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INNOVATION AND PRODUCTIVITY PERFORMANCE: HOW DOES MINAS GERAIS COMPARE TO OTHER MAJOR STATES? EVIDENCE FROM PINTEC 2000 AND PIA 1996-2001

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INNOVATION AND PRODUCTIVITY PERFORMANCE: HOW DOES MINAS GERAIS COMPARE TO OTHER MAJOR STATES? EVIDENCE FROM PINTEC 2000 AND PIA 1996-2001*

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TABLE OF CONTENTS

ABSTRACT

This paper uses data from a recent survey on the technological activity of Brazilian firms, organized according to international standard guidelines, to analyze their innovation performance, their trends in technical change, and the evolution of their technical efficiency. The first part of the study uses the survey to assess the innovation performance of the Brazilian firms in terms of R&D investment and patenting activity, the second part matches this recent one-time survey with a panel data, built from the yearly manufacturing census surveys done in 1996-2001, to analyze technical change evolution and efficiency trends in the country manufacturing divisions. The results corroborate the hypotheses that firm size affects both R&D investment and patenting activity, and patenting is also driven by R&D expenditures. Firms located in Minas Gerais (MG) are more likely to invest in R&D than the ones in Rio de Janeiro (RJ) but they lag behind their peers in Rio Grande do Sul (RS). The ranking of these states in terms of output shifts from a baseline production function shows each of them taking turns in leading the other ones in two of the six manufacturing divisions analyzed; however, their ranking in terms of efficiency shifts shows a more lopsided outcome: the states of RS and RJ hold the leading position three times each leaving no division to be claimed by the state of MG. In general there is a downward productivity trend in the period coupled with generalized increase of technical inefficiency. The outcome characterizes a situation in which pushing up the technological frontier matters less than diffusing the best-practice, and the extent and rate of this type of diffusion process are extremely relevant for government and private sector policies to encourage productivity growth.

RESUMO

Esse artigo se utiliza de dados de um censo recente sobre atividades de inovação junto a empresas brasileiras, organizado de acordo com metodologia internacionalmente estabelecida, para analisar o desempenho das mesmas em termos dessas atividades, sua evolução tecnológica, e sua trajetória de eficiência técnica. A primeira parte do artigo usa o censo tecnológico para avaliar o desempenho das empresas em termos de investimento em P&D e atividade de patenteamento, a segunda parte concatena esse censo com um painel de dados, construído a partir de informações da Pesquisa Industrial Anual (PIA) em 1996-2001, para empreender o estudo de tendências de mudança técnica e eficiência na indústria brasileira. Os resultados corroboram as hipóteses de que o tamanho da firma afeta tanto o investimento em P&D como a atividade de patenteamento, e essa, por sua vez, é também afetada pelo investimento em P&D. Firmas localizadas em Minas Gerais (MG) têm maior probabilidade de investir em P&D do que firmas localizadas no Rio de Janeiro (RJ), mas menor probabilidade de faze-lo de que seus pares no Rio Grande do Sul (RS). A ordenação desses três estados em termos de ganhos de produto em relação a um nível determinado por uma função de produção subjacente comum mostra que os estados fazem rodízio de posições de liderança de forma que cada um ocupa essa posição em dois dos seis gêneros industriais analisados; contudo, a ordenação em termos de ganhos de eficiência com relação a um nível subjacente comum tem resultado desigual: RS e RJ têm posição de liderança em três gêneros cada um não dando margem a resultado favorável a MG. Existe um quadro evolutivo de declínio de produtividade (mudança técnica) combinado a uma tendência a aumento de ineficiência. Esse resultado caracteriza uma situação em que a expansão da fronteira tecnológica importa menos do que a difusão da melhor prática tecnológica, e a abrangência e a taxa de disseminação desse tipo de processo de difusão são extremamente relevantes para políticas de estímulo à produtividade tanto do governo quanto do setor privado.

I. INTRODUCTION

Although the transformation of scientific knowledge into information applicable to production processes has been a permanent topic of interest in Economics, it has been also hindered by the non-availability - or imperfection - of data on it. The situation stands in contrast with the existence of many tested procedures to overcome the lack of data - or the limitations of available information - on standard economic variables such as capital, skilled labor, unskilled labor. In spite of these difficulties, however, there has been a steady building up and growing diffusion of methodology to gather information related to innovation activities. This paper uses data from a recent survey on the technological activity of Brazilian firms, organized according to international standard guidelines, to analyze innovation performance, trends in technical change, and the evolution of technical efficiency in the country manufacturing divisions.

The paper is organized as follows. Section II describes the database and methodology, Section III discusses the innovation performance of the Brazilian firms in terms of R&D investment and patenting activity, Section IV analyzes technical change and efficiency trends in the country manufacturing divisions, and Section V concludes the paper.

II. DATABASE AND METHODOLOGY

II.1. Database

The study uses two data sets, the 2001 Industrial Survey on Technological Innovation Activities (Pesquisa Industrial – Inovação Tecnológica, PINTEC) and a 1996-2001 panel data of firms surveyed by the Annual Manufacturing Survey (Pesquisa Industrial Anual, PIA). The Brazilian Central Statistical Office (Instituto Brasileiro de Geografia e Estatística, IBGE), the agency in charge of these surveys, grants researchers *in site* access to firm level data but releases only the statistical results of their empirical studies to preserve the anonymity of the sources of information.

PINTEC collects firm level information on technological innovation activities in 1998-2000 from a sample of manufacturing Brazilian firms. The survey follows the methodology suggested by "Manual Oslo" (OECD, 1997), which emphasizes the importance of distinguishing between inputs and outputs in technological innovation processes. PINTEC collects data on firms' expenditures in research and development (R&D), which are typical inputs to technological innovation activities, information on firms' characteristics - such as the origin of capital (domestic, foreign, or mixed origin) and the main geographic destination of the firm's output, and information on possible outputs of innovation activities. The questionnaire gathers detailed information on R&D expenditures. For example, one entry records the firm disbursement on its own R&D, a number of entries reports diverse possibilities of the firm acquiring externally R&D - purchasing know how or technologically improved equipment, another item informs the firm expenditures in training personnel in handling upgraded inputs to its productive process. A number of subjective questions refer to the impact of innovations on the quality of products or processes – four categories of assessment are made available for these entries, and two yes/no entries request the firm to report the existence of: i) a granted patent; ii) an application for a new patent.

IBGE uses the stratified sampling approach in defining samples for most of its socioeconomic surveys – taking into account, for example, the participation of different class sizes in the population of firms in manufacturing major divisions; however, the sporadic nature of innovation activities led it to forgo the standard procedure and build the PINTEC sample by selecting firms with high probability of being innovators. The selection uses a set of technological indicators drawn from other databases, as described in "PINTEC 2000, Aspectos Metodológicos" (IBGE, 2003). From a population of 70,000 manufacturing firms with 10 or more employees, 22,699 implemented some technologically new product or process in 1998-2000. The sample includes all firms either with more than 500 employees or presenting at least one of the main technological indicators, and randomly selected business units from a subset containing firms that reach a predetermined minimum score in terms of secondary technological indicators. The sample size sums up to 11,044 units.

