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# TECHNOLOGY, TRADE AND SKILLS IN BRAZIL:

# SOME EVIDENCE FROM MICRODATA

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# TECHNOLOGY, TRADE AND SKILLS IN BRAZIL: SOME EVIDENCE FROM MICRODATA

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***Abstract***

Brazil was characterised by a marked process of trade liberalisation in the '90s, resulting in a dramatic increase in the volumes of exports and imports since the year 2000. Over the same period, the relative demand for skilled labour has increased substantially. To investigate whether these two simultaneous phenomena are linked is the purpose of this paper.

More in particular, this study focuses on the possible impact of domestic technology, capital complementarity and trade openness on the relative demand for skilled labour in Brazilian manufacturing firms, using a unique panel database (resulting from merging three different statistical sources) of Brazilian manufacturing firms over the period 1997-2005.

Descriptive statistics show that the increase in the relative demand for skilled labour was mainly driven by the within-industry variation, supporting the hypothesis that technology (and in particular technological transfer from richer countries) may have played a role in determining the skill-upgrading of Brazilian manufacturing firms.

The econometric results further support this hypothesis. Indeed, the estimations show that domestic technology and capital formation are complements for the skilled workers and that imported capital goods clearly act as a skill-enhancing component of trade.

**Keywords:** *Skill Biased Technological Change, Capital-skills Complementarity; Skill-Enhancing Trade; Brazil.*

**JEL classification:** *O33, O54, F16*

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## 1. Introduction

This paper deals with the relationship between trade openness – with particular reference to technology transfer - and the relative demand for skilled labour in Brazilian manufacturing firms.

Brazil was characterised by a marked process of trade liberalisation in the '90s, resulting in a dramatic increase in the volumes of exports and imports since year 2000. An important aspect of this process might be its effect on labour demand, and, more specifically, its impact on the relative demand for skilled labour. Indeed, over the same period, the relative demand for skilled labour has increased substantially, affecting the equilibrium employment level in presence of a significant increase in the supply of skilled labour. To investigate whether these two simultaneous phenomena are linked is the purpose of this paper.

The theoretical literature offers different predictions regarding the impact of trade liberalisation on labour demand in a middle income developing country (DC). On the one hand, according to the central tenet of traditional trade theory - expressed in the Heckscher-Ohlin theorem and in its Stolper-Samuelson corollary (HOSS hereafter) - we may expect a relative decrease in the demand for skilled labour since openness should benefit a country's relatively abundant factor, which in the case of Brazil is unskilled labour. On the other hand, if the HOSS assumption of homogeneous production functions between countries (that is absence of technological differentials) is relaxed, international openness may facilitate technology transfer from richer countries to middle income DCs. In this context, trade may act as a stimulus for technological upgrading and shift the production function towards more skill-intensive technologies; in addition, if the dominant technological paradigm is skill-biased, trade may induce and foster both domestic and imported skill-biased technological change (SBTC).

This paper contributes to the debate, presenting new empirical evidence. We estimate the impact of domestic technologies and trade openness on the labour demand for the skilled and unskilled workers, using a unique panel database (obtained by merging three different statistical sources) of Brazilian manufacturing firms over the period 1997-2005.

The remainder of this paper is organised as follows: the next section reviews the theoretical and empirical literature on the interaction between trade openness, technological transfer and the relative demand for skilled labour, mainly focusing on DCs. Section 3 is devoted to a closer investigation of recent Brazilian economic trends. Section 4 introduces and describes the data. In Section 5 we explain our empirical strategy and present and discuss our econometric results. Finally, the last section briefly proposes some concluding remarks.

## 2. Literature

After more than two decades of an ongoing debate focusing on the competing explanations for the increase in inequality in developed countries[2], a recent stream of literature on the determinants of inequality in low or medium income countries (LMICs) is now emerging. The shift in focus from the former to the latter originated in the discussion of the role played by trade: simply put, if inequality is driven by a specialisation effect (countries with skill abundance will reallocate their production towards it) one should observe at the same time an increase in inequality in the advanced countries (abundant in skilled labour) and a reduction of inequality in LMICs, abundant in unskilled labour.

However, this argument is proved invalid by the macroeconomic data (Acemoglu, 2003), showing an increase of within-country income inequality in both the developed and the DCs. This outcome can be ascribed to the various theoretical problems affecting the hypotheses of the Hecksher-Ohlin and Stolper-Samuelson (HOSS) theorems (see Leontief, 1953; Trefler, 1995; Davis *et al*., 1996 for an overall discussion). On the one hand, the core of the matter is that neither consumers' preferences nor production functions can be assumed to be homogeneous[3]. Indeed, richer countries and LMICs are endowed with very different technological capabilities (Abramowitz; 1986; Lall, 2004), and trade may act as a pervasive channel of technological transfer.

From a microeconomic point of view, it is worthwhile to notice that - in a developing country - firms' reactions to trade openness are usually very heterogeneous. Some firms are simply crowded-out by international competition and are eliminated from the market, others adapt their production processes to the new competitive environment - opting for technical/operational efficiency through outsourcing and imports of embodied technology - whilst others rely on innovation and accumulation of domestic technological capabilities as their main competitive strategies. This process is well documented in De Negri and Turchi (2007) for Brazil and Argentina.

