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Trade, skill-biased technical change and wages in Mexican manufacturing*

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Abstract

This paper analyses and quantifies the effects of trade liberalisation and skill-biased technical change, both exogenous and trade-induced, on the skill premium and real wages of unskilled and skilled workers in the Mexican manufacturing sector, using industry- and firm-level data for 1984-1990 from the *Encuesta Industrial Anual*. The novelty of the paper lies in its strategy for identifying causality, which uses differences across industries over time in the relative price of machinery and equipment in the US as an instrument for skill-biased technical change. The effect of trade-induced SBTC on wages, and especially on wage inequality, appears substantial. The regressions show that trade liberalisation and changes in the relative price of equipment in the US, which induce exogenous SBTC in Mexico, explain one quarter of the increase in relative skilled wages between 1984 and 1990. This rise in the skill premium due to SBTC and trade liberalisation mainly reflect a rise in real skilled wages, although with some specifications it was amplified by a fall in the real wages of unskilled workers.
Keywords: trade liberalisation, skill-biased technical change, wage inequality, real wages, Mexico, manufacturing.
JEL Classification: F14, J30, L60, O30.

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1 Introduction

The last 25 years have witnessed an increase in wage inequality not only in developed countries, but also in some low-income and many middle-income developing countries. This increase in wage inequality – more specifically a rise in the mean wage of skilled workers relative to the mean wage of unskilled workers – mainly reflect a rise in real skilled wages, although in some countries it was amplified by a stagnation or a fall in the real wages of unskilled workers (see Anderson, 2005; Goldberg and Pavcnik, 2007).

Two other changes during this period have been linked by economists to this increase in relative skilled wages. First, many developing countries have become more integrated with the rest of world, particularly through reductions in tariff rates, quotas and other non-tariff barriers. The rising relative wages of skilled workers in developing countries are at odds with the prediction usually made from the Stolper-Samuelson theorem, based on the assumption that developing countries are abundant in unskilled labour. Wood (1997), however, points out that Latin American countries, in many of which the rise in the skill premium was marked, were relatively skill abundant when they opened to trade in the 1980s.

Second, since most of the world's technical progress originates in a few rich countries (Schmidt, 2010), which are relatively skill abundant, machinery and equipment, hereafter M&E, tends to be complementary to skill (Riaño, 2009). When new technologies, such as personal computers, are adopted by firms in developing countries, they are thus likely to increase the relative demand for skilled workers, a process that has been referred to in the literature as (*exogenous*) skill-biased technical change, hereafter SBTC (see Acemoglu, 2002a;b).

While there is still debate about the relative importance of trade liberalisation and SBTC as causes of the rise in the skill premium in developed countries, a combined hypothesis to explain outcomes in developing countries has been suggested by Acemoglu (2002a; 2003) and analysed further in several recent papers (Caselli, 2010; Burstein and Vogel, 2009; Bustos, 2009; Riaño, 2009; Schmidt, 2010). These authors have suggested that when a developing country reduces its barriers to trade, firms are able to import new technology embodied in M&E at a lower price, which induces the adoption of skill-biased technologies. Thus, trade liberalisation can raise the skill premium even in skill-scarce developing countries, a process which can be referred to as *trade-induced* or *endogenous* SBTC. Acemoglu (2002b) also suggests that SBTC can be induced by other forms of openness, such as foreign direct investment (FDI) inflows, and other characteristics of the economy, such as labour market institutions.

This paper explores the effects of trade liberalisation and SBTC, both exogenous and trade-induced, on the skill premium and real wages of unskilled and skilled workers in the Mexican manufacturing sector. The data used are at industry and firm level, cover the period 1984-1990, and come mainly from the *Encuesta Industrial Anual*, Annual Manufacturing Survey, conducted by the *Instituto Nacional de Estadistíca y Geografía* (INEGI). The novelty of the paper lies in the new identification strategy applied to infer causality, based on Leonardi (2007) and the model developed by Caselli (2010), and is enhanced by its focus on both real and relative wages.

Caselli (2010) builds a model of international trade with heterogeneous firms *à la* Melitz (2003). It extends the model by Vannoorenberghe (2008) to two sectors that differ in terms of their intensity in the use of skilled and unskilled labour and two countries, North and South, as in Bernard *et al.* (2007). It includes imported M&E as a third factor of production. M&E is modelled as complementary to skilled workers and substitutable for unskilled workers (see Krusell *et al.*, 2000). This framework makes it possible to study the different effects of trade liberalisation on wages identified by Bernard *et al.* (2007), i.e. Stolper-Samuelson effects, increase in product variety and endogenous industry-level productivity gains. Additionally, it analyses new effects due to firm heterogeneity in the productivity of skilled workers (see Vannoorenberghe, 2008) and equipment-skill complementarity.

Decreases in the price of imported M&E due to reductions in tariffs or in its international price lead to an increase in the relative demand for skilled workers, the complementary factor in production, especially in more productive firms that employ relatively more skilled workers and M&E. In turn, this leads to increases in the real wages of skilled workers, while unskilled workers may gain or lose depending on the type of variable trade costs assumed. This implies that, even if unskilled labour is the abundant factor of production and therefore Stolper-Samuelson effects push the skill premium downwards, this new effect leads to overall increases in skilled workers' real wages and in wage inequality following trade liberalisation.

Caselli (2010) also shows that the increase in the demand for skilled workers by more productive firms is reflected in increased in the variance across firms in each sector of the ratio between M&E and unskilled labour, a proxy for SBTC (see Leonardi, 2007).[1] However, increases in this variance can be associated with other changes too, which are not related to SBTC and accompanied by increases

[1]For simplicity, the model assumes a Leontief technology with perfect complementarity between skilled labour and M&E. This implies that SBTC causes larger increases in the variance of the equipment-unskilled labour ratio than in the variance of the equipment-labour ratio.

in the relative demand for skilled labour and relative skilled wages.

Based on this model, it is possible to design an empirical strategy to explain the increase in the relative demand for skilled labour and, consequently, in the skill premium that has been observed in Mexican manufacturing between 1984 and 1990 by several papers, including Riaño (2009) and the present one. This paper uses variation across industries over time in the price of M&E relative to the consumer price index in the US as an instrument for exogenous SBTC in the analysis of Mexican labour market dynamics and thus avoids some of the problems faced by earlier work in arguing for a causal impact of trade liberalisation and technical change on wages.