PIA collects yearly economic information about firms in the 27 divisions of the manufacturing sector. This study uses a 1996-2001 panel data of firms included in the PIA surveys in the period - all of them follow the methodology upgrade of 1996. There are two subsets of manufacturing sector business units included in the survey since then: 1) a non-random sample of all Brazilian manufacturers having more than 30 employees; 2) a randomly selected sample of small firms with at least 5 employees. The main entries refer to the number of employees, payroll information, revenue sales, taxes paid, a number of itemized investment expenditures – such as buildings and machinery, and diverse cost components. The panel data includes information on 10,398 firms in 1996-2001. Currency-based variables are deflated using manufacturing division specific wholesale price indices (índices de preços por atacado – oferta global, IPA-OG) but the manufacturing average IPA-OG is the deflator of choice whenever the manufacturing division specific index is not available.

II.2. A Binary Response Framework for Patent Applications

The PINTEC survey includes a yes/no type of question regarding firms' decision to apply for patent application making it suitable for a standard binary choice modeling, which assumes that the probability of a firm submitting a patent application relates to a set of its attributes. Analogously, a relevant information on the decision of a firm to engage or not in spending resources in R&D is its probability of doing so, which also relates to a set of its characteristics. The standard binary response model reads as:

(1) $p(y=1 \mid \mathbf{x}) = G(\mathbf{x}\boldsymbol{\beta}) \equiv p(\mathbf{x})$

where $G(\mathbf{x}\boldsymbol{\beta})$ is specified, in general, as one the two following types of cumulative distribution function – normal (probit model) or standard logistic (logit model).

It is noteworthy that the non-random sample nature of the selection of firms included in the PINTEC survey affects the representativeness of the probabilities to be estimated: they are associated with a particular subset of the Brazilian manufacturing sector which includes firms with high probability of being innovators. As mentioned in Section II.1, the sample selection uses a set of technological indicators drawn from other databases to identify the 11,044 firms, out of 70,000 in the manufacturing sector, to be surveyed by PINTEC. The selection draws two subsets of this larger set, one including all firms with size greater than 500 employees or with strong technological activity, as assessed by the indicators, and another one comprising of a random selection of firms with weak but discernible technological activity. Because of the non-availability of a key component of the sample selection rule (technological indicators), the Heckman procedure to deal with selectivity bias is not applicable here. The question to be addressed by the estimation of expression (1) is, then, what factors affect the probability of an innovation-prone firm in Brazil to submit a patent application, or to engage in R&D activities?

II.3. A Stochastic Frontier Production Function Including R&D Indicators

Basic microeconomics textbooks describe production function frameworks in which it is assumed that every producer allocates efficiently inputs and output(s) ending up on their profit functions. However, empirical evidence lends support to the idea that not all producers are successful *optimizers*, and, given the technology, a number of them make sub-optimal utilization of resources at their disposal.

The textbook maintained hypothesis of widespread efficiency-in-production notwithstanding, the idea of existence of differential efficiency among producers is well established in the literature. The concept of efficiency in production, as proposed by Koopmans (1951), characterizes the efficient producer as the one who can produce more of any output only by reducing the production level of some other output or by increasing the use of one or more inputs. The concept gets a sharper meaning with the work of Farrell (1957), who defines cost efficiency and decomposes it into an allocative component, associated with the firm's ability to optimize the use of inputs given a set of prices, and into a technical component, related to the firm's ability to maximize output given a set of inputs (quantities). Charnes and Cooper (1962) set up the non-parametric linear programming framework to analyze producing units from the efficiency viewpoint, and Charnes, Cooper, and Rhodes (1978) develop a full-blown version of the linear programming efficiency analytical tool known as Data Envelopment Analysis (DEA). It is worth noting that the DEA approach was initially used to analyze the efficiency performance of decision-making units not operating in a fully profit driven environment such as diverse types of government agencies.

In contrast with the DEA framework, the stochastic frontier analysis (SFA) approach uses econometric methods to fit data into a parametric production function. The merits of the initial development are shared by Meeunsen and van den Broeck (1977), and Aigner, Lowell and Schmidt (1977). The key idea is to define a composed error structure for the function. The expression $y = f(x:\beta).e^{v-u}$ summarizes the model: y is scalar output, x is a vector of inputs, β is a vector of technology parameters, $v \sim N(0,\sigma_v^2)$ is the error component associated with statistical noise, $u \geq 0$ is the error component related to effects of technical inefficiency. Maximum likelihood estimation of SFAs requires an additional assumption about the distribution of the error component u. The literature has proposed a number of options, for example, half-normal, exponential, gamma. The truncated normal distribution $u \sim N(\mu,\sigma_u^2)$ is an alternative suggestion proposed by Stevenson (1980), who argues that the half normal distribution has the implicit assumption that the distribution mode sits at the zero inefficiency level. By setting $\mu = 0$ the truncated distribution yields the half normal distribution, and for any $\mu > 0$ the truncated normal distribution has its mode at some sub-optimal efficiency level.

Battese and Coelli (1993) propose a model expressed by

(2) $y_{it} = e^{\mathbf{x}_{it}\beta + v_{it} - u_{it}}$

where y_{it} is the observed production at the t-th period (t=1, 2, ...,T) for the i-th firm (i=1,2,...,N), $\mathbf{x}_{it}$ is a (1 x k) vector of values of inputs of production associated with the i-th firm at the t-th period, β is a (k x 1) of technology parameters to be estimated, the v_{it} are assumed to independent identically distributed (iid) $N(0,\sigma_v^2)$ random errors. The non-negative random variables u_{it} are related to technical inefficiency of production and independently distributed of the v_{it}. The authors assume the following structure for the technical inefficiency error component u_{it} :

(3) $u_{it} = \mathbf{z}_{it}\delta + w_{it}$

where $\mathbf{z}_{it}$ is a (1 x m) vector of firm-specific variables that may vary over time, δ is a (m x 1) vector of unknown coefficients of the firm-specific inefficiency variables, the random variable w_{it} is the truncation of the normal distribution $N(0,\sigma^2)$ such that the point of truncation is $-\mathbf{z}_{it}\delta$. w_{it} assumes values in the interval $(-\mathbf{z}_{it}\delta \leq w_{it} < \infty)$, and, accordingly, $u_{it}'s$ are non-negative truncations of the $N(\mathbf{z}_{it}\boldsymbol{\delta},\sigma^2)$ distribution. This study uses the Battese and Coelli (1993) framework to analyze the efficiency performance of firms in the Brazilian manufacturing sector in 1996-2201. It includes capital, labor, year, own-R&D as $\mathbf{x}$ variables in the frontier equation, and year, acquired-R&D as $\mathbf{z}$ variables in the efficiency equation. The variables related to R&D expenditures are firm-specific but time-invariant because the PINTEC survey was done just one single time.

III. INNOVATION PERFORMANCE AND RELATED RESULTS

III.1. Introduction

The concept of innovation activity embodies a widespread phenomenon in modern economies but, being a typical latent variable, presents the known difficulties of finding proxy variables to make the idea operational. Statistics on patents or figures on the amount of resources committed to R&D are two widely employed proxies. Although the PINTEC survey has data on both of them, it does not report on the size of firms, presumably a factor affecting the intensity of innovation activities reflected by those two proxies, and the information has to be retrieved from the manufacturing survey PIA. The key to link information on the same firm drawn from both databases is the firm tax number code. The 9,130 firms matched in both databases are used in the empirical analyses of Sections III.2 and III.3 below.

