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trade liberalization**

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UNDERSTANDING DEMAND FOR SKILLS AFTER TECHNOLOGICAL TRADE LIBERALIZATION

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ABSTRACT

This paper investigates the effects of the reduction of barriers to trade in the computer technology sector on the Brazilian labor market. We show that the adoption of computers affected labor demand in favor of non-routine tasks, which are complementary to labor, as opposed to routine ones, which are substitutes. Using the end of the non-tariff barriers in Brazil ("Informatics Law") as an instrument, and relying on detailed information on sectors and occupations, we found evidence that industries and occupations intensive in computer use displayed greater shifts toward non-routine and away from routine tasks for most educational group and genders.

Key Words: Labor Demand; Skills; Trade and Labor Market Interactions; Technological Change.

JEL Codes: J23; J24; F16; O3.

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1. INTRODUCTION

Results from the theory of trade show that liberalization works to improve industrial productivity. This happens through two distinct channels: reallocation of productive resources and the adoption of new technologies (e.g., Melitz, 2003; Bernard et al., 2003; Yeaple, 2005; Bustos, 2011). The most recent literature on trade stresses the effect of trade liberalization on the choice of new technologies, wages and firms' choice to export (as in Yeaple, 2005 and Bustos, 2011).

In this paper we investigate the effects of technological trade liberalization on demand for different skills in the labor market. We took advantage of the end of the non-tariff barriers imposed by the Informatics Law from 1984 to 1992 in Brazil. After the repeal of this law, the use of computers increased drastically in the Brazilian market (Botelho et al, 1999). Using measures of skills, resources required for each occupation, occupational frequency, and a theoretical framework proposed by Autor, Levy and Murnane (2003), we analyze how this technological trade liberalization impacted demand for non-routine and routine tasks.

From a policy perspective, it is crucial to understand how the labor market is affected by this trade orientation, and which kinds of skills are more demanded. From the government's view, strategies that subsidize and invest in the labor market can be designed to maximize the productivity gains from the dissemination of computers. Bloom et al. (2012) evidence higher productivity gains from technology when firms are more able to manage people and their skills. This paper contributes to this understanding by documenting the effects of technological trade liberalization on the labor market.

Previous studies have pointed to the strong correlation between the adoption of computer technologies and the increased demand for highly educated workers (see Katz and Autor, 1999; Berman, Bound and Griliches, 1994; Berman, Bound and Machin, 1998; Machin and Van Reenen, 1998). Nonetheless, the literature on skill-biased technological change (SBTC henceforth) fails to explain the causes of the shift in the demand for highly educated professionals and to elucidate how computers change the market structure to increase the demand for more educated workers.

Our paper studies, in contrast, the impact of technological trade liberalization on demand for different types of routine and non-routine tasks. Intuitively, a decline in the price of computers due to trade liberalization should cause a contraction in the demand for routine tasks, which are replaced by computers, and an expansion in the demand for non-routine tasks, which are complemented by them.

We test our hypothesis in the context of the sudden end of a computer technology barrier: the end of the Informatics Law in Brazil. This law was enacted in 1984 to control the importation of computers, for the purpose of nurturing a homegrown computer industry. The end of this policy in 1992 was part of the overall liberalization of the Brazilian economy, and the importation of informatics products rose nearly 400% from 1992 to 1997 (Botelho and Tigre, 2001).

Based on this episode, we estimate the impact of this type of trade liberalization on demand for each kind of task in the Brazilian labor market. Using panel regressions with fixed effects, we show that the end of this trade barrier increased the demand for non-routine tasks and reduced the demand for routine tasks, regardless of gender or educational experience of workers. We also show that the changes in demand for tasks were not a consequence of a general reduction of the import tariffs implemented in the Brazilian market between the end of the 1980s and the beginning of the 90s.

This paper contributes to the recent literature that relates trade liberalization, technological changes and its effects on demand for workers with different skills. Yeaple (2005) presented a theoretical model of the economic implications of trade and the endogenous choice of technological level. Since firms choose to employ different technologies, they systematically hire different types of workers and pay different wages. Bustos (2011) studied the impact of a regional free trade agreement on technological upgrade. The results indicated that the most productive firms export and choose to use more advanced technology. Unlike these authors, we analyze a particular end of a trade barrier, concerning computer technologies. This allows us to study the specific effect of computer technology dissemination. Also, we contribute to the literature on demand for job skills by shedding light on the change in labor market dynamics caused by the end of a trade barrier. From a policy perspective, it is relevant to understand how

the end of such a barrier to technology should be implemented to maximize its gains and how the choice of technology is linked with the type of job tasks.

This paper also adds to previous studies which have investigated the impact of trade barriers on economic variables. In the early 1990s, Dornbush (1992) and Edwards (1992, 1993; 1998) investigated the reasons and consequences of trade liberalization in many developing countries. Empirically, Edwards (1992) showed that economies which are more open tend to grow faster than economies with trade distortions. However, Edwards (1992) and Rodriguez and Rodrik (2000) were skeptical about the empirical validity of this claim, mainly due to the difficulty of constructing trade orientation metrics that can be used in time-series and cross-section analysis. Galiani and Sanginetti (2003), Galiani and Porto (2010), Gonzaga et al. (2006) and Esquivel and Rodriguez-Lopez (2003) studied the consequences of trade liberalization on wage differentials in Latin American countries. They compared specific economies before and after the trade liberalization but did not use measures of trade orientation. Like Galiani (2003), Galiani and Porto (2010), Gonzaga et al. (2006) and Esquivel and Rodriguez-Lopez (2003), this study benefits from a change in trade orientation, but in this case we analyze a particular end of a trade barrier, concerning computer technologies.