In this context, skill upgrading can be related to technology diffusion, either through the complementarities with domestic R&D and capital formation, or through the learning-by-doing/technology adoption effect (Arrow, 1962; Nelson and Phelps, 1966) connected with the implementation of imported technologies, initially

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2 See Acemoglu (2002) for a discussion of the literature with focus on the US, where the debate started. The two competing explanations of inequality in developed countries are that focusing on the role of trade (see Wood, 1994; Freeman, 1995) and that indicating new technologies as the main drivers of a skill-bias, in turn increasing wage dispersion and inequality. Berman, Bound, and Griliches (1994) were the first to point out the skill-biased nature of current ICT technologies (see also Katz and Autor, 1999 and Machin and Van Reenen, 1998 for an extension to the OECD countries; Caroli and Van Reenen, 2001, Aguirregabiria and Alonso-Borrego, 2001 and Piva, Santarelli and Vivarelli 2005 for analyses on single European countries),

3 The literature that extended HOSS, weakening its basic assumptions, is very extensive. For instance, Dornbush (1980) extended the model to multiple goods; Wood (1994) added multiple skills, Davis (1995 and 1996) introduced the concept of "cones of diversification".

introduced in richer countries.

As far as the first perspective is concerned, Berman and Machin (2000 and 2004), found strong evidence for an increased demand for skills in middle-income DCs in the '80s and related it to the diffusion of skill-biased technological change from the richer developed countries to the middle income ones. In this framework, a country as Brazil – characterised by a certain degree of indigenous innovation efforts – might well exhibit a positive correlation between domestic technologies and skill upgrading. By the same token, domestic capital is also a vehicle of "embodied technological change" (see Salter, 1960 and Solow, 1960) that can be skill biased in nature; hence, capital/ skills complementarity (see Griliches, 1969) may also have an important role in the skill upgrading of the Brazilian labour force.

As far as the second perspective is concerned, Robbins and Gindling (1999) and Robbins (2003) have put forward the so-called 'skill-enhancing trade (SET)' hypothesis, pointing out the potential skill biased effect of in-flowing technologies resulting from trade liberalisation. The idea is that trade liberalisation accelerates the flows of imported embodied technologies in capital goods (especially machineries): the resulting technology transfer would induce an adaptation to the modern skill-intensive technologies currently used in the most advanced countries, involving a substantial increase in the demand for skilled labour within the recipient developing countries (for more extensive analyses, see Lee and Vivarelli, 2004 and 2006; Almeida and Fernandes, 2008). Obviously, this technology-related effect may more than counterbalance the HOSS predictions[4].

As far as the empirical literature is concerned, there is a growing body of studies associating trade and a rise in inequality in DCs. For instance, Hanson and Harrison (1999) reported that trade liberalisation was related to a rise in inequality in Mexico. Manacorda, Sanchez-Paramo and Schady (2006) found that the relative demand for skilled workers rose in Argentine, Mexico, Chile and Colombia, and found mixed results in Brazil.

Following this line of research, Meschi and Vivarelli (2009), using a sample of 65 developing countries over the period 1980-99, found that trade with high income countries made the income distribution more unequal in middle income DCs, through both imports and exports[5]. By the same token, Meschi, Taymaz and Vivarelli (2008) showed that in Turkey during the period 1980-2001 SET was an important factor in explaining the rise of the skilled labour cost share[6].

4 Interestingly enough, if the technological effect dominates the HOSS one in the DCs, inequality rises both in the developed and in the devoloping countries, that is what has been observed for the last two decades (see Feenstra and Hanson 1996 and 1997).

5 Similarly, Vivarelli (2004), using data for 45 DCs in the '90s, found that – at least in the early stages of the opening process – imports may imply an increase in the domestic income inequality of the recipient developing country.

6 The authors show that the increase in the skilled labour cost share was mainly driven by the 'within' effect (increase in the demand for skills within the industrial sectors, due to new technologies) rather than by the 'between' effect (skilled labour relocation between sectors, as a possible outcome of the HOSS specialisation).

As far as Brazil is concerned, previous literature on the subject is scarce. According to Gonzaga, Menezes-Filho and Terra (2006), wage differentials between skilled and unskilled workers decreased during the 1988-1995 period, during which trade liberalisation in Brazil started to be implemented. The authors provided some evidence that HOSS mechanisms may have had some role in this process[7].

However, Menezes-Filho and Giovanetti (2006) analyzed the evolution of skilled employment in Brazil over the subsequent 1990-1998 period. First, they detected – partially in contrast with Gonzaga, Menezes-Filho and Terra (2006) – an increase in the skilled labour share; this increase was entirely due to the 'within-industry' effect, while the 'between-industries' effect was negative, in line with the HOSS predictions. Then, inspired by Machin and Van Reenen (1998), they ran an econometric equation to test the trade induced skill bias hypothesis. Their variable was input tariffs, the hypothesis being that the reduction of input tariffs should have induced the importation of technologically-advanced inputs, in turn raising the demand for skilled labour. Consistently with their hypothesis, they found that tariffs were negatively related to skill-upgrading, and that this effect was stronger in those sectors that use inputs more complementary to skills.

Relatively to Menezes-Filho and Giovanetti (2006), our paper has three distinctive characteristics. Firstly, while that work analysed the most intense period of trade openness, we cover the aftermath of this severe reshaping of industrial sectors in Brazil and part of the export boom triggered in 2002 (our data cover the period 1997-2005). The second distinctive characteristic is that our dataset, which consists of firm-level microdata, comes from the merging of several databases[8]. Finally, our data allow us to use a direct and precise indicator of the SET effect (see below).