This identification strategy relies on factor immobility across industries, an assumption supported by the descriptive evidence presented. The paper shows that a reduction in the relative price of M&E in the US translates into a reduction in the relative price of M&E in Mexico because of the latter's historic dependency on US M&E and technology. Lower input tariffs are shown to have a similar negative effect on the relative price of M&E in Mexico. In turn, lower prices lead to increased use of M&E by Mexican firms, especially by more productive firms, and, given the complementarity, an increase in the relative demand for skilled labour. This shows up in the data as an increase in the within-industry variance of the equipment-labour ratio, which is used as a proxy for SBTC. After controlling for other time-variant industry and economy-wide characteristics, the paper shows that the higher variance in the equipment-labour ratio leads to increases in the skill premium and the real wages of skilled workers, thus providing evidence for trade-induced SBTC.

The results also reveal that lower output tariff rates increase the skill premium, which highlights the distinctive role of output tariffs compared to input tariffs in wage determination (Amiti and Konings, 2007). This result also suggests that trade liberalisation had an effect in Mexico in the 1980s similar to what would be predicted by the Stolper-Samuelson theorem for a country relatively abundant in skilled labour, as argued by Wood (1997). However, while the arguments in Wood (1997) are based on a HOS model and, therefore, factor mobility across industries within a country, the data show that a specific-factor model with immobile labour would be more realistic for such a short time period. Therefore, this paper will explain the positive effect of trade liberalisation on the skill premium using a specific-factor framework.

In order to argue that trade liberalisation has a causal impact on relative and real skilled wages through induced SBTC, the instrument used needs to be informative and valid. While the empirical analysis reveals that the instrumental variable (IV) approach is informative, the paper relies on Leonardi (2007) and the framework developed in Caselli (2010) to argue the validity of the instrument. In terms of the magnitude of the estimated effects, SBTC and trade liberalisation can explain one quarter of the overall increase in the skill premium during the period 1984-1990 and most of this is due to SBTC, both exogenous and trade-induced.

The instrument used in this paper, i.e. the relative price of M&E in the US, is at the 3-digit industry level and, thus, the above results are based on regressing average industry wages on a set of explanatory variables measured at the industry level, including tariff rates and the instrumented proxy for SBTC. However, the paper also shows results based on regressing real and relative wages at plant level on both plant- and industry-level variables. In these regressions, it is possible to study the impact of SBTC on wages by including the instrumented within-industry variance of the equipment-labour ratio or more standard plant-level measures of SBTC, such as royalties paid on new technologies and M&E imports (see the literature review by Chennells and Van Reenen, 1999). The unit of observation in the dataset used is a plant rather than a firm, which poses problems of identification because firms may re-organise production among the plants they own. However, the plant-level results in general seem to confirm the findings at the industry level.

Mexico has been frequently chosen as a country in which to study the effects of trade liberalisation on wages. Not only did the country go through a substantial trade liberalisation process, with production-weighted average tariffs declining from 28.5 percent in 1985 to 12.5 percent in 1990 (Ten Kate, 1992) and trade as a fraction of GDP rising from 20 percent in 1980 to 55 percent in 1995, but also the skill premium increased by almost 30 percent between 1985 and 1994, remaining stable afterwards (Riaño, 2009).

A limitation of most previous work on the liberalisation process in Mexico is its focus only on wage inequality, neglecting real wages. Another limitation is its reliance on the HOS model and one of its corollaries, the Stolper-Samuelson theorem (Hanson and Harrison, 1999; Feliciano, 2001; Esquivel and Rodríguez-López, 2003), which have met some criticism. Hanson and Harrison (1999) argue that the increase in the skill premium can be explained using a HOS framework because the pattern of tariffs before liberalisation was such that unskilled-labour-intensive industries were more protected. Esquivel and Rodríguez-López (2003) instead use Leamer (1998)'s methodology, which also relies on perfect mobility of all factors across industries, and, in contrast to previous studies, find that trade has tended to reduce relative skilled wages, while skill-biased technical change tended to raise them. However, none of these studies based on the 'mandated wage' approach finds strong evidence for the channel through which the Stolper-Samuelson theorem works in theory, since the correlation between changes in output prices and relative wages at the industry level is extremely low (Riaño, 2009).

Other studies have investigated alternative possible causal connections between greater openness and the increase in wage inequality. Among them, Feenstra and Hanson (1997) argue that FDI towards *maquiladoras*, assembly plants for re-exports, has been the cause of the increase in relative skilled wages after the trade liberalisation of 1985-1987, and Verhoogen (2008) shows that new export opportunities following the 1994 Mexican peso devaluation led to an increase in within-industry wage inequality due to quality upgrading by the most efficient plants.

Two other papers study the links between trade and technology adoption and are, therefore, more closely related to Caselli (2010). Riaño (2009) develops and estimates a structural model of trade and technology adoption with heterogeneous firms. Firms produce using skilled and unskilled labour and can choose between two technologies: a 'traditional' technology characterised by high marginal costs but low fixed costs, and a 'modern' technology that has low marginal costs but high fixed costs. By identifying plants that purchase imported M&E as using the modern technology, the author estimates the response of technology adoption and the skill premium to a unilateral trade liberalisation of a similar magnitude to the one that took place in Mexico after 1985. In the baseline model, he finds that trade liberalisation leads to an increase in the relative demand for skills and an increase in the skill premium of around 2.4 percent. Allowing for the reduced sunk cost of technology adoption due to the falling import tariffs, the impact of trade liberalisation on the skill premium is stronger, raising it by 4.2 percent. Riaño's model is similar to Bustos (2009), except that the latter model is static, assumes that skilled and unskilled labour are perfect complements in production and does not allow for the possibility of cheaper technology due to falling import tariffs. However, while in these two papers there are only two technologies characterised by a trade-off between fixed and marginal cost, Caselli (2010) uses a continuous measure of technology adoption that allows larger and more productive firms to expand further in size, even though all firms upgrade their skills and technology to a degree.

The rest of the paper is organised as follows. Section 2 briefly reviews the Mexican liberalisation process in the 1980s. Sections 3 and 4 describe the data used and provide some descriptive evidence of an increase in the relative demand for skilled labour between 1984 and 1990. Section 5 outlines the identification strategy and the econometric specification. This section explains why the relative price of M&E in the US can be used as an instrument for SBTC in a first-stage regression and how SBTC is measured. Section 6 presents the results of the regression analysis. Section 7 concludes.

