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CRESCIMENTO E PRODUTIVIDADE DA INDÚSTRIA DE INFORMÁTICA BRASILEIRA

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PRODUCTIVITY AND GROWTH IN THE BRAZILIAN INFORMATICS INDUSTRY

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Abstract

The informatics industry (ISIC 30 – office, accounting and computing machinery) is one of the fastest growing sectors in manufacturing in the World and in Brazil, and receives special tax breaks in Brazil (the so called "Informatics Law"). We investigate this sector after its liberalization using complementary methods. First, interviews with industry leaders to learn the qualitative aspects of their growth experience. The interviews suggested that firm growth was based either on product differentiation in the business machines subsector (using close software complementarities) or retail chains as distribution channels in computer manufacturing. Access to imported technology is relevant to productivity growth and universities were not an appropriate technology source. Second, we looked at econometric evidence on the role of observable characteristics and, in particular, of the Informatics Law benefits on productivity growth. Our results indicate that firm productivity growth in the sector can be attributed to within firm growth with a positive contribution of market selection, but a negative reallocation effect. The qualitative assessment of the Informatics Law is positive overall for the firms, but its quantitative impact on productivity growth is not significant. On average, less productive firms obtain more Informatics Law benefits, questioning the efficiency of R&D incentives in its current design in Brazil.

Keywords: Informatics industry; tax incentives, total factor productivity.
JEL Classification:L63, O30, D24

Resumo

O setor de informática (ISIC 30 – equipamento de escritório e computadores) é um dos setores da indústria que mais crescem no Mundo e no Brasil, onde recebe fortes incentives fiscais (a chamada Lei de Informática). Invetigamos este setor após sua liberalização usando métodos complementares. Primeiro, entrevista com empresas do setor para recuperar aspectos qualitativos do seu crescimento. As entrevistas sugerem que o crescimento foi baseado ou em diferenciação de produto (com complementariedade com softwares) no subsetor de equipamentos de escritório ou acesso a canais de distribuição no varejo de eletro-eletrônicos e crédito (computadores). O acesso à tecnologia importada é importante para crescimento, embora universidades não sejam uma fonte apropriada de tecnologia. Segundo, usamos dados de todas as empresas do setor nas pesquisas industriais para gerar evidência econométrica sobre os fatores de crescimento e o papel da Lei de Informática. Nossos resultados indicam que o crescimento da produtividade no setor pode ser associado ao crescimento intra-firma, com efeito positivo da seleção no mercado, mas efeito negativo de realocação. Embora a avaliação qualitative da Lei de Informática seja boa em geral, seu impacto quantitative na produtividade é insignificante. Na media empresas menos produtivas obtêm os benefícios da lei de Informática, sugerindo ineficiências nos incentivos de P&D atuais no Brasil para o setor.

PRODUCTIVITY AND GROWTH IN THE BRAZILIAN INFORMATICS INDUSTRY[♦]

1. Introduction

Computers are ubiquitous in our daily lives. Computers, peripherals (such as printers) manufacturers are classified under 30 (Manufacture of office, accounting and computing machinery) of ISIC 3.1. It also includes other electronic business machines such as bar code readers, automated access controls and others. These are differentiated products, but share a common technological base (microprocessors). Some are general purpose products (computers and printers, for instance) and are thus sold across several market segments, while some as targeted to specific uses, such as cash registers.

The informatics industry is one of the fastest growing sectors in the World. Average firm's expenses in R&D and average skilled labor employment share are higher than the industrial average in Brazil (IBGE/PINTEC) as well as in other countries. The industry is characterized by significant nominal price decreases, stemming from progress in computing power, other technological advances and fierce competition. Using the BLS CPI index for personal computers and peripheral equipment in the US, prices fell 11% in nominal terms and more than 50% in real terms from 1996 to 2005 (see also Jorgenson, 2001).

This industry as one of the growth engines of Asia in the recent decades, particularly for Taiwan, Korea and Japan and, more recently, China, according to Rowen et al (2007), *et al.*. Their synthesis of the Asian experience concludes that firms benefited from participating in international production chains, where there was learning and technology transfer from foreign firms, strong government support (financing and tariffs), and research institutes technology transfers.

In Brazil, the informatics industry has also attracted significant interest from researchers and policy makers. It was a highly protected sector in the 1970´s and 1980´s, with close to total bans on imports of computers in the late 1980´s. There were strong efforts to create an

[♦] We thank IBGE for data access, as part of a larger joint project with IPEA on understanding Brazilian firm growth. The statistics presented here have been cleared by IBGE to ensure confidentiality, and Carmen Páges (IADB) and James Tybout (Penn State) for encouragement and comments. Partial financial support from IADB and CNPq is acknowledged. We are solely responsible for data manipulation and interpretation. The opinions expressed in this paper do not represent the official view of IPEA, IBGE, IADB, or UFRJ. Comments from project participants have greatly improved the analysis, as well as research assistance from Leonardo Rocha and Bruno Ottoni (UFRJ) and Eric Jardim and Nayara Lopes (IPEA). The paper would have not been carried out without the generous time of firm managers for the interviews. Authors' emails: *eribeiro@ie.ufrj.br*, vpk@ufrj.br, João.denegri@ipea.gov.br, respectively.

autonomous computer industry in all segments (Evans and Tigre, 1996, Schmitz and Cassiolato, 1992). Radical change came in the 1990´s in the wake of trade liberalization, leading to a homogeneous tariff under Mercosul at 16% and no import licences. While in the early period of liberalization in 1991-1992 it was believed that the industry would disappear, domestic production of computers and peripherals now account for more than 1% of GDP. Employment levels in computer and peripheral manufacturing rose from about 5,000 in 1990 to more than 25,000 in 2005.[1] From 1996 to 2005, ISIC 30 value added increased five fold and sector total factor productivity more than doubled, according to our estimates, while manufacturing productivity rose about 20% only.

The aim of this case study is to understand the Brazilian informatics industry growth, focusing on the productivity distribution and dynamics. We seek to shed light on the productive structure of the sector and the factors behind firm and productivity growth. In particular, we estimate the impact of the tax subsidies offered by the so called "Informatics Law". This Law provides extensive tax breaks for computers and peripherals manufacturers with a minimum domestic content and undertake a minimum R&D effort (5% of their revenue). The first measure would provide incentives the adoption of import substitution strategies by the benefitted firms and that the second benefit would counterbalance the potential inefficiencies brought by the first one, resulting in more innovative strategies and more competitive firms.

In order to reach these objectives, we explore firm growth and productivity evolution of the sector from 1996 to 2005 using two complementary approaches, as in Javorcik, Keller and Tybout (2008). First, we carry out interviews with firm managers to learn the actual competitive pressures and firm growth obstacles. Second, testing the hypothesis delineated in the first approach, we use manufacturing survey firm data on output and input use to measure productivity and basic observable characteristics of the firms.

The first source of information used to understand productivity and growth in the sector is a set of in-site interviews with eight firms in all ISIC 30 subsectors (business machines, computers, and peripherals) across the country and also eight interviews with government officers and known specialists in the field. The interviews are an excellent way to obtain

[1] Data from *Panorama do setor de informática 1991* and RAIS/MTEC, respectively. In 1990 the informatics industry employed about 100,000 workers according to the same source. Yet at least two thirds were in "data processing", that has been largely automated since the last decade, and another large share was on software development, that is not classified under ISIC 30.

qualitative information on firm growth strategies and competition issues. The selected firms are mainly industry leaders so that we can learn about success stories. It should be noted that smaller firms are hard to reach as there is no computer cluster in the country.

There are two clear firm types: computer manufacturers making fairly similar products (desktops and notebooks and printers) and business machines producers that focus on product differentiation using software complementarities and business tailored solutions to the different vertical markets (hospitality, food, retail, etc.). In the computer production segment, Brazilian owned firms used to compete in price with subsidiaries of large multinationals firms, which based their advantage in quality and branding. Recent revisions of the Informatics Law (the so-called “Lei do Bem”) lowered taxed for computers and at the same time, the pro-poor growth of the past years skyrocketed the demand for low end computers. The Brazilian firms locked in this demand with distribution agreements with retailers that target such income strata, gaining significant market share.

Firms in the second group (producers of printers, turnstiles, and peripherals and electronic devices, for example) base their competitive advantage on product differentiation. While multinational firms introduce the most recent technical advances, domestic owned firms were well succeeded in niches in which the products needed to be adapted to Brazilian idiosyncrasies. Two examples are fiscal printers and time and attendance and access control devices, which must respectively cope with the frequent changes and the complexity of the Brazilian fiscal and labor legislations (see, e.g., IADB, 2004).

As common echoes in the interviews, we understand that the growth in the informatics sector depends on reaping economies of scale, coping with macroeconomic hindrances (high interest rates and the volatility of the exchange rate) and the lack of domestic technology sources. According to the interviewees, one of the most important reasons for the survival and grow of the Brazilian Informatics industry was the Informatics Law. The firms believe that the tax breaks provide good incentives to grow. The Brazilian experience seems different from the Asian case, insofar leading domestic firms do not participate in international productive chains.

The complementary research strategy uses national firm manufacturing surveys and a matched data set with trade data and an Informatics Law beneficiary roster to run econometric estimates on productivity levels and growth determinants.

In particular, our econometric analysis of productivity follows Hsieh and Klenow (2008) in calculating a multi-input disembodied technology index from a Cobb-Douglas production function under monopolistic competition in the product market. These simplifying hypothesis allow us to calculate a true total factor productivity index (TFP) from revenue data (Takayama, Lu and Tybout, 2009). In addition, we calculate the more common revenue based TFP measure that depends on output and input prices and firm heterogeneity in labor and capital shares. Within sector heterogeneity can generate firm productivity differentials and aggregate output losses from misallocation if the differentials are considered not generated by the market. We evaluate whether firm productivity can be explained by observable characteristics, particularly, age and size, labor quality and international trade, following the interviews conclusions.

An important source of the heterogeneity of the output price and the capital cost across firms is the beneficial treatment from the so called "Informatics Law". We evaluate whether receiving this benefit has positive impacts on productivity. In principle, there shouldn´t be any effect on true productivity, unless firms innovate when implementing the PPB or are self selected from a low TFP pool. On the other hand, we expect a positive effect on revenue TFP as output prices are differentiated for the firms that receive the benefit from the law.

Advancing our quantitative results, the significant productivity growth was within firm and driven by market selection, with surviving more productive firms exhibiting below average size growth. Productivity is positively related to size and negatively with age, consistently with the productivity decomposition. Firms that use imported inputs have higher TFP even after controlling for unobserved characteristics. There is no clear pattern for the link between Informatics Law grants and productivity. The simple mean negative TFP difference for firms that receive the Law benefits become insignificant once firm observed and unobserved characteristics are controlled for. This suggests low TFP firms self select for Informatics Law benefits, echoing the interviewees opinion.

The article is divided as follows. The first section discusses the evolution of the informatics industry in the world and in Brazil, as well as providing a quick overview of the Asian experience. The second section presents the industry in Brazil, with basic statistics and main policies to the sector, including a description and discussion of the Informatics Law. The fourth section presents the summary from the interviews. The following section has the analysis of the productivity in the sector and the impacts of the Informatics Law. Final comments conclude the article.

2. Recent evolution of the world ICT and informatics industries

The informatics industry is particularly relevant for an economic policy study, due to the significant impact of this sector on the productivity of the other sectors. For instance, OECD states that "… ICT [information and communication technologies] is having substantial impacts on economic performance and the success of individual firms, in particular when it is combined with investment in skills, organizational change and innovation."(OECD, 2004, 5). This view is shared by UNCTAD (2007).

As seen in Table 1, the ICT sector is quite dynamic, with world output growth above the manufacturing average. The computer industry (informatics industry) share is significant. World PC Sales grew from 140 million in 2001 to 257 million in 2007.

Table 1: Electronic output revenues (current US$ million); country shares and average growth between 1992 and 2005, and average growth, compared to manufacturing growth.