Finally, our paper contributes to the literature that investigates the effect of computer technology on the labor market. This literature demonstrates that the spread of computers has been biased in favor of workers who have attained higher educational levels (SBTC), supported by the assumption that these workers are more able to use these technologies. It is mainly supported by the positive correlation between computer technologies and the demand for highly educated workers (Katz and Autor, 1999). This correlation has been observed for different industries, as documented by Berman, Bound and Griliches (1994), Berman, Bound and Machin (1998), Machin and Van Reenen (1998), and on the level of firms by Levy and Murnane (1996) and Bresnahan, Brynjolfsson and Hitt (2002). Bloom et al. (2012) add evidence that productivity gains from technology are bigger when firms have tougher personnel management practices. Autor, Katz and Krueger (1998) also estimated a significant effect of the spread of computers and the higher demand for educated workers on the rise of wage inequalities in developed

markets. Autor, Levy and Murnane (2003) went deeper in analyzing the demand in the labor market. They showed that the adoption of computers was directly linked with increasing demand for non-routine tasks and a corresponding reduction of demand for routine tasks within each industrial sector in the US labor market. Spitz-Oener (2006), Black and Spitz-Oener (2010), and Bergmann and Mertens (2011) found similar evidence for Germany. Goos and Manning (2007) added evidence for Great Britain and Goos, Manning and Salomons (2009) added data for 16 European countries. Our contributions to this literature are two: first, our method, unlike previous studies, took advantage of a single event in the economy to perform our empirical investigation; second, we contribute supporting evidence for the effects in a developing country.

The remainder of this paper is organized as follows: section 2 describes the Brazilian market reserve policy; section 3 discusses the interaction between labor tasks and computer technology; section 4 presents the database; section 5 reports the empirical results; and section 6 concludes.

2. THE BRAZILIAN MARKET RESERVE POLICY

In the early 1970s, Brazil started the first initiative to protect the computer industry. In this period, the country was experiencing significant economic growth and computer needs were mostly served through imports and by local subsidiaries of foreign companies.

In 1976 the Brazilian government implemented a strategic computer policy. This policy intended to reserve the market for powerful computers (mainframe computers) for multinational corporations (such as IBM, Hewlett-Packard and others). On the other hand, a plan for developing local productive capabilities gave priority to the market for small computers and peripherals, presumably with technology that was easier to master. Together with this action, the government also controlled all purchases of data-processing hardware and software by public entities (Pedersen, 2005).

In 1984 the government enacted the Informatics Law. For eight years it imposed a limit on access by foreign companies to the manufacture of small computers, extended the market reserve policy to the telecommunication sector and provided various support mechanisms for strictly nationally controlled

companies. This strategy was a dismal failure in promoting homegrown capability to match international developments in this sector. Consequently, local industrial users of computers and other microelectronic goods were unable to access the latest international innovations.

The market reserve policy ended in 1992 as part of the overall liberalization of the Brazilian economy, being replaced by a tax policy and financial incentives. As a consequence, most private Brazilian producers in the informatics sector went bankrupt, sold out to foreign competitors or left this market completely. The importation of information technology products rose nearly 400% from 1992 to 1997. In the same period, the Brazilian information technology market grew by 16% a year on average (Tigre and Botelho, 1999).

The diffusion of information technology throughout the Brazilian economy was highly uneven, with large firms and advanced industrial sectors responding rapidly, while smaller firms, peripheral regions and government entities remained marginal users of information technology.

In this paper we try to shed light on the effect of this abrupt opening of the computer technology market on the demand for routine and non-routine tasks.

3. COMPUTERS AND CHANGES IN TASK DEMAND

Here, we use the term “computers” to represent a varied set of machines, such as microprocessors, automation and telecommunication equipment, and also software (such as enterprise resource planning systems) and networks (such as Internet) that are used together with computer hardware by workers. In the labor market, computers are solidly established nowadays for various purposes in all economic sectors. However, they still are similar to those of previous decades: machines able to run quickly and accurately a set of tasks deterministically specified through a logical and unambiguous code, using a programming language (Autor, Levy and Murnane, 2003). Of course, due to advances in the capability of microprocessors and algorithms, complex calculations, such as those needed to optimize a system with many variables in operational research, which would have taken hours to be processed on mainframe

computers some years ago, can now be performed in minutes on a personal computer, available at affordable prices by a wide variety of firms.

Computers are widely used for tasks such as performing calculations or saving, retrieving and distributing information. Furthermore, the use of robots able to automate processes on assembly lines is now common, such as in the automotive sector, or to store and retrieve products in distribution warehouses.

From this view of computer technology, Autor, Levy and Murnane (2003) defined work as a sequence of tasks to be performed, and classified these tasks in five groups, according to the capability to automate them: routine cognitive, routine manual, non-routine analytical, non-routine interactive and non-routine manual activities.

According to this definition, routine tasks are those that can be performed by computers, i.e., they are repetitive tasks that can be previously specified unambiguously using a computer program. Some of these routine tasks need cognitive ability, such as to perform the calculation of the amount of tax on an invoice. Current computer systems are able to calculate tax rates, make the accounting entries and update the inventory records all within a single operation. Thus, one sequence of routine tasks, performed years ago by several people, is currently performed automatically, faster and with reduced error risk by computers.

On the other hand, another kind of routine task depends on manual skills. As an example, we can discuss the process of storing goods in a distribution warehouse. Upon receiving an order, packages need to be moved to a specific location in the warehouse. Using current technology, this process can be performed by a computerized system that determines the best location for product storage, and a robot or machine which performs the physical movement of the product to the place previously determined.