## 3. Data

The data used in this paper are the result of the Instituto de Pesquisa Econômica Aplicada's (IPEA, Institute for Applied Economics Research - Brasilia) efforts to merge several different databases:[9]

a) PIA: PIA is the Brazilian annual industrial survey on manufacturing firms conducted by IBGE (Brazilian Institute for Geography and Statistics), available for the years 1996-2005, and including all firms with more than 30 employees and a random sample of the firms having between 10 and 30

7 For instance, their decomposition analysis of the increase in the skilled labour share in total employment showed that in Brazil there was a negative 'between-industries' effect and this is consistent with the HOSS predictions.

8 Instead, Menezes-Filho and Giovanetti (2006) used a micro-aggregated database, in which each observational unit is a weighted average from three firms. For further details, see Menezes-Filho, Muendler and Ramey (2003).

9 The 'key' for merging all the databases is a firm's identification number called CNPJ, which is used for tax purposes.

employees;

b) RAIS: RAIS is conducted by the Brazilian Ministry of Labour and Employment; it is an employee-level database, including major information for all formal jobs; it is available for the time span 1993-2005;
c) SECEX: it is provided by the Ministry of Development, Industry and Foreign Trade and includes data on import and export transactions, covering the period 1997-2005.

Through a detailed identification of relevant firms marked by a census indicator, we were able to merge these three databases, covering the years from 1997 to 2005. The sample thus is limited to manufacturing and it is a *balanced* panel of 11,219 firms covered by all surveys.[10] All data refer to industries with CNAEs[11] from 10 to 37 and to firms which employ 30 or more employees the year before the survey.[12]

In our empirical specification, we used workers with secondary education and beyond to proxy skilled labour. We made this choice – instead of using occupational proxies, such as the share of non-production workers – for three reasons. First, Brazil has very good information regarding schooling of the labour force; in particular about 30% of the labour force has completed high school. Second - as stated by Gonzaga, Menezes-Filho and Terra (2006) - neither occupation nor educational measures provide exact measures of skill intensities; for instance, in countries like Brazil, the occupational proxy is problematic since there are a lot of non-production tasks that do not require particular skills. Finally, Menezes-Filho and Giovanetti (2006) ran their estimates with both measures and did not perceive qualitative differences in their results.

Consistently with the "skill-enhancing trade" hypothesis discussed in the previous section, we used the imports classified as capital goods as a proxy for SET.[13]

From the industrial surveys we extracted the variables indicating sales, capital (calculated with the perpetual inventory method) and the expenditures on royalties.[14]

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[10] The sole available proxy for domestic technological effort was the royalties variable. Missing values in this variable, in the capital measure and in the skilled and unskilled labour reporting limited the final sample size to 10,810 and 10,785 firms, respectively for the unskilled and skilled labour equation. The balanced nature of the final selected panel is over-representing Brazilian medium and large firms at the expenses of the SMEs. However, our aim is not to construct a representative sample, but rather to investigate firms likely affected by globalization and technological change, to see whether these phenomena have an impact upon the demand for skills. In this respect, Brazilian SMEs do not play a crucial role.

[11] *Classificação Nacional de Atividade Econômica*, the National Classification of Economic Activities, the Brazilian equivalent of SIC, the Standard Industrial Classification.

[12] The selection of firms with 30 employees or above eliminates the randomised portion of the PIA database.

[13] This classification was made possible due to a conversion from the harmonised system (HS) product classification to a fourfold classification: capital goods, non-durable consumption goods, durable consumption goods and intermediate goods, provided by IBGE. For further details, see Appendix A.

[14] Brazil is the Latin American country with the best score in terms of total expenditure on R&D per employee; thus it is natural to include a proxy for domestic innovative effort. Unfortunately,

From RAIS we extracted the employment (number of employees) and wage variables.[15]

All variables are in constant prices with base year 1997; for the import of capital goods, we transformed USD prices into BRR using the average exchange rate of the year. In the Appendix the reader can find further details on the construction of the database.

In the following table we report the descriptive statistics. We also split the period into three sub-periods: 1997-1998 *i.e.* before the Brazilian financial crisis; 1999-2001 *i.e.* from Brazil's to Argentina's crisis; the rest of the period: 2002-2005.

**Table 1: Descriptive Statistics.**

| Variable | Mean 1997-2005 | Mean 1997-1998 | Mean 1999-2001 | Mean 2002-2005 | Unit |
|---|---|---|---|---|---|
| Skilled Employment | 111.21 | 80.72 | 97.76 | 136.65 | NE[a] |
| Unskilled Employment | 136.65 | 152.67 | 134.39 | 130.01 | NE[a] |
| Skilled Wage | 5.55 | 6.74 | 5.87 | 4.73 | MLMW[b] |
| Unskilled Wage | 3.61 | 4.06 | 3.75 | 3.27 | MLMW[b] |
| Capital | 34.9 | 16.5 | 26.6 | 50.1 | 1997 million BR |
| SETI | 711623.4 | 462010.5 | 687770.4 | 854319.7 | 1997 BR |
| Royalties | 707520.6 | 113401.3 | 466625.1 | 1183650 | 1997 BR |
| Sales | 52.9 | 26.5 | 42.4 | 74.1 | 1997 million BR |

Source: PIA-RAIS-SECEX. The mean are calculated at firm level.
[a] Number of employees
[b] Multiples of Legal Minimum Wage, see footnote 15 for an example

## 4. Facts and figures about Brazilian industry

Brazil's recent economic history is largely comparable to that of other Latin American countries: after industrialization driven by import substitution policies through the use of high tariffs and active state intervention, the country underwent a step-by-step

PIA does not provide information on R&D and we have to rely on indirect proxies, such as expenditures on royalties, considered as a signal of a direct involvement in technological activities.

