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ABSTRACT

The Role of "Skill Enhancing Trade" in Brazil: Some Evidence from Microdata*

Brazil was characterised by a marked process of trade liberalisation in the 1990s, 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 impact of trade openness and technology transfer 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 capital is a complement of the skilled workers and that imported capital goods clearly act as a skill-enhancing component of trade. Hence, our results support the view that embodied technological change through the importation of capital goods has involved a clear skill-biased impact in Brazilian manufacturing.

JEL Classification: O33, O54, F16

Keywords: skill-enhancing trade, skill-bias, panel data, Brazil

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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, leading to a larger wage-gap between skilled and unskilled workers. 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 channel 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 skill-biased technological change (SBTC).

This paper contributes to the debate, presenting new empirical evidence. We estimate the impact of trade openness on labour demand by 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. Theoretical Background and Related Literature

After more than two decades of competing explanations for the increase in inequality in developed countries[2], there is now a developing stream of literature on the

[2] See Acemoglu (2002) for a discussion of the literature with focus on the US, where the

determinants of inequality in low or medium income countries (LMICs). 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 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), while trade and FDI act as pervasive channels of technological transfer.

On the other hand, we should remember that HOSS theory is a long-run model, and so its empirical predictions are likely to be irrelevant for describing some medium-run dynamics, where there is an entire set of HOSS hypotheses that fail. For instance, one cannot assume perfect factor mobility within the country or even among industries[4] and so educated workers are likely to be paid more than what is expected in a general equilibrium steady state[5]. Finally, technology matters: the opening-up of the economy is pushing a market selection and can represent a strong competitive pressure to adopt new techniques of production.

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

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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".

4 Labour Market Rigidities are important in Latin America, as documented by Heckman and Pages (2000).

5 This is also consistent with empirical evidence on developed countries; see Eckstein and Nagypal (2004) for the US.

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 innovation processes, or through the learning-by-doing/technology adoption effect (Arrow, 1962; Nelson and Phelps, 1966) connected with the implementation of imported technologies, initially introduced in richer countries.

On this last issue, Robbins (2003) has 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 machineries, intermediate inputs, components and even final goods that can act as benchmarks for domestic production and can be subjected to reverse engineering. The technology transfer from the developed to the developing countries would induce an adaptation to the modern skill-intensive technologies currently used in the most advanced countries, resulting in a substantial increase in the demand for skilled labour within the developing countries (for a more extensive analysis, see Lee and Vivarelli, 2004 and 2006). These technology-related effects increase the domestic demand for skilled workers and can more than counterbalance the HOSS predictions.

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.

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 absorption of skill-biased technological change (SBTC) imported by richer developed countries. 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 worsened the income distribution in middle income DCs through both imports and exports. 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].

As far as Brazil is concerned, results are mixed. 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 was implemented. The authors provided some evidence that HOSS mechanisms may have had some role in this process[7].

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[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).

[7] For instance, their decomposition analysis of the increase in the skilled labour share in total

Menezes-Filho and Giovanetti (2006) directly tested the SET hypothesis in Brazil, over the 1990-1998 period. First, they found that - as in Gonzaga, Menezes-Filho and Terra (2006) - the increase in the skilled labour share was entirely due to the 'within' effect, while the 'between' 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 SET hypothesis. Their SET 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 Menezes-Filho and Giovanetti (2006) 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 in firm-level microdata, comes from the merging of several databases[8]. Finally, our data allow us to use more direct and precise indicators 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) effort 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 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.

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employment showed that in Brazil there was a negative 'between' 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.

We merged these three databases at firm level, covering the years from 1997 to 2005. The sample thus is limited to manufacturing and it is a *balanced* panel of 10,778 firms.[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 econometric model, 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.

As a proxy for the imported capital embodying new technologies (the SET hypothesis), we used the imports classified as capital goods[13].

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

From RAIS we extracted the employment and wage variables[15].

All variables are in constant prices with base year 1997; whenever necessary, we transformed USD prices into BRR using the average exchange rate of the year. In Appendix A 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 1997-1998, i.e. before the financial crisis, 1999-2001, from Brazil's to Argentina's crisis, and the post-peso collapse, 2002-2005.

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[10] The sole available proxy for indigenous technological effort was the royalties variable. Missing values in this variable and in the capital measure limited the final sample size to 10,778 firms.

[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. PIA does not provide information on R&D and we have to rely on indirect proxies, such as expenditures on royalties.