Tasks that cannot be precisely specified in a logical sequence of steps are called non-routine tasks. These tasks can be manual or cognitive in nature. Among the cognitive analytic tasks are those which depend on reasoning ability and creativity, such as those performed by an engineer to design a new

production process. Since these activities depend on the creation of a new model or concept, current technology does not allow their automation. However, computer technology can complement engineers' design task by providing computer-aided design (CAD) systems, to support them in creating and designing new products.

Still within the group of non-routine cognitive, interactive tasks are those that depend on direct interaction with other agents, such as persuading customers to buy a certain product or coordinating activities of subordinates. With regards to persuading a customer, currently there are a number of online shopping systems available by which one can purchase directly on the Internet, without the intervention of any sales agent. However, the process of persuading a customer to choose one product over another depends on several parameters beyond price, and still cannot be fully automated using current technology.

Another task group, although dependent on manual skills, does not follow a clear set of rules in the way it can be performed by computers, i.e., it involves non-routine and manual tasks. One example is the case of driving a bus. Although drivers perform mostly manual tasks, the ranges of possibilities and non-standard events that can occur in traffic are so high that until now no one has been able to develop the software and robots capable of performing this task without jeopardizing the lives of passengers. If one looks carefully, this kind of task could be performed using current technology. Note that a robot could be used to carry certain objects from one place to another, such as discussed in the case of storing goods in a warehouse. However, in the previous case, robots are operated in controlled environments and not in a complex traffic pattern, as in the case of driving a bus.

From this viewpoint that computers can substitute human labor in performing routine tasks and can complement human labor in performing non-routine tasks, Autor, Levy and Murnane (2003) proposed a general equilibrium model in which these tasks are combined in a production function. Based on this model, they derived the propositions below:

Proposition 1: Due to the complementarity between routine and non-routine inputs, a decline in the price of computer capital raises demand for non-routine input. Thus, sectors that invest more

in computer capital will show larger increases in labor input of non-routine tasks and larger decreases in labor input of routine tasks.

Proposition 2: For a given (computer) price decline, the proportionate increase in demand for routine tasks is larger in routine-task-intensive industries.

In the following sections we use these propositions to analyze the effects of the computer trade liberalization in Brazil and its consequences on demand for different types of tasks.

4. DATA

We used two different data sources in this study (see Table 1). Information on the frequency of workers in each occupation, educational group, industry and gender came from the Annual Social Information Report (*Relação Anual de Informações Sociais - RAIS*). This database is a record of employment in the formal market, and must be sent to the Labor Ministry by all government controlled and private companies that operate in all sectors of the economy (agriculture, commerce, industry, services, among others). It has the advantage of covering almost all formal workers in the Brazilian market.

In this paper we analyze the demand for tasks in two periods of time: before and after the computer dissemination in the Brazilian market. We choose 1985 as the ending point of the period when computers did not have a significant impact in the Brazilian market. This is also the oldest data available from the RAIS database, and taking into account that personal computers only started to be sold in 1981 in the US and that the Informatics Law from 1984 controlled the importation and production of computers, we argue that this technology was not disseminated in the Brazilian market until 1985. Mainframe computers were available, but due to their expensive prices, their use was restricted to a very small portion of the labor force. Between 1985 and 1992, local producers offered personal computers in the Brazilian market but the adoption of this technology was limited to a small number of firms due to its high prices. According to the Brazilian magazine *Info Exame* published in June 1988, prices of computers in Brazil were more than three times higher than in international markets.

We compare data from 1985 against data from 2002. After the end of non-tariff barriers in October 1992, there was steep growth in computer use in Brazil (Botelho et al, 1999). However, this diffusion was highly uneven, with leading firms and advanced industrial sectors responding rapidly, while smaller firms and peripheral regions remained marginal users of information technology (Botelho et al, 1999). In 2002, a decade after liberalization, computer technology had been disseminated in all sectors of the Brazilian market, allowing us to measure its effect.

For the analysis of the impact of computers, we created a measure of the tasks carried out by workers and computed the changes in task demand over time (see Table 1). To measure tasks we used our second source of data: the Brazilian Occupational Classification (*Classificação Brasileira de Ocupações* – CBO), also available from the Labor Ministry, published only in 1994 and 2002. This database describes the occupations and tasks performed by employees who work in these occupations. The CBO follows the standards found in the International Standard Classification of Occupations (ISCO) from the United Nations, and it is a mandatory reference for administrative records for all public- and private-sector companies in Brazil.

In this paper we use the most disaggregated occupational level available in the RAIS database (occupational families); a three digit code for CBO 1994, with 354 occupations; and a four digit code for CBO 2002, with 602 occupations. To compare CBO 1994 and 2002 occupations, we use the conversion table published by the Labor Ministry, containing a total of 321 compatible occupations.

To investigate changes in demand for tasks within each occupation, we took the CBO's occupational descriptions and classified each task according to the typology proposed by Autor, Levy and Murnane (2003). In this classification, we used Table 2, aiming to maintain the standardization of task classification regardless of occupation. In this way, we used Table 2 as a reference to ensure that, for example, the task "planning" is classified as non-routine analytical in all occupations in which this task is performed.

After classifying each activity, we calculated the proportion of each type of task in each occupation (p_{ks}). For example, the proportion of non-routine analytical tasks for each occupation s is:

$p_{NA,s}$ = (number of non-routine analytical tasks) / (total number of tasks) per occupation. Similarly, we calculated the proportions $p_{NI,s}$, $p_{RC,s}$, $p_{RM,s}$, $p_{NM,s}$, $p_{RTS,s}$ and $p_{NRTS,s}$ respectively, for non-routine interactive, routine cognitive, routine manual, non-routine manual, routine RTS (cognitive and manual), and non-routine cognitive NRTS (analytic and interactive) tasks.