[15] In the available official statistics, wages are expressed as multiples of the minimum wage, used as the measurement unit. To make it clear: if the legal minimum wage is 3 and the wage of the worker is 24, then the reported wage is 8.

liberalisation policy. The first phase of liberalisation was conducted during 1988-1994, when there was a drastic reduction in tariffs. By the end of 1995, the average tariff was below 14%, compared to over 42% in 1988 (Kume, 2002). Since 1995, there have been no major changes in tariffs, except for the elimination of specific tariff peaks and tariff reduction rounds conducted by the WTO (the end of the Multifiber Agreement is an example).

Indeed, in Brazil the opening of the economy induced a radical restructuring process in industry. However, the opening of the economy did not generate the highly specialisation trade pattern predicted by traditional comparative advantage models, like HOSS.  While it is true that certain sectors lost significantly in the first instance, it is also true that others gained formerly unseen comparative dynamic advantages. Consider, for example, the successful case of the metal/mechanical complex, most notably the aircraft and automotive segments.

Although the sectoral profile was not dramatically altered, in many firms the opening of the economy implied important changes in their competitive strategies and in their ownership. To adapt to the new international competitive environment, most Brazilian firms privileged short-term technical/operational efficiency, through deverticalization, outsourcing and the introduction of process innovations via the importation of machineries and intermediate inputs (Castro and Ávila, 2004). In contrast, the majority of firms failed to invest in long-term competitive strategies, such as product innovation and R&D investment.

Nevertheless, there is an elite set of Brazilian industrial firms able to compete via innovation, product differentiation and emerging brands. These firms have a strong presence on foreign markets and receive premium prices for their products. According to De Negri, Salerno and Castro (2005), approximately 1,200 firms that chose to adopt this strategy retain a fourth of total industrial revenues, despite representing no more than 2% of the total number of enterprises. This reorientation of resources towards export and more productive firms is consistent with the theoretical prediction of Melitz (2003).

Turning our attention to the macroeconomic scenario, since 1994 Brazilian industrial output has grown by 40%, according to IBGE. However, aggregate industrial performance is closely linked to the macroeconomic environment and has revealed a stop-and-go pattern[16].

[16] The industrial output rose by 7.6% in 1994; unfortunately, this performance was not repeated in either 1995 (+1.83%) or 1996 (+1.73%), mainly due to the Mexican crisis. A partial recovery occurred in 1997, when industrial output rose by 3.88%, but the financial crisis that culminated in the dismissal of the foreign-exchange anchor affected the Brazilian economy in the following years; thus, industrial output dropped by 2.03% in 1998 and 0.66% in 1999. Then in 2000, as a result of a new macroeconomic context (fiscal discipline, a floating exchange rate and inflationary goals), industrial output increased by 6.64%. This performance was subsequently interrupted in 2001 by both domestic (energy crisis) and international events (terrorist attacks, recession in the United States and Argentina), the result being that output increased by a mere 1.57%. In 2002, financial speculation and the restrictive monetary policy of the second semester held output growth at 2.7%. The monetary policy restrictions continued throughout the first semester of the following year, so industrial output remained

Most striking in this period has been the notable growth of exports and imports, with a dramatic upward trend starting from 2002. Exports totalled US$ 46.5 billion in 1995 and closed at US$ 60.3 billion in 2002. By 2005, this value had nearly doubled, reaching US$ 118.3 billion. In 2008, exports totalled almost US$ 200 billion. Indeed, exports have accounted for a great part of the growth in Brazil's industrial output.

Part of this increase is explained by a rise in the prices of commodities Brazil is exporting, but one must consider that the *quantum* exported has also increased significantly. Moreover, the composition of the export list reflects the heterogeneity of the Brazilian productive sector. For example, among the segments that most grew in volume exported, products such as cell phones, aircraft and automobiles are found alongside traditional commodities such as coffee, sugar and iron ore.

On the other hand, imports, which closed in 2002 at US$ 47.2 billion (slightly under the US$ 50 billion registered in 1995), reached US$ 73.5 billion in 2005. In 2008, they more than doubled, reaching US$ 173 billion. Brazilian exports and imports are depicted in Figure 1.