[15] In the official statistics, wages are expressed as multiples of the minimum wage, used as the measurement unit.

Table 1: Descriptive Statistics.

Variable	Mean 1997-2005	Mean 1997-1998	Mean 1999-2001	Mean 2002-2005
Skilled Employment	111.21	80.72	97.76	136.65
Unskilled Employment	136.65	152.67	134.39	130.01
Skilled Wage	5.55	6.74	5.87	4.73
Unskilled Wage	3.61	4.06	3.75	3.27
Capital	3.49E+007	1.65E+007	2.66E+007	5.01E+007
SETI	711623.4	462010.5	687770.4	854319.7
Royalties	707520.6	113401.3	466625.1	1183650
Sales	5.29E+007	2.65E+007	4.24E+007	7.41E+007
Value Added	4.48E+007	2.58E+007	4.06E+007	6.81E+007

Source: PIA-RAIS-SECEX

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 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 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). However, 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.

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].

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,

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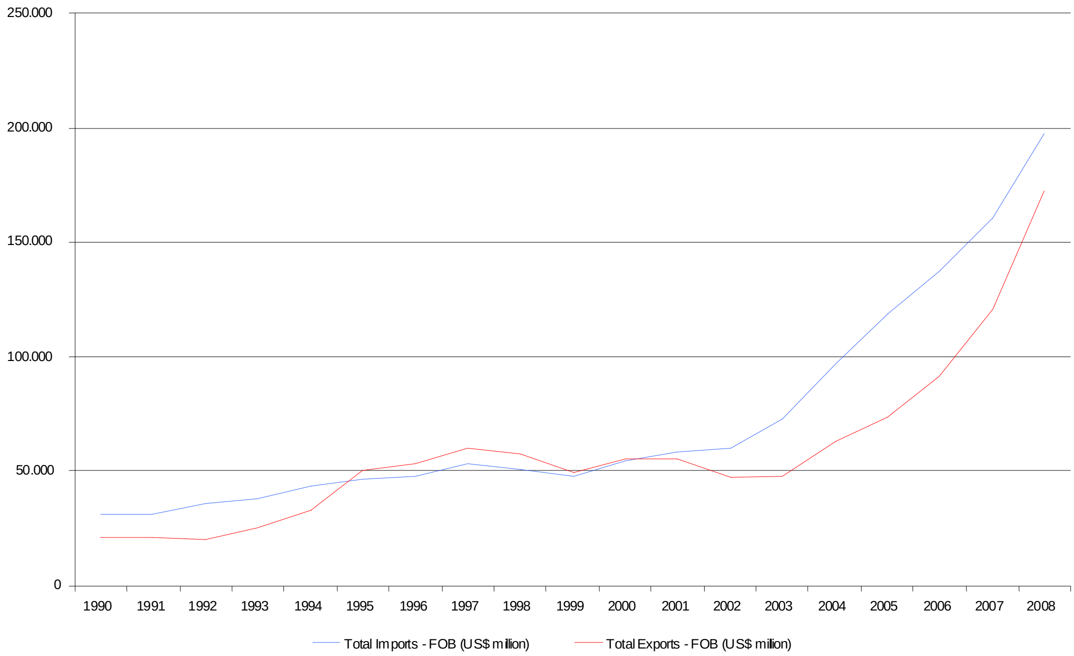
16 The industrial output rose by 7.6% in 1994; unfortunately, this performance was not repeated in either 1995 (+1.83%) or 1996 (+1.73%), mainly due to the Mexican crisis. A partial recovery occurred in 1997, when industrial output rose by 3.88%, but the financial crisis that culminated in the dismissal 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 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.

they more than doubled, reaching US$ 173 billion. Brazilian exports and imports are depicted in Figure 1.

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



Source: SECEX

Turning our attention to the main focus of this study, that is the demand for skilled and unskilled labour in Brazilian industry, we can use our data to show the trend in the share of skilled workers in total employment (Figure 2).