2 Mexico's trade policy in the 1980s

This section describes the main characteristics of the programme of trade liberalisation introduced in Mexico in the period 1985-1987 and demonstrates that the Mexican government was committed during this period to trade liberalisation encompassing all industries. Several detailed accounts can be found of this trade reform, one of the most far-reaching of any developing economy (see, among others, Ten Kate, 1989; 1992).

During the import substitution phase of the late 1950s to the late 1970s three main forms of trade controls were applied: *ad valorem* import tariffs, official minimum prices for customs valuation and a system of quantity restrictions in the form either of quotas or of licensing. It is generally agreed that the most restrictive element of the Mexican import regime was the system of quantity restrictions. A recurrent policy of the Mexican government, when it was experiencing a lack of foreign exchange, was to reintroduce import controls and alter the exchange rate, rather than reducing domestic expenditure (Ten Kate, 1992).

However, in the early 1980s pressures mounted for the liberalisation of trade. After the oil boom of the late 1970s, Mexico relied almost exclusively for foreign exchange on crude oil export earnings and borrowing. Therefore, it is no surprise that in the early 1980s, after the weakening of the oil market and the sharp increase in interest rates in the US, the Mexican economy was in a difficult situation. The balance-of-payments crisis led to a collapse of the peso, bank runs and a deep recession as well as to the reversal of the modest trade liberalization attempts of the late 1970s. Therefore, the Mexican government turned to radical trade liberalisation, exchange rate devaluation, privatisation of state-owned companies and a more tolerant attitude towards private foreign investments. This recipe was also part of the Baker Plan and the structural adjustment programmes proposed at the annual meeting of the World Bank and the International Monetary Fund in Seoul in October 1985.

The ambitious unilateral trade liberalisation programme was launched in July 1985. In a relatively brief period, tariff rates on most products were reduced, reference prices were progressively removed and non-tariff controls were drastically decreased or eliminated, as can be seen in Table 1. Licenses were eliminated

Table 1: Protection measures for Mexican manufacturing in the 1980s

	1985 Jun	1985 Dec	1986 Dec	1987 Dec	1988 Dec	1989 Dec
Production-weighted tariff averages	23.5	28.5	24.5	11.8	10.2	12.5
Domestic production value covered by import licensing	92.2	47.1	39.8	25.4	21.3	19.8
Domestic production value covered by official import prices	18.7	25.4	18.7	0.6	0.0	0.0

Source: Ten Kate (1992).

for almost 3600 tariff lines, which left only 908 under control, while the license coverage decreased from 92.2 to 47.1 percent between July and December 1985 and reached 25.4 percent by December 1987. Initially, to compensate for the protection lost with the elimination of licenses, production-weighted tariff averages were increased from 23.5 to 28.5 percent, but by December 1987 they had fallen to 11.8 percent, with the initial tariff cuts concentrated on intermediate and capital goods (Ten Kate, 1992). At the same time, the domestic production value covered by official import prices was reduced to virtually zero by December 1987, down from 18.7 percent in July 1985, to comply with Mexico's membership of GATT from July 1986.

Mexico's accession to the GATT did not imply an intensification of the liberalisation process but should rather be considered as a signal by policy makers of their intention to continue the liberalisation process (Ten Kate, 1992). A further simplification and fine-tuning of the tariff structure was carried out after the enactment of the Economic Solidarity Pact in 1987, in which the government, business organisations and trade unions agreed to promote macroeconomic stabilisation and a speeding-up of trade reform in the hope that stiffer competition from abroad would help to reduce inflation. The emphasis was on reducing the dispersion in tariff rates with the objective of producing a broadly uniform system of effective protection, which led to further reductions in production-weighted average tariffs to 10.2 percent, license coverage to 21.3 percent and production value covered by official import prices to zero by December 1988. The process of trade liberalisation advanced further when Mexico jointly with the US and Canada signed the North American Free Trade Agreement (NAFTA) in December of 1992, which came into effect on January 1st of 1994.

These trade reforms had a large impact on the pattern of trade in Mexico. The volume of trade has increased significantly since 1985 and, in particular, non-oil exports rose threefold in value between 1981 and 1990. Coupled with a decrease in the relative price of petroleum, this led to a decline in petroleum's share of exports from 75 percent in 1981 to 35 percent in 1990. At the same time, the importance of the US as a trading partner has become more pronounced as Mexico's share of trade with the US rose from 56 percent in 1982 to 70 percent in 1992 (Riaño, 2009). The exchange rate depreciation was reversed after 1987 with the consequence of an increase in imports, which contributed to more competition from abroad as advocated by Mexican policy-makers to fight inflation (Ten Kate, 1992).

3 Data

The data used in this paper come mainly from the *Encuesta Industrial Anual* (Annual Industrial Survey, EIA), provided by the *Instituto Nacional de Estadistíca y Geografía*, INEGI, the national institute of statistics of Mexico. The database contains information on 3218 manufacturing plants for the period 1984-1990 (for a total of 22526 plant-year observations) and it is by design a balanced panel that covers roughly 80 percent of all manufacturing value-added. The data distinguish

Table 2: Descriptive statistics

	1985		1990	
	Mean	S.D.	Mean	S.D.
Skill premium (ratio of ws/wu)	1.94	0.28	2.63	0.44
Real skilled wages (1994 pesos per day)	117.30	23.45	125.10	32.29
Real unskilled wages (1994 pesos per day)	63.42	11.48	50.08	11.04
Tariff rate on final goods	0.36	0.20	0.16	0.03
Tariff rate on inputs	0.23	0.09	0.12	0.03
Variance of equipment-labour ratio (× 10000)	0.74	1.59	1.38	6.25
Relative price of M&E (Mexico)	1.31	0.09	1.21	0.12
Relative price of M&E (US) (× 10)	1.68	0.08	1.62	0.05
Royalties paid (1994 pesos) (× 1000)	17.59	80.25	32.77	249.89
M&E imports (1994 pesos) (× 1000)[2]	38.12	377.21	81.32	521.79

129 industries, classified according to the CMAE75 (Clasificación Mexicana de Actividades Económicas, 1975). Omitted from the data are plants with missing information on the employment and wage bill of production and non-production workers, some odd observations, entrants and exiters because by construction this is supposed to be a balanced panel and incomplete series (for more information on the EIA and the cleaning procedure see Iacovone, 2008 and Riaño, 2009). Firms belonging to the oil production sector are also eliminated because this sector is controlled by the government. The final sample contains 16891 observations, that is, 2413 per year. Table 2 shows the descriptive statistics of some of the variables included in the analysis for 1985 and 1990.