	Electronics Sales (US $ mi) 1992	Electronics Sales (US $ mi) 2005	Share of World electronics sales 1992	Share of World electronics sales 2005	Annual Avg. Yearly growth 92/05
Brazil 1	12.527	27.957	1,9	2,3	6,4
Brazil informatics	4.169	10.039	0,6	0,8	7,0
Newly Industrialized States 2	69.861	193.469	10,8	15,6	8,2
Southeast Asia 3	21.810	94.963	3,4	7,7	12,0
China	13.126	250.471	2,0	20,2	25,5
East Asia	104.797	538.903	16,2	43,5	13,4
United States	173.609	221.360	26,9	17,9	1,9
European Union – 15	139.413	172.224	21,6	13,9	1,6
Japan	177.890	177.845	27,6	14,4	0,0
Other	37.442	100.605	5,8	8,1	7,9
World electronics market	645.678	1.238.894	100,0	100,0	5,1
World Manuf. Output (US bi)	24.242,05	44.880,77			4,9

Notes: 1 Brazil data includes electronic , informatics, telecommunications, eletrical and electronic components. 2 -Hong Kong, Korea, Singapure and Taiwan. 3 - Indonesia, Malasya, Phillipines and Thailand.
Source: Brazil - SPI (1997) and Abinee (2008). Adapted from Grangnes e Assche (2008) and http://www.econstats.com/weo/CWorl1.htm, on 5/08/2008

The ICT international trade also grew faster than manufacturing trade (Table 2). Between 1996 and 2005, world exports of ICT goods grew 8.9% a.a.. The share of ICT in world exports rose from 13 to 15%. Over time, output and trade shifted from Europe, US and Japan to Asian countries, where most output is now produced. Investment migration to Asia benefited those countries exports and imports, allowing more specialization and learning. Table 2 presents an interesting trend for Brazil, where exports grew faster than imports, contrary to other countries where exports and imports grew at a similar pace. We will come back to the Brazilian case latter.

Table 2 Imports and Exports of ICT (US$ Billion)

ICT Exports	1996	2000	2005	Yr.Gr. (%a.a.) 96-05	Yr.Gr. (%a.a.) 00-05
Developed countries	458	648	716	5,1	2,0
Developing countries	243	462	795	14,1	11,5
Asia	224	418	742	14,2	12,2
Lat.Am./Caribb.	18	43	50	12,0	3,1
México	16	36	44	11,5	4,1
Brazil	1,0	2,5	4,0	16,7	9,9
ICT Imports	1996	2000	2005	Yr.Gr. (%a.a.) 96-05	Yr.Gr. (%a.a.) 00-05
Developed countries	481	717	863	6,7	3,8
Developing countries	232	406	691	12,9	11,2
Asia	194	339	604	13,4	12,2
Lat.Am./Caribb.	31	59	74	10,2	4,6
Brazil	7,3	9,1	10,6	4,2	3,1

Source: OECD

The expansion of modularity[2] in electronics and, particularly, in informatics facilitated global productive chains as the international production transfer was accompanied by a fragmentation of the productive process. The growing connection between ´commercial integration` and ´fragmentation of the production` as Feenstra (1998) expressed it, was a result of the adoption, by developed countries leading firms, of a new organizational model (global productive chain or, subcontrating systems – OEM) Hobday (2008). It is an evolution of the

[2] Modularity, which is a common practice in the industry, is "the degree to which a set of designs (or tasks) is partitioned into components, called modules, that are highly dependent within a module, nearly independent across modules" (Baldwin, 2006).

previous organization model, the fordist model, which emphasized vertical integration and in which a multinational enterprises made isolated investments in host countries. General determinants of this trend were: market liberalization; the diffusion of communication technologies themselves; and international competition efficiency pressure (Ernst and Kim, 2002).

Companies located in developing countries become part of the global production networks or chains, contracted to perform specific tasks. The observed upgrading in companies that are connected to the global production chain is in general observed in four steps. First companies tend to upgrade their processes, then their products (undertaking the design and the release of new products). Later, firms execute new functions in the chain and lastly they tend to diversify to new products. A potential disadvantage is that firms located in developing countries may become subordinated to firms in developed countries.

The participation in global productive chains foster TFP growth, through knowledge accumulation in Asia (Hobday, 2000 and Hsieh,2002). In the case of Thailand, Saliola and Zanfei (2009) found evidence of knowledge transfer via value chain relationships. The massive penetration of western markets by high-tech products from Asian countries (see table 2), also suggests positive results from knowledge accumulation, including the fast growth of China's R&D expenditures (OECD, 2008b). Positive FDI externalities are another mechanism of TFP growth by participation global productive chains. FDI pressures supplier productivity and quality, and these positively affect indigenous competitors of the multinational firms. (*e.g.*, Alfaro and Rodrigues-Clare, 2004).

The participation of Asian countries in global productive chains generated favorable ICT manufacturing performance, evolving from low cost (assembling) to components manufacturing and higher value added products. This was backed by local policies. Some are general across countries other are country specifics. According to Rowen et al (2007), the similarities across countries' main strategies are:

i. All Asian countries exploited lower trade barriers; reduction of telecommunication costs; lower labor costs; good infrastructure; welcoming offshoring and ousourcing by U.S., European and Japanese firms, followed by the same strategy by leading Korean, Taiwanese, etc. firms and finally the upgrading strategies of the Asian countries suppliers.

ii. All invested heavily in skilled labor with technical education, although universities did not play the role of technology providers. Research institutes were more relevant in this role.

iii. The initial developing phase was marked by the purchase of foreign technology, parts and inputs;

iv. Research institutes networks were the main source of technology for firms.

On the other hand, there were country-specific strategies (Rowen et al, 2007):

i. Korea, as well as Japan fostered entry and participation of large technology intensive indigenous firms in the ICT sector;

ii. Taiwan experienced an important role for public organizations in electronics R&D, that disseminated this knowledge to thousand of SME;

iii. Hong Kong and Singapore relied more on multinationals` FDI.

iv. Singapore´s Educational system investment allowed an upgrade on more sophisticated products such as electronic components, developing from the low level assembly as in other area countries;

v. Last but not least, China attracted foreign investment using its abundant labor, R&D capacity investment, the openness of its domestic market (local manufacturing) and general government subsidies and support.

These policies were complemented by strong targeted policies, as argued by some authors. For example, "Singapore influenced resource allocation by targeting and guiding foreign investment. Korea and Taiwan intervened significantly in trade, using the whole range of quantitative restrictions, tariffs, procurement, and other administrative measures to promote selected industries." Lall (2000, 40)

Thus, historically globalization of the electronics sector has been very beneficial to firms located in Asian developing countries as can be seen on Table 2. The data indicates that investment migration to Asia benefited those countries, allowing more specialization and learning. As seen in the next section, Brazil did not follow the same path and an important question is if this strategy is still available and whether it is feasible to it.

The development of Brazil´s informatics sector, in light of the Asian experience cannot be divorced from the changing technology standards and productive structures of the informatics and ICT sectors over time. Three issues are believed to shape the future of the informatics sector. First, the technological evolution in the production of semiconductors, that is believed to follow the so called Moore´s Law[3]. The popular understanding of Moore´s Law is that every two years the processing power of chips of the same cost doubles. Moore himself believes that his law will be valid for at least another 15 or 20 years (Stiroh, 2008), will some more pessimistic estimates. Second, the diffusion of broadband internet. The number of tasks a computer is able to perform grows exponentially ("People with broadband access use the Internet more often and more intensively, and broadband drives online shopping, education, use of government services, playing or downloading digital content and video telephony." – OECD (2008, XX). The diffusion of broadband internet generates strong complementarities between the internet and computers. Third, continuous integration of the informatics industry with the communication technologies, shifts the demand for informatics goods.

Interestingly, the characteristics cited above are external to the informatics industry[4]. In this sense the industry, particularly personal computers, has a tendency of becoming more *commoditized*, as its more important characteristics are developed outside the sector. This is sanctioned by modularity, since it allows for standardization of the parts making it easier to assemble them.

A counter-tendency to commoditization is the growing interaction between informatics and technical fields like biology, nanotechnology, medicine etc. For instance, access to the R&D area of one of the companies interviewed below, was conditional on clearing through a biometric control system that was developed and manufactured by the company. Also, new products combining these and other sciences and technical fields and informatics are expected to be released in the near future in sectors like retail, banking and informatics itself. These products could potentially create lucrative niches and Schumpeterian rents.

3. Brazilian ISIC 30 sector: basic statistics and industrial policy.

The Informatics sector is one of the fastest growing sector in the economy since the mid 1990´s expanding at a faster pace than GDP. Its value added increased three fold from 1997 to 2007, while share in GDP increased from 0.9 to 1.2% (Table 3). The number of firms and employees

[3] After Gordon Moore from Intel. The original version of Moore´s Law states that: "The complexity for minimum component costs has increased at a rate of roughly a factor of two per year" – Moore (1965).
[4] Microprocessors are classified under industry 32, actually.

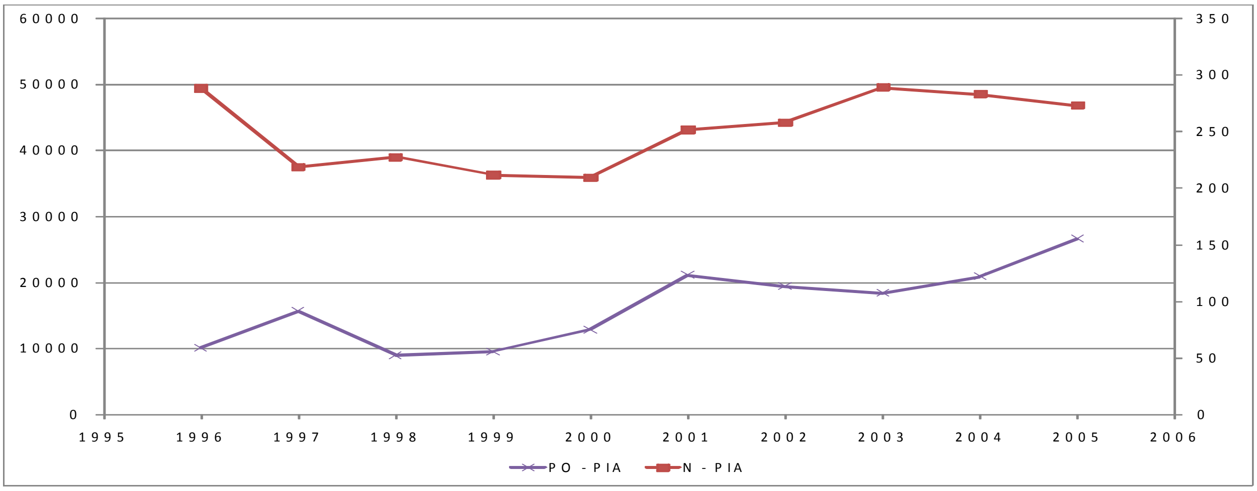
also grew over time, but with a somewhat gentler trend, as seen in Figure 1. The number of employees rose 2,5 times from 1996-2005, with sharp increases in 2001 and 2005, while the number of firms fell from 1996 to 2000 and then rebounding to the same level as in the start of the series by 2003. There was a shift in firm sizes, as can be inferred from the different growth rates of firm sizes and totals. Figure 2 indicates that the proportion of micro and small firms (up to 99 workers) fell steadily from 1999, when an upward trend in employment starts. The HHI index calculated from firm size classes is fairly stable over time, but increases in 2005.

Table 3 – Value Added and GDP Share – ISIC 30 (Informatics) Industry – Brazil, 1996-2007

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
V.A. (R$MM)	7.52	8.79	9.65	10.59	12.81	14.73	13.39	16.70	20.62	24.43	29.42	31.44
GDP Share	0.89	0.94	0.99	0.99	1.09	1.13	0.91	0.98	1.06	1.14	1.26	1.23

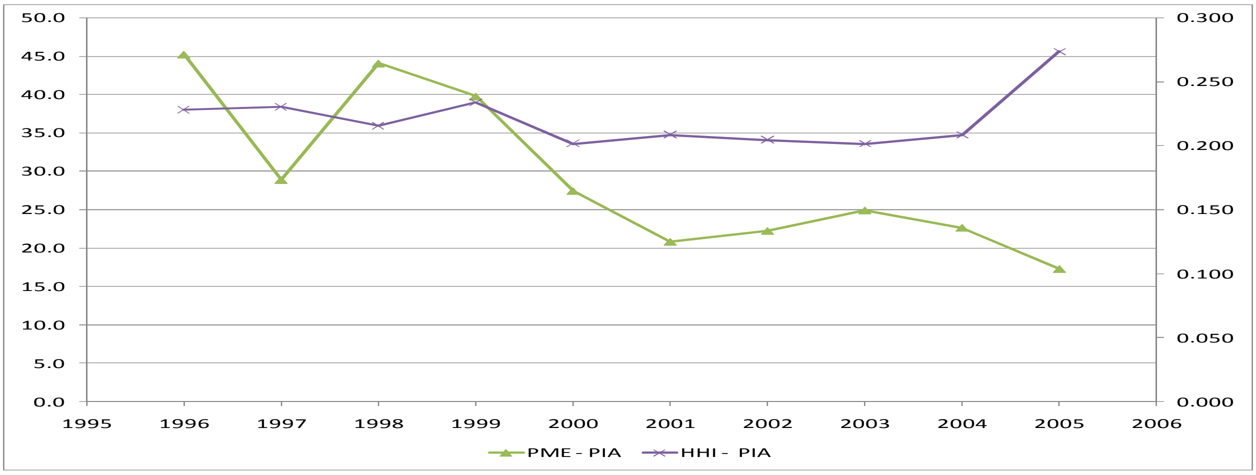
Source: IBGE – National Accounts.