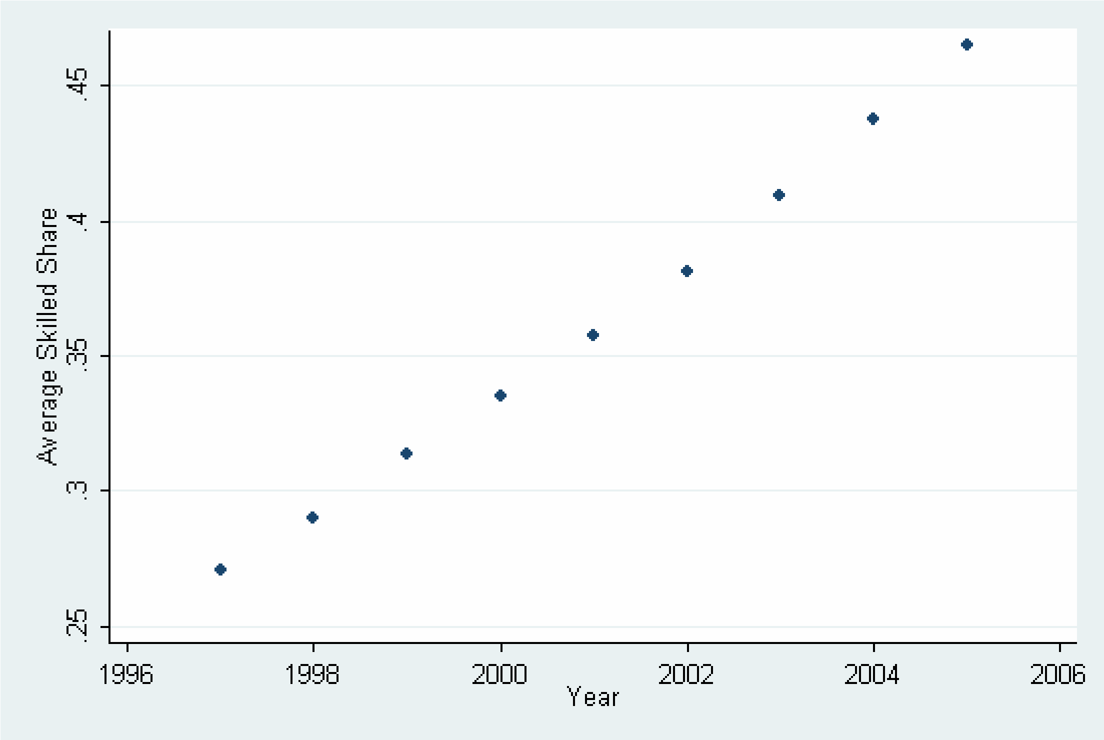


Figure 2. Average Skilled Share of Employment

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.

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 (ΔSL) 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 manufacturing 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).

The results of this decomposition (at two-digit CNAE) are shown in Table 2.

Table 2: Decomposition of the Share of Skilled Employment.

	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 of Brazilian manufacturing.

Other preliminary evidence is obtained by considering the distribution of skilled employment and the skilled share alternatively in the overall sample and in the sub-sample of firms who import capital goods (re-labelled as technological adopters) (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.

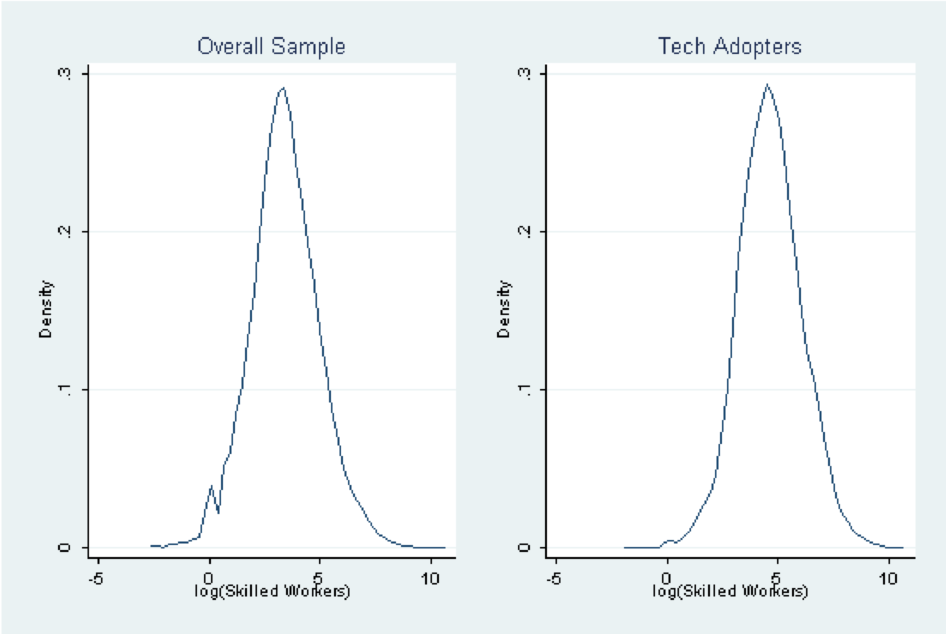


Figure 3: Density of (Log) Skilled employment for the overall sample and for the capital-importing firms (technological adopters).