This database provides a wide array of information on each individual plant, including information on the total number of blue-collar (or production) workers, whose main activities include machine operation, production supervision, repair, maintenance and cleaning, and white-collar (or non-production) workers, such as managers, administrators, professionals and salesmen, total number of hours

[2] The values of M&E imports for 1985 refer to 1986 because this is the first year in which information on imports and exports are collected in this survey.

worked for each type of worker, total remuneration, production, input use, stock of and investment in different capital goods, including M&E imports, and exporting status (from 1986 onwards). Therefore, this paper distinguishes between skilled and unskilled workers on the basis of occupation rather than education. The classification of workers into production and non-production groups in order to approximate skilled and unskilled labour respectively is not ideal because skills are better described by classifications based on educational characteristics, as pointed out by Gonzaga *et al.* (2006) and Bustos (2009). However, this categorisation is very common in the literature (Berman *et al.*, 1994; Feenstra and Hanson, 1996; Leamer, 1998; Meschi *et al.*, 2009) because it is often the only one available in firm-level data. Berman *et al.* (1994) also argue that it yields results similar to those obtained using education categories.

From the information provided it is possible to extract the following variables that will be used later in the analysis. Skilled wages are measured as the average daily wages for non-production workers (ws), unskilled wages as the average daily wages for production workers (wu) and the skill premium (wi), the measure of wage inequality, as the ratio of skilled to unskilled wages. These factor prices are deflated using different consumer price indices depending on the level of the salary to account for the fact that consumers buy different goods in different proportions depending on their incomes (Broda and Romalis, 2008). In order to do this, data from the Bank of Mexico on the inflation rate that different income groups face depending on their income is used and matched to the salaries of production and non-production workers depending on their average sectoral wages. Four income groups for the price indices are provided by the Bank of Mexico: people who earn up until the minimum salary, those between 1 and 3 times the minimum salary, those between 3 and 6 times the minimum salary and, finally, those above 6 times the minimum salary.

The EIA provides data on capital and its different components, including M&E imports, investment and capital stock, at the firm level. Each type of capital is deflated using specific indices that differ across sectors, provided by the INEGI. Using this data and information on employment at the firm level, the ratio between the capital stock of M&E and total labour is calculated for each firm and, in turn, its variance across firms within the same industry is computed (*varel*). The within-industry variance of the equipment-labour ratio is not the only proxy for SBTC that is used in the regressions below. The firm-level regressions also use the amount of money spent on royalties for the use of new technologies (*royalties*) and M&E imports (*eimp*).

The output share of each firm in its industry (*soutput*) is also calculated using data from the EIA, together with the normalised Herfindahl-Hirschman Index (*nhhi*), a measure of competitiveness at the industry level.[3] The degree of unionisation in an industry is calculated as the percentage of workers that belong to a recognised trade union, taken from the National Survey on Household Income and Spending (ENIGH) provided by the INEGI (*union*).

Production-weighted average tariff rates on final goods (*taro*) are taken from Ten Kate (1989; 1992). These data, combined with input-output tables provided by the INEGI, are used to calculate the production-weighted average tariff rates on inputs (*tari*). The relative price of M&E in Mexico is constructed as the ratio of the price of M&E to the consumer price index and is also taken from the INEGI

[3]The following formula is used to calculated the normalised Herfindahl-Hirschman Index: $nhhi_i = (\sum_k^n soutput_{k,i}^2 - 1/n)/(1 - 1/n)$, where $soutput_{k,i}$ is the share of firm k in industry i and n is the number of firms in industry i.

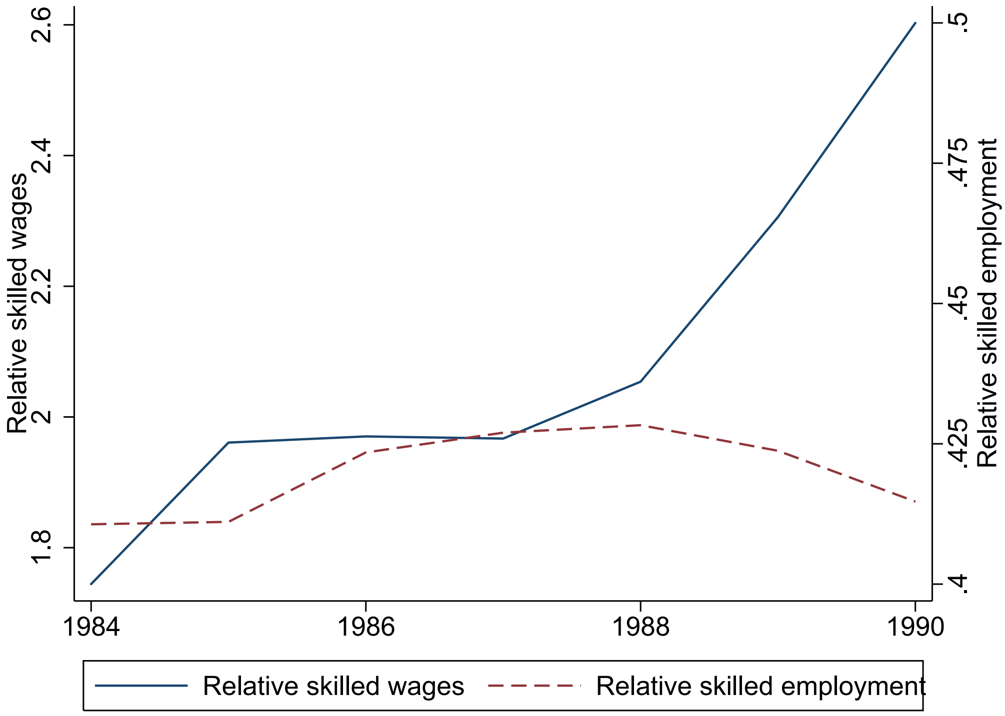
(*pmex*). The relative price of M&E in the US is constructed in the same way with data taken from the Bureau of Economic Analysis (BEA) (*pus*). The relative prices of M&E in the US and in Mexico are not directly comparable because they are constructed using non-comparable indices. All variables just described are available at the 3-digit industry level.