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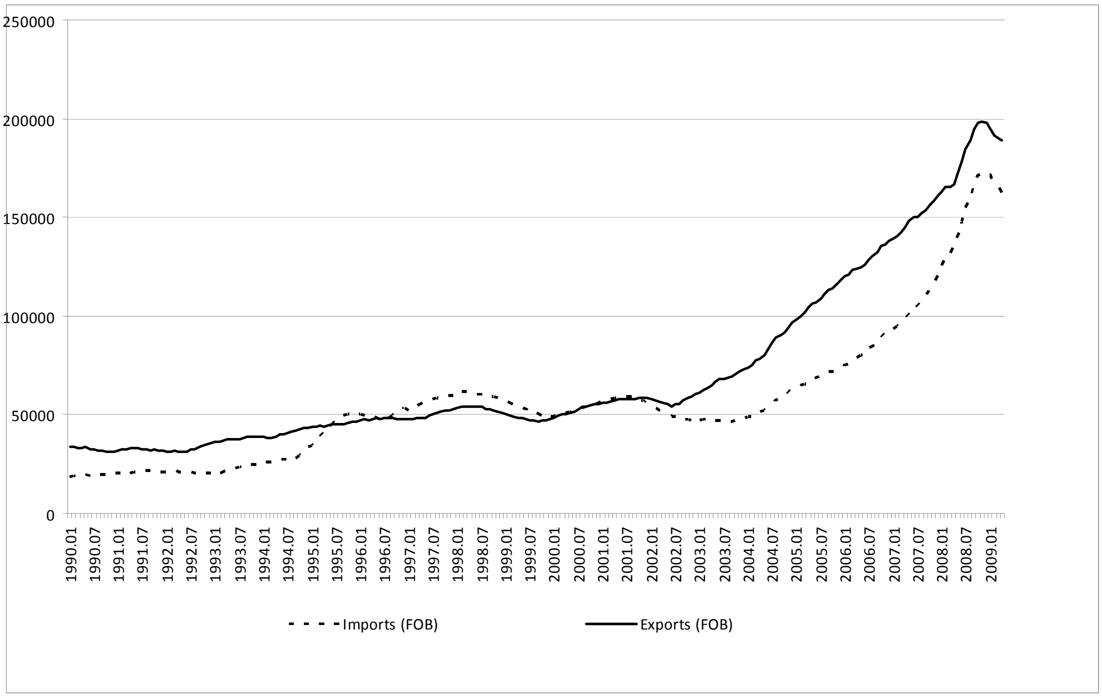
practically unaltered (+0.1%). The opposite occurred in 2004, when the monetary policy restrictions were lifted and the international scenario turned quite favourable, thereby permitting the strong recovery of industrial growth (+8.4%). This growth trend, though somewhat weakened and not as sectorally homogeneous as in 2004, was maintained in 2005, when industrial output climbed to 3.1%. In fact, industrial production kept rising in Brazil in 2006 and 2007, and this growth pattern was interrupted only in the second semester of 2008 due to the world financial crisis.

**Figure 1. Brazilian Foreign trade, 1990-2008 (In US$ millions)**

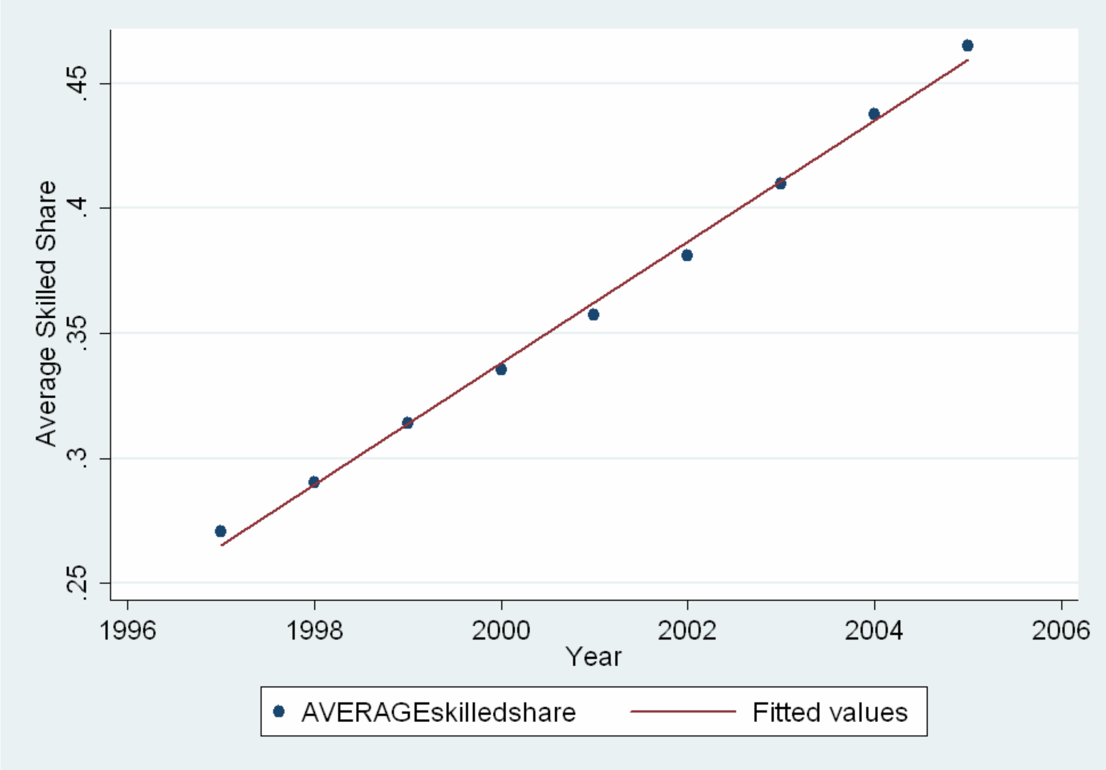



Source: SECEX

Turning our attention to the main focus of this study, i.e. the demand for skilled and unskilled labour in Brazilian industry, we can use our data – concerning 10,785 manufacturing firms - to show the trend in the share of skilled workers (defined as employees with secondary education or more) in total employment (Figure 2).

Figure 2 clearly suggests an increasing trend; indeed, at the end of the period considered the share of skilled workers is close to half the firms' workforce.

**Figure 2. Average Skilled Share of Employment.**




Source: RAIS

An initial attempt to determine the main forces behind skill upgrading can be made by splitting the revealed increase in the demand for skilled labour into its between- and within-industry components. In fact, the aggregate increase in the demand for skills may be driven by (a) employment reallocation across industries (for a number of reasons, such as trade shift, structural change, changing tastes, or changes in economic policy) or by (b) skill upgrading within industries (mainly due to technological change). Therefore, we decompose the aggregate change in the demand for skilled labour ($\Delta SL$) in the $i$ = 1,…, N industries (with N going from sector 10 to sector 37) according to the following formula:

$$\Delta SL = \sum_{i=1}^{N} \Delta SL_i \overline{P_i} + \sum_{i=1}^{N} \Delta P_i \overline{SL_i} \qquad \textbf{(1)}$$

The first term is the within-industry component of skill upgrading (weighted by $\overline{P_i}$, the relative size of industry $i$ – i.e. industry $i$'s share in terms of total employment – where the bar is a time mean). The second term measures the contribution of between-industry shifts, i.e. how much bigger or smaller an industry is becoming over time (weighted by time-averaged skill demand).