Figure 1 – Informatics industry employment (left axis) and firm numbers (right axis), 1996-2007



Source: Author´s calculation from PIA/IBGE raw data
Notes: PO – Employment (workers on Dec.31); N- number of firms.

Figure 2 – Informatics industry employment share of small and micro firms (up to 99 workers) – left axis – and HHI index – right axis, 1996-2007



Source: Author´s calculation from IBGE raw data.
Notes: PME-PIA share of small and micro enterprises; HHI-PIA, Hisrshman-Herfindal Index. HHI index calculated from 9 size classes.

Sector sales growth has been followed by international trade growth in final goods (Table 4) and components and parts (Table 5).[5] Over the 1996-2005 period, its revenues grew approximately 30% a.a. in real terms, while revenue growth in the manufacturing sector was only 2% a.a.. The correlation between revenues and parts imports suggests that the sector relies heavily on imported inputs. The growth in exports has been steady over the period, indicating some degree of competitiveness for domestic producers. The negative growth in 2002 was due to the economic crisis for the period and the valuation of the exchange rate seems to be explaining the negative growth of exports in 2007.

Table 4 – Revenue and international trade growth in the informatics sector in Brazil (US $ million)

Year	1997	1998	1999	2000	2001	2002
Revenues	8,148	8,311	5,856	7,047	6,263	4,576
Annual growth rate		2.0	-29.5	20.3	-11.1	-26.9
% exports/ revenues	3.1	2.8	5.5	4.9	4.1	2.6
% imports/ revenues	15.1	13.1	14.6	15.3	16.6	16.1
Year	2003	2004	2005	2006	2007	2008
Revenues	5,438	7,049	10,039	13,512	16,138	19,199
Annual growth rate	18.8	29.6	42.4	34.6	19.4	19.0
% exports/ revenues	3.6	3.7	3.9	3.0	2.1	1.6
% imports/ revenues	12.1	11.0	10.1	10.4	11.7	11.7

Sources: MDIC e ABINEE

[5] The components and parts sector also supplies the industrial automation, telecommunications and the consumer electronic sectors. While not included in ISIC 30, we include the data for comparison purposes.

Table 5 - Revenue and international trade growth in the components sector in Brazil (US $ million)

Year	1997	1998	1999	2000	2001	2002
Revenues	2,573	2,456	2,204	2,587	2,237	2,022
Annual growth rate		-4.5	-10.3	17.4	-13.5	-9.6
% exports/ revenues	41.8	49.8	57.4	58.7	73.2	84.9
% imports/ revenues	201.1	193.4	219.6	255.5	278.5	257.8
Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Revenues	2,239	2,973	3,555	4,322	5,209	5,170
Annual growth rate	10.7	32.8	19.6	21.6	20.5	-0.7
% exports/ revenues	78.6	67	64.3	62.7	60.5	63.9
% imports/ revenues	256.1	263.2	270.5	275.6	262	344.8

Sources: MDIC e ABINEE

Despite the incentive for innovation, the percentage of innovative firms in the informatics industry slightly declined from 71% in 2001/2003 to 69% in 2003/2005. The average expenditure in innovation in the innovative firms also slightly decreased[6]. These numbers are already very high in comparison to the Brazilian average. In fact, in 2003/2005 only 34.4% of the Brazilian industrial firms innovated and their average expenditure in innovation in 2005 was 80% lower than the average expenditure of the firms from the informatics industry.

The productive structure of the ISIC 30 sector is surprisingly similar to the US, as seen in Table 6 below, where cost shares are presented. We see that the sector spends very little on energy, and about 50% of its costs are on materials. This is quite similar between the US and Brazil. On the other hand, Brazilian firms are more capital intensive and less labor intensive than US firms.

There is a noticeable decrease in capital service expenditures over time and an increase in Materials use. This may be due to the different deflators used. While the Capital and Labor deflators are the aggregate investment and consumer price indices, respectively, materials (and revenue) is deflated according to the informatics sector price deflator, that experienced a 50% *decrease* over the period (see appendix for details). When considering only capital and labor expenditures, the shares are more stable over time.

[6] Source: Brazilian Innovation Surveys: Pintec/IBGE 2001/2003 and 2003/2005.

Table 6 –Expenditure Shares Evolution for ISIC 30, selected years, Brazil.

Year	Capital	Labor	Energy	Materials	Capital(VA)	Labor(VA)
1996	0.607	0.128	0.001	0.263	0.830	0.170
2000	0.440	0.089	0.001	0.470	0.835	0.165
2005	0.206	0.060	0.004	0.730	0.778	0.222
Average	0.42	0.09	0.01	0.49	0.823	0.177
SIC 357	0.33	0.17		0.50	0.707	0.293

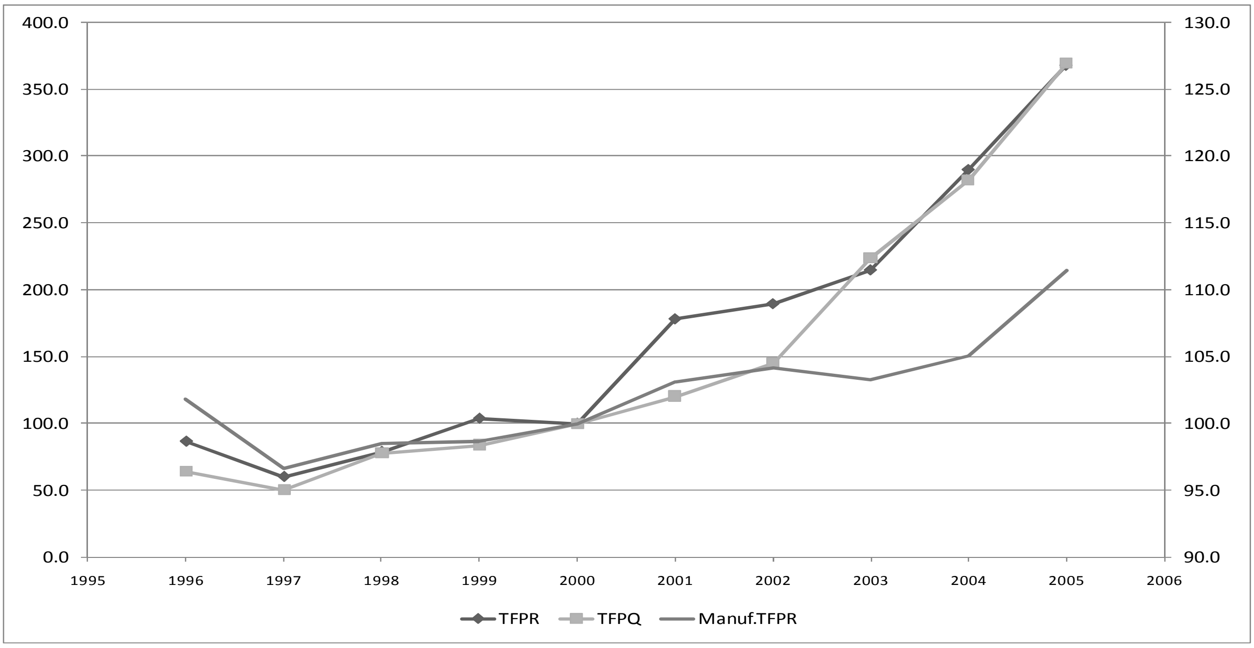
SIC 357 – US average shares for the 1990-1995 period, based on the NBER Productivity Database.
Note: Details on variable definitions, please see Appendix. Authors calculations based on PIA primary data.

The differing trends for output and input prices amplify the productivity growth over the period. The informatics industry experienced significant growth in total factor productivity measured from sector deflated firm revenue (TFPR) over 1996-2005, as seen in Figure 4, well above the total manufacturing average. It was stagnant up to 2000, following somewhat the aggregate trend, but increasing sharply after 2000. This coincides with a fall in product prices, as seen above. Nevertheless the output price index does not seem to be driven by the exchange rate, as the latter appreciated remarkably only after 2005.

We recognize that the TFP measure based on revenue (or value added) does not truly measure multifactor productivity. An appropriate productivity measure should use output, instead, as Foster, Haltiwanger and Syverson (2008) and Katayama, Lu and Tybout (2009) point out. The revenue TFP actually reflects changes in input and output firm specific and aggregate relative prices and is not related to any true multifactor productivity index.

Under a monopolistic competition model with isoelastic output demand, one can recover output from revenue as in Hsieh and Klenow (2008). With this output measure, we calculate a quantity (value added) based TFP (TFPQ), a true multifactor productivity measure, as described in the Appendix. From Figure 3, it is interesting to note that our TFPQ measure follows the TFPR trend.

Figure 3 – TFP Evolution, ISIC 30 and Manufacturing – Brazil, 1996-2005.



Source: authors´ estimates using raw data from PIA.
Note: All indices normalized to 2000=100. Left axis: ISIC 30 TFPR, TFPQ; Right axis: Manufacturing TFPR.

Table 7 – Basic Statistics on TFPR – ISIC 30, Brazil

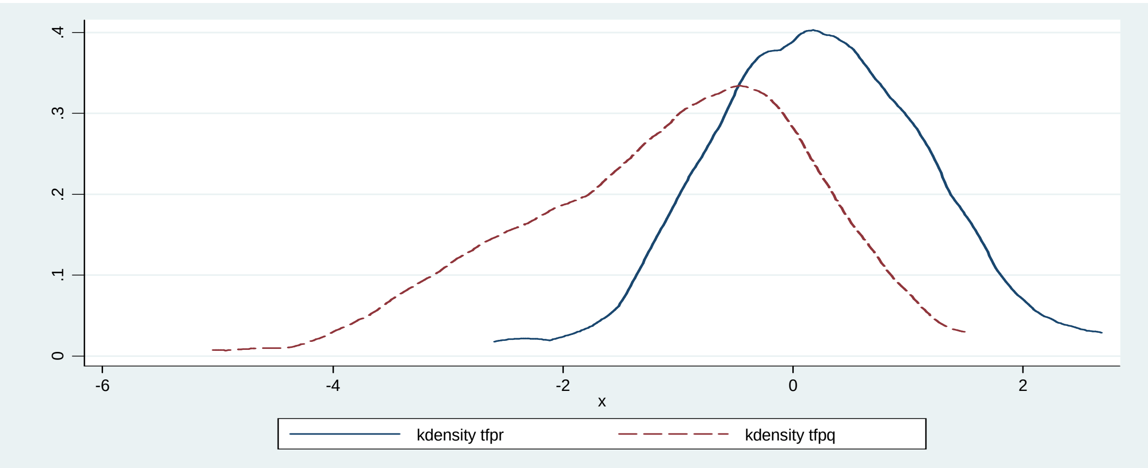
	TFPQ			TFPR		
Year	Sd	Q90-Q10	75-Q25	sd	Q90-Q10	75-Q25
1996	1.145	2.812	1.818	0.882	2.069	1.021
1997	1.475	3.143	1.558	1.072	2.696	1.318
1998	1.401	3.257	1.580	0.953	2.194	1.187
1999	1.309	3.207	1.640	0.962	1.861	0.941
2000	1.239	3.062	1.697	0.965	2.246	1.280
2001	1.531	3.928	2.001	1.203	2.917	1.453
2002	1.855	5.017	2.358	1.303	3.124	1.688
2003	1.502	3.900	1.899	1.174	2.795	1.218
2004	1.799	3.984	1.925	1.245	2.758	1.438
2005	1.656	4.013	2.009	1.127	3.130	1.545

Note: Authors calculations based on PIA primary data. The statistics are the standard deviation, 90-10% quantile difference and Interquartile range for log TFPQ and TFPR standardized by 4 digit means and weighted by value added.

The sector productivity index obscures significant heterogeneity. Table 7 presents the TFPR and TFPQ within sector heterogeneity over time. As common in this literature, TFPQ variance is larger than TFPR variance. The heterogeneity grows over time, following sector aggregate TFP. As the number of firms grew over time, it suggests that the sector expansion allowed less productive firms to survive or entering firms are less productive on average. It is interesting to note that the interquartile range and the 90-10% quantile range are only about 5 to 10% smaller than what we would expect with a log normal distribution for TFP measures, suggesting that a Log-Normal distribution is may be a reasonable approximation for firm productivity.

