39.998	-3.7E-07	27.703
159	-2.1E+00	353.988	1.2E-03	1.666	9.9E-08	0.024
170	-2.0E+00	483.485	4.2E-03	56.936	-1.2E-06	29.735
179	-2.0E+00	1139.736	6.8E-03	58.837	-1.9E-06	37.666
180	-2.7E+00	2848.281	2.8E-03	8.135	-7.9E-07	0.556
190	-2.3E+00	1556.860	2.3E-03	25.591	-4.2E-07	7.955
200	-2.2E+00	2252.997	2.4E-02	79.922	-4.3E-05	28.915
210	-2.1E+00	776.933	1.3E-03	17.406	-7.8E-08	7.107
220	-2.5E+00	1228.240	7.5E-03	20.979	-4.5E-06	9.302
232	-1.5E+00	34.937	1.2E-03	4.679	-2.0E-09	2.992
240	-1.5E+00	304.720	3.6E-04	32.943	-9.0E-09	15.487
241	-1.1E+00	176.439	3.4E-03	34.122	-9.3E-07	17.229
245	-1.3E+00	341.995	7.4E-04	32.685	-3.4E-08	13.416
247	-2.6E+00	259.965	5.0E-03	39.565	-2.1E-07	18.975
248	-2.6E+00	107.230	2.1E-03	16.596	-8.1E-08	8.307
249	-1.6E+00	383.177	9.2E-04	13.883	-5.6E-08	6.947
251	-1.7E+00	733.672	2.9E-04	3.268	-6.8E-09	0.713
252	-1.7E+00	2250.982	2.6E-03	77.159	-4.2E-07	27.691
260	-2.4E+00	578.728	1.9E-03	1.736	3.4E-07	0.076
261	-2.7E+00	65.051	3.1E-02	16.038	-1.7E-05	0.377
264	-3.6E+00	109.346	7.3E-03	15.130	-1.2E-06	0.406
269	-2.6E+00	406.162	5.5E-03	46.081	-5.4E-07	24.168
278	-1.6E+00	246.398	8.0E-04	21.891	-2.7E-08	12.294
279	-1.9E+00	547.334	3.2E-03	32.285	-5.1E-07	6.073
280	-2.1E+00	977.524	2.4E-02	86.059	-4.5E-05	52.309
283	-1.9E+00	1133.370	7.2E-03	23.096	-5.3E-06	8.447
284	-1.4E+00	419.261	1.4E-03	12.148	-1.4E-07	6.146
289	-2.0E+00	1375.403	6.9E-03	109.713	-1.1E-06	68.995
290	-1.4E+00	920.532	1.8E-03	21.504	-2.8E-07	15.628
291	-1.8E+00	303.783	1.0E-03	38.347	-5.1E-08	9.260
292	-1.6E+00	820.707	3.6E-03	125.035	-5.4E-07	95.773
293	-1.6E+00	341.662	5.9E-04	10.853	-3.4E-08	5.094
294	-2.3E+00	115.132	-3.9E-01	0.000	3.1E-05	0.000
295	-1.7E+00	165.170	2.5E-03	6.123	-4.3E-07	1.526
298	-1.2E+00	121.345	1.6E-03	9.432	-4.7E-08	4.174
299	-2.0E+00	213.970	1.9E-02	35.283	-2.1E-05	21.612
311	-1.7E+00	147.743	1.2E-03	3.459	-6.4E-08	0.967
312	-1.9E+00	172.600	1.9E-03	8.598	-2.9E-07	2.638
321	-1.3E+00	167.158	2.1E-03	5.661	-3.0E-07	0.278
322	-1.5E+00	79.822	5.1E-04	10.867	-6.3E-09	4.903
323	-1.4E+00	79.620	3.3E-04	0.408	-2.0E-08	0.116
330	-1.2E+00	159.996	5.6E-03	21.034	-1.8E-06	6.758
331	-2.1E+00	182.827	4.8E-03	49.577	-8.5E-07	30.799
332	-1.1E+00	41.824	6.1E-04	2.365	-2.2E-08	0.517
340	-7.9E-01	9.654	1.6E-05	1.718	-3.8E-11	0.520
343	-1.6E+00	231.127	9.2E-04	2.767	-5.4E-08	0.109
344	-1.5E+00	592.018	5.5E-04	32.992	-2.2E-08	11.137
361	-2.1E+00	2330.269	1.1E-02	87.126	-7.3E-06	29.952
997	-2.4E+00	128.141	-8.3E-02	0.000	1.8E-05	0.000
998	-2.5E+00	590.536	6.8E-04	3.253	-2.2E-08	0.681
999	-1.8E+00	1405.661	5.4E-03	29.225	-2.0E-06	17.456