Information about patent application in 1998-2000 is a binary response entry in the PINTEC questionnaire, and information about positive or zero R&D expenditures in the period is constructed from the R&D data available in the survey. The variables included in the qualitative response models (probit and logit) are:

R&D, binary variable: 1 if the sum of in-house R&D and all types of acquired R&D services is positive; 0 otherwise;

R&D, continuous variable: sum of in-house R&D and all types of acquired R&D services

patent application, binary variable: 1 if yes; 0 if no;

# of employees, continuous variable: firm size indicator;

sales, continuous variable: alternative firm size indicator;

foreign-owned, binary variable: 1 if firm capital is partially or totally foreign; 0 otherwise;

export-driven, binary variable: 0 if main product market is Brazil; 1 otherwise. The questionnaire has three options of domestic market, state level, regional level, the whole country – all set the variable to 0, and 7 alternative destinations abroad, Mercosul, United States, all Americas but the U.S., Asia, Europe, Australia /Africa, the whole world;

d-st, binary variable: 1 if firm is located in the state st; 0 otherwise; Tables 2, 3, and 5 report results including 6 binary variables like these. The suffix st assumes the following codes representing state names: rj = Rio de Janeiro, sp = São Paulo, mg = Minas Gerais, pr = Paraná, sc = Santa Catarina, rs = Rio Grande do Sul;

d-99, binary variable: 1 if the firm manufacturing division is 99; 0 otherwise; Tables 4 and 6 report results including 10 binary variables like these. The suffix 99 assumes the following codes representing manufacturing divisions: 24 = Manufacture of Chemicals and Chemical Products, 25 = Manufacture of Rubber and Plastic Products, 28 = Manufacture of Fabricated Metal Products, except Machinery and Equipment, 29 = Manufacture f Machinery and Equipment, 30 = Manufacture of Office Goods and Information Technology Equipment, 31 = Manufacture of Electrical Machinery and Apparatus, 32 = Manufacture of Electronic Devices and Communications Equipment, 33 = Manufacture of Medical, Precision and Optical Instruments, Watches And Clocks, 34 = Manufacture of Motor Vehicles and Related Products, 36 = Manufacture of Furniture.

III.2. Factors affecting R&D investment

Table 1 below, reproduced from IBGE (2002), summarizes information gathered by the PINTEC survey about the status of innovation activities in a selected number of Brazilian manufacturing divisions. The figures reproduced here are the ones related to the divisions well represented in the 9,130 firms database used here. IBGE reports that 22,699 firms, 31.5% of over 70,000 business units in its register of Brazilian manufacturers, were involved in some type of innovation activity in 1998-2000 – product innovation, process innovation, or a mix of the two. The share of firms engaged in innovation activities ranges from 32.8% in division 28, Manufacture of Fabricated Metal Products, Except Machinery and Equipment, to 68.5% in division 30, Manufacture of Office Goods and Information Technology Equipment. As for the percentage of sales spent in innovation activities in broad sense, the 3.1% figures of division 30 are the lower bound whereas the 7.1% result of division 34, Manufacture of Motor Vehicles and Related Products, is the upper bound. Lower and upper bound figures on the percentage of sales allocated to in-house R&D are 0.24% for division 36, Manufacture of Furniture, and 1.77% for division 33, Manufacture of Medical, Precision and Optical Instruments.

Tables 2, 3, and 4 report statistics about factors affecting the probability of R&D investment - prob(R&D). A strong (but expected) result is the positive correlation between prob(R&D) and firm size, independently of the size indicator of choice – either # of employees as in Table 2, or sales figures as in Table 3. Also, prob(R&D) is higher for firms whose capital is at least partially foreign (positive sign in foreign_owned coefficient), or firms whose products have the domestic market as the main destination for their products (negative sign in export_driven coefficient). It is interesting to check how the location of a firm in any of the six more active states in terms of innovation activities - Minas Gerais (MG), Paraná (PR), Rio de Janeiro (RJ), Rio Grande do Sul (RS), Santa Catarina (SC), and São Paulo (SP) - affects prob(R&D). The ranking of the states of SC, RS, and RJ does not depend on the firm size indicator: whether the indicator of choice is the # of employees (Table 2) or sales (Table 3), SC and RS rank in first and second places, respectively, and RJ holds the last position. On the other hand, the state of SP, which is the location of nearly half of the firms in the database, has its intermediary ranking position dependent on the size indicator. For two "same size" firms located in SP and MG with no foreign capital and selling their product only to the domestic market, the size indicator is key to determine which one is more likely to decide for R&D investment: same size measured by the # of employees implies that the firm located in SP has higher probability of doing R&D than the one in MG, same size measured by sales yields the opposite result. Other than the state of SP, which has firms included in the database representative of all manufacturing divisions, the other states have firms classified in some (never in all) of these divisions. Because some manufacturing divisions are more likely to be engaged in R&D investment than others, the geographic distribution of these divisions may be a factor in the ranking discussed above. Table 4 presents the results of the estimation of prob(R&D) with the same core of factors included in Table 3 but adding manufacturing division binary variables instead of state binary variables. Other things equal, the likelihood of a firm to be engaged in R&D investment depends on its manufacturing division. In descending order, firms have higher prob(R&D) if they are classified in: 1) 33, Manufacture of Medical, Precision and Optical Instruments; 2) 32, Manufacture of Electronic Devices and Communications Equipment; 3) 30, Manufacture of Office Goods and Information Technology Equipment; 4) 29, Manufacture f Machinery and Equipment; 5) 31, Manufacture of Electrical Machinery and Apparatus.

TABLE 1

Innovation activities in 1998-2000
Selected Divisions of the Brazilian Manufacturing Sector

Manufacturing Division	% of firms engaged in innovation activities	% of revenue sales spent in	
		innovation activities in broad sense	in-house R&D
Industry at large	31.9	3.9	0.65
24 Manufacture of Chemical Products	46.1	4.0	0.65
25 Manufacture of Rubber and Plastic Products	39.7	4.5	0.42
28 Manufacture of Fabricated Metal Products	32.8	3.5	0.35
29 Manufacture of Machinery and Equipment	44.4	4.1	1.15
30 Manufacture of Office Goods and IT Equipment	68.5	3.1	1.30
31 Manufacture of Electrical Machinery and Apparatus	48.2	5.8	1.76
32 Manufacture of Electronic Devices and Communications Equipment	62.5	4.8	1.60
33 Manufacture of Medical, Precision and Optical Instruments	59.1	5.0	1.77
34 Manufacture of Motor Vehicles and Related Products	36.4	7.1	0.89
36 Manufacture of Furniture	36.2	3.3	0.24

Source: IBGE (Brazilian Central Statistical Office)

TABLE 2

Factors Affecting the Probability of R&D Investment in 1998-2000
(# of employees as firm size indicator, state dum. var., standard errors in parentheses)

Independent variable: R&D, yes or no	Logit	Probit	Logit	Probit
intercept	-2.0725	-1.2754	-2.3010	-1.4174
	(0.0970)	(0.0584)	(0.1093)	(0.0658)
ln_#employees	0.4221	0.2597	0.4194	0.2582
	(0.0206)	(0.0124)	(0.0207)	(0.0125)
Foreign_owned	0.8241	0.5065	0.8398	0.5162
	(0.0760)	(0.0457)	(0.0771)	(0.0464)
export_driven	-0.3724	-0.2282	-0.4209	-0.2575
	(0.0941)	(0.0579)	(0.0959)	(0.0590)
d_rj			-0.0978*	-0.0587*
			(0.1067)	(0.0653)
d_sp			0.2879	0.1780
			(0.0643)	(0.0396)
d_mg			0.2223	0.1376
			(0.0898)	(0.0553)
d_pr			0.2652	0.1656
			(0.0985)	(0.0607)
d_sc			0.5027	0.3126
			(0.0985)	(0.0608)
d_rs			0.4863	0.3027
			(0.0869)	(0.0536)
number of observations	8631	8631	8631	8631
percent correctly predicted	65..2	65.2	65.8	65.8
log_likelihood (lnL) value	11267.92	11267.75	11208.97	11207.93
lnL value, only intercept	11962.03	11962.03	11962.03	11962.03

all coefficients are significant at 5% level unless stated otherwise
* statistically non significant