The larger dispersion of TFPQ and possible departures from a Log-Normal distribution may be easier to see in a density estimate. Figure 4 presents the cross section (2000), 4 digit standardized TFPQ and TFPR densities. Two characteristics stand out: as seen in Table 11, TFPQ is more dispersed across firms than TFPR; second, TFPQ is asymmetric to the left, compared to TFPR.

Figure 4 – TFPR and TFPQ density ISIC 30 – Brazil, 2000.



Source: authors´ estimates using raw data from PIA. Solid line: log TFPR standardized by 4 digit sector average; Dashed line: log TFPQ standardized by 4 digit sector average.

Looking further into the Informatics Industry productivity heterogeneity, we present the Foster, Haltiwanger, and Krizan (2001) decomposition of TFP growth on within(W) and between(B) firm terms, as well as an interaction(I) and net entry (NE) effect.[7] The within effects

[7] See appendix for calculation details.

indicates what share of TFP growth can be attributed to average firm growth, using initial period firm weights, while the between effect summarizes firm reallocation TFP growth.

Overall, the results indicate that a large share of TFP growth came from firm specific growth (W and NE effects), regardless of the TFP measure. The between effect is negative in all periods, for both TFPR and TFPQ, suggesting that more productive firms in the beginning of the period that survived did not experience positive productivity growth. The net entry effect is positive and large for TFPQ, indicating that market selection is contributing to TFP growth.[8] It is troubling to see that initially productive firms actually lost market share and were not capable of sustain competitiveness despite their high productivity. On the other hand, market selection seems to contribute to productivity as the net entry effect is positive.

Table 8 – Productivity Growth decomposition – ISIC 30, Brazil

TFPR	W	B	I	NE
1997-2005	0.5056	-0.0996	-0.0803	0.6743
1997-2001	0.3341	-0.1873	0.2300	0.6232
2001-2005	0.7379	-0.1358	0.2118	0.1860

TFPQ	W	B	I	NE
1997-2005	0.4245	-0.1080	-0.0631	0.7467
1997-2001	0.3097	-0.2491	0.2580	0.6814
2001-2005	0.4619	-0.0716	0.1530	0.4567

Note: Authors calculations based on PIA primary data. W- within effect period TFP change share; B – between effect period TFP change share, I – interaction term share, NE – net entry share of TFP change. Entries add up to 1 in each row.

In order to understand the differences between TFPR and TFPQ we calculate Hsieh and Klenow (2008) input and output price within firm differentials, denoted τ_k and τ_y. These differentials, or distortions as in the original paper, are measured as a firm labor input

[8] Exit effects compares firms that did not survive from the beginning to the last year of period, and Entry rates are based on the productivity evolution of firms that entered after the period first year and survived until the last year of the period. Hence, the firms used in the 2001-2005 comparison are not the same as those used in the 1997-2005 comparison.

expenditures share differentials with respect to a 4 digit sector average (τ_y), and firm capital and labor shares differentials (τ_k), respectively, under a Cobb-Douglas production function.

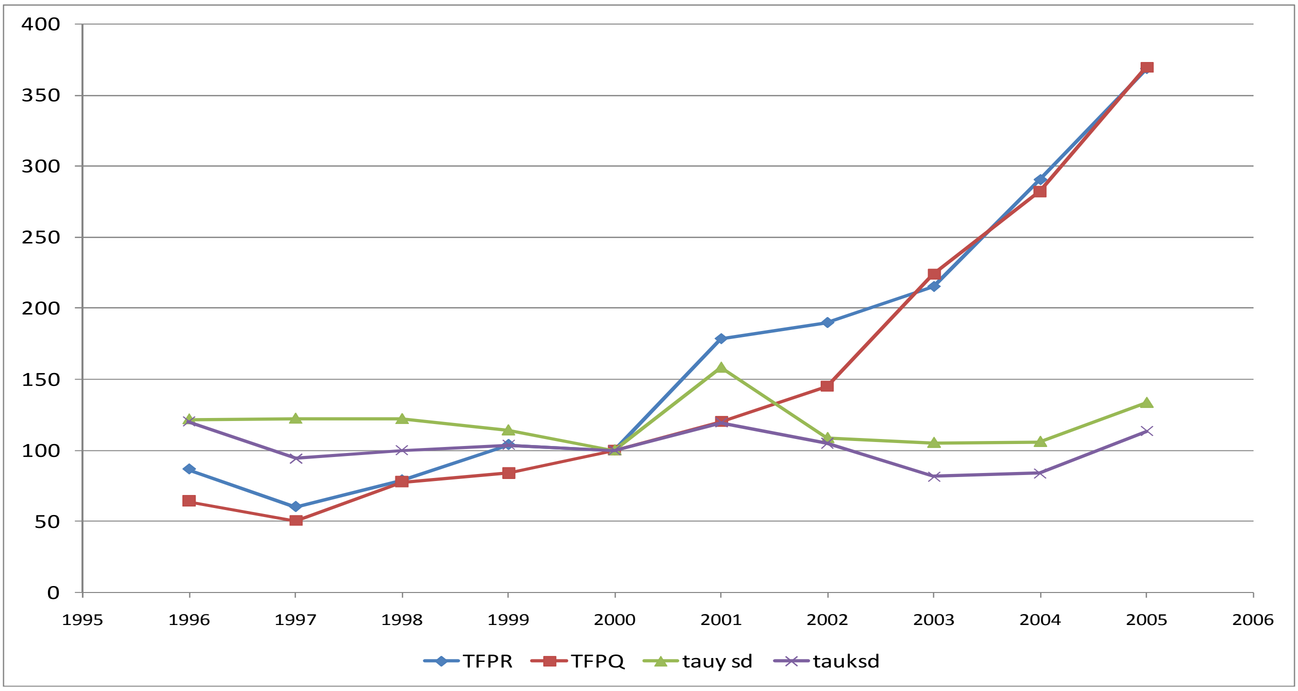
Table 9 – Basic Statistics on output and input differentials – ISIC 30, Brazil

	τ_y			τ_k		
Year	sd	Q90-Q10	75-Q25	sd	Q90-Q10	75-Q25
1996	1.145	2.812	1.818	0.882	2.069	1.021
1997	1.475	3.143	1.558	1.072	2.696	1.318
1998	1.401	3.257	1.580	0.953	2.194	1.187
1999	1.309	3.207	1.640	0.962	1.861	0.941
2000	1.239	3.062	1.697	0.965	2.246	1.280
2001	1.531	3.928	2.001	1.203	2.917	1.453
2002	1.855	5.017	2.358	1.303	3.124	1.688
2003	1.502	3.900	1.899	1.174	2.795	1.218
2004	1.799	3.984	1.925	1.245	2.758	1.438
2005	1.656	4.013	2.009	1.127	3.130	1.545

Note: Authors calculations based on PIA primary data. See appendix for definitions and data manipulation. The statistics are the standard deviation, 90-10% quantile difference and Interquartile range for firm log(1-τ_y) and log(1-τ_k) standardized by 4 digit means and weighted by value added and the capital stock respectively.

There is no clear pattern for distortions dispersion over time. Except in 1997, the dynamics of τ_y and τ_k are similar, with τ_y exhibiting higher time variance. The increase in dispersion in 2001 coincides with a widening gap between TFPR and TFPQ. When the dispersion of τ_y and τ_k are stable over time or grow similarly, TFPR and TFPQ follow the same trend as in 2003-2005.

Figure 5 – Output – τ_y – and Capital – τ_k– price differentials (distortions) standard deviation and TFPR and TFPQ ISIC 30 – Brazil, 2000



Source: authors´ estimates using raw data from PIA.
Note: All variables normalized to 2000=100. ISIC 30 TFPQ and TFPR from Figure 1. τ_y and τ_k standard deviation from Table 13.

In short, TFP growth in the sector has been remarkable. We aim to shed light on the determinants of such productivity growth over time, considering institutions and tax benefits, and other factors. We shall use two alternative methods, namely, interviews with industry leaders and econometric estimates. One particular aspect of the informatics sector is the government support it receives.

In general, Brazil has not pursued strong industrial policies since the 1980´s. While recently this has changed, with two main programs launched by the Federal Government (*PITCE — Política Industrial e de Comércio Exterior* in 2003 and *PDP – Política de Desenvolvimento Produtivo* in 2008). The informatics sector is one of the few sectors that has always received support. There are substantial differences between the Brazilian environment and incentives to the informatics industry and the economic environment and the incentives given to the same industry by the above mentioned Asian governments. Several of the above mentioned Asian governments closely supervised the integration of their economies in the global economy, including China. One remarkable difference is the weak incentives for ties in international production chains (note that up to 1997, Brazil had a 17% sales tax on exports).

After a series of failed economic plans and more than ten years with three digit yearly inflation rates, the Brazilian strategy of global integration can be argued to be more macroeconomic oriented. Brazil pursues low inflation rates, attraction of foreign loans and capitals and large fiscal primary surplus. The microeconomic factors do not lead macroeconomic policy. The macroeconomic environment impact on firms is seen as double edged. Brazilian interest rates are among the highest in the world and firms therefore avoid banking loans. Asian firms rely much more on bank loans. The Brazilian exchange rate is frequently overvalued and the interviewed firms complained about its volatility, which makes long range planning difficult. China, for instance, is known by its relatively undervalued exchange rate.

The informatics industry has attracted significant government attention and received benefits not available to other economic sectors, by means of the so-called "Informatics Act".[9] The "Lei de Informática" is actually a series of three laws: Law 8248 (Oct.1991), that came into effect only in 1993; Law 10176 (Jan.2001) and Law 11077 (Dec, 30, 2004). The key benefits of the law are a reduction in the Federal manufacturing goods value added tax (IPI) of up to 95%, for the products certified to follow a PPB (Basic Productive Process), specified by the government, and that invest 5% of its annual revenues on R&D. This last expense also grants to the firm an income tax deduction. Note that the IPI tax rate is usually 15% on ISIC 30 goods[10].

Changes over time of the law were due to either an extension (the 1991 law benefits were to be phased out from 2001) or changes in regional treatments and depreciation treatment of R&D machinery. The PPB is a "minimum set of operations in the plant that characterized the manufacturing – as opposed to assembly – of a specific product" (Law 8.248/1991). The federal government determines the PPB for each new product in the industry. For instance, each of the ink-jet printers producers interested in the tax reduction has to submit to the government its project to follow the ink jet printers guidelines etc. To earn the benefits, each project has to be approved by three distinct Ministries (Science and Technology; Industrial Development and Trade; and the Finance Ministry.

The main purpose of the law was to replace the pre 1991 regulations that actually banned imports. The PPB requirements and tax breaks would provide incentives to firms to internalize as

[9] There is an earlier (pre 1991) set of Informatics Acts, described, e.g., in Evans (1986) and Evans and Tigre (1989) and Fajnzylber (1994). Imports were subject to licenses and production was organized by the Federal Government with strict import controls. This represented a significant effort "to promote indigenous innovation in the computer industry" (Evans and Tigre, 1989). There are also specific policies targeted to software development.

[10] Sales taxes should be added to final consumer prices.

many parts of the manufacturing process as possible. In order to counterbalance the potential inefficiencies brought by this import substitution measure, the law also grants R&D tax incentives. It is argued that higher R&D expenditures should foster product development in the country, lead to knowledge accumulation, higher efficiency and increased competitiveness. [11]

Detailed information on the firms that benefited from the law can be obtained from the website of the "Ministério da Ciência e Tecnologia" of the Brazilian Government. Each product in each plant with approved PPB has its information posted on the Federal Gazette (*Diário Oficial*) and reproduced in the Ministry web site from 2001, where there was a law change. There is no information on previous benefits. Benefits are assigned to a specific product and are valid over the product lifetime, unknown to us.

In 2006 the National Budget Office expected tax breaks from the law to reach US $ 0.8 billion (Exchange rate R$2.00/US$1.00). When merging the data from the MCT with the manufacturing survey (PIA), and restricting the sample to the ISIC 30 firms[12], we estimate that only about 8% of the firms in the industry received the benefit.

Benefit use is quite heterogeneous, increasing with firm size. While the proportion of firms that received the benefit is close to the industry average for firms with less than 99 employees[13], the proportion of large firms (1,000 employees or more) that receive the benefit reach almost 40% (see Table 10). There does not seem to be sharp differences in the proportion of firms that receive the benefit according to firm age.