The *Encuesta Industrial Anual* was also conducted between 1994 and 2003, the period in which NAFTA was implemented. However, this additional data will not be used in this paper for several reasons. Although Mexico liberalised trade *vis-à-vis* the US, average tariff rates actually remained stable or increased slightly during this period. The main reason is that NAFTA was designed in such a way that most tariff cuts, especially in protected industries, were delayed as long as possible. This makes it difficult to establish a link between tariff rates on inputs and the relative price of M&E and, in turn, with the within-industry variance in equipment-labour ratios because there is not enough variability in these variables. Therefore, a different empirical strategy would need to be designed to estimate the impact of trade-induced SBTC on wages, possibly one that used data directly at the firm level. However, the full firm-level database of the *Encuesta Industrial Anual* and the *Encuesta Industrial Mensual*, the Monthly Manufacturing Survey that provides information on wage bills, employment and exports, is not readily available due to statistical secrecy.

4 Descriptive evidence

Figure 1 plots the movement of relative skilled wages (left axis) and relative skilled employment (right axis) during 1984-1990. The figure shows that both relative

Figure 1: Relative skilled wages and employment in Mexican manufacturing



Source: Own calculations based on *Encuesta Industrial Anual*, 1984-1990, INEGI.

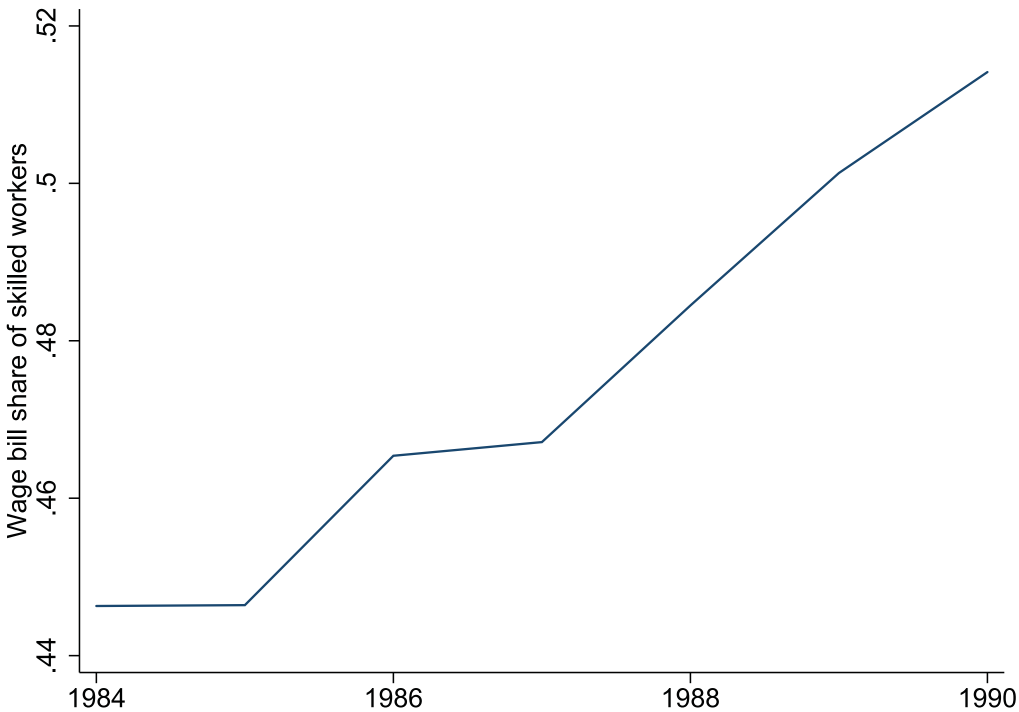
wages and relative employment tended to rise until 1988 – that is, during the rapid trade liberalisation process. Although the increase in relative employment is much more modest, this simultaneous increase in relative wages and relative employment necessarily implies an increase in the relative demand for skilled labour (Meschi *et al.*, 2009). In the period 1988-1990, when tariff rates increased slightly in all sectors, there seems to be an inverse relationship between relative skilled wages and employment. This pattern of relative wages and employment is also consistent with an increase in the relative demand for skilled labour, while it is unlikely that the increase in the relative supply of unskilled labour (see Atkin, 2010) played an important role since the change in relative skilled employment is again small.

Figure 2 plots the evolution of the wage bill share of skilled labour. This variable can be also used to determine whether the relative demand for skilled labour increased and, therefore, to distinguish the effects of labour supply from those of labour demand, under the assumption that the elasticity of substitution between skilled and unskilled labour is equal to one (Berman and Machin, 2000).[4] If the elasticity of substitution is one, the wage bill share of skilled labour is invariant to movements along the relative demand curve and, therefore, can be considered a measure of the demand for skills (Meschi *et al.*, 2009). The figure shows that the wage bill share of skilled labour increased during this period and, thus, confirms the rising demand for skills.

While figure 1 plots average relative skilled wages, figure 3 analyses what happened between 1985 and 1990 to relative skilled wages in all 46 sectors. Similar figures for skilled and unskilled real wages are provided in the Appendix. The figure shows that there is a general tendency for relative skilled wages to increase (all observations are above the 45-degree line that represents no change in relative wages between the two years), as observed in the previous figure and in table 2. However, in some industries relative wages increased by more than in others and, through the econometric analysis described later, this paper will relate these differential movements of wages across sectors to the shocks described earlier, i.e. trade liberalisation and both exogenous and trade-induced SBTC. These differential movements of wages also resulted in an increase in the variance and in the coefficient of variation, which can be calculated from table 2 as the ratio of the standard deviation to the mean. Figure 3 does not show whether the within-sector

[4] This value is considered to be a lower bound for the elasticity of substitution between skilled and unskilled labour (Acemoglu, 2002b; Behar, 2009).