TABLE 3

Factors Affecting the Probability of R&D Investment in 1998-2000
(Revenue sales as firm size indicator, state dum. var., standard errors in parentheses)

Independent variable: R&D, yes or no	Logit	Probit	Logit	Probit
intercept	-5.1282	-3.0948	-5.3884	-3.2575
	(0.2222)	(0.1324)	(0.2306)	(0.1372)
ln_sales	0.3203	0.1933	0.3231	0.1951
	(0.0141)	(0.0084)	(0.0143)	(0.0085)
foreign_owned	0.3969	0.2518	0.4307	0.2731
	(0.0797)	(0.0481)	(0.0805)	(0.0486)
export_driven	-0.3061	-0.1859	-0.3862	-0.2355
	(0.0935)	(0.0575)	(0.0954)	(0.0587)
d_rj			-0.1442*	-0.0888*
			(0.1094)	(0.0667)
d_sp			0.1952	0.1209
			(0.0661)	(0.0405)
d_mg			0.3067	0.1924
			(0.0927)	(0.0568)
d_pr			0.3198	0.2018
			(0.1022)	(0.0627)
d_sc			0.5477	0.3385
			(0.1010)	(0.0620)
d_rs			0.4771	0.2963
			(0.0890)	(0.0546)
number of observations	8447	8447	8447	8447
percent correctly predicted	67.2	67.2	67.8	67.7
log_likelihood (lnL) value	10903.49	10909.32	10841.09	10845.76
lnL value, only intercept	11708.96	11708.96	11708.96	11708.96

all coefficients are significant at 5% level unless stated otherwise
* statistically non significant

TABLE 4

Factors Affecting the Probability of R&D Investment in 1998-2000
(Revenue sales as firm size indicator, manufacturing division dummy variable, standard errors in parentheses)

Independent variable: R&D, yes or no	Logit	Probit
intercept	-5.3692	-3.2346
	(0.2283)	(0.1352)
ln_sales	0.3192	0.1921
	(0.0144)	(0.0086)
foreign_owned	0.1873	0.1186
	(0.0823)	(0.0496)
export_driven	-0.1666*	-0.0981*
	(0.0952)	(0.0585)
d_24	0.6596	0.4060
	(0.0975)	(0.0590)
d_25	0.2328	0.1423
	(0.0945)	(0.0584)
d_28	0.3413	0.2092
	(0.0955)	(0.0589)
d_29	0.9408	0.5783
	(0.0935)	(0.0568)
d_30	1.3222	0.7957
	(0.3517)	(0.2022)
d_31	0.7622	0.4754
	(0.1402)	(0.0855)
d_32	1.3824	0.8384
	(0.2256)	(0.1313)
d_33	1.3869	0.8441
	(0.2177)	(0.1282)
d_34	0.5974	0.3715
	(0.1281)	(0.0783)
d_36	0.5461	0.3345
	(0.0953)	(0.0588)
number of observations	8447	8447
percent correctly predicted	69.7	69.7
log_likelihood (lnL) value	10653.05	10657.74
lnL value, only intercept	11708.96	11708.96

all coefficients are significant at 5% level unless stated otherwise
significant at 10% level : prob. = 0.08 and prob. = 0.093, respectively

III.3. Factors affecting patent applications

Tables 5 and 6 present evidence on factors affecting the probability of firms applying for a patent grant in 1998-2000 – prob(PAT). The robust results refer to the positive correlation between prob(PAT) and firm size (sales as size indicator), and between prob(PAT) and R&D investment; in contrast, the coefficients referring to the variables foreign_owned and export_driven are not robust to the specification of alternative sets of additional variables – state or manufacturing division indicators.

The results referring to the correlation between the firm location and prob(PAT), reported in Table 5, show that among firms in the six major states assumed to: 1) invest the same amount of resources in R&D; 2) have the same sales figures; 3) produce for the domestic market, the ones located in the state of RS are more likely to apply for a patent grant. All six states considered, the descending order ranking is RS, SP, SC, RJ, PR, MG.

It is well established in the literature that patenting is higher in the science-based industries – an early and careful discussion of the issue is found in Bound at al. (1984) - so the distribution of patent applications among manufacturing divisions in uneven. Table 6 presents the results of the estimation of prob(PAT) with the same core of factors included in Table 5 but adding manufacturing division binary variables instead of state binary variables. Firms have higher prob(PAT) if they are classified in the following five divisions, ranked in descending order: 1) 29, Manufacture of Machinery and Equipment; 2) 33, Manufacture of Medical, Precision and Optical Instruments; 3) 36, Manufacture of Furniture; 4) 28, Manufacture of Fabricated Metal Products, Except Machinery and Equipment; 5) 30, Manufacture of Office Goods and Information Technology Equipment. The division Manufacture of Furniture is an exception to the "science-based industries" criterion as a predictor of higher level of patent applications but it is well known that submissions of applications for utility (or design) patent grants are prevalent in this division. The PINTEC survey has a yes/no question associated with possible patent applications by firms in 1998-2000 but it does not deal with the degree of scientific complexity of the requests to the Patent Office.

TABLE 5

Factors Affecting the Probability of Patent Application in 1998-2000
(Revenue sales as firm size indicator, state dum. var., standard errors in parentheses)

Independent variable: Patent application, yes or no	Logit	Probit	Logit	Probit
intercept	-5.2012	-3.0179	-6.1578	-3.5195
	(0.4381)	(0.2387)	(0.4763)	(0.2575)
ln_sales	0.1549	0.0909	0.1577	0.0919
	(0.0298)	(0.0161)	(0.0305)	(0.0165)
ln_R&D	0.1734	0.0943	0.1721	0.0938
	(0.0203)	(0.0106)	(0.0206)	(0.0108)
foreign_owned	0.0888*	0.0605*	0.0181*	0.0197*
	(0.1062)	(0.0613)	(0.1092)	(0.0629)
export_driven	-0.4922	-0.3025	-0.4542	-0.2725
	(0.1763)	(0.0972)	(0.1800)	(0.0993)
d_rj			0.9647	0.5057
			(0.2261)	(0.1210)
d_sp			1.1388	0.6116
			(0.1550)	(0.0792)
d_mg			0.6390	0.3449
			(0.2095)	(0.1084)
d_pr			0.7445	0.3939
			(0.2202)	(0.1154)
d_sc			1.0327	0.5488
			(0.2051)	(0.1088)
d_rs			1.1604	0.6219
			(0.1827)	(0.0963)
number of observations	4784	4784	4784	4784
percent correctly predicted	68.5	68.6	70.7	70.7
log_likelihood (lnL) value	3992.14	3988.64	3915.75	3912.73
lnL value, only intercept	4287.28	4287.28	4287.28	4287.28

all coefficients are significant at 5% level unless stated otherwise
* statistically non significant

TABLE 6

Factors Affecting the Probability of Patent Application in 1998-2000
(Manufacturing division dummy variable, standard errors in parentheses)