Source: RAIS and SECEX.

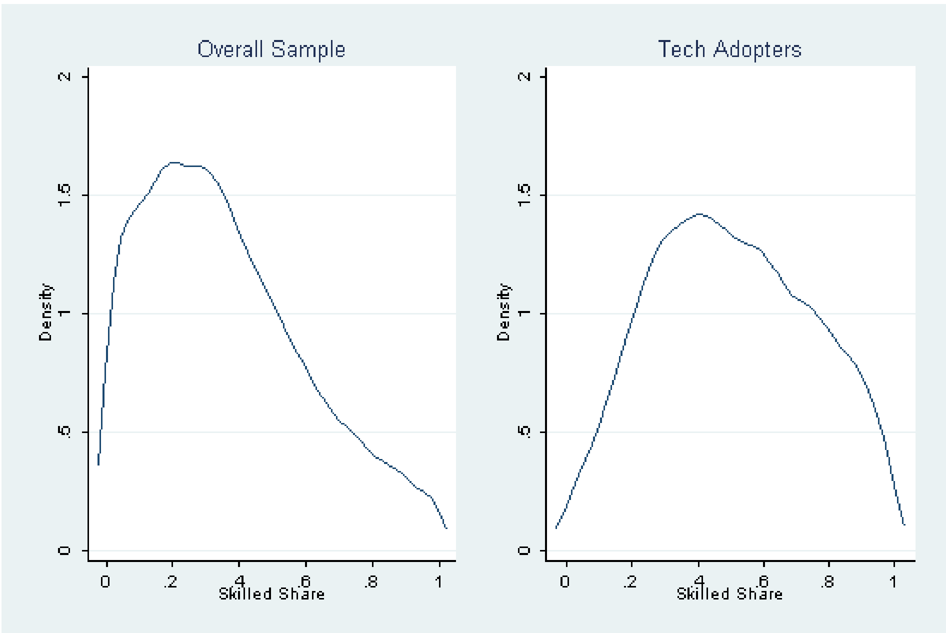


Figure 4: Density of the Skilled Share for the overall sample and for the capital-importing firms (technological adopters).

Source: RAIS and SECEX.

5. Econometric Analysis

In order to test the determinants of labour demand and its composition, we chose to estimate the demand for skilled and for unskilled labour. The reason for running two distinct equations is that this allows us to capture possible differences in the relevant relationships, rather than only focusing on the relative effects (for instance, capital skill complementarity may be more obvious for skilled labour than for unskilled). However, in Appendix B, the estimate in terms of the skilled share of labour cost is also reported.

$$\log(S_{it}) = \alpha_0 + \rho\log(S_{it-1}) + \alpha_1\log(Y_{it}) + \alpha_2\log(K_{it}) + \alpha_3\log(R\&D_{it}) + \alpha_4\log(SET_{it}) + \alpha_5\log(ws_{it}) + \alpha_6\log(wu_{it}) + \varepsilon_i + u_{it} \qquad \textbf{(2)}$$

where S is the number of workers with at least secondary education, Y is the output (we alternatively used either production or sales), K is capital (see Appendix A for definitions), R&D is a variable for domestic innovation (here proxied by royalties), SET is the importation of capital goods, *ws* the wage of skilled workers, *wu* that of unskilled workers and the closing expression is an error component term. 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 [17].

The corresponding equation for unskilled labour is:

$$\log(U_{it}) = \beta_0 + \psi\log(U_{it-1}) + \beta_1\log(Y_{it}) + \beta_2\log(K_{it}) + \beta_3\log(R\&D_{it}) + \beta_4\log(SET_{it}) + \beta_5\log(ws_{it}) + \beta_6\log(wu_{it}) + \nu_i + e_{it} \qquad \textbf{(3)}$$

where U stands for the unskilled, those workers with primary education or less.