Figure 2: Wage bill share of skilled labour in Mexican manufacturing

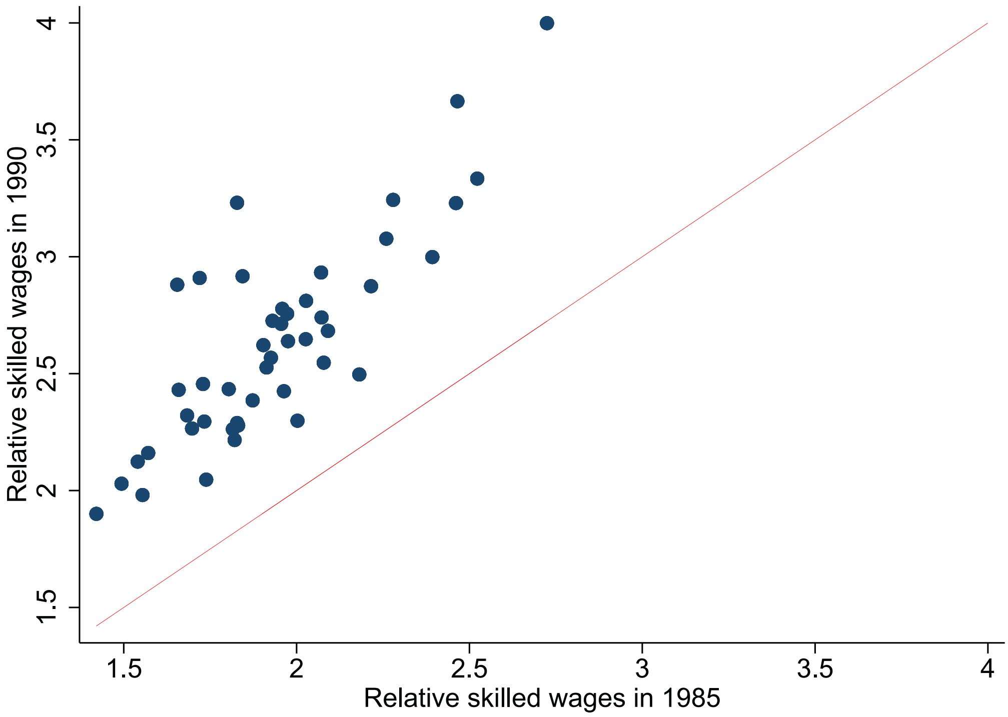


Source: Own calculations based on *Encuesta Industrial Anual*, 1984-1990, INEGI.

increase in wages is due to a general increase in wages in all firms within a sector or an increase in the within-sector variance of wages across firms. This issue will be discussed in more detail as part of the robustness checks.

In order to make a first attempt at understanding the main forces behind the skill upgrading documented in the figures above, the aggregate changes in the relative employment of skilled labour and in the wage bill share of skilled workers will be split into their between- and within-industry components. Following Bustos (2007) and Meschi *et al.* (2009), the aggregate increase in the demand for skills may be driven by (a) employment reallocation across industries caused by a trade shift,

Figure 3: Relative skilled wages at the 3-digit industry level in 1985 and 1990



Source: Own calculations based on *Encuesta Industrial Anual*, 1984-1990, INEGI.

structural change, changing tastes, or changes in economic policy, or by (b) skill upgrading within industries mainly due to technological change. The following formulas are used to decompose the aggregate changes in the relative employment of skilled labour (S/U) and in the wage bill share of skilled workers (WS/W) respectively:

$$\Delta\left(\frac{S}{U}\right) = \sum_j \left(\overline{\frac{S}{U}}\right)_j \Delta\left(\frac{U_j}{U}\right) + \sum_j \Delta\left(\frac{S}{U}\right)_j \left(\overline{\frac{U_j}{U}}\right) \tag{1}$$

$$\Delta\left(\frac{WS}{W}\right) = \sum_j \left(\overline{\frac{WS}{W}}\right)_j \Delta\left(\frac{W_j}{W}\right) + \sum_j \Delta\left(\frac{WS}{W}\right)_j \left(\overline{\frac{W_j}{W}}\right)_j , \tag{2}$$

where the subscript j denotes 3-digit industries[5], a Δ before a term denotes change over time and a bar over a term denotes a mean over time. In both formulas, the first term is the between-industry component of skill upgrading, i.e. how much bigger or smaller an industry becomes over time, weighted by time-averaged skill demand. The second term measures the contribution of within-industry variations, weighted by the relative size of industry j.

At the industry and at the aggregate level, the observed change in the demand for skilled labour may reflect within-firm as well as between-firm variations and, therefore, additional decompositions will be done to analyse changes due to their between- and within-firm components. These decompositions will use the same formulas as above, the only difference being that the subscript j will denote firms. All decompositions will be done for the whole 1984-1990 period and for the 1984-1988 and 1988-1990 sub-periods in order to relate the increase in the relative demand for skilled labour more closely to the trade liberalisation process.

As observed in figure 1, table 3 shows that over the period 1984-1990 the relative employment of skilled labour increased only by 0.4 percentage points. Since the aggregate change in relative skilled employment is small, in the following analysis this paper will mainly focus on the decomposition analysis of the wage bill share of skilled workers. However, it is worth noting that both between- and within-industry components of the aggregate change in relative employment of skilled labour are positive and that 45 percent of the aggregate increase can be explained by within-industry changes. While the positive between-industry variation implies that there was a reallocation of resources towards more skill-intensive industries,

[5]The decomposition analysis is also available at different levels of aggregation, i.e. 2-digit and 4-digit industry level, but the additional tables are not included and discussed because the results are similar to those using 3-digit industries.

Table 3: Decomposition of changes in relative skilled employment

	Between	Within	Total
1984-1990			
Industries at 3-digit CMAE75 (46)	0.0022	0.0018	0.0040
Firms (2413)	-0.0026	0.0066	0.0040
1984-1988			
Industries at 3-digit CMAE75 (46)	0.0009	0.0167	0.0176
Firms (2413)	-0.0018	0.0194	0.0176
1988-1990			
Industries at 3-digit CMAE75 (46)	0.0011	-0.0147	-0.0136
Firms (2413)	0.0006	-0.0142	-0.0136

Source: Own calculations based on *Encuesta Industrial Anual*, 1984-1990, INEGI.

holding skill intensity within industries constant, the positive within-industry variation implies that skill intensity increased within industries, holding industry size constant. When changes are disaggregated at the firm level, between-firm changes are negative, meaning that there was a reallocation of resources towards skill-scarce firms, while within-firm variation remains positive and accounts for 165 percent of the overall variation.

Table 4 reports the between and within decompositions of the aggregate change in the wage bill share of skilled labour. The wage bill share of skilled labour increased by 6.8 percentage points between 1984 and 1990. This increase happened during both sub-periods considered, i.e. 1984-1988 and 1988-1990, and with similar magnitudes.