Independent variable: Patent application, yes or no	Logit	Probit
intercept	-7.5937	-4.2437
	(0.5102)	(0.2739)
ln_sales	0.2564	0.1421
	(0.0331)	(0.0179)
ln_R&D	0.1598	0.0871
	(0.0214)	(0.0113)
foreign_owned	-0.2295	-0.1059*
	(0.1137)	(0.0652)
export_driven	-0.3438*	-0.2076
	(0.1866)	(0.1027)
d_24	0.7029	0.3697
	(0.1528)	(0.0846)
d_25	1.1644	0.6355
	(0.1653)	(0.0921)
d_28	1.4987	0.8247
	(0.1649)	(0.0930)
d_29	1.8667	1.0372
	(0.1338)	(0.0759)
d_30	1.4389	0.8022
	(0.3408)	(0.2040)
d_31	1.3808	0.7457
	(0.1989)	(0.1150)
d_32	1.0722	0.6145
	(0.2509)	(0.1438)
d_33	1.7870	0.9800
	(0.2413)	(0.1425)
d_34	0.4589	0.2267**
	(0.2177)	(0.1194)
d_36	1.6664	0.9083
	(0.1593)	(0.0901)
number of observations	4784	4784
percent correctly predicted	75.9	75.9
log_likelihood (lnL) value	3688.99	3686.22
lnL value, only intercept	4287.28	4287.28

all coefficients are significant at 5% level unless stated otherwise
* marginally significant at 10% level : prob. = 0.1042
** significant at 10% level : prob. = 0.057

IV. INNOVATION AND PRODUCTIVITY PERFORMANCE

IV.1 Introduction

This section discusses the fitting of a Cobb-Douglas stochastic frontier production function to Brazilian manufacturing data. The Battese and Coelli (1993) model is flexible enough to accommodate the standard relationship between output and inputs (frontier production function component, equation (2) in Section II.3) and to estimate an average measure of firms' departure from the best-practice technology (technical efficiency component, equation (3) in Section II.3). The variables are constructed as follows:

output y: the firm value added proxy is set as the difference between the entry “net revenue sales” and the entry “raw materials, ancillary materials, components;”

capital k: there is no information on firms’ capital stock in the PIA surveys done from 1996 to 2001 but data on information flows allows the construction of a proxy. The approach adopted here follows closely a suggestion by Young (1995), who uses the standard perpetual inventory method approach with geometric depreciation in analyzing a series of 38 years of investment flows with no reliable anchoring figures for the initial capital stock. He computes the initial capital stock as $C_0 = I_0 /(g_j + \delta_j)$, where “ I_0 is the first year of investment for asset j, δ_j is the depreciation rate for asset j, g_j is the average growth of investment in asset j in the first five years of the investment series.” The *ad hoc* procedure chosen here has I_0 defined as the average net firm investment flow over the 6 years period and three alternative values for $(g_j + \delta_j)$, 0.10, 0.15, and 0.20. The firm net flow investment is set as the difference between “acquisition of machines and industrial equipment” and “machines and industrial equipment write-off.” Because the three alternative values for $(g_j + \delta_j)$ yield very similar estimated equation coefficients – capital and labor, for example, have the same first two figures, all the tables below report the results of the “0.10” assumption as representative of the set of estimations under alternative hypotheses. It is worth emphasizing that these hypotheses are maintained just to compute an initial value for firms’ capital stock.[1]

labor l: reported annual average of the number of workers in production;

year: 1, 2, …, 6;

own-R&D: amount of in-house R&D expenditures;

acquired-R&D: the amount of resources spent in acquiring R&D or in purchasing one of the following: know-how, software, machinery and equipment for the production of (implementation of) of technologically upgraded products (processes). Expenditures with workers’ training related to upgraded production processes or marketing activities linked to new products are, also, summed up here;

d-st, binary variable: 1 if firm is located in the state st; 0 otherwise. The suffix st assumes the following codes representing state names: rj = Rio de Janeiro, sp = São Paulo, mg = Minas Gerais, pr = Paraná, sc = Santa Catarina, rs = Rio Grande do Sul.

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[1] Consider, for example, the manufacturing division 25, Manufacture of Rubber and Plastic Products. Assumption “0.10” yields the following coefficients estimated for the frontier equation reported in Table 7.A: 8.9027 (intercept), 0.2254 (capital), 0.7763 (labor), and -0.0413 (year); assumption “0.15” yields the coefficients: 9.0001 (intercept), 0.2247 (capital), 0.7763 (labor), and -0.0472 (year); assumption “0.20” yields the coefficients: 9.0545 (intercept), 0.2249 (capital), 0.7754 (labor), and -0.0497 (year). In terms of the efficiency equation, the figures are -25.92 (intercept) and 0.8180 (year), -25.63 (intercept) and 0.8443 (year), -25.63 (intercept) and 0.8332 (year) – for the three hypotheses, respectively.

IV.2. R&D as a factor in technical change and efficiency

The stochastic frontier analysis (SFA) model expressed in equations (2) and (3) relates firms' output to a set of input variables while maintaining the hypothesis of a composed error structure including a deterministic component and another component that is the sum of two random variables - a standard statistical noise and a term related to the effects of technical inefficiency.

Tables 7.A and 7.B report the results of the estimation of the model set with a frontier equation relating output to capital, labor, and year, and an efficiency equation associating the error term to year. The year coefficient in the frontier equation can be understood as a raw measure of average productivity change in the period, and the coefficient sign carries a straightforward interpretation - a positive (negative) sign means frontier expansion (contraction). On the other hand, the year coefficient in the efficiency equation can be understood as a measure of the evolution of efficiency dispersion among firms in the period, and the coefficient sign carries the following interpretation - a positive (negative) sign means increasing (decreasing) disparity of efficiency levels among firms in the period.

The results, reported for selected manufacturing divisions, show two of them, Manufacture of Electrical Machinery and Apparatus and Manufacture of Medical, Precision and Optical Instruments, recording productivity growth in the period (4.76% and 4.16%), and all divisions presenting a time trend associated with increasing average inefficiency level (positive year coefficient). It is arguable that increasing inefficiency coupled with decreasing productivity characterizes a worse economic environment than the one which combines increasing inefficiency with increasing productivity: the former situation is the case of the divisions Manufacture of Rubber and Plastic Products (time trend of -4.13% in the frontier equation), Manufacture of Fabricated Metal Products, Except Machinery and Equipment (-3.04%), and Manufacture of Electronic Devices and Communications Equipment (-3.34%). There is also a division showing no discernible productivity tendency, Manufacture of Machinery and Equipment.

The availability of firm-specific information on R&D allows for a less parsimonious specification of the SFA. The specification yields a more refined assessment of productivity tendencies because it makes explicit some of the individual firm effects formerly compounded with other effects in the error structure. This extended SFA specification has a frontier equation relating output to capital, labor, year, and own-R&D, and an efficiency equation associating the error term to year, and acquired-R&D. As before, productivity tendencies are inferred from the year coefficients.