Next we applied a first difference transformation to get rid of the unobserved firms' heterogeneity, obtaining the following two equations:

$$\Delta\log(S_{it}) = \psi\Delta\log(S_{it-1}) + \beta_1\Delta\log(Y_{it}) + \beta_2\Delta\log(K_{it}) + \beta_3\Delta\log(R\&D_{it}) + \beta_4\Delta\log(SET_{it}) + \beta_5\Delta\log(ws_{it}) + \beta_6\Delta\log(wu_{it}) + \mathbf{T}'\gamma + \mathbf{S}'\delta + \Delta u_{it} \qquad \textbf{(4)}$$

[17] In fact, the coefficient for the lag of S from a regression on its lag and a constant turns out to be 0.96

$$\Delta\log(U_{it}) = \psi\Delta\log(U_{it-1}) + \beta_1\Delta\log(Y_{it}) + \beta_2\Delta\log(K_{it}) + \beta_3\Delta\log(R\,\&\,D_{it}) + \beta_4\Delta\log(SET_{it}) + \alpha_5\Delta\log(ws_{it}) + \alpha_6\Delta\log(wu_{it}) + \mathbf{T}'\lambda + \mathbf{S}'\kappa + \Delta e_{it} \quad \textbf{(5)}$$

The terms preceding the errors are time and industry dummies (at two digit CNAE).

The above dynamic equations (3) and (4) 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 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.

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. However, in order to preserve efficiency, we restricted the number of moment conditions to two lags.

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[18].

[18] 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 three 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.
Method: GMM-SYS with robust standard errors; Instruments: up to third lag. Number of Instruments:179. Standard errors in brackets: *significant at 10%, **at 5%, *** at 1%

	(1)	(2)
Log(Unskilled Workers)	0.827	0.826
(First Lag)	[0.017]***	[0.017]***
Log(Skilled Wage)	-0.155	-0.152
	[0.033]***	[0.033]***
Log(Unkilled Wage)	-0.395	-0.394
	[0.062]***	[0.062]***
Log(Sales)	0.152	
	[0.011]***	
Log(Value Added)		0.162
		[0.012]***
Log(Capital)	0.011	0.005
	[0.012]	[0.012]
Log(Royalties)	-0.001	-0.001
	[0.002]	[0.002]
Log(SET)	-0.001	-0.000
	[0.003]	[0.000]
Constant	-0.972	-1.027
	[0.194]***	[0.198]***
Year Dummies	*Yes*	*Yes*
Industry Dummies	*Yes*	*Yes*
Firms	10788	10788
AR(1)	-16.92	-16.91
p-value	0.00	0.00
AR(2)	0.39	0.4
p-value	0.69	0.69
Wald Test	37591.19	37394.58
p-value	0.00	0.00

Table 4. Skilled Workers.

Dependent Variable: Log of Skilled Workers.
Method: GMM-SYS with robust standard errors. Instruments: up to third lag. Number of Instruments:179. Standard errors in brackets: *significant at 10%, **at 5%, *** at 1%

	(1)	(2)
Log(Skilled Workers)	0.701	0.690
(First Lag)	[0.014]***	[0.014]***
Log(Skilled Wage)	-0.561	-0.582
	[0.036]***	[0.036]***
Log(Unskilled Wage)	0.192	0.158
	[0.055]***	[0.055]***
Log(Sales)	0.241	
	[0.011]***	
Log(Value Added)		0.276
		[0.013]***
Log(Capital)	0.035	0.025
	[0.012]***	[0.012]**
Log(Royalties)	0.001	-0.001
	[0.002]	[0.002]
Log(SET)	0.010	0.013
	[0.003]***	[0.003]***
Constant	-2.489	-2.551
	[0.168]***	[0.170]***
Year Dummies	*Yes*	*Yes*
Industry Dummies	*Yes*	*Yes*
Firms	10776	10776
AR(1)	-21.8	-22.03
p-value	0.00	0.00
AR(2)	-0.74	0.7
p-value	0.46	0.48
Wald Test	82525.1	81188.69
p-value	0.00	0.00

Tables 3 and 4 clearly show that the demand for both skilled and unskilled labour are path dependent and positively affected by output expansion (measured either with sales or production). While these results are not surprising, it is worthwhile noticing that the output elasticity of skilled labour is greater than that for the unskilled component of the labour force. This can be seen as evidence of a structural trend in favour of the skilled workers.

As far as the link between the production factors 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. This is an evidence in favour of the capital/skill complementarity hypothesis (see Griliches, 1969).