**Table 2: Decomposition of the Share of Skilled Employment[17].**

| | Within | Between | Overall | Within/Overall |
|---|---|---|---|---|
| 1997-2005 | 0.23 | -0.01 | 0.22 | 1.04 |
| 1997-1998 | 0.03 | 0.00 | 0.03 | 1.00 |
| 1999-2001 | 0.06 | -0.01 | 0.05 | 1.20 |
| 2002-2005 | 0.08 | 0.00 | 0.08 | 1.00 |

Source: PIA-RAIS-SECEX

Table 2 shows that the increase in the demand for skilled labour was driven by the within-industry variation, which basically represents the overall change. This interesting preliminary evidence supports the hypothesis that technology (and in particular technological transfer from richer countries) may have played a crucial role in determining the skill-upgrading in Brazilian manufacturing.

Other preliminary evidence is obtained by considering the density functions of the skilled employment and the skilled share, alternatively in the sub-sample of those firms that do not import capital goods and in the sub-sample of those ones that do import capital goods (Figures 3 and 4). Since in both cases we can see that the distribution is more right skewed for the sub-sample of the technological adopters, we again find some empirical evidence in favour of the SET-hypothesis.

[17] We remind that the sum of rows 2, 3 and 4 does not sum up to row 1, since we are not considering the financial crises years of 1998 and 2001.

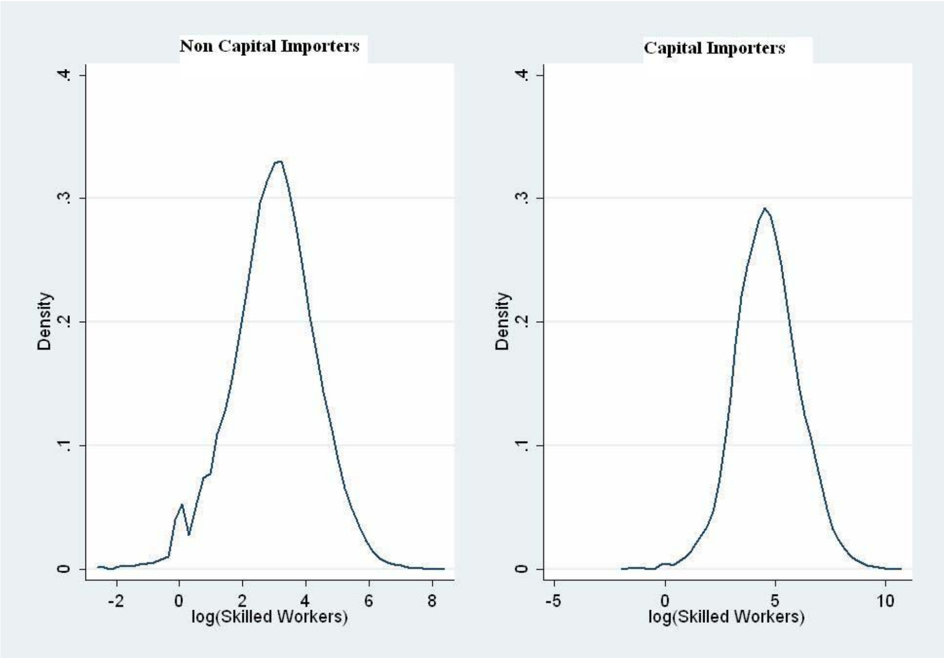



**Figure 3: Density of (Log) Skilled employment for the non importers of capital goods (left) and for the capital-importing firms (right).**

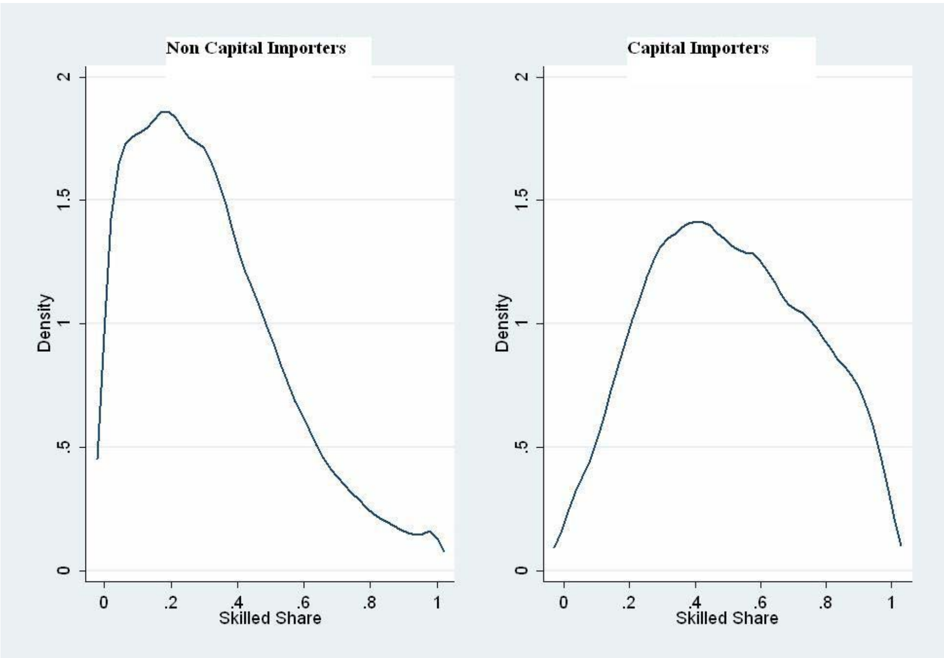



**Figure 4: Density of the Skilled Share for the non importers of capital goods (left) and for the capital-importing firms (right).**