Table 10 – Proportion of firms that receive tax breaks under Law 10176 and Law11077, according to firm characteristics, ISIC 30, Brazil, 2001-2005.

Age	Share of fims	Size	Share of fims
<=5 yrs	7%	10 – 19	2%
6-10 yrs	4%	20 – 49	9%
11 + yrs	9%	50 – 99	7%
		100 – 249	10%
		250 - 499	19%
		500 - 999	23%

[11] There are conditionalities on the 5% R&D intensity expenditures. A portion of these expenditures (about 1/3 out of the 5%) must be spent on joint projects with universities or research centers, and 4/9 of those expenditures with centers located in the Northeast and North regions, the poorest regions in the country.
[12] There are a few firms that benefit from the "Lei de Informática" that are actually instruments or mobile phone manufacturers, i.e., outside the ISIC 30 sector. This is allowed under the law.
[13] Curiously, this is the threshold for small firm classification in Brazil.

1000+	38%

Source: authors' tabulation of raw data from MCT/Brazil and PIA (size) and RAIS (age). Size measured as number of employees.

If we restrict the analysis to firms that innovate or report R&D activities, the PINTEC survey data suggest that at least half the firms in ISIC 30 used such government support. The intensity of use of such benefits is much higher among this subset of firms, as seen in Table 11 below.

Table 11 – Proportion of firms that innovate or report R&D expenditures that receive tax breaks under Law 10176 and Law11077, according to firm characteristics, ISIC 30, Brazil, 2003 and 2005.

Age	Share of fims	Size	Share of fims
<=5 yrs	35%	10 – 19	6%
6-10 yrs	42%	20 – 49	51%
11 + yrs	50%	50 – 99	44%
		100 – 249	78%
		250 - 499	72%
		500 - 999	83%
		1000+	91%

Source: authors' tabulation of raw data from MCT/Brazil and PINTEC (size) and RAIS (age). Size measured as number of employees.

Tabulating on Informatics Law benefits indicates that the number of plants with approved products decreased and then increased over time, somewhat following the business cycle of the informatics industry with a lag of one or two years (Table 12). There is a sharp increase in 2002, reflecting the 2001 posting of the act, a period low in 2004 reflecting the economic downturn from 2002-2003 and a sharp increase in the last years, echoing the sustained economic growth and consumer credit and income boom.

Table 12 – Number of plants receiving tax benefits over time, under Law 10176 and Law11077

Year	Number of plants receiving the Law tax break	Yearly growth (%)	Sector revenue growth (%)
2001	40		-11,1
2002	92	130,0	-26,9

2003	55	-40,2	18,8
2004	17	-69,1	29,6
2005	46	170,6	42,4
2006	53	15,2	34,6
2007	68	28,3	19,4
2008	106	55,9	
TOTAL	477		

Source: authors' tabulation of raw data from MCT/Brazil and PIA/IBGE.

Our data covers the 2000s. During the 90's, the application of the informatics law and its impact has brought strong criticism. According to Garcia and Roselino (2004), in the 1990's most benefits were highly concentrated on few firms. Between 1993 and 2000, 61% of the tax breaks were concentrated on ten firms, and 83% were allocated to 30 firms.

The benefits seem less concentrated after 2001, but certainly not uniform. As Table 13 shows, 18.4% of the tax breaks are now concentrated on ten firms and 34.3% are allocated to 34 firms. Twelve per cent of the firms received 42% of the benefits. One firm alone received up to 41 benefits (a CEM – Contracting Equipment Manufacturing, a component manufacturer).

A recurrent critique of the Informatics Law, as means of developing the complete computer industrial productive chain, is that, in practice, the local manufacture of the processor board was all that was required to meet PPB standards. According to Roselino and Garcia (2004) and Gutierrez and Alexandre (2003), firms had little problems to have their projects approved. The former claim that the weak requirements as well as the small scale of the Brazilian market for certain inputs made the Informatics Law unable to actually internalize the manufacturing process. Gutierrez e Alexandre (2003, p. 169), share the same conclusions pointing out that the manufactured goods are designed outside Brazil, and are received as assembly kits. This would shorten the supply chain and hinders any local market for components and parts.

Table 13 – Number of tax breaks granted to a firm, under Law 10176 and Law11077

Number of tax breaks granted to a firm	Number of firms	Inverse cumulative distribution of the number of firms	Inverse cumulative distribution of the total number of tax breaks in each class
1	298	100,0	100,0

2	94	33,3	64,4
3	21	12,3	41,9
4	8	7,6	34,3
5	5	5,8	30,5
6	4	4,7	27,5
7	4	3,8	24,6
8	3	2,9	21,3
9	2	2,2	18,4
10	1	1,8	16,3
12	2	1,6	15,1
14	2	1,1	12,2
15	1	0,7	8,9
18	1	0,4	7,1
41	1	0,2	4,9
836	447		

Source: authors' tabulation of raw data from MCT/Brazil.

The authors also criticize the 5% minimum R&D level as too high. For example, the world manufacturing firms in the sector (denoted CEMs – Contracting Equipment Manufacturing firms) invest less that 1% on average on R&D in their home countries. The exceedingly high threshold required for the tax benefits, as well as the difficulty to pinpoint R&D expenditures led to great incentives to accounting gerrymandering. They indicate that most expenses were on low value added activities, such as software programming. Another detail of the law is that the 5% R&D expenditures are earmarked on a series of outlets or activities, such as minimum regional expenditures and the requirement of university agreements.

Since 2005 there have been a number of additional benefits to the sector. The most important one was the so called "Lei do Bem" (Goodness Act), Law 11,196 (Nov. 2005) that gave an additional 9.25% tax break on gross revenues (from payroll tax exemption) to all PC´s (desktops or laptops) sold for up to R$2,500 (or approx. US$1,000 at the time of the law). The limit was extended to R$4,000 by 2007.

The joint effect of rising personal income levels, consumer credit supply and government support, led to a sharp increase in informatics goods sales recently. The percentage of poor families with a computer at home is growing. In 2007, 9% (24%) of families who earn between one and two (two and three) minimum wages[14] owned a computer, compared to 3% (6%) in

[14] A minimum wage is approximately US $ 200.00 using June 2009 exchange rates.

2005[15]. Similar trends appear for other market segments. For instance, the number of ATMs has increased from 128.724, in 2003, to 166.773, in 2007 (FEBRABAN).

We now summarize the interviews to learn about the remarkable growth in the informatics sector. After, the evidence from the interviews is compared with the sector average experience, using firm level data and our productivity measures.

4. A closer look at the Brazilian informatics industry: interviews synthesis.

As mentioned in the introduction, eight firms were interviewed. They include the biggest in their respective subsectors, and have been growing faster than the market. The interviewed firms have been chosen because they have been very successful. They reported growth rates between 20/50% per year in the last five years and expect to keep growing in the same pace in the near future.

From the interviews[16], we conclude that the success of local firms and foreign subsidiaries are quite different and they can be explained by the local impact of their global presence (development of innovative products that are transferred to Brazil for instance), by good management and the growth of the Brazilian market. The same happens with a Brazilian firm that is linked to a foreign producer and acts almost as a subsidiary.

The remaining Brazilian firms can be divided in two groups, that produce differentiated products sold to retail and banking markets and firms that make computers and notebooks. Success in differentiation is a key aspect of the competitive advantage of the former group but not for the latter. The former provides solutions to specific problems of Brazilian businesses, lowering operational costs. Labor and tax codes are quite complex in Brazil. The automation of these operations in general saves a lot of money to the clients, so solutions suppliers have a strong competitive edge. In additions the codes change frequently[17] requiring firms to be very agile.

These differentiated solutions preclude competition from imports from East Asia, which in some cases are cheaper than the Brazilian products. They also avoid the competition from

[15] "Survey On The Use Of Information And Communication Technologies In Brazil 2007" - Brazilian Internet Steering Committee.

[16] Firm questionnaires are available upon requests from the authors. The interviews were structured around a questionnaire, with freedom to engage in discussions on specific topics. The interviews were personally carried out by the authors.

[17] One may recall than from 1986 to 1995 the country changed its currency four times. See also the Doing Business in Brazil publication from IFC.

multinational firms established in Brazil, which in general sell standard products (HP printers, Dell notebooks, Samsung monitors, etc.) instead of solutions to specific market segments. Bematech, for instance makes receipt printers with different software for each of several vertical markets (food, hospitality, retail, etc…) while HP produces only general printers.

The second group, that sells computers and notebooks, include foreign subsidiaries and domestic producers. The foreign subsidiaries benefit from their international brand recognition and arguably higher quality. The Brazilian owned firms in this group are pioneers on high volume sales of computers and notebooks to lower income families. These sales were made by retail stores that focus on lower income customers. The change in Brazil's income distribution in favor of the poor as well as government measures reducing the taxes over the sale of computer equipment (after 2005, as seen in section 2 above) have multiplied sales several times in the last four years. For instance, *Positivo Informática* is the largest producer of computers in Brazil today and the tenth biggest producer in the world. Recently, Dell, which is famous for direct consumer marketing, has also embraced this strategy.

Market segmentation by size is also present in the differentiated products group. Those firms focus on selling to small and medium firms. The large companies are still attended by foreign firms. One of the individuals that was interviewed said that "…(firms that are) more adapted to the local market perform mass customization. The subsidiaries of foreign enterprises do not have this skill or capacity."

Size was selected by everyone that was interviewed as one of the conditions for entrepreneurial success ("firms in the market of high technology have to grow or die", summarized one of the individuals that was interviewed). Their firms are seen as smaller than the international market leaders. One of the Brazilian companies that import the processor for their desktops said that "the problem is not technology it is scale. A Chinese producer makes five million per month."

Since the Brazilian market is relatively small, Brazilian firms try to invest in foreign markets in order to keep growing. The firms that differentiate products have been extremely successful in this strategy for the same reasons that explain their success in the Brazilian market: the development of hardware solutions, software and services development and that cater to the specificities of the Brazilian economy. The adaptation of these products to international markets that operate under different rules, according to the individuals that were interviewed, has not been a significant challenge, because firms are used to adapt their products (particularly software).

Two other important drivers of success are sales networks and brand. All interviewed Brazilian firms have well distributed sales networks and technical assistance that help them penetrate local markets. Brand recognition is seen as a consequence of product quality, sales networks and other characteristics like advertising[18].

A second characteristic which may help in explaining the success of domestic firms in this sector are their relationships with suppliers from Asia. They reported that complex parts of their products come from suppliers located in Taiwan and China. They exchange a lot of technical information with those suppliers, acting as active technology transfer sources. The information exchanged is more of an operational character helping the Brazilian firms to maintain the quality of their products. This information also feeds the adaptive R&D activities, the intense software development work and the service network they have established. The downside of this dependence is exchange rate volatility exposure, seen as more deleterious to business than the exchange rate level itself and red tape on import.

At the same time, some of the firms claimed that their competitive success comes mainly from their R&D activities. In these cases the level of creativity of the firms is higher, comparing product range and applications. They seek information abroad to maintain their technological leadership. In a small interviewed firm, the R&D department employs one in every eight employees of the firm or one in every four workers in production. It spends 5% of its net revenues in R&D. In the large one, the percentage of expenditures in R&D was 3.1% of its net revenues in 2007.[19] It is worth noting though that the main strategic efforts seem to be directed to software development. The creation of solutions to specific market segments is viewed as the most prominent route to profitable growth.

Innovation knowledge sources, in addition to foreign input and technology suppliers, are also consumers and clients (particularly for the differentiated business machinery firms) and their own R&D. The firms also point out that skilled workers actively contribute to innovation. It is interesting to note that Universities or technological infrastructure are not active innovation

[18] In a survey conducted in 29 countries, Brazilian consumers are close to the average when it comes to how brand affects their decision to buy services or technological products See http://www.b2bmagazine.com.br/UserFiles/File/Converg%C3%AAncia%20Marcas.ppt.

[19] Not surprisingly the 5% and the 3% R&D intensity levels are thresholds for receiving tax benefits under the Informatics Law and the "Lei do Bem".

knowledge sources. This is at odds with the emphasis of the Informatics Law on such ties. We will come back to this issue later.

While worker quality is seen as a source for innovation, the interviewees, but for a smaller firm, did not indicate that there is a shortage of skilled workers. Most likely, the smaller firm is not able to compete with larger firms on wages and benefits. The four Brazilian firms that differentiate product and the two multinationals informed that their employees are more qualified on average than the employees of their competitors. The two firms that specialize in the production of computers informed that the average qualification of their employees is similar to that of their competitors. All firms unanimously indicated that wages and taxes on labor are high and represent a hurdle to firm growth. Firms suggest that updating labor laws could help solve the problem if that generates higher flexibility and lower costs with benefits.