In the following step, for the combination of each occupation s within an industry j , we calculated the percentage of each kind of task k : T_{ksj} , i.e., the percentage of task k in a given industry j and occupation s (see Table 1). It is based on the occupational frequency per industry, N_{sj} , the total number of workers per industry, N_j , and the proportion of tasks per occupation, p_{ks} . Then, we calculated the differences in demand for each kind of task k per industry j and occupation s between 1985 and 2002: $\Delta T_{ksj,2002-1985}$. The proportion of tasks per industry in 2002 was calculated by merging occupational frequency from RAIS 2002 and proportion of tasks from CBO 2002. The proportion of tasks per industry in 1985 was calculated by merging occupational frequency from RAIS 1985 and proportion of tasks from CBO 1994. In the last case, the data available was not ideal due to the gap between 1985 and 1994, but CBO 1994 is the oldest one available. For a robustness check, we also calculated the percentage of tasks in a given industry, T_{kj} , for each year from 1988 to 2002. In these calculations we kept the proportion of tasks by occupation (p_{ks}) constant, according to the CBO 1994, and calculated the demand for tasks based on the number of workers in each occupation and industry. This allowed us to verify the gradual changes in demand for tasks caused by the differences in the occupational frequency (but not changes in occupations).

Lastly, with regards to the percentage of workers using computers in the labor market, we created a measure based on the resources used by professionals working in each occupation (CBO 2002). For occupations in which workers reported the use of computers in CBO 2002, we considered that all workers in these occupations used computers. Then, we calculated the percentage of workers using computers in a given combination of industry j and occupation s , by dividing the number of employees working in occupation s (that use computers or not) in industry j , by the total number of employees in industry j ,

called C_{sj} . For our robustness check, we also calculated the percentage of workers using computers in a given industry C_j , for each year from 1988 to 2002.

[TABLE 1 HERE]

[TABLE 2 HERE]

5. EMPIRICAL RESULTS

In this section we present the analysis of the effects of computer trade liberalization on the labor market. First, subsection 5.1 examines how the demand for different types of tasks changed due to the end of the Informatics Law in Brazil, taking into account changes in the educational level and women's share in the labor market. We also analyze whether or not our results on task demand were caused by the tariff liberalization in the Brazilian market between 1988 and 1994. Finally, subsection 5.2 analyzes whether the potential effects of computers were the same in different industrial sectors.

(a) Changes in Task Demand

We start the discussion about the effects of trade liberalization by presenting the change in demand for tasks in the Brazilian market (ΔT_k). Figure 1 illustrates the changes between 1985 and 2002. It shows that in 1985, the tasks most in demand were routine manual ones, representing almost 40% of the total share. As expected, the demand for these tasks fell sharply during this period and, in 2002 demand for these tasks represented only 23% of the market. Demand for routine cognitive tasks took the opposite trajectory, increasing from 25% in 1985 to 38% in 2002, probably at least partially a consequence of the overall trade liberalization, which shifted employment from skilled (non-routine) to unskilled (routine) intensive sectors (Gonzaga, Menezes-Filho and Terra, 2006).

With regard to non-routine tasks, the figure shows an increase from 17% to 22% in demand for interactive tasks and from 7% to 14% in demand for analytical tasks, both results as expected from the theoretical model. Also, there was a sharp decrease of manual tasks, from 11% in 1985 to only 2% in 2002. As non-routine manual tasks are the most basic ones, this evidence could also be explained as a

consequence of the rising educational level and experience of the Brazilian labor force, mainly in the groups with only primary and/or secondary education (see Table 6).

[FIGURE 1 HERE]

Now we verify whether these changes were really caused by the dissemination of computers after the end of non-tariff barriers. We argue that the shift toward computer usage raised demand for non-routine tasks (skilled workers) and reduced demand for routine tasks (low skilled workers) in a given industry-occupation. To verify this statement, we tested the following statistical model, using fixed effects on industry and occupation:

$$\Delta T_{ksj,1985-2002} = \alpha_j + \delta_s + \beta_k \cdot C_{sj,2002} + \varepsilon_{sj} \quad (1)$$

where $\Delta T_{ksj,1985-2002}$ represents the difference in the percentage of tasks k , per occupation s and industry j , between 1985 and 2002, and $C_{sj,2002}$ is the percentage of workers using computers in 2002 in occupation s and industry j .

The results presented in Table 3 show a positive relationship between computers and non-routine analytical tasks, and also a negative relationship between computers and routine manual tasks, between 1985 and 2002. Nonetheless, these results are not statistically significant for non-routine interactive, routine cognitive and non-routine manual tasks.

[TABLE 3 HERE]

Although the results are not significant for non-routine interactive and routine cognitive tasks, the general effect on non-routine tasks is positive and significant, and the general effect on routine tasks is negative and significant, as presented in columns NRTS and RTS in Table 3. These results confirm that the dissemination of computers in the Brazilian labor market increased demand for skilled workers, typically associated with non-routine tasks, and decreased demand for unskilled workers, typically associated with routine ones.

However, our results could be biased by other factors that could also have affected the labor market without being correlated to the dissemination of computers. Now we analyze whether our results change if we study the effects near the year of the event, and if we consider three other factors in our base model: the share of women in the labor market; the improvement in the educational level; and finally, the changes in import tariffs.