During all the periods analysed, both between- and within-industry changes are positive and the within-industry changes explain most of the overall change by accounting for about 90 percent of the variation. Moreover, most of this change is explained by skill upgrading within firms. The lack of information on entry and exit implies that the reallocations across industries and firms that occur through these channels are missed in these calculations. However, since the balanced panel

Table 4: Decomposition of changes in the wage bill share of skilled labour

	Between	Within	Total
1984-1990			
Industries at 3-digit CMAE75 (46)	0.0074	0.0604	0.0678
Firms (2413)	0.0162	0.0516	0.0678
1984-1988			
Industries at 3-digit CMAE75 (46)	0.0043	0.0339	0.0382
Firms (2413)	0.0098	0.0284	0.0382
1988-1990			
Industries at 3-digit CMAE75 (46)	0.0024	0.0272	0.0296
Firms (2413)	0.0058	0.0238	0.0296

Source: Own calculations based on *Encuesta Industrial Anual*, 1984-1990, INEGI.

represents 80 percent of manufacturing output, skill upgrading within industries and firms was clearly an important source of the overall increase in the relative demand for skilled labour and the skill premium.

The analysis of wage bills shows that not only did skill-intensive industries and firms expand relative to less skill-intensive industries and firms, but also that all industries and firms raised their skill intensity. If HOS theory were an accurate description of the changes that occurred during this period and labour were perfectly mobile, then within-industry changes would be equal to zero since reallocation would only happen between sectors. Moreover, according to HOS theory, between-industry changes in the wage bill share of skilled labour should be negative for skill-scarce countries because, following trade liberalisation, the price of less skill-intensive goods would increase relatively and, consequently, less skill-intensive sectors would expand, leading to a decrease in the relative demand for skilled labour.

The data tend to confirm that, as argued by Wood (1997), Mexico was not an unskilled labour abundant country in the 1980s, since between-industry changes in the wage bill share of skilled labour are positive. However, it is also the case that between-industry variation accounts for only a small percentage of the aggregate change, so that other explanations are needed to throw light upon the small positive between-industry changes and the large positive within-industry and within-firm changes.

An alternative theory for the large within-industry and within-firm changes occurred in Mexico is trade liberalisation under the assumption of imperfect labour mobility, as in a specific-factor model. If labour immobility were due to the existence of sector-specific skills, then skilled labour would be less mobile than unskilled labour. Moreover, if the country were skilled labour abundant, trade opening would cause the prices of less skill-intensive goods to decrease and, consequently, the sectoral structure of outputs would shift towards skill-intensive goods. This would imply a small positive between-industry change, as observed in the case of Mexico, because imperfect labour mobility would prevent a full reallocation of labour across sectors.

In addition to these two hypotheses, trade could have contributed in other ways to the increase in the relative demand for skilled labour. In particular, as shown by the new trade models with firm heterogeneity following the seminal paper by Melitz (2003), trade liberalisation may lead to within-industry resource reallocations since more productive firms find it profitable to scale up their production aimed at the export market at the expense of less productive firms, which may drop out of the market. If more productive firms used skilled workers more intensively, then a reallocation of resources towards them would imply an increase in the relative demand for skilled labour and positive within-industry changes. However, positive within-industry changes in this case would be associated mainly with between-firm changes because not all firms would increase their relative demand for skilled labour.

Another hypothesis to explain the large within-industry and within-firm changes is SBTC. As new skill-biased technologies (i.e. M&E) are introduced, due to either a decrease in their price on international markets or a decrease in tariffs on these inputs, all firms and industries tend to increase their demand for skilled labour, although possibly in different magnitudes, resulting in positive within-industry and within-firm variations.

When comparing these findings with those from other middle-income countries, the most important difference is that in the case of Mexico the between-industry component of the changes in relative skilled employment or in the wage bill share of skilled labour are positive throughout the whole period. This is in contrast with the findings of Gonzaga *et al.* (2006) for Brazil in 1988-1995, Bustos (2007) for Argentina in 1992-1996 and Meschi *et al.* (2009) for Turkey in 1983-1988, which show that these middle-income countries experienced negative between-industry and -firm changes in the relative demand for skilled labour when they liberalised trade. The present results resemble more closely the findings in Berman *et al.* (1994) for the US, a high-income country relatively abundant in skilled labour. On the other hand, the within-industry and within-firm components of the aggregate change in the relative demand for skilled labour are positive in all these studies, which is consistent with SBTC – both in its exogenous and trade-induced formulations – being pervasive for middle-income countries as defined by Berman and Machin (2004).

The preceding decomposition analysis has left all the main explanations of the increase in the relative demand for skilled labour in Mexican manufacturing during the 1980s, namely trade liberalisation, SBTC and trade-induced SBTC, as possible candidates. Thus, this paper next turns to the predictions of models that incorporate all these explanations in order to design an effective strategy to identify more formally the role that each of these shocks has played in increasing the demand for skilled labour.

Models of directed technical change *à la* Acemoglu (2002b) may explain these results, through exogenous and trade-induced SBTC and the direct effect of trade liberalisation, but do not allow for the role of firms that are heterogeneous in terms of their productivity. Not only do the data analysed in this paper show much firm heterogeneity even within narrowly defined industries (4-digit CMAE75, equivalent to 4-digit SIC), but also that this distribution changes over time.

Table 5 presents the distribution of output, exports, imported M&E, royalties paid and M&E investment and capital at book value across the whole sample of plants in 1990, of which the last four variables are different measures of technology spending and upgrading. Each distribution is measured by dividing the whole distribution of firms into deciles and then calculating the share of each decile for each variable. The table clearly shows that for each of these variables the plants in the tenth decile of the distribution account for at least 66 percent of the total, with a peak for exports, where the largest 10 percent of the plants account for over 88 percent of total manufacturing exports. This is in line with the findings of Bernard *et al.* (2009) for US manufacturing firms. Of the 2413 plants in the sample, only 29.4 percent exported in 1990, 31.5 percent engaged in direct import of M&E from abroad, 16.9 percent both exported their products and imported M&E and 21 percent paid royalties on licenses for technologies.