The informal market is seen as a weak threat to firm expansion. This could be due to an increase in personal income, and availability of credit, and lower prices that channel consumers to the formal market. In addition, it is perceived that there have been stronger efforts by the Brazilian customs to hinder unregistered parts trade.

Credit availability is important to firm expansion. Few firms use bank credit to expand, relying mainly on retained earnings. It does not seem to be a problem of collateral, according to the interviews. The major difficulty seems to be the level of interest rates in Brazil. Funds from BNDES are seen as important for firm expansion for some firms (larger) and irrelevant for others (smaller)[20]. Suppliers are also a very important source of credit in the sector.

Government policy has helped firms grow, according to all firms. The more important programs for the sector are the "*Computadores para todos*" and the tax benefits from the "Lei de Informatica", as discussed in section2. At the time of the interviews, both policies were further enhanced with the "Lei do Bem" (see footnote 5 and section 2).

Seven out of the eight companies that were interviewed declared that the Informatics Law is one of the factors responsible for the competitiveness of the industry in Brazil. Some of the interviewees were more sanguine about it and stated that "without it the informatics sector in Brazil would not survive". One of them said that "that the informatics sector suffered many

[20] Here we see a kind of self-resignation: smaller firms consider BNDES (subsidized) credit irrelevant, as they cannot reach such credit outlays. It does not mean that if BNDES reduces the fixed costs of applying for credit, smaller firms will not tap on this credit source.

losses between 1990 and 1993, period during which the Informatics Law was still unknown. Companies stopped producing and focused on buying and selling."

When the Informatics Law was set and the PPB defined, "The goal of the PPB (Basic Productive Process plan) was to absorb workforce in the productive process but the operations related to assembling changed from work intensive to capital intensive." These changes in the production process of the industry have made the future of PPB uncertain. While some players in this market support the PPB (particularly parts producers), there is a group that suggest revisions to it. In fact, one of the companies of the sample claimed not to participate in the PPB since it uses an automated machine that does not require welding of its parts (a robot). The PPB requires the main components of the machine to be welded in Brazil. The idea behind this requirement was to generate jobs, despite the fact that they would be low skill jobs. The company said that it does not make sense to require the welding to be done in Brazil since the components are not made in Brazil. A manager from the second group of firms stated that "… the PPB should focus on the final product which is still work intensive instead of focusing on the assembling of processors (motherboards) which is capital intensive (capital that is imported)."

State sales taxes can be an important business differential, as its statutory level is as high as the Federal IPI (17%-12%). The State sales tax (ICMS) is origin based and states can grant discount particularly on interstate trade. Paraná State is particularly keen on these benefits and attracted two very large manufacturers (*Positivo* and *Bematech*, mentioned above). This incentive distorts the spatial distribution of companies since it benefits firms located in the State of Paraná (and the district of Ilhéus, at the state of Bahia). The city of Manaus also offers incentives to companies that decide to operate there, in addition to the fourty year old Special Economic Zone (Zona Franca de Manaus) that provides special tax treatments of imports (much like a EPZ).

In summary, the Brazilian informatics sector growth experience and strategies seem quite different from the Asia experience. Brazil is not part of the international productive chain, as it produces mainly end-user goods. On the other hand, the links with international suppliers are not weak and several kinds of cooperation relations were found. Successful differentiation strategies have avoided the competition of larger firms. The expansion of the informatics industry in Brazil does depend on the exploitation of software scope economics and retail and distributor agreements. These factors help firms achieve more efficient sizes. Interviewees perceived the need to expand beyond national borders, but not necessarily as large international firms as most of them sell differentiated products. There is dire need to improve the scientific technological base of the country to foster innovation information transit. The current focus of public policies on Universities is misplaced since, while the latter may generate knowledge, they are not suited to provide technological solutions to firms. Regarding the lack of skills in the workforce it was not seen as a problem. Last but not least the government policy of recent years was applauded in reducing taxes on computers and parts. Together with access to imported inputs – a very important source of knowledge–, these factors are seen as key to foster growth in the sector.

5. Productivity growth in the Brazilian ISIC 30 sector – an exploratory analysis

To shed further light on the level, dispersion and growth of our estimated TFP and output and input heterogeneity measures, we ran a number of regressions to identify possible associations of firm observable characteristics and productivity in the Informatics industry in Brazil. These regressions are specified with an eye on the main conclusions from the interviews. The observable characteristics are firm size (measured by log employment), firm age, share of skilled workers (to proxy labor quality), output taxes paid over revenue (i.e., an average revenue tax rate, to proxy beneficial tax treatment), imported input expenditure over value added (to proxy for product quality), trade volume over net revenue (to proxy for participation in international supply chains and unobserved quality) and whether a firm imports and whether it exports. Aggregate trends are controlled for using year dummies. Lagged size and skills are used to minimize endogeneity bias.

Export activity and import activity are signals of higher quality (productivity) in the literature. The larger, arguably more productive firms, claimed that there are no skill shortages, while smaller firms appear to have proportionally less skilled workers. Firm size is used to guage possible scale economics (note that we estimate TFP under a constant returns to scale hypothesis) suggested by interviewees. Trade volume over net revenues reveal if the Asian experience has positively contributed to productivity growth. Taxes paid should not influence TFPQ but are positively correlated with TFPR, as seen in the Appendix, following Hsieh and Klenow (2008).

Few clear patterns show up. First, the measurement of TFP does not change the results, even though TFPR and TFPQ measure quite different things, under the monopolistic competition hypothesis. Second, firm size is positively related to productivity, as argued by the interviewees. Third, older firms exhibit smaller productivity, suggesting that there is no learning in this sector. While this may be counterintuitive, note that this result is conditional on size. The learning process seems to be superseded by a vintage effect. Last but not least, except for the use of imported inputs, the other explanatory variables are not significant. It is comforting to see that productivity is not correlated with labor quality, as a correctly measured TFPQ tracks neutral (disembodied) technical progress. Yet, firms that use imported inputs have higher productivity. This may be explained as firms that use imported material or capital either have better quality and command a differential price (in the case of TFPR), or are able to combine better capital and labor to process the better (imported) materials (in the case of TFPQ).

Table 15 below looks at firm input and output differentials (or distortions). As expected the mean tax-revenue ratio is positively related to the output price distortion.[21] Surprisingly, this type of distortion is unrelated to size, age or other variables. We expected the output differential to be related to size and imports, as larger firms or firms that use imported inputs could use either its market power or product quality to command differentiated prices. It seems that the constant (isoleastic) demand curve is correctly approximating the price differentials across firms.

Table 14 – Firm productivity and observable characteristics – ISIC 30 – Brazil 1996-2005.

deviation from sector mean lnTFPQ

Size	0.6121	***	0.6396	***	0.6619	***	0.6383	***
Age	-0.0788	**	-0.0918	***	-0.0841	**	-0.0722	**
Share skill.	0.1508		0.2099		0.2217		0.0978	
Taxes/Rev			-1.4357		-1.1415		-0.9335	
Imports/VA			-0.0474		-0.0105		-0.026	
Trade Chn.					0.7553		0.8007	
Importer							0.5646	**
Exporter							0.2907	
R^2	0.0959		0.1102		0.1147		0.1336	

[21] Our taxes over net revenue is measured as (taxes paid)/(gross revenue – taxes paid).

F	4.5503		4.2734		4.0679		4.1754	

deviation from sector mean lnTFPR

Size	0.2925	***	0.3148	***	0.3332	***	0.3202	***
Age	-0.0462	**	-0.053	**	-0.0482	**	-0.0417	*
Share skill.	0.1471		0.1836		0.1908		0.1235	
Taxes/Rev			-0.7795		-0.6077		-0.4968	
Imports/VA			-0.0243		0.0005		-0.008	
Trade Chn.					0.5625		0.5863	
Importer							0.3087	**
Exporter							0.153	
R^2	0.0927		0.1062		0.1138		0.1262	
F	4.385		4.0985		4.0297		3.9098	
Sample	640		624		618		618	

Note: Size: log employment; Share skill.:share of skilled workers; Trade Chn: sum of imports and exports over revenue. *** - signif. at 1% level;** - signif. at 5% level; * - signif. at 10% level. Year dummies included. Fixed Effects estimation.

Table 15 – Firm output and input differentials and observable characteristics – ISIC 30 – Brazil 1996-2005.

deviation from sector mean $ln(1-\tau_y)$								
Size	0.1254		0.0979		0.0858		0.0937	
Age	0.0318		0.0400	*	0.0352		0.0312	
Share skill.	0.3623		0.341		0.3368		0.3797	
Taxes/Rev			1.2089	**	1.0788	*	1.0003	*
Imports/VA			-0.0036		-0.0147		-0.0096	
Trade Chn.					-0.6574		-0.6756	
Importer							-0.1894	
Exporter							-0.1158	
R^2	0.0792		0.089		0.0929		0.0988	
F	3.6881		3.3724		3.2157		2.9669	
deviation from sector mean $ln(1+\tau_k)$								
Size	0.5996	***	0.5964	***	0.6016	***	0.5917	***
Age	0.0111		0.0116		0.0128		0.0177	
Share skill.	0.6947	***	0.7269	***	0.7283	***	0.6816	***
Taxes/Rev			0.4202		0.4941		0.5541	
Imports/VA			-0.0106		0.0231		0.0167	
Trade Chn.					-0.1005		-0.0904	
Importer							0.2297	**
Exporter							0.0672	
R^2	0.2476		0.2551		0.2583		0.2711	
F	14.116		11.8156		10.9291		10.0662	
Sample	640		624		618		618	

Note: Size: log employment; Share skill.:share of skilled workers; Trade Chn: sum of imports and exports over revenue. *** - signif. at 1% level;** - signif. at 5% level; * - signif. at 10% level. Year dummies included. Fixed Effects estimation.

On the other hand, the capital-labor relative cost differential (distortion) is positive for larger firms and it increases with the share of skilled workers used by a firm. This suggests that firms with higher employment (our firm size measure) are using too much labor with respect to capital based on a sector average benchmark. On the other hand, the positive association between the share of skilled workers and the relative capital-labor cost could be explained by mismeasurement of the wage rate due to labor input quality[22]. Firms that use more skilled labor

[22] Note that our wage bill includes social secutiry taxes and benefits paid.

seem to pay a wage premium over the industry average relative capital-labor input cost, so that the wage bill is above the industry average, relative to the capital expenditure.

So far our analysis has not focused on the important government support that the industry receives, namely the "Lei de Informática" (Informatics Act) discussed in earlier sections. Information on such benefits can be obtained from 2001 on from the Science and Technology Ministry with individual firm data, as discussed above[23]. We analyze the effects of the in the evolution of productivity in three ways. First, a descriptive model of who receives the benefits. Second, a differences model, with and without controls, to measure the average impact of the law on productivity.

Moving to the first results, it is not easy to typify a firm that receives benefits from the Informatics Act based on observable characteristics. Using the model reported on Table 16, we see that only the information of whether a firm uses imported inputs or exports is relevant for differentiating firm that receive and did not receive the benefit from 2001-2005. The fixed costs of applying do not seem to matter as larger firms are not more likely to receive the benefit than smaller firms.

Table 16 – Logit model for receiving the Informatics Act benefits in a given year on firm observable characteristics, ISIC 30, Brazil, 2001-2005.

Variable	Coeff.	s.e.	t-stat	Variable	Coeff.	s.e.	t-stat
Size	0.102	0.191	0.53				
				5-9 empl.	17.802	1.296	13.74***
				10-19 empl.	16.579	0.978	16.95***
				20-49 empl.	17.636	0.831	21.23***
				50-99 empl.	17.258	0.797	21.64***
				100-249 empl.	17.029	0.714	23.85***
				250-499 empl.	17.655	0.754	23.40***
				500-999 empl.	17.714	0.958	18.50***
6-10 yrs.	-0.602	0.694	-0.87	6-10 yrs.	-0.727	0.669	-1.09
11+ yrs	-0.366	0.699	-0.52	11+ yrs	-0.501	0.621	-0.81
Shr.skilled labor	1.293	1.061	1.22	Shr.skilled labor	1.374	0.949	1.45
Importer	2.567	0.885	2.90***	Importer	2.737	1.031	2.66***
Exporter	0.761	0.435	1.75*	Exporter	0.782	0.483	1.62*

Note: Size: log employment. N=543. *** - signif. at 1% level;** - signif. at 5% level; * - signif. at 10% level. Year and sector dummies included.