First, we analyze the sensitivity of our results when we estimate the same relation using just the few years around the end of the Informatics Law. Our benefit from this estimation is better isolation of the effects provided by the end of the barrier on demand for labor tasks from another shock that happened during the 90s and affected the labor market as well. On the other hand, we have the cost of losing information about changes in the tasks in each occupation, since such information comes from the CBO 2002. Thus, all the variation concerns the migration of workers between sectors.

To verify the robustness of our previous results, we ran a panel model with industry and year fixed effects of the percentage of tasks in the use of computers for each industry, as specified below:

$$T_{kj} = \alpha_j + \psi_t + \beta_k \cdot C_j + \varepsilon_j.$$

Since the end of the Informatics Law occurred in 1992, we estimated this model using three different samples: from 1989 to 1995, from 1988 to 1996 and from 1988 to 2002.

The results presented in Table 4 suggest the same behavior evidenced in our previous model (see Table 3), for all sample periods, with an increase in non-routine tasks and a decrease in routine ones. The magnitude is similar in both estimations, mainly for the first two sample periods (panels A and B).

The only difference comes from the source of changes in non-routine tasks. Previous results gave all the credit to an increase in the analytical tasks while the latter results evidence an increase in both analytical and interactive tasks. Such difference could be driven by the lack of variation in the type of tasks involved in each occupation, present in the latter specification.

[TABLE 4 HERE]

The second potential bias comes from the fact that the share of women in the in the Brazilian labor market has increased in recent decades (see Table 5) and proportionally women use computers more than men (67% against 46%). Thus, we can argue that the increasing demand for non-routine tasks was a consequence of the increasing proportion of women in the labor force, given the higher rates of women using computers and that computers complement non-routine tasks.

To consider this fact in our model we include a gender variable in equation (1). Here we want to verify if the use of computers caused the increased demand for non-routine tasks, or if it is an effect of the higher proportion of women in the labor market. The fixed effects (on industry and occupation) model is presented in Equation 2:

$$\Delta T_{ksj,1985-2002} = \alpha_j + \delta_s + \beta_{1k} \cdot C_{sj,2002} + \beta_{2k} * \Delta Prop_Fem_{sj,1985-2002} + \varepsilon_{sj} \quad (2)$$

where $\Delta Prop_Fem_{sj,1985-2002}$ is the difference in the percentage of women in the labor market between 2002 and 1985, $\Delta T_{ksj,1985-2002}$ and $C_{sj,2002}$ as described above.

[TABLE 5 HERE]

Table 6 shows that the results from equation (2) maintain the positive relationship between computers and non-routine tasks (NRTS), and the opposite effect between computers and routine tasks (RTS). The increasing proportion of women caused a significant increase in demand for routine tasks, of 0.460, mainly in cognitive activities. The test results for non-routine tasks were not significant.

[TABLE 6 HERE]

The positive relationship between the percentage of women and routine tasks reinforces the hypothesis that computers substitute routine tasks, since the increasing rate of women in the market caused the opposite effect, i.e., while computers decreased routine tasks, the higher proportion of women contributed to increase the demand for this kind of task.

Another variable we must consider in our model is educational level. During the period of our analysis, there was a positive trend in the educational level of the Brazilian workforce, mainly in the

group of workers with high school diplomas, which rose from 19% to 32%, as presented in Table 7. However, even considering this feature, the average level of education of the Brazilian labor force is still very low compared to developed countries. For example, in 1999, 16% of German workers had a university degree and 71% a high school diploma (Spitz-Oener, 2006). In the Brazilian case, 13% had a degree and only 32% had completed high school in 2002. We can also note that computers are more frequently used by employees with higher educational levels (Table 7).

[TABLE 7 HERE]

To verify the effect of workers' educational level on demand for tasks, we extended the model presented in Equation (1) by adding the educational level dummies (represented by D_Educ_e , leaving the none or primary incomplete category in the constant term) and its interaction with the computer use variable. Equation (3) presents the specification:

$$\Delta T_{ksj,1985-2002} = \alpha_j + \delta_s + \beta_{1k} \cdot C_{sj,2002} + \sum_{e=2}^4 \lambda_e D_Educ_{sje} + \sum_{e=2}^4 \phi_e D_Educ_{sje} \cdot C_{sj,2002} + \varepsilon_k \quad (3).$$

Table 8 shows that the results still hold if we consider education and the heterogeneous effect of computer dissemination. Note that the average effect is still aligned with our previous results. Also, from the parameter ϕ_e we conclude there is a heterogeneous effect related to the educational level. The effect is equal for those not completing primary school (ϕ_2 non significant for all regressions) with the technological liberalization reducing most routine tasks and increasing non-routine tasks. For those with high school diplomas, the effect is represented by the sum of β_1 and ϕ_3 . Notice that the effect on routine manual tasks is lower than the average effect, but there is still a reduction.

Finally, the greatest heterogeneous effect is on workers with higher level of education (university degree). All the estimated effects are smoothed when examining this group, and the sum of β_1 and ϕ_4 is closer to zero in all regressions that show a significant effect of the trade liberalization. To check whether the effect is still significant for the higher educated group, we performed a joint test with parameters β_1 and ϕ_4 ($\beta_1 + \phi_4 = 0$). The results indicate there is no effect on this group concerning routine tasks, which is

intuitive since highly educated workers are mostly allocated to non-routine tasks. Also, there is still an increase in demand for non-routine tasks for this group, but with a smaller magnitude.

The analysis of the changes in demand for tasks by each educational group provides evidence that the changes occurred in all educational groups and were not biased in favor of highly educated workers, as proposed in the SBTC hypotheses. More precisely, the groups most affected by the technological trade liberalization were people with at most incomplete primary school, primary school graduates and high school graduates.