Turning our attention to the main focus of analysis, domestic technologies (proxied by royalties) turn out to be not significant; however, this result has to be taken cautiously, given the limitations of our chosen proxy.

Finally, results concerning our key variable SET support our main interpretative hypothesis. The imported capital goods clearly act as a skill-enhancing component of trade: indeed, SET is positive and highly significant in the skilled labour equation, while it turns out to be not significant (and negative) in the unskilled workers equation.

Together with what emerges from the estimate of the relative demand for labour (see Table A1 in the Appendix), our results support the view that technological transfer through the import of capital goods has had a clear skill-biased impact in Brazilian manufacturing.

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 10,778 Brazilian manufacturing firms over the period 1997-2005.

Preliminary 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 domestic capital is a complement of skilled workers and that imported capital goods clearly act as a skill-enhancing component of trade. Hence, our results support the view that technological transfer through the importation of capital goods has had a skill-biased impact in Brazilian manufacturing.

References

Abramovitz, M., (1986): “Catching-up, Forging Ahead and Falling Behind”, *Journal of Economic History*, Vol. 46, pp.385-406

Acemoglu, D. (2002) “Technical Change, Inequality and the Labor Market”, *Journal of Economic Literature*, Vol. 40, pp. 7-22

Acemoglu, D. (2003) “Patterns of Skill Premia” *Review of Economic Studies*, Vol. 70, pp. 199-230.

Aguirregabiria, V., and C. Alonso-Borrego (2001) “Employment Occupational Structure, Technological Capital and Reorganisation of Production”, *Labour Economics*, Vol. 8, pp. 43-73.

Arellano, M. and Bond, S. (1991) “Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations”, *Review of Economic Studies*, Vol. 58, pp. 277-297.

Arrow, K. (1962) “The Economic Implications of Learning by Doing”, *Review of Economic Studies*, Vol. 29, pp. 155-173.

Berman, E., J. Bound, and Z. Griliches (1994) “Changes in the Demand for Skilled Labor within U.S. Manufacturing Industries: Evidence from the Annual Survey of Manufacturing”, *Quarterly Journal of Economics*, Vol. 109, pp.367-397.

Berman, E. and Machin, S. (2000) “Skill-Biased Technology Transfer Around the World” *Oxford Review of Economic Policy*, Vol. 16, pp. 12-22.

Berman, E. and Machin, S. (2004) Globalization, Skill-Biased Technological Change and Labour Demand. In Lee, E. and Vivarelli, M. (2004) (Eds), *Understanding Globalization, Employment y Poverty Reduction*, New York: Palgrave Macmillan, pp. 39-66.

Blundell, R. and Bond, S. (1998) “Initial Conditions and Moment Restrictions in Dynamic Panel Data models”, *Journal of Econometrics*, Vol. 87, pp. 115-143.

Blundell, R. and Bond, S. (2000) “GMM Estimation with Persistent Panel Data: an Application to Production Function”, *Econometric Reviews*, Vol. 19, pp. 321-340.

Caroli, E. and Van Reenen, J. (2001): “Skill Biased Organizational Change? Evidence from a Panel of British and French Establishments”, *Quarterly Journal of Economics*, Vol. 116, pp. 1449-1492.

Castro, A. B. and Ávila, J. (2004) “Uma Política Industrial e Tecnológica Voltada para o Potencial das Empresas.” *Presented at the 16th Fórum Nacional*, Rio de Janeiro, 2004.

Davis, D. R. (1995) “Intra-Industry Trade: A Heckscher-Ohlin-Ricardo Approach” *Journal of International Economics*, November 1995.

Davis, D. R. (1996) “Trade Liberalization and Income Distribution” *NBER working paper* w5693

Davis, Donald R., Weinstein, David E., Bradford, Scott C., and Shimpo, Kazushige. (1996) “The Heckscher-Ohlin-Vanek Model of Trade: Why Does It Fail? When Does It Work?” *National Bureau of Economic Research, Working Paper* No. 5625.

De Negri, J. and Turchi, L. (eds). (2007). *Technological Innovation in Brazilian and Argentine Firms*. Brasília: IPEA.

De Negri, J. A., Salerno, M. and Castro, A. B. (2005) “Inovações, Padrões

Tecnológicos e Desempenho das Firmas Industriais Brasileiras.” In De Negri, J. A. and Salerno, M. S. *Inovações, Padrões Tecnológicos e Desempenho das Firmas Industriais Brasileiras*. Brasília, IPEA, 2005.