Tables 8.A and 8.B present the outcomes. First, considering the estimates of the frontier equation, the division Manufacture of Electrical Machinery and Apparatus records a solid productivity growth (5.13%) and positive firm-specific individual effects "own-R&D" (3.68%); in contrast, Manufacture of Medical, Precision and Optical Instruments, which has positive productivity change in the Table 7 specification (4.16%), and Manufacture of Machinery and Equipment, which has no significant productivity change in Table 7, show no discernible productivity tendency in the Table 8 estimation, and no individual effects "own-R&D" either. The division Manufacture of Electronic Devices and Communications Equipment inverts these results: Table 8 reports strong positive "own-R&D" (9.08%) individual effects coupled with no statistically significant productivity trend, while

Table 7 records negative productivity trend (-3.34%). Finally, the divisions Manufacture of Rubber and Plastic Products and Manufacture of Fabricated Metal Products, Except Machinery and Equipment record negative productivity tendencies (-4.88% and –2.72%, respectively) in the results of Table 8, consistent with the signs of productivity trends reported in Table 7 (-4.13% and -3.04%), while showing significant positive individual effects “own-R&D” (3.54% and 1.34%). As for the results of the efficiency equation, the firm-specific individual effects “acquired-R&D” coefficients are all significantly negative as expected – the interpretation is that acquiring R&D allows firms to reduce their inefficiency level. The specification of an efficiency equation including individual R&D effects takes away the generalized findings of increasing average inefficiency level over time reported in Table 7: this is the case for Manufacture of Rubber and Plastic Products, Manufacture of Electronic Devices and Communications Equipment, and Manufacture of Medical, Precision and Optical Instruments, which show no defined time trend in Table 8. Table 8 presents, also, evidence of increasing average inefficiency level over time for the divisions Manufacture of Fabricated Metal Products Except Machinery and Equipment, Manufacture of Machinery and Equipment, and Manufacture of Electrical Machinery and Apparatus, as in the estimation reported in Table 7 (positive year coefficient).

TABLE 7A

Stochastic Frontier Production Functions Parameter Estimates
Selected Manufacturing Divisions in 1996-2001
(time-varying technical efficiency equation, standard errors in parentheses)

Frontier equation	Division 25	Division 28	Division 29
intercept	8.9027	9.0464	9.2707
	(0.0777)	(0.0720)	(0.0774)
ln_capital	0.2254	0.2199	0.2426
	(0.0059)	(0.0063)	(0.0063)
ln_labor	0.7762	0.7846	0.6872
	(0.0139)	(0.0155)	(0.0135)
year	-0.0413	-0.0304	0.0064*
	(0.0067)	(0.0063)	(0.0102)
intercept	-25.9195	-26.0663	-16.6055
	(3.4279)	(3.6238)	(0.0484)
year	0.8180	1.7770	1.3102
	(5.9735)	(0.2099)	(0.5307)
Sigma-squared	9.6759	9.0960	3.9749
	(1.2539)	(1.1932)	(0.7963)
Gamma	0.96391	0.9606	0.8725
	(0.0050)	(0.0059)	(0.0254)
Log likelihood	-4763.50	4782.78	5718.15
Likelihood ratio	183.21	235.52	28.43
number of observations	n=736, t=6	n=717, t=6	n=826, t=6

all coefficients are significant at 5% level unless stated otherwise
* statistically non-significant
25 Manufacture of Rubber and Plastic Products
28 Manufacture of Fabricated Metal Products, Except Machinery and Equipment
29 Manufacture of Machinery and Equipment

TABLE 7.B

Stochastic Frontier Production Functions Parameter Estimates
Selected Manufacturing Divisions in 1996-2001
(time-varying technical efficiency equation, standard errors in parentheses)

Frontier equation	Division 32	Division 33	Division 31
intercept	7.6449	9.4937	9.0453
	(0.9383)	(0.2251)	(0.1185)
ln_capital	0.4115	0.3075	0.2003
	(0.0251)	(0.0201)	(0.0114)
ln_labor	0.5265	0.5235	0.8097
	(0.0503)	(0.0406)	(0.0255)
year	-0.0334	0.0416	0.0476
	(0.0120)	(0.0200)	(0.0125)
Efficiency equation			
intercept	--01902*	-38.3475	-27.9714
	(1.7177)	(15.9475)	(6.4559)
year	(0.0001)*	1.7722	1.3796
	(0.0694)	(0.7751)	(0.3416)
Sigma-squared	1.1409	20.2988	10.9604
	(0.3842)	(8.0268)	(2.3348)
Gamma	0.0050	0.9755	0.9545
	(0.1132)	(0.0106)	(0.0112)
Log likelihood	-853.71	-996.87	-2249.83
Likelihood ratio	13.27	35.64	47.72
number of observations	n=96, t=6	n=126, t=6	n=304, t=6

all coefficients are significant at 5% level unless stated otherwise
* statistically non-significant
31 Manufacture of Electrical Machinery and Apparatus
32 Manufacture of Electronic Devices and Communications Equipment
33 Manufacture of Medical, Precision and Optical Instruments, Watches And Clocks

TABLE 8

A Stochastic Frontier Production Functions Parameter Estimates
Selected Manufacturing Divisions in 1996-2001
(R&D as a factor in technical change and efficiency, standard errors in parentheses)

Frontier equation	Division 25	Division 28	Division 29
intercept	9.1813	9.3474	9.7332
	(0.0735)	(0.0795)	(0.0814)
ln_capital	0.2213	0.2119	0.2322
	(0.0062)	(0.0062)	(0.0062)
ln_labor	0.7318	0.7427	0.6298
	(0.0154)	(0.0158)	(0.0149)
year	-0.0488	-0.0272	0.0045*
	(0.0071)	(0.0097)	(0.0093)
ln_own_R&D	0.0354	0.0134	0.0085*
	(0.0065)	(0.0066)	(0.0057)
Efficiency equation			
intercept	-13.3507	-6.3313	-1.1258
	(0.8952)	(1.1932)	(0.3701)
year	0.1105*	0.5893	0.1527
	(0.0889)	(0.099)	(0.0309)
ln_acquired_R&D	-0.6682	-0.7572	-0.4601
	(0.0310)	(0.1378)	(0.1023)
Sigma-squared	6.3385	3.0162	1.0514
	(0.4692)	(0.3932)	(0.1062)
Gamma	0.9461	0.8866	0.5569
	(0.0033)	(0.0155)	(0.0524)
Log likelihood	-4728.78	4742.93	5638.78
Likelihood ratio	201.61	284.03	127.83
number of observations	n=736, t=6	n=717, t=6	n=826, t=6

all coefficients are significant at 5% level unless stated otherwise
* statistically non-significant
25 Manufacture of Rubber and Plastic Products
28 Manufacture of Fabricated Metal Products, Except Machinery and Equipment
29 Manufacture of Machinery and Equipment

TABLE 8.B

Stochastic Frontier Production Functions Parameter Estimates
Selected Manufacturing Divisions in 1996-2001
(R&D as a factor in technical change and efficiency, standard errors in parentheses)

Frontier equation	Division 32	Division 33	Division 31
intercept	8.6075	10.5279	9.4877
	(0.2702)	(0.2976)	(0.1318)
ln_capital	0.3951	0.2924	0.1879
	(0.0237)	(0.0192)	(0.0115)
ln_labor	0.3845	0.3846	0.7369
	(0.0518)	(0.0413)	(0.0265)
year	-0.0297*	0.0359*	0.0513
	(0.0312)	(0.0259)	(0.0156)
ln_own_R&D	0.0908	0.0221*	0.0368
	(0.0154)	(0.0158)	(0.0089)
Efficiency equation			
intercept	-2.1818*	-0.5787*	-8.7395
	(1.9037)	(1.3535)	(2.2866)
year	0.0605)*	0.0988*	0.6492
	(0.0843)	(0.1060)	(0.1004)
ln_acquired_R&D	-0.6775	-0.4562	-0.7524
	(0.3194)	(0.2228)	(0.1844)
Sigma-squared	2.2550	2.2847	4.2702
	(07250)	(0.9223)	(0.9175)
Gamma	0.6152	0.8511	0.8885
	(0.1359)	(0.0529)	(0.0273)
Log likelihood	811.48	963.64	-2216.96
Likelihood ratio	10.90	72.04	71.23
number of observations	n=96, t=6	n=126, t=6	n=304, t=6

all coefficients are significant at 5% level unless stated otherwise
* statistically non-significant
31 Manufacture of Electrical Machinery and Apparatus
32 Manufacture of Electronic Devices and Communications Equipment
33 Manufacture of Medical, Precision and Optical Instruments, Watches And Clocks

IV.3 How does Minas Gerais compare to other states?