[TABLE 8 HERE]

Finally, the last issue to be considered is the Brazilian tariff change. In section 2 we explained the Brazilian Market Reserve Policy and highlighted that the end of this policy in 1992 was part of an overall trade liberalization process in the Brazilian market. This trade liberalization was introduced in three steps, between 1988 and 1994 (Kume, Piani and Souza, 2003), resulting in a drastic change: between 1988 and 1995 the average import tariff fell from 42.6% to 13.4% (Gonzaga, Menezes-Filho and Terra, 2006).

As a consequence of this liberalization, employment shifted from skilled to unskilled intensive sectors (see Gonzaga, Menezes-Filho and Terra, 2006). We can interpret this employment shift as a change from sectors intensive in demand for non-routine tasks (usually associated with skilled jobs) to sectors intensive in demand for routine tasks (associated more commonly with unskilled jobs). Thus, we can argue that the trade liberalization changed the demand for tasks, increasing demand for routine tasks and decreasing demand for non-routine tasks and biasing our results. This could explain the increase in demand for routine cognitive tasks presented in Figure 1.

In order to verify the effect of the tariff change on demand for tasks, we tested the occupation fixed effects model in this section in an extended version in which we introduced the change in the average import tariff by sector between 1987 and 2002 as an explanatory variable:

$$\Delta T_{ksj,1985-2002} = \delta_s + \beta_{1k} \cdot C_{sj,2002} + \beta_{2k} \cdot \Delta TAR_{j,1987-2002} + \varepsilon_k \quad (4)$$

where $\Delta\text{TAR}_{j,1987-2002}$ is the difference between 1987 and 2002 of the average import tariff for each sector j . The other variables remain as described in section 5. We used the variation between 1987 and 2002 because of data availability.

[TABLE 9 HERE]

The regression analysis presented in Table 9 shows that the reduction of import tariffs had no effect on task demand, in contrast with the use of computers. In all cases the tariff change had no economically significant effect on demand for tasks. This is an important result because it allows us to distinguish the impact of computers and tariffs on the demand for tasks. The results confirm that the task change was caused by the rapid diffusion of computers in the market and we add evidence that the tariff liberalization process did not interfere with task demand in the Brazilian market. However, it is also important to highlight the limitations of our analysis, since the change in import tariffs is available only for 7 of the 25 industrial sectors previously analyzed in section 5.

(b) Effects on Industries

Lastly, we analyze whether the effects of computers were the same in different industrial sectors. Since computer technology can perform routine tasks, intensive routine-task industries should benefit more from the fall of computer prices, as long as the technology becomes cheaper than human capital. Thus, we expect that routine-task-intensive industries would have adopted computers in a higher proportion than other industries. We tested the following model:

$$C_{sj,2002} = \alpha + \beta \cdot \text{RTS}_{sj,1985} + \varepsilon \quad (5)$$

where $C_{sj,2002}$ is the percentage of workers using computers in 2002 in their occupation s and industry j , and $\text{RTS}_{sj,1985}$ is the percentage of routine tasks (cognitive and manual) in occupation s and industry j ($\text{T}_{\text{RTS}_{sj}}$) in 1985. We ran the model for 321 occupations in 25 distinct industries.

[TABLE 10 HERE]

The results, presented in Table 10, show that the use of computers in a given industry in 2002 was positively related to the intensity of routine tasks demanded in 1985. For each 1% of routine-task-intense index ($RTS_{sj,1985}$) in a given industry, the demand for computers in this industry in 2002 increased 0.60%.

Table 10 also presents the results of two additional tests. First, we weighted the regression by the added value from each industry in the Brazilian economy in 1985. We found that, although less intense, the relationship between the recent use of computers and the intensity of routine tasks demanded before the introduction of this technology. Secondly, we ran a panel data regression, controlling for fixed effects within an industry and occupation. The results were similar to those presented previously and reinforce our argument.

6. CONCLUSION

The end of non-tariff barriers for computer technology (by the repeal of the Informatics Law) produced a huge change in the demand for different skills in the Brazilian labor market. The dissemination of computers increased the demand for tasks complementary to it (non-routine ones) and reduced the demand for routine tasks by replacing them. The results are independent of the change in women's share of the labor market and from the increase in the educational level of workers, but we provide evidence that it affected mainly workers with low and medium levels of education. We also show that the changes in demand for tasks were not a consequence of a general change in import tariffs.

It is hard to over-emphasize the relevance of these results. Understanding this dynamic in the labor market helps to maximize gains from technology dissemination, thus improving potential productivity gains.

In terms of policy it is a very relevant instrument. It can orient strategies which subsidize and invest in developing labor market skills, training people for specific tasks as a complementary effort to computer dissemination.

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Table 1: Variable Description