Dornbush, (1980) *Open Macroeconomics* New York: Basic Books.

Eckstein, Z. and E. Nagypal (2004) “The Evolution of U.S. Earnings Inequality: 1961-2002”. *Federal Reserve Bank of Minneapolis Quarterly Review*. Vol. 28, pp. 10- 29

Freeman, R. (1995) “Are Your Wages Set in Beijing?” *Journal of Economic Perspectives,* Vol. 9, pp. 15-32

Gonzaga, Menezes-Filho and Terra (2006). “Trade Liberalization and Evolution of Skill Earnings Differentials in Brazil”, *Journal of International Economics*, Vol. 68, pp 345-67.

Griliches, Z. (1969) “Capital-skill Complementarity”, *Review of Economics and Statistics*, Vol. 51, pp. 465-468.

Hanson, G., and Harrison, A. (1999) “Trade Liberalization and Wage Inequality in Mexico” *Industrial and Labor Relations Review*, Vol. 52, pp. 271-288.

Heckman, J. and Pages, C. (2000) “The Cost of Job Security Regulation: Evidence from Latin American Labour Market”, *NBER Working Paper* 7773

IBGE, (2004) “*Pesquisa Industrial 2004*”, Rio de Janeiro, Vol, 23 (1)

Katz, L. F. and D. H. Autor (1999) “Changes in the Wage Structure and earning Inequality”, Handbook of Labor Economics, chap. 3, pp. 1463-1555

Kume, H. (2002): “A política brasileira de importação no período 1987-99: Descrição e Avaliação” May, mimeo.

Lall, S. (2004): “The Employment Impact of Globalization in Developing Countries”, in Lee, E. and Vivarelli, M. (2004) (eds) “*Understanding Globalization, Employment and Poverty Reduction*”, Palgrave Macmillan, New York, pp. 73-101.

Lee, E. and Vivarelli, M. (2004) (Eds.). *Understanding Globalization, Employment and Poverty Reduction*. New York: Palgrave Macmillan.

Lee, E. and Vivarelli, M. (2006) “The Social Impact of Globalization in the Developing Countries, *International Labour Review*, Vol. 145, pp. 167-184.

Leotief, W. (1953) “Domestic Production and Foreign Trade: The American capital position Re-Examined” *Proceeding of the American Philosophical Society*, Vol. 97, 332-349

Machin, S. and Van Reenen, J. (1998) “Technology and Changes in Skill Structure: Evidence from Seven OECD Countries,” *Quarterly Journal of Economics*, Vol. 113, pp. 1215–1244.

Manacorda, M., Sanchez-Paramo, C. Schady, N. (2006): “Changes in Returns to Education in Latin America: The Role of Demand and Supply of Skills.” *World Bank*, mimeo.

Menezes-Filho, N. and Giovanetti, B. (2006) “Trade Liberalization and Demand for Skills in Brazil”. *IBMEC Working Paper* 9.

Menezes-Filho, N. A., Mundler, M., Ramey, G. (2003) “Trade liberalization and worker displacement from Brazilian manufacturing, 1990-1998 – Request for data match and tabulations”. *UCSD*, mimeo.

Meschi, E. and M. Vivarelli (2009) “Trade and Income Inequality in Developing Countries.” *World Development*, Vol. 37, pp. 287-302.

Meschi, E., E. Taymaz and M. Vivarelli (2008) “Trade Openness and the Demand for

Skills: Evidence from Turkish Microdata” *IZA Discussion Papers 3887*
Nelson, R. and Phelps, E. (1966): “Investment in Humans, Technological Diffusion, and Economic Growth”, *American Economic Review*, Vol. 56, pp. 69-75.
Nickell, S. (1981) “Biases in Dynamic Models with Fixed Effects”. *Econometrica*, Vol. 49, pp. 1417-1426.
Nickell, S. (1984) “An Investigation of the Determinants of Manufacturing Employment in the United Kingdom” *Review of Economic Studies,* Vol. 51, pp. 529-57
Piva, M., E. Santarelli, and M. Vivarelli (2005), “The Skill Bias Effect of Technological and Organisational Change: Evidence and Policy Implications”, *Research Policy*, Vol. 34, pp.141-157.
Robbins, D. (2003) “The Impact of Trade Liberalization upon Inequality in Developing Countries - A Review of Theory and Evidence”, *ILO Working Paper*, n.13, International Labour Organization (ILO), Geneva.
Roodman, D. (2006) “How to do xtabond2: An introduction to “Difference” and “System” GMM in Stata”, *CGD working paper* n. 103, Center for Global Development (CGD), Washington DC.
Trefler, D. (1995) “International Factor Prices Differences: Leontief Was Right!” *Journal of Political Economy*, 101, 961-987
Van Reenen, J. (1997) “Employment and Technological Innovation: Evidence From UK Manufacturing Firms” *Journal of Labor Economics*, Vol. 15, pp. 255-284.
Wood, A. (1994) “*North-South Trade, Employment, and Inequality: Changing Fortunes in a Skill-driven World*”, Clarendon Press, Oxford.