## 5. Econometric Analysis

In order to test the determinants of labour demand and its composition, we run two dynamic estimates of the demand for skilled and for unskilled labour. Starting from the former:

$$\log(S_{it}) = \alpha_0 + \rho \log(S_{it-1}) + \alpha_1 \log(Y_{it}) + \alpha_2 \log(K_{it}) + \alpha_3 \log(R \,\&\, D_{it}) + \alpha_4 \log(SET_{it}) + \alpha_5 \log(ws_{it}) + \mathbf{T}'\gamma + \mathbf{S}'\delta + \varepsilon_i + u_{it} \quad \textbf{(2)}$$

where S is the number of workers with at least secondary education, Y is the output (sales), K is the capital stock (see the Appendix for definitions), R&D is a variable for domestic innovation (here proxied by royalties expenditures), SET is the importation of capital goods, *ws* the wage of skilled workers. The lagged dependent variable captures the very likely event that cost of adjustments occurs (see Nickell, 1984; Van Reenen, 1997), making the demand for labour sticky and persistent [18]. The terms preceding the errors are time and industry dummies (at two digit CNAE)[19].

The corresponding equation for unskilled labour is:

$$\log(U_{it}) = \beta_0 + \psi \log(U_{it-1}) + \beta_1 \log(Y_{it}) + \beta_2 \log(K_{it}) + \beta_3 \log(R \,\&\, D_{it}) + \beta_4 \log(SET_{it}) + \beta_5 \log(wu_{it}) + \mathbf{T}'\gamma + \mathbf{S}'\delta + \nu_i + e_{it} \quad \textbf{(3)}$$

where U stands for the unskilled, those workers with primary education or less and *wu* is the unskilled workers' wage.

The above dynamic equations (2) and (3) cannot be consistently estimated by OLS or WG estimators (Nickell, 1981) and we have to rely on panel estimators such as the GMM-DIF (Arellano and Bond, 1991) and its improved version GMM-SYS (Blundell and Bond, 1998), which takes into account both the difference equations and the

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[18] The coefficient for the log of S from a regression on its lag and a constant turns out to be 0.96. Indeed, labour demand asks for a dynamic specification and in fact the first applications of the dynamic econometric methodologies used the demand for labour as a testing benchmark (see Arellano and Bond, 1991).

[19] Since we do not want the log transformation to affect our sample size (think, for example, at SET which displays a mass of zero values) we keep the log variable to be zero when the level variable is also zero and we calculate the log only for positive values. Since there is no single case in which the original variable is equal to one this is not inducing any noise.

original equations in levels. The latter estimator is more efficient in the presence of short time series (such as that used in this study, 9 years) and very persistent dependent variables such as the employment indicators used in this empirical analysis; thus, GMM-SYS was chosen as our estimation technique. We used robust standard errors (and apply Windmeyer correction).

Since the wage terms are obviously endogenous, we instrumented them. However, we suspect that all the other regressors (except the dummies) are endogenous, being part of an extended production function and turning out to be highly persistent as well. Hence, instrumentation was applied to all the variables. Since we do not have to face small sample properties, we use all lags.

In order to detect potential supply effect, apart for controlling for the endogeneity of wage, we added time dummies, detecting the trend effect of the raise in the share of labour force having at least secondary education.

We expect capital skill complementarity to hold, especially for skilled labour, and we expect both SET and domestic generation of innovation to play a skill-biased role.

Results are shown in the following Tables 3 and 4[20].

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[20] As far as the diagnostic tests are concerned, in the following tables the AR(1) and AR(2) tests always confirm the validity of the adopted specifications.

In contrast, the Sargan tests always turn out to be significant, hence rejecting the null of adequate instruments. Indeed, the Sargan test of overidentifying restrictions verifies the overall validity of the GMM instruments where the null hypothesis suggests that the instruments are uncorrelated to some set of residuals. In our regressions, the null hypothesis is always rejected; however we are not overly worried by the failure of the test for four reasons. First, the Sargan test “should not be relied upon too faithfully, as it is prone to weakness” (Roodman, 2006, p. 12). Second, in their Monte Carlo experiments Blundell and Bond (2000) “observe some tendency for this test statistic to reject a valid null hypothesis too often in these experiments and this tendency is greater at higher values of the autoregressive parameter” (Blundell and Bond, 2000, p. 329). Third, the very large number of observations makes the occurrence of a significant Sargan more likely. Finally, the Wald test on the overall validity of the regression is always reassuring.