Among the firms included in the panel, the shares of manufacturing businesses located in Minas Gerais (MG), Paraná (PR), Rio Grande do Sul (RS), Rio de Janeiro (RJ), Santa Catarina (SC), and São Paulo (SP) vary from 76.6% in the division Manufacture of Electronic Devices and Communications Equipment to 96% in Manufacture of Machinery and Equipment. It is interesting to check which state, among the ones hosting most of the manufacturing activity, is the most advantageous to locate a firm. The time-varying frontier/efficiency setting, presented in Table 7 and expanded to include state dummy variables, helps to address the issue. The added variables are associated in the frontier equation with location-specific shifts in output with respect to the baseline production function level of the manufacturing division. The prerequisite of preserving the panel nature of the data set to be analyzed in the expanded time-varying specification leads to the loss of observations with respect to the data used in the original specification: all the state dummy variables added to the new set refer to firms having no change of location in 1996-2001.

Comparing Tables 7 with Table 9 it is noteworthy that: 1) two divisions keep the sign and the magnitude order of their productivity tendency (year coefficient), namely 25-Manufacture of Rubber and Plastic Products (–4.13% in Table 7.A and –4.04% in Table 9.A), and 28-Manufacture of Fabricated Metal Products, except Machinery and Equipment (-3.30% and –3.17%); 2) division 31-Manufacture of Electrical Machinery and Apparatus, keeps the sign and doubles the magnitude of its productivity growth (from 4.76% to 9.36%); 3) division 29-Manufacture of Machinery and Equipment has no (statistically) discernible productivity tendency in both specifications; 4) division 32-Manufacture of Electronic Devices and Communications Equipment changes its pattern from decreasing productivity trend (-3.34%) to no defined tendency, whereas division 33-Manufacture of Medical, Precision and Optical Instruments changes from productivity growth trend (4.16%) to no discernible tendency. Tables 9.A and 9.B show, also, efficiency equations with positive year coefficients (associated with increasing dispersion of efficiency levels among firms over time) for divisions 25, 28, 32, and 31, and no defined tendency for divisions 29 and 33.[2]

Below is the ranking of the major states in descending order with respect to output and efficiency shifts, from the baseline production function respective levels, in selected manufacturing divisions:

25 Manufacture of Rubber and Plastic Product; output shift: MG, SP, RJ, SC, RS, PR; efficiency level: RS, PR, SC, SP, MG, RJ.

28 Manufacture of Fabricated Metal Products Except Machinery and Equipment; output shift: RJ, SC, SP, RS, MG, PR; efficiency level shift: RS, PR, MG, SC, SP, RJ.

29 Manufacture of Machinery and Equipment; output shift: RJ=SC[3], MG, SP, PR, RS; efficiency level shift: RS, PR, SP, MG, SC[4], RJ.

31 Manufacture of Electrical Machinery and Apparatus; output shift: RS, SC, PR, SP=MG,[5] RJ; efficiency level shift: RJ, MG=PR=SP, [6] SC, RS.

32 Manufacture of Electronic Devices and Communications Equipment; output shift: SP, SC,[7] MG, RS, PR, RJ; efficiency level: PR, RJ, RS, MG, SC,[8] SP.

33 Manufacture of Medical, Precision and Optical Instruments: output shift: SP, RS, PR, RJ, MG, SC; efficiency level: PR, RJ, RS, SC, MG, SP.

The state of SP, which has nearly the same number of firms as the all the other states in the panel, is expected to record poorly in terms of efficiency shift (ES) because of the large spectrum of

[2] It is worth bearing in mind that positive (negative) coefficient signs are associated with factors negatively (positively) correlated with efficiency.

[3] RJ and SC have statistically non-significant coefficients and are set to zero efficiency level shift.

[4] SC has statistically non-significant coefficient and is set to zero efficiency level shift

[5] MG and SP have statistically non-significant coefficients and are set to zero efficiency level shift.

[6] MG, PR, and SP have statistically non-significant coefficients and are set to zero efficiency level shift.

[7] SC has statistically non-significant coefficient and is set to zero output shift.

[8] SC has statistically non-significant coefficient and is set to zero efficiency level shift.

the technological practice among firms located there; on the other hand, the state leads the ranking of output shift (OS) in two of the divisions analyzed. The state of PR does note rank well in OS but has two leading positions in ES. The state of RJ has two leading positions in terms of OS but ranks last in ES in three of the six divisions examined. The state of RS leads two divisions in OS and in three divisions in ES; in contrast, the state of MG has also a leading position in OS but does not hold any first place in ES. A more evenhanded comparison matches the states of MG, RS, and RJ, which have nearly the same state product size. In terms of OS, the ranking of this subset shows each of the three states leading the other ones in two of the six divisions analyzed; however, the ranking of ES shows a lopsided outcome: the states of RS and RJ hold the leading position three times each in the group leaving no division to be claimed by the state of MG. Comparing to the state of RJ, the intermediary ranking position of the state of MG in ES stands out: in those divisions led by the state of RS, the state of RJ ranks last.

TABLE 9.A

Stochastic Frontier Production Functions Parameter Estimates
Selected Manufacturing Divisions in 1996-2001
(State dummy variables, standard errors in parentheses)

Frontier equation	Division 25	Division 28	Division 29
intercept	9.1010	9.8778	11.9169
	(0.2002)	(0.5482)	(0.5222)
ln_capital	0.2565	0.2658	0.2825
	(0.0103)	(0.0092)	(0.0092)
ln_labor	0.7483	0.7502	0.6360
	(0.0215)	(0.0231)	(0.0177)
year	-0.0404	-0.0317	-0.0029*
	(0.0142)	(0.0136)	(0.0134)
d_mg	-0.3303**	-1.5414	-2.5816
	(0.2002)	(0.5074)	(0.5123)
d_sp	-0.4096	-1.1386	-2.6188
	(0.1327)	(0.5073)	(0.5358)
d_rj	-0.5485	-0.8931**	0.7007*
	(0.2041)	(0.4917)	(0.4441)
d_sc	-0.5809	-0.9924	-0.4005*
	(0.1899)	(0.5230)**	(0.3304)
d_pr	-0.8755	-1.5529	-3.2809
	(0.1534)	(0.4677)	(1.3003)
d_rs	-0.7304	-1.4312	-9.4580
	(0.1532)	(0.5011)	(2.1677)

all coefficients are significant at 5% level unless stated otherwise
* statistically non-significant
** significant at 10% level
25 Manufacture of Rubber and Plastic Products
28 Manufacture of Fabricated Metal Products, Except Machinery and Equipment
29 Manufacture of Machinery and Equipment

TABLE 9.A
Stochastic Frontier Production Functions Parameter Estimates (cont.)