Variable	Source	Description
Industry	RAIS	26 industries: Mining; Non metallic mineral products; Metallurgy; Mechanical and machinery; Electronics; Transport equipment; Wood and furniture manufacturing; Paper, publishing and graphics; Rubber, tobacco and leather; Chemicals; Textiles; Shoes; Food and beverages; Public services; Construction; Retail; Wholesale; Financial institutions; Professional and technical activities; Transport and communications; Accommodation services; Medical and dental activities; Education; Public administration; Agriculture.
Educational group	RAIS	None or primary incomplete (less than 9 years), primary complete (more than 9 years and less than 12 years), secondary complete (more than 12 years and less than university degree completed) and university degree (baccalaureate or higher).
Gender: proportion of women	RAIS	Number of women employed in industry j and occupation s / total employment in industry j and occupation s
Occupation	CBO	321 comparable occupations between CBO 1994 and 2002.
p_{ks}	Calculation based on CBO	Proportion of tasks k per occupation s = number of tasks k in occupation s / total number of tasks in occupation s
N	RAIS	Total number of workers at a given time
N_j	RAIS	Number of workers in industry j
N_s	RAIS	Number of workers in occupation s
N_{sj}	RAIS	Number of workers in occupation s per industry j
T_{ksj}	Calculation based on CBO and RAIS	Percentage of tasks k in a given industry j, due to each occupation s = $100 \times p_{ks} \times (N_{sj} / N_j)$
T_k	Calculation based on CBO and RAIS	Proportion of tasks k in the whole market at a given time = $\sum [p_{ks} \times (N_s)]$, for all occupations s and all industries j
T_{kj}	Calculation based on CBO and RAIS	Percentage of tasks k in a given industry j = $\sum T_{ksj}$, for all occupation s
C_s	CBO 2002	Dummy variable indicating whether computers are used (or not) in the occupation s.
C_{sj}	Calculation based on CBO and RAIS	Percentage of workers using computers in occupation s and industry j: = $100 \times (N_{sj} \times C_s) / N_j$
C_j	Calculation based on CBO and RAIS	Percentage of workers using computers in occupation s and industry j: = $\sum C_{sj}$, for all occupation s

Table 2: Examples of the correspondence between tasks in CBO and the classification proposed by Spitz-Oener (2006)

As proposed by Spitz-Oener (2006)	Correspondence in CBO
<i>NON-ROUTINE ANALYTIC</i>	
Researching	Researching, Investigating
Analyzing	Analyzing, Examining, Studying
Evaluating and Planning	Evaluating, Planning, Budgeting, Making diagnosis, Judging
<i>NON-ROUTINE INTERACTIVE</i>	
Negotiating	Negotiating, Practicing Law
Coordinating	Coordinating, Leading people
Teaching or training	Teaching, Training, Spreading knowledge, Instructing
Selling	Selling, Marketing
<i>ROUTINE COGNITIVE</i>	
Calculating	Calculating, Programming, Transforming
Bookkeeping	Bookkeeping, Recording
Measuring	Measuring, Verifying
<i>ROUTINE MANUAL</i>	
Operating or Controlling Machines	Operating, Distributing, Transporting
Equipping Machines	Equipping, Assembling
<i>NON-ROUTINE MANUAL</i>	
Repairing or Renovating	Repairing, Renovating
Serving or Accommodating	Serving, Accommodating, Cleaning.

Table 3: Effects of the use of computers on demand for tasks

	NA	NI	NRTS	RC	RM	RTS	NM
Use of Computers	0.478*** (0.005)	0.004 (0.915)	0.480*** (0.005)	-0.015 (0.868)	-0.465*** (0.008)	-0.481*** (0.003)	-0.002 (0.228)
R ²	0.649	0.16	0.526	0.329	0.56	0.500	0.332
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Robust regression, p-value in brackets. Change in proportion of tasks from CBO 1994 merged with RAIS 1985, and from CBO 2002 merged with RAIS 2002. Proportion of use of computers from CBO 2002 and RAIS 2002.

Note 1: *, **, *** Significance levels of 10%, 5% and 1% respectively. Constant suppressed.

Note 2: NA: Non-routine Analytical; NI: Non-routine Interactive; NRTS: Non-routine tasks overall; RC: Routine Cognitive; RM: Routine Manual; RTS: Routine tasks overall; NM: Non-routine Manual.

Number of observations: 8,025 (25 industries x 321 occupations)

Table 4: Robustness tests on the effects of the use of computers on demand for tasks

Panel A: From 1989 to 1995 (125 observations)

	NA	NI	NRTS	RC	RM	RTS	NM
Use of Computers	0.057** (0.034)	0.318*** (0.016)	0.420** (0.025)	0.064 (0.410)	-0.483** (0.050)	-0.419** (0.025)	0.044 (0.431)

R ²	0.744	0.746	0.674	0.845	0.749	0.674	0.519
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Panel B: From 1988 to 1996 (175 observations)							
	NA	NI	NRTS	RC	RM	RTS	NM
Use of Computers	0.056** (0.030)	0.306*** (0.017)	0.399** (0.029)	0.064 (0.380)	-0.463* (0.054)	-0.399** (0.029)	0.036 (0.521)
R ²	0.763	0.801	0.729	0.865	0.786	0.729	0.589
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Panel C: From 1988 to 2002 (375 observations)							
	NA	NI	NRTS	RC	RM	RTS	NM
Use of Computers	0.054** (0.022)	0.276*** (0.009)	0.294* (0.065)	0.078 (0.211)	-0.373* (0.074)	-0.294* (0.065)	-0.037 (0.529)
R ²	0.827	0.883	0.821	0.899	0.871	0.821	0.655
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Robust regression, p-value in brackets.

Note 1: *,**,*** Significance levels of 10%, 5% and 1% respectively. Constant suppressed.

Note 2: NA: Non-routine Analytical; NI: Non-routine Interactive; NRTS: Non-routine tasks overall; RC: Routine Cognitive; RM: Routine Manual; RTS: Routine tasks overall; NM: Non-routine Manual.

Table 5: Proportion of workers by gender in the Brazilian market

	% 1985	% 2002	% using computers in 2002
Female	33.5	40.6	67.1
Male	66.5	59.4	45.6
Total			54.3

Source: RAIS 1985 and 2002; CBO 2002.