**Table 3. Unskilled Workers.**

Dependent Variable: Log of Unskilled Workers
GMM-SYS with robust standard errors (in brackets)
*significant at 10%, **at 5%, *** at 1%

| | |
|---|---|
| Log(Unskilled Workers) | 0.7990 |
| (First Lag) | [0.0142]*** |
| Log(Unkilled Wage) | -0.2911 |
| | [0.0473]*** |
| Log(Sales) | 0.2377 |
| | [0.0087]*** |
| Log(Capital) | -0.0970 |
| | [0.0121]*** |
| Log(Royalties) | -0.0006 |
| | [0.0008] |
| Log(SET) | 0.0010 |
| | [0.0005]* |
| Constant | -0.7774 |
| | [0.1498]*** |
| Year Dummies | *Yes* |
| Industry Dummies | *Yes* |
| Firms | 10810 |
| N observation (nT) | 80951 |
| AR(1) | -16.04 |
| p-value | 0.000 |
| AR(2) | 1.72 |
| p-value | 0.085 |
| Wald Test | 37926.00 |
| p-value | 0.000 |

**Table 4. Skilled Workers.**

Dependent Variable: Log of Skilled Workers
Methodology: GMM-SYS with robust standard errors (in brackets)
*significant at 10%, **at 5%, *** at 1%

| | |
|---|---|
| Log(Skilled Workers) | 0.6729 |
| (First Lag) | [0.0111]*** |
| Log(Skilled Wage) | -0.6538 |
| | [0.0294]*** |
| Log(Sales) | 0.2569 |
| | [0.0095]*** |
| Log(Capital) | 0.1019 |
| | [0.0120]*** |
| Log(Royalties) | 0.0019 |
| | [0.0008]** |
| Log(SET) | 0.0038 |
| | [0.0006]*** |
| Constant | -2.6376 |
| | [0.1892]*** |
| Year Dummies | *Yes* |
| Industry Dummies | *Yes* |
| Firms | 10785 |
| N observation (nT) | 79619 |
| AR(1) | -20.61 |
| p-value | 0.000 |
| AR(2) | -0.09 |
| p-value | 0.926 |
| Wald Test | 59444.31 |
| p-value | 0.000 |

Not surprisingly, Tables 3 and 4 clearly show that the demands for both skilled and unskilled labour are strongly path dependent, positively affected by output expansion and negatively affected by the relevant wage. Hence, the obtained estimates support the adopted dynamic specification of a standard demand for labour, split by skills.

As far as capital formation is concerned, results clearly show that capital is a complement to skilled workers, since the corresponding regressor is positive and significant only in Table 4, while negative and significant in Table 3. This is a strong evidence in favour of the capital/skills complementarity hypothesis.

Turning the attention to domestic technology (proxied by royalties), it is a positive driver of the upskilling trend (the correspondent coefficient is positive and significant in the skilled labour equation, but not significant in the unskilled labour one). This evidence points out the skilled biased nature of Brazilian domestic technologies, supporting the thesis that SBTC is spreading from high to middle income countries (see Section 2).

Finally, results concerning the key variable SET support our hypothesis. The imported capital goods act as a skill-enhancing component of trade: although positive in both the equations, the SET coefficient is highly significant only in the skilled labour equation, where it exhibits a magnitude that is almost four times larger than the one estimated in the unskilled labour equation.

## 6. Concluding Remarks

This study has investigated the impact of trade openness and technology transfer on the relative demand for skilled labour in Brazilian manufacturing firms, using a unique panel database of almost 11,000 Brazilian manufacturing firms over the period 1997-2005.

Results show that the increase in the relative demand for skilled labour registered in that period was mainly driven by within-industry variation, supporting the hypothesis that technology (and in particular technological transfer from richer countries) may have played a role in determining the skill-upgrading of Brazilian manufacturing firms.

The econometric results further support this hypothesis. Indeed, the estimations show that capital stock and domestic technology are complements of skilled workers. Moreover, the imported capital goods clearly act as a skill-enhancing component of trade. Hence, our results support the view that capital/skills complementarity, domestic skill biased technological change and skill-enhancing trade all play an important role in shaping the Brazilian manufacturing workforce.

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# Appendix

**The Sample and the variables**

We chose to build a large balanced panel of 11,219 manufacturing firms observed for nine years: this is the largest panel obtainable by merging the PIA, RAIS and SECEX original databases. After the cleaning of unreliable observations and obvious outliers, we ended up with 10,785 firms for which we have information on skilled employment and 10,810 for which we have information on unskilled employment.
We deflated expenditure variables using the Consumer Price Index (IPCA, from IBGE), with base year 1997. Since import data are provided in USD, we transformed them in BRR using the average exchange rate for the year of reference.
We used SECEX to construct a SET variable, capturing imported capital embodying technology. IBGE makes available a classification of products into four categories, according to the harmonised system (HS) code of reference for foreign trade. These four macro categories are: capital goods, non-durable consumption goods, durable consumption goods and intermediate goods. This classification incurred into some small changes in 2002 and it is not possible to find a one to one mapping from the old to the new categories. However, the non-classified import transactions are less than 5% of the total, thus we simply used the updated taxonomy, leaving aside the unclassifiable imports.
Since SECEX is a registry data, we can legitimately assume that missing value for imports are actually zeros. Given our use of log scale data, the log transformation of zero values would have dropped a significant portion of the sample; thus, we constructed log(SET) as zero if capital good import was zero and we applied the log transformation only to positive values (the absence of values equal to one makes this exercise meaningful).
Regarding PIA, we used a capital measure obtained from IBGE using the perpetual inventory methodology applied on investment data.
From PIA we also took total sales and the expenditure on royalties (in fact, in the PIA questionnaire there is specific question in Section C5 about the expenditure on royalties and technical assistance; see IBGE, 2004).
With regard to employment, we used a firm level database, which is extracted from RAIS, provided by the Ministry of Labour and Employment. We considered as skilled the workers with secondary or tertiary education. Thus, the unskilled workers ended up to be those with primary education or the dropouts. Wages are at firm level for the two categories and are expressed as multiples of the minimum wage.