Selected Manufacturing Divisions in 1996-2001
(State dummy variables, standard errors in parentheses)

Efficiency equation	Division 25	Division 28	Division 29
intercept	0.1845*	1.3595	3.0054
	(0.3159)	(0.6489)	(0.5488)
year	0.1261	0.1367	0.0443*
	(0.0403)	(0.0451)	(0.0331)
d_mg	-1.4881	-4.1511	-3.0607
	(0.4209)	(0.6704)	(0.5471)
d_sp	-2.1509	-3.2685	-3.9555
	(0.2743)	(0.5506)	(0.6933)
d_rj	-0.9558	-2.7284	0.9835
	(0.3568)	(0.6114)	(0.4954)
d_sc	-2.5873	-3.3666	-0.4540*
	(0.4956)	(0.6942)	(0.3885)
d_pr	-4.2497	-9.4575	-6.8805
	(0.6255)	(2.6201)	(1.3003)
d_rs	-7.6740	-10.8154	-9.4580
	(1.2183)	(2.8047)	(2.1677)
Sigma squared	1.0968	1.5689	0.9573
	(0.0863)	(0.1979)	(0.0477)
Gamma	0.7312	0.8188	0.6347
	(0.0278)	(0.0271)	(0.0295)
Log likelihood	1945.73	2068.21	2755.55
Likelihood ratio	979.34	150.69	133.64
number of observations	n=328, t=6	n=331, t=6	n=436, t=6

all coefficients are significant at 5% level unless stated otherwise
* statistically non-significant

TABLE 9.B
Stochastic Frontier Production Functions Parameter Estimates
Selected Manufacturing Divisions in 1996-2001
(State dummy variables, standard errors in parentheses)

Frontier equation	Division 32	Division 33	Division 31
intercept	10.5923	11.00	9.3893
	(0.4849)	(0.4791)	(0.3093)
ln_capital	0.4101	0.3573	0.2066
	(0.0344)	(0.0234)	(0.0171)
ln_labor	0.3324	0.3859	0.8241
	(0.0672)	(0.0503)	(0.0351)
year	0.0343*	0.0139*	0.0936
	(0.0383)	(0.0333)	(0.0256)
d_mg	-1.7989	-2.0094	-0.2678**
	(0.2972)	(0.3202)	(0.9984)
d_sp	1.4394	-1.2469	-0.2182**
	(0.3032)	(0.3068)	(0.2059)
d_rj	-1.9479	-1.5183	-0.7990
	(0.3101)	(0.3165)	(0.3157)
d_sc	-0.2955**	-2.1893	0.7915
	(0.4802)	(0.3652)	(0.3889)
d_pr	-1.9286	-1.5009	0.6142*
	(0.3332)	(0.4690)	(0.3750)
d_rs	-1.8189	-1.3243	2.0880
	(0.2376)	(0.3827)	(0.6435)

all coefficients are significant at 5% level unless stated otherwise
* marginally significant at 10% level
** statistically non-significant
31 Manufacture of Electrical Machinery and Apparatus
32 Manufacture of Electronic Devices and Communications Equipment
33 Manufacture of Medical, Precision and Optical Instruments, Watches And Clocks

TABLE 9.B

Stochastic Frontier Production Functions Parameter Estimates (cont.)
Selected Manufacturing Divisions in 1996-2001
(State dummy variables, standard errors in parentheses)

Efficiency equation	Division 32	Division 33	Division 31
intercept	1.3022	2.0270	0.4192**
	(0.3785)	(0.5308)	(0.5145)
year	0.1358	-0.0294*	0.1279
	(0.0631)	(0.0880)	(0.0539)
d_mg	-2.2537	-3.8494	-0.0503**
	(0.9864)	(1.1749)	(0.4878)
d_sp	1.6655	-2.7153	-0.0465**
	(0.4268)	(0.6063)	(0.3790)
d_rj	-6.9447	-8.3223	-6.3770
	(1.3659)	(2.4823)	2.3241
d_sc	-0.7424**	-4.0964	0.9013*
	(0.7479)	(1.4601)	(0.5505)
d_pr	-10.2696	-10.1156	0.6844**
	(2.6686)	(4.1656)	(0.5658)
d_rs	-6.1283	-5.8802	2.0633
	(2.7146)	(1.7262)	(0.6291)
Sigma squared	1.3107	1.3242	0.7311
	(0.1260)	(0.2178)	(0.0872)
Gamma	0.8803	0.7632	0.6879
	(0.0350)	(0.0570)	(0.0745)
Log likelihood	524.80	463.65	-1088.46
Likelihood ratio	54.22	37.89	36.28
number of observations	n=64, t=6	n=70, t=6	n=167, t=6

all coefficients are significant at 5% level unless stated otherwise
* marginally significant at 10% level
** statistically non-significant
31 Manufacture of Electrical Machinery and Apparatus
32 Manufacture of Electronic Devices and Communications Equipment
33 Manufacture of Medical, Precision and Optical Instruments, Watches And Clocks

V. CONCLUSION

This paper uses firm level data to study issues related to innovation performance, productivity, and technical efficiency in the Brazilian manufacturing sector.

The evidence examined corroborates the hypothesis that the probability of a firm investing in R&D is correlated with its size. This probability is higher for firms whose capital is at least partially foreign, or firms whose products have the domestic market as the main destination for their products. Among the six more active states in innovation activities, other things equal, firms located in the state of Santa Catarina have the highest probability of being engaged in R&D investment whereas firms located in the state of Rio de Janeiro have the least. Firms classified in Manufacture of Medical, Precision and Optical Instruments and Manufacture of Electronic Devices and Communications Equipment have higher probability of doing R&D than the ones in other manufacturing divisions.

The results also confirm the hypotheses that firm size and R&D investment are positively correlated with the probability of a firm submitting a patent application. Additionally, the location of a firm correlates with the probability of patent application: *ceteris paribus*, this probability decreases from the state of Rio Grande do Sul to the state of Minas Gerais, while the state with the largest product in the country, São Paulo, holds the second position. Firms classified in Manufacture of Machinery and Equipment Manufacture of Medical, Precision and Optical Instruments and Manufacture of Electronic Devices and Communications Equipment have higher probability of submitting a patent application than the ones in other manufacturing divisions.

A frontier/efficiency framework allows for the estimation of productivity and efficiency trends in 1998-2001 using firm level panel data. The specification has a frontier production relating output to capital, labor, year, and firm specific own-R&D, and an efficiency equation associating the efficiency level to year, and firm specific acquired-R&D. Productivity and efficiency trends in the manufacturing divisions are inferred from the year coefficients. Three of the six selected divisions analyzed record significant productivity trends: 5.1% for Manufacture of Electrical Machinery and Apparatus, –2.7% for Manufacture of Fabricated Metal Products, Except Machinery and Equipment, and -4.9% for Manufacture of Rubber and Plastic Products,. The efficiency trends reveal a general increase of technical inefficiency over time in the two first divisions listed above and no significant tendency in the last one.

The ranking of the major states descending order with respect to output and efficiency shifts from the baseline production function respective levels allows for a comparison among the states of MG, RS, and RJ, which have nearly the same state product size. In terms of output shift (OS), the ranking of these states shows each of them taking turns in leading the other ones in two of the six divisions analyzed; however, the ranking of efficiency shift (ES) shows a lopsided outcome: the states of RS and RJ hold the leading position three times each in the group leaving no division to be claimed by the state of MG. Comparing to the state of RJ, the intermediary ranking position of the state of MG in ES stands out: in those divisions led by the state of RS, the state of RJ ranks last.

While a tendency in increasing technical inefficiency over time within a context of positive productivity time trend means that some firms are shifting up the best-practice technology frontier in spite of the efficiency performance of the manufacturing division being spread out - the example of Manufacture of Electrical Machinery and Apparatus, the same technical inefficiency pattern in a situation of negative productivity time trend has no mitigating factor – this is the case of Manufacture of Fabricated Metal Products. The latter is a situation in which pushing up the technological frontier matters less than diffusing the best-practice technology. The extent and rate of this type of diffusion processes are extremely relevant for government and private sector policies to encourage productivity growth.

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