Appendixes

APPENDIX A. 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 PIA-RAIS-SECEX. The panel got reduced to

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. Our key variable SET becomes the import of capital goods.

Since SECEX is a registry data, we can legitimately assume that missing value for imports are actually zeros (neatly from some black market transactions, which cannot be accounted for). Given our use of log scale data, the mass probability in zero will drop a significant size of the sample, thus we constructed log(SET) as zero if capital good import is zero and the log of it when positive[19].

Regarding PIA, we use a capital measure obtained from IBGE using perpetual inventory method on investment and depreciation data.

From PIA we also took total production, total sales[20] and the expenditure on royalties[21].

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 skilled workers the employees with secondary or tertiary education and so the skilled share is simply the share of these workers over the total workforce. 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 in number of minimum wages.

APPENDIX B. Estimating the determinants of the share of skilled workers

In order to check the robustness of the results reported in Section 5, we run a specification for the share of skilled workers (SS). Consistently with the literature, we chose a translog specification for the labour cost function, such that when we apply Sheppard's Lemma - deriving the cost function for the skilled wage - we get the share of skilled labour cost on overall labour cost.

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19 The absence of values equal to one makes this exercise meaningful.

20 The IPA-OG is an inflation index that can be disaggregated at the 3-digit CNAE/SIC level.

21 In PIA questionnaire there is specific question in Section C5 about the expenditure on royalties and technical assistance (see IBGE, 2004).

$$\Delta SS_{i,t} = \vartheta \Delta SS_{i,t-1} + \gamma_1 \Delta \log(y_{i,t}) + \gamma_2 \Delta \log(k_{i,t}) + \gamma_3 \Delta \log(R\,\&\,D_{i,t}) + \\ + \gamma_4 \Delta \log(SET_{i,t}) + \gamma_5 \Delta \log(ws_{i,t}) + \gamma_6 \Delta \log(wu_{i,t}) \mathbf{T}'\gamma + \mathbf{S}'\delta + z_{i,t} \quad \textbf{(6)}$$

We estimated it using GMM-SYS with robust standard errors;.as before, we instrumented all the regressors. The results are shown in the following Table A1 and are consistent with those obtained in Section 5. One interesting point is that capital is losing significance: we can thus appreciate the two equations estimation technique, which was able to detect the capital skill complementarity which occurs only for the skilled component of employment.

Table A1. Econometric Results.

Dependent Variable: Skilled Share.
Method: GMM-SYS with robust standard errors. Instruments: up to third lag. Number of Instruments:179. Standard errors in brackets: *significant at 10%, **at 5%, *** at 1%

	(1)	**(2)**
Skilled Share	0.841	0.842
(First Lag)	[0.012]***	[0.012]***
Log(Skilled Wage)	-0.065	-0.066
	[0.007]***	[0.007]***
Log(Unskilled Wage)	0.140	0.139
	[0.012]***	[0.012]***
Log(Sales)	0.005	
	[0.002]**	
Log(Value Added)		0.003
		[0.002]
Log(Capital)	0.000	0.001
	[0.002]	[0.002]
Log(Royalties)	-0.000	-0.000
	[0.001]	[0.000]
Log(SET)	0.001	0.001
	[0.000]***	[0.000]***
Constant	-0.094	-0.084
	[0.045]**	[0.045]*
Year Dummies	*Yes*	*Yes*
Industry Dummies	*Yes*	*Yes*
Firms	10775	10775
AR(1)	-27.95	-27.97
p-value	0.00	0.00
AR(2)	1.08	-1.08
p-value	0.28	0.28
Wald Test	101857.2	102462.07
p-value	0.00	0.00