[23] There is information on the *Lei de Informática* at PINTEC. This data is not used as there are few firms that can be matched with PIA and the calculated productivity data in the ISIC 30 industry (less than 30 every year of the PINTEC sample, namely 2003 and 2005).

Our attempts at evaluating the impact of the Informatics Law on productivity and firm differentials with and without controls appear on Table 17. In general, a firm receives benefits from the informatics law does not influence productivity once observed and unobserved characteristics are controlled for. A simple mean difference (first column) indicates that firms that receive the benefits of the Informatics Act are less productive using either measure of productivity (true productivity TFPQ or revenue productivity TFPR). Once firm characteristics are controlled for, the significance disappears, although unobserved characteristics are more important to distinguish the effect of the informatics law on TFPQ and less so on TFPR (as the significance disappears once observed controls are used in the latter case, before fixed effects are used). The Informatics Law dummy significance changes from pooled estimates to FE suggest that conditionally low productivity firms are the ones that receive Informatics Law benefits. According to the interviews, this can be interpreted as a consequence of the productive process conditionalities, precluding the use of more advanced techniques (such as robots). At the same time, these less productive firms have the incentive to seek tax breaks from the Informatics Law to compete.

Comparing Table 17 with Table 14, we confirm that productivity is positively influenced by size and negatively associated with age, for both TFP measures[24]. Revenue over an input index (TFPR) is better characterized by firm fixed effects than with observable characteristics such as skilled workforce or whether a firm imports or exports. We ran additional regressions using *lagged* benefits of the Informatics Law and the lack of correlation between receiving the tax benefits and productivity conclusion is maintained. Lagged (two year) indicators are used as there may be time needed to reap the benefits of the law in the market or to implement the product line that benefited from the tax break. Results are available upon request.

Finally, Table 18 presents the estimates for the firm specific output price and capital cost differentials. Recall that one of the Informatics Law main benefits is a reduction in the federal value added tax (IPI) for the goods that have enough domestic content in their manufacturing process (PPB). There are additional benefits regarding depreciation and income (IRPJ) tax treatment of R&D expenses. Interestingly, firms that receive the benefit of the Informatics tax have a higher price than others, on average. An alternative interpretation, as may be seen in the

[24] The result is stronger once we realize that table 18 uses lagged variables and covers the 1996-2005 period and table 21 uses current variables and covers 2001-2005 only.

appendix, is that firms that receive Informatics Law benefits spend too much on labor, as a share of value added, on average, than would be expected from a sector benchmark. Yet this differential disappears once unobserved characteristics are controlled for, suggesting that it is not actually the benefit from the Informatics Law that was generating the differential but firm characteristics correlated with price and Informatics Law status.

Table 17, Effect of Informatics Law on productivity, Brazil ISIC 30, 2001-2005.

deviation from sector mean lnTFPQ

	LS(n.c.)		LS		FE	
Informatics Law	-0.339	*	-0.582	**	-0.143	
Size			0.335	***	0.794	***
Age			0.001		-0.122	***
Share skilled work.			0.269		1.186	*
Importer			-0.210		0.099	
Exporter			-0.036		0.065	
R^2	0.1653		0.3242		0.1461	
F	5.07		7.01		10.89	

deviation from sector mean lnTFPR

	LS(n.c.)		LS		FE	
Informatics Law	-0.357	**	-0.248		-0.159	
Size			-0.095	*	0.457	***
Age			-0.002		-0.078	***
Share skilled work.			-0.496	*	0.675	
Importer			-0.458	***	-0.046	
Exporter			-0.232	**	0.013	
R^2	0.0703		0.293		0.1061	
F	2.25		17.67		7.56	
Sample	737		645		645	

Note: Size: log employment; Share skill.:share of skilled workers. LS(n.c.):least squares without controls (but for year and sector dummies); LS least squares; FE: fixed effect estimation. *** - signif. at 1% level;** - signif. at 5% level; * - signif. at 10% level. Year dummies included. 4 digit sector dummies included except in Fixed Effects estimation.

Table 18, Effect of Informatics Law on firm output and input differentials – ISIC 30 – Brazil 2001-2005.

deviation from sector mean ln(1-τ_y)

	LS(n.c.)		LS		FE	
Informatics Law	0.393	***	0.293	**	0.172	
Size			0.151	***	-0.154	*
Age			-0.007	*	0.019	
Share skilled work.			0.241		0.044	
Importer			-0.524	**	-0.011	
Exporter			-0.005		0.036	
R^2						
F	0.0075		0.1296		0.0177	

deviation from sector mean ln(1+τ_k)

	LS(n.c.)		LS		FE	
Informatics Law	-0.094		0.112		-0.084	
Size			0.059		0.473	***
Age			-0.015	***	-0.016	
Share skilled work.			-0.432		0.777	**
Importer			-1.434	***	-0.033	
Exporter			-0.392	*	0.104	
R^2						
F	0.0106		0.2472		0.1769	
Sample	0.2124		31.27		13.68	

Note: Size: log employment; Share skill.:share of skilled workers. LS(n.c.):least squares without controls (but for year and sector dummies); LS least squares; FE: fixed effect estimation. *** - signif. at 1% level;** - signif. at 5% level; * - signif. at 10% level. Year dummies included. 4 digit sector dummies included except in Fixed Effects estimation.

Regarding the relative capital cost differential *(τ_k)*, there does not seem to be any difference between firms that received and did not receive the benefit, with or without controls. Comparing the rightmost column of the lower half of Table 22 with the rightmost column of the lower half of Table 19, one confirms the results that larger firms and firms that use more skilled workers are the ones with a relative labor expenditure share of input larger than sector average. This difference could be explained by true technology differences (production function coefficients) or misspecification of the wage cost. In the former case, Brazilian technology in the informatics sector seem to be biased towards labor for larger firms. In the latter case, larger firms would face a relatively higher capital costs. This is counterintuitive, particularly in light of BNDES credit, that is subsidized and biased towards large firms, as subscribed by the interviews.

6. Concluding comments

In this paper we set out to study the informatics industry (ISIC 30) growth and productivity in Brazil. This is a sector that changed radically in the last twenty five years, moving from a virtual ban on imports to an open sector with common Mercosur tariffs. At the same time, there were international changes in manufacturing processes, processing power and applications that reshaped the industry. Computers are now ubiquitous in our lives and their use is intertwined with mobile and digital communication technologies. In Brazil the sector still receives special support from specific legislation giving tax breaks (sales, payroll and corporate taxes) to firms with higher domestic content on their manufacturing process and high R&D expenditures. These benefits are referred to as “Lei de Informática” (*Informatics Act*).

Our analysis followed complementary routes. We start with interviews with market leaders, in all ISIC 30 subsectors, and in many regions of the country. This provided us with a first view of sector dynamics and factors that influence competitiveness and growth. The Brazilian sector experience can be contrasted with the Asian experience, where the informatics, as well as the larger ICT (information and communication technologies) and electronics sectors, are seen as engines of growth. While in the Asian countries the informatics sector has strong international ties, as part of a global productive chain, in Brazil firms usually sell consumer products domestically. They do use international suppliers to tap more advanced technology, but do not participate in global productive chains.

Second, we use manufacturing survey firm level data, to study the association between productivity and observed characteristics (and unobserved ones as fixed effects). In particular, we provide econometric evidence on the effect of Informatics Law benefits on productivity.

Our productivity analysis followed Hsieh and Klenow (2008), using their analytical framework to estimate revenue productivity and true (output) productivity under monopolistic competition with Cobb-Douglas technology and exploring firm output price and capital relative cost differentials. These differentials also measure firm labor and capital share heterogeneity. The differentials can be interpreted as distortions (non-market generated distortions) under the assumed model or may reflect true within sector technology differentials and or input and output market price differentials.

We estimate significant TFP growth for the sector over time, particularly after 2000. Productivity heterogeneity is increasing also. When decomposing TFP gains from 1996 to2005, we see that most productivity gain was within sector, with a negative contribution of between firm reallocation for continuing firms and a positive market selection (net entry) effect.

From the interviews a consistent picture of the industry can be observed. First, in the business machine sector, firms tend to differentiate their products with close software complementarity, tailoring to firm needs. This is also a strategy by domestic producers to avoid head on competition with large multinationals, exploiting niches. Differentiation and flexibility comes from dealing with the complex labor and tax codes in Brazil. On the other hand, computer manufacturers have a growth strategy that exploited distribution deals with retail chains, in the wake of the pro-poor growth experience since 2003. These chains focus middle and low income classes, with site credit. This avoided direct competition with upscale, international brands.

All firms stated that international suppliers are a very important source of credit and of technology and innovations for the firms in the sector. While, in general, Brazilian public policy focuses on the role of Universities for technological innovation, firms in the industry do not tend to use it as a technology source. Regarding growth hindrances, expansion is generally limited by high market interest rates and exchange rate volatility. The Informatics Law has positive reviews, but there seem to be room for improvement, particularly on the R&D conditionalities and the domestic content manufacturing requirements.

We take these results and use them to build descriptive models of TFP levels and growth, based on observed characteristics, using firm level data from 1996 to 2005. Regression analysis of TFP on observed and unobserved characteristics indicates that larger firms are more productive and older firms are (conditionally) less productive. When firms use imported inputs their productivity levels are above average.

Informatics Law benefit recipient status does not influence productivity, once firm characteristics, such as size, age and skills are controlled for. The negative effect in simple mean differences and insignificant results from fixed effect estimates suggest that structurally less productive firms are the ones that tend to seek Informatics Law benefits. The law tax breaks seem to lower costs for less productive firms, allowing them to survive, counteracting the pro-productivity market selection effect revealed by the productivity decomposition.

In short, the Informatics industry in Brazil has experienced large and robust productivity growth over the period under study. Domestic firms as well as multinationals seem to be expanding their operations, exploring the low computer use intensity rates in the country. The industry has focused on end-users, with parts and suppliers from abroad, taking a different route than Asian countries.

It must be stressed that we did not propose to evaluate the "*Lei de Informatica*" as a whole as our focus was on productivity. The Informatics Law may have impacts on firm size, value added and innovation that are not accounted for here. One important issue is whether firms that tap the Informatics Law benefits use less productive technology to begin with, or the domestic content clauses of the Law hinders the use of automated, more productive, technology. This is clearly a topic for future research.

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Appendix
Variable definitions

We present here the data transformations made to generate the TFP estimates and other variable definitions.

TFP estimates: Total Factor Productivity is calculated using a constant cost share method, using US cost shares, as in Hsieh and Klenow (2008), namely:

$$tfpr_t=\omega_{it}= y_{it} - ((1-\alpha)\, l_{it} + \alpha\, k_{it})$$

where y measures log value added, l is the log labor used (the wage bill) and k the log capital stock; $\alpha = C_K/C$, and C_j represent expenditures on input j ($j=L,K$) and $C=\Sigma_j C_j$. This is the measure we denote *revenue* TFP, or TFPR. The capital share is set to the corresponding US level, available at the NBER Produtctivity Data Base, using the 1990-1995 average at the 4 digit level. In detail, we use .2403 for CNAE 3012 (Business machines), .3261 for CNAE 3021 (computers), and .3137 for CNAE 3022 (printers and peripherals).

Following Hsieh and Klenow (2008) an output adjusted TFP measure is dubbed TFPQ and exploits a monopolistic competition model, with demand function $P=Y^{-\sigma}$. This implies that output may be recovered from value added using $Y=(PY)^{\sigma/(\sigma-1)}$. The elasticity parameter is set to $\sigma=3$. Thus, log TFPQ is measured as

$$tfpq_t= (3/2)y_{it} - ((1-\alpha)\, l_{it} + \alpha\, k_{it})$$

Value added (y) is measured by the deflated difference between net sales (plus inventory changes) and manufacturing costs (materials and energy costs). The deflator used is an IPA (wholesaleprice index for printers). Results do no change much if computer price indices are used.

Labor is measured by the number of permanent workers and labor cost by the total wage bill (including social security payments). The wage bill is deflated using the national inflation index used for minimum wage and retirement earnings adjustments (INPC).

The capital stock is calculated from a perpetual inventory model on net investment. Investment is deflated using the price deflator for machinery and equipment (IPA-DI). The estimated capital stock for each year is augmented with rented or leased equipment and buildings values, under a 10% rental rate. The initial capital stock is based on average depreciation expenditures over time, and we use a 5% depreciation rate. Capital expenditures are measured by a 5% cost of capital in addition to rental and leasing expenditures. The rent or leased capital stock adjustments are required so to keep total capital stock from decreasing sharply over time and account for the fact that firms have increasingly used leasing or equipment rent over time.