Table 6: Changes in demand for different kinds of tasks caused by the spread of computers – by gender

	NA	NI	NRTS	RC	RM	RTS
Computers:	0.480*** (0.005)	0.008 (0.844)	0.485*** (0.004)	-0.000 (0.998)	-0.458** (0.012)	-0.458*** (0.010)
Δ Prop_Fem	0.043 (0.368)	0.075 (0.249)	0.109* (0.098)	0.315*** (0.004)	0.144 (0.196)	0.460*** (0.000)
R2	0.650	0.180	0.533	0.417	0.573	0.587
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000

Robust regression, p-value in brackets. Change in percentage of tasks from CBO 1994 merged with RAIS 1985, and from CBO 2002 merged with RAIS 2002. Proportion of use of computers from CBO 2002 and

RAIS 2002. Difference in percentage of women calculated from RAIS 1985 and 2002. Constant suppressed.

Note 1: *,**,*** Significance levels 10%, 5% and 1% respectively. Tests for non-routine manual tasks were not significant and were omitted from this table.

Note 2: NA: Non-routine Analytical; NI: Non-routine Interactive; NRTS: Non-routine tasks overall; RC: Routine Cognitive; RM: Routine Manual; RTS: Routine tasks overall; NM: Non-routine Manual.

Number of observations 8.025 (25 industries x 321 occupations)

Table 7: Proportion of workers by educational level

Educational level	% 1985	% 2002	% using computers in 2002
None or primary incomplete	51.44	29.79	27.64
Primary complete	19.13	25.36	46.18
Secondary complete	19.48	32.05	72.78
College degree or higher	9.95	12.80	86.15
Total			54.30

Source: RAIS 1985 and 2002; CBO 2002.

Table 8: Changes in demand for different kinds of tasks caused by the spread of computers and educational level

	NA	NI	NRTS	RC	RM	RTS
Computers	0.512*** (0.000)	0.048 (0.152)	0.548*** (0.000)	0.065 (0.197)	-0.517*** (0.000)	-0.452** (0.013)
Comput.x D_Educ ₂	-0.053 (0.818)	-0.026 (0.516)	-0.070 (0.741)	-0.090 (0.304)	0.104 (0.585)	0.014 (0.946)
Comput. x D_Educ ₃	-0.172 (0.406)	-0.059 (0.438)	-0.219 (0.279)	-0.208* (0.068)	0.388** (0.021)	0.180 (0.353)
Comput. x D_Educ ₄	-0.376** (0.027)	-0.011 (0.893)	-0.376** (0.015)	-0.008 (0.926)	0.515*** (0.000)	0.506*** (0.008)
$\beta_1 + \phi_4$	> 0 (0.006)	= 0 (0.893)	> 0 (0.009)	= 0 (0.498)	= 0 (0.926)	= 0 (0.442)

R ²	0.556	0.441	0.428	0.384	0.434	0.369
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000

Robust regression, p-value in brackets. Change in the percentage of tasks from CBO 1994 merged with RAIS 1985, and from CBO 2002 merged with RAIS 2002, by educational level. Percentage of computer usage from CBO 2002 and RAIS 2002. Constant suppressed.

Note 1: *, **, *** Significance levels 10%, 5% and 1% respectively. Tests for non-routine manual tasks were not significant and were omitted from this table.

Note 2: NA: Non-routine Analytical; NI: Non-routine Interactive; NRTS: Non-routine tasks overall; RC: Routine Cognitive; RM: Routine Manual; RTS: Routine tasks overall; NM: Non-routine Manual.

Number of observations: 32.100 (25 industries x 321 occupations x 4 educational groups)

Table 9: Effects of the use of computers and tariffs on demand for tasks

	NA	NI	NRTS	RC	RM	RTS
Use of Computers	0.757*** (0.000)	0.010 (0.276)	0.763*** (0.000)	0.007 (0.344)	-0.751*** (0.000)	-0.743*** (0.000)
ΔTariff	-0.001** (0.049)	0.000 (0.965)	-0.001 (0.162)	0.002 (0.547)	0.000 (0.517)	0.001 (0.367)
R ²	0.942	0.261	0.923	0.402	0.870	0.852
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000

Robust regression, p-value in brackets. Change in percentage of tasks from CBO 1994 merged with RAIS 1985, and from CBO 2002 merged with RAIS 2002. Percentage of computer usage from CBO 2002 and RAIS 2002. ΔTariff is the difference in the Brazilian import tariffs by sector between 1987 and 2002. Number of observations: 2,247 (7 industries x 321 occupations).

Note 1: *, **, *** Significance levels 10%, 5% and 1% respectively. Tests for non-routine manual tasks were not significant and were omitted from this table.

Note 2: NA: Non-routine Analytical; NI: Non-routine Interactive; NRTS: Non-routine tasks overall; RC: Routine Cognitive; RM: Routine Manual; RTS: Routine tasks overall; NM: Non-routine Manual.

Table 10: Computer use in 2002 according to the demand for routine tasks in 1985, by industry

	Use of computers in 2002	Use of computers in 2002 (weighted by the value added by each industry)	Use of computers in 2002 (Panel data with fixed effects for industry and occupation)
Proportion of routine tasks by industry in 1985	0.603*** (0.000)	0.260*** (0.000)	0.667*** (0.000)
Intercept	0.019 (0.496)	0.069*** (0.000)	0.018 (0.501)
R ²	0.519	0.213	0.639
Prob > F	0.000	0.000	0.000

Robust regression, p-value in brackets. Percentage of routine tasks calculated from CBO 1994 and RAIS de 1985. Percentage of use of computers from CBO 2002 and RAIS 2002. In the last column is present a Panel Data regression by Industry x Occupation, using robust and fixed effects.

Note: *, **, *** Significance levels 10%, 5% and 1% respectively.

Number of observations: 8,025 (25 industries x 321 occupations)