As in Hsieh and Klenow (2008) we explore within sector firm differences in output prices and relative capital cost. Firm profits are maximized according to

$$\pi = (1-\tau_{y,it})(PY)_{it} - wL_{it} - (1+\tau_{k,it})rK_{it} \qquad \text{s.t. } y_{it}=tfpq_{it}+((1-\alpha_s)\, l_{it} + \alpha_s k_{it}) \text{ and } P=Y^{-\sigma}$$

Note that labor and capital costs (w and r, respectively), as well as technology parameters, are equal to all firms (within a 4 digit sector s). From the profit maximization FOC we can calculate

$$(1-\tau_{y,it}) = \sigma/(\sigma-1)\ (1/(1-\alpha))wL_{it}/(PY)_{it}$$
$$(1+\tau_{k,it}) = (\ \alpha/(1-\alpha))wL_{it}/rK_{it}.$$

It is not hard to see that these factors ($\tau_{y,it}$ and $\tau_{k,it}$) reflect relative differences between the firm capital and labor cost shares and the assumed sector cost shares, where $rK_{it}/(rK_{it}+wL_{it})=\alpha_{it}$, and we use the fact that $(rK_{it}+wL_{it}) = (\sigma-1)/\sigma\,(PY)_{it}$ in our monopolistic competition model with constant returns to scale.

$$(1-\tau_{y,it}) = (1-\alpha_{it}) / (1-\alpha)$$
$$(1+\tau_{k,it}) = [(1-\alpha_{it}) / (1-\alpha)\ ] / (\ \alpha_{it} / \alpha\ )$$

Hsieh and Klenow (2008) name $\tau_{k,it}$ $\tau_{y,it}$ as “wedges” or distortions. We use a more general term heterogeneity differences, as some of these distortions may be special treatments some firms receive (as the sales tax benefit of the informatics law) or tax evasion, or may be true factor price or technology differences. Of course each reader prior about factor market prices competitiveness (or absence of adjustment costs and even measurement error) influence the interpretation of the factors $\tau_{k,it}$ and $\tau_{y,it}$.

The estimated output TFPQ measure may be dependent on our monopolistic competition hypothesis. This would appear as a positive association between TFPQ and size. The figures below present a non-parametric local regression smoother (lowess) of value added rank and sector normalized log TFPQ. There is a positive association between firm size and TFPQ, while this pattern is less clear (if not negative) for TFPR. The negative, possibly flat association between TFPR and size was obtained for US manufacturing by Hsieh and Klenow (2008).

Sector TFP is obtained using a revenue weighted firm TFP average, following Hsieh and Klenow (2008). Time series variation is adjusted for aggregate output expenditures and aggregate prices, as suggested by J. Tybout (personal communication).

TFP decomposition

We decompose Sector TFP change, ΔTFP_t using the well known Foster, Haltiwanger and Krizan (2001) decomposition.

$$\Delta TFP_t = \Sigma_{i\in C}\ \theta_{it-1}\ \Delta tfp_{it} + \Sigma_{i\in C}\ (tfp_{it-1} - TFP_{t-1})\Delta\theta_{it} + \Sigma_{i\in C}\ \Delta\theta_{it}\ \Delta w_{it}$$
$$+ \Sigma_{i\in N}\ \theta_{it-1}\ (tfp_{it} - TFP_{t-1}) + \Sigma_{i\in X}\ \theta_{it-1}\ (tfp_{it-1} - TFP_{t-1}),$$

where TFP_t is the revenue wheighted average (aggregate) productivity for period t,(i.e., $TFP_t=\Sigma_i\ \theta_{it}\ tfp_{it}$) where $\theta_{it}=y_{it}/\Sigma_i\ y_{it}$, i.e., θ_{it} is the share of each firm for total revenue, C indicates continuing firms, N new (entering firms) and X exiting firms.

Additional Results

Table A1 –Expenditure Shares Evolution for ISIC 30, Brazil.

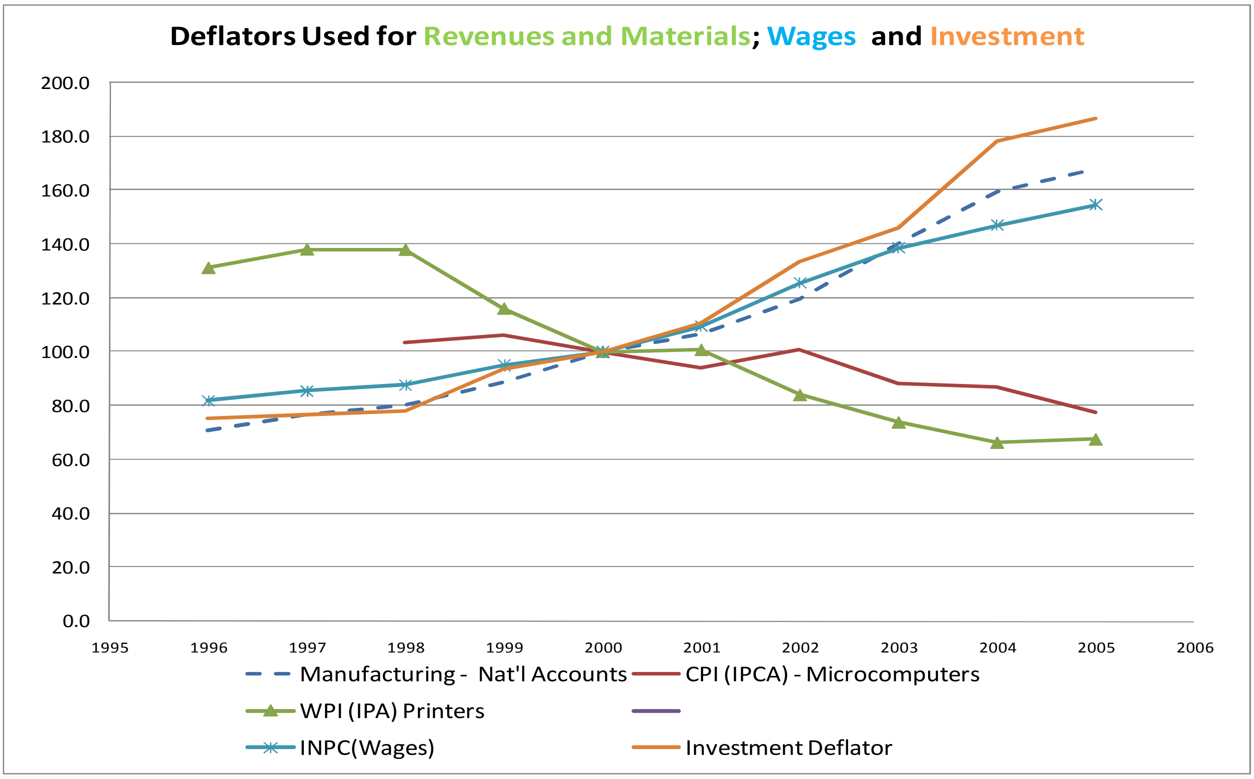
Year	Capital	Labor	Energy	Materials	Capital(VA)	Labor(VA)
1996	0.607	0.128	0.001	0.263	0.830	0.170
1997	0.562	0.129	0.001	0.307	0.816	0.184
1998	0.544	0.120	0.001	0.335	0.823	0.177
1999	0.501	0.095	0.002	0.402	0.844	0.156
2000	0.440	0.089	0.001	0.470	0.835	0.165
2001	0.426	0.076	0.001	0.496	0.851	0.149
2002	0.367	0.068	0.006	0.559	0.847	0.153
2003	0.292	0.068	0.002	0.638	0.815	0.185
2004	0.231	0.063	0.002	0.704	0.791	0.209
2005	0.206	0.060	0.004	0.730	0.778	0.222
Average	0.42	0.09	0.01	0.49	0.823	0.177
SIC 357	0.33	0.17		0.50	0.707	0.293

SIC 357 – US average shares for the 1990-1995 period, based on the NBER Productivity Database.
Note: Details on variable definitions, please see Appendix.
Authors calculations based on PIA primary data.

Deflators Used

Deflators play an important role in the informatics sector on output and value added trends calculations, as this industry has faced strong price *decreases* over time, from technological advances (*e.g.* processing power). As mentioned above, we used as deflator for revenues and materials the wholesale price index for printers (IPA) calculated by FGV. This deflator (green line with triangles below) fell about 50% from its 1996 value up to 2005. It is interesting to note that the consumer price index for computers (IPCA – computadores) follow basically the same decreasing trend but at a slower pace (a 25% decrease from 1998). The latter index is not used due to its limited time coverage (only from 1998). The deflators used for investment (national accounts implicit deflator for gross investment) and wages (the national consumer price index, INPC) show steady increases over time, particularly in 1999 and 2002, where the exchange rate depreciated considerably. The manufacturing value added deflator from the national accounts follow the same trend. It is presented here only as a benchmark to aggregate manufacturing prices.

Figure A1 – Different deflators ISIC 30, Brazil, 1996-2005.



Data sources.

a. Pesquisa Industrial Anual (PIA) [25]

Pesquisa Industrial Anual is an annual survey sampling formally established Brazilian mining and manufacturing firms and plants, conducted by the census bureau *IBGE* (*InstitutoBrasileiro de Geografia e Estatística*). In 1996 it experienced major transformations both in the sampling scheme and the information collected from the sampled firms. The change in 2005 can be considered a minor one since it is limited to include firms that employ less than five workers in the sampling scheme. During this time the sample of firms in *PIA* is drawn from two strata: a non-random sample of all Brazilian mining and manufacturing firms with a labor force of 30 or more workers and employees (*Estrato Final Certo*, receiving a complete questionnaire called *modelo completo*), and a random sample of small to medium-sized firms with a labor force of five to 29 workers and employees (*Estrato Final Amostrado*, receiving a simplified questionnaire called *modelo simplificado*).

A firm is eligible to be sampled in *PIA* only if at least half of its revenues stem from manufacturing and if it is formally registered as a tax payer with the Brazilian tax authorities. In 2004, *PIA* sample covers 42,371 firms among 155,656 eligible ones.

PIA contains three main groups of variables: (a) Information about longitudinal relations across firms, (b) balance sheet and income statement information, and (c) economic information beyond the balance sheet and income statement.

[25] We thank Carlos H. Corseuil for the information below.

The main longitudinal information in group (a) is the register number as a tax payer firm (CNPJ code). This allows us to link observations longitudinally, as well as combining it with other sources such as RAIS. Among other variables in group (a) are the ones that indicate the state of activity of a firm in a given year (such as whether it operates all year, only part of the year, or exits) and its structural changes (such as whether it emerges from a pre-existing firm or whether it creates a spin-off firm itself, and the like). Variables in group (b) include cost, revenue, and profit information, detailed in a manner similar to a typical Brazilian income statement. In the revenue side, for example, we are able to rip-off non operational revenues, while on the cost side it is possible to identify intermediate inputs, among other details. Variables in group (c) go beyond the income statement and include data such as investment flows by type of asset, numbers of workers and employees. Employment is broken down in production and non-production workers.

b. Pesquisa de Inovação Tecnológica (PINTEC)

This is a regular survey by IBGE on manufacturing firms, aiming to measure and understand the innovation process. Sampling weights are used to compensate the deliberate oversampling of firms that engaged in some form of innovation or acquisition of machinery. Detailed quantitative and qualitative information on R&D expenditures and innovation is provided. The design of the survey is based on CIS-4 surveys of the European Community. There is data for 2003 and 2005, as well as 2000, with a slightly different questionnaire. The sampling scheme includes all firms with 500 workers or more or firms that have engaged in at least one type of innovation information and a sample of firms with 5 employees or more. The sample size of PINTEC surveys are about 10,000.

c Relação Anual de Informação Sociais (RAIS)

Relação Anual de Informações Sociais is an administrative file maintained by the Brazilian Ministry of Employment and Labour (Ministério do Trabalho e Emprego - MTE). All registered taxpaying establishments must send every year to the Ministry information about every single worker who had been employed by the establishment anytime during the reference year.

The RAIS files provide a matched employer-employee longitudinal data set, similar to those available in developed countries. The novelty differential of these data is to combine the matched employer-employee structure with detailed information available on workers' occupation. This characteristic of the data allow us to build a precise categorization of workers in “blue” and “white” collar from the information on both education and occupation. So the main use of RAIS it to provide the labor inputs variables. In addition it is used to generate a proxy for firm age, by looking at the longest tenure in the firm, for the start year a firm appears in the sample.

d Trade Data (SECEX)

These are the raw files of firm import and export activity, by year, including import and values. The data build upon official customs registry. Firm information refers to the importing entity. If a firm purchases imported inputs or machinery though a trading company, this is registered as the trading company imports.