Moreover, some recent papers highlight the role of firm heterogeneity and

Table 5: Distribution of output, exports and inputs in 1990

Decile	Output	Export	M&E Import	Royalties	M&E Inv.	M&E Cap.
1	0.001	0.000	0.000	0.000	0.000	0.000
2	0.004	0.000	0.002	0.002	0.001	0.001
3	0.007	0.001	0.004	0.005	0.003	0.002
4	0.011	0.002	0.007	0.009	0.005	0.004
5	0.019	0.004	0.011	0.018	0.010	0.009
6	0.030	0.008	0.017	0.029	0.018	0.016
7	0.046	0.013	0.032	0.045	0.033	0.029
8	0.077	0.026	0.057	0.070	0.060	0.057
9	0.145	0.063	0.126	0.136	0.135	0.123
10	0.660	0.882	0.743	0.686	0.734	0.757

Source: Own calculations based on *Encuesta Industrial Anual*, 1984-1990, INEGI.

present empirical findings in which skill and technology upgrading is mainly done by new exporting firms, as in Bustos (2007; 2009) for Argentina and, to a smaller extent, in Riaño (2009) for the case of Mexico. The reason is that in these models firms can only choose between two technologies, a "traditional technology" characterised by high marginal costs and low fixed costs and a "modern technology" characterised by low marginal costs but high fixed costs. As a country liberalises its trade, exporting becomes more profitable. Continuing exporters will continue employing the modern technology and, therefore, will not need to upgrade. However, new exporters that were previously using the traditional technology will choose to upgrade as they can spread the higher fixed costs over a larger output.

These models are not confirmed by the data used in this paper from Mexican manufacturing plants. Table 6 shows how changes over the 1984-1990 period in different measures of technology spending are related to skill upgrading over the same period and the type of exporting plant. The inclusion of 4-digit industry dummies allows these regressions to compare plants within the same industry, rather than across widely different industries.

While these results are based on all available measures of technology spending, the rest of the paper will use mainly M&E investment and its accumulated stock. The reason is that the data on imported M&E, which is the preferred measure of technology spending in Riaño (2009), exclude purchases of imports via other domestic firms (eg. specialised importers). Moreover, the design even of domestically produced M&E is heavily influenced by that of imported M&E and of M&E used abroad, which domestic producers copy either under licence (for which they pay royalties) or by making something similar. Therefore, imported M&E is important, both in itself and as a model for local producers to copy, but it is not the whole of the new technology story. Also, using royalties paid on licenses for new technologies, which is the preferred measure in Bustos (2007; 2009), excludes the possibility that some plants acquire new technologies by the simple act of buying and investing in a new piece of M&E.

Table 6 shows that plants that upgrade technology according to the M&E investment measure also tend to employ relatively more skilled workers, but there seems to be no statistical difference in technology spending, independently of the measure used, between new and continuing exporters. Firms are categorised as new exporters if they exported in 1990 but not in 1984 and as continuing exporters if they exported throughout the whole period. This behaviour can be explained by a model with a continuous type of technology, as in Caselli (2010). In this model, as a country liberalises its trade, larger firms tend to employ more skilled workers and invest more in M&E in absolute terms, but since there are no large jumps in technology adoption the pattern of skill and technology upgrading is similar in relative terms across all firms.

While the above regressions are an interesting informative tool, they are just simple correlations between technology and skill upgrading and cannot be used to

Table 6: Skill upgrading and changes in technology spending

	ΔS/U OLS (1)	ΔS/U OLS (2)	ΔS/U OLS (3)	ΔM&E Inv. OLS (4)	ΔM&E Imp. OLS (5)	ΔRoyalties OLS (6)
ΔM&E Investment	0.023					
	(0.008)***					
ΔM&E Import		-0.003				
		(0.002)				
ΔRoyalties			-0.012			
			(0.049)			
Continuing Exporters				-1.036	-0.327	0.158
				(0.857)	(0.404)	(0.117)
New Exporters				-0.436	-0.031	0.018
				(0.413)	(0.118)	(0.068)
Export Quitters				-3.247	1.370	0.069
				(3.374)	(1.342)	(0.117)
Industry dummies	yes	yes	yes	yes	yes	yes
Observations	2407	2034	2405	2407	2034	2405
R-squared	0.066	0.060	0.064	0.088	0.010	0.054

Notes: Omitted category is "Never Exporters", i.e. firms that never exported between 1984 and 1990. Robust standard errors are shown in parenthesis. One, two and three asterisks indicate coefficients significantly different from zero at 10%, 5% and 1% level respectively.

assess causality. Also, they do not show how trade liberalisation may have affected the relationship between technology and skill upgrading and how this has affected relative skilled wages. Thus, the next section will lay out an empirical strategy that will be used to answer these questions and, in particular, to understand the role of each possible explanation in the increase in the relative demand for skilled labour.

5 Identification strategy and econometric specification

To establish a causal link between trade liberalisation, SBTC and wages, it is essential to deal with endogeneity issues because, at the same time as firms set workers' wages, they also decide how many of them to employ and of what type, and how much M&E to install. This implies that the within-sector variance of the equipment-labour ratio, a proxy for SBTC, suggested by Leonardi (2007), is an endogenous variable in this context. Moreover, Caselli (2010) shows that increases in this variance can be associated with other changes not related to SBTC.[6] Therefore, it is necessary to design an identification strategy based on the theoretical framework in Caselli (2010).

Caselli (2010) shows that, in a small country that imports its M&E, changes in the exogenous international price of M&E and in variable trade costs levied on them affect the price of M&E, and, in turn, this affects the demand for this input as well as for skilled and unskilled labour. It also shows that changes in the price of M&E affect the within-industry variance of the ratio between M&E and labour, the proxy for SBTC. Even though the within-industry variance of the equipment-labour ratio changes for reasons other than SBTC, the use of the price of M&E as an instrument for this variable makes it possible to study the effect of both exogenous and trade-induced SBTC on wages. While Caselli (2010) models M&E as an intermediate good for modelling purposes, this paper mainly treats it as a capital good. This difference does not seem to change the main arguments, except that the process of technology adoption takes longer when M&E is modelled as a capital good.

The intuition behind the use of the within-industry dispersion of the capital-labour ratio and other similar ratios as a measure of SBTC follows from Caselli (1999), Acemoglu (2003) and Leonardi (2007). These papers argue that more efficient firms that employ relatively more skilled workers are favoured in absolute terms by technological developments biased towards skilled workers and, therefore,

[6] More specifically, Caselli (2010) uses the variance of the ratio between imported M&E and unskilled labour because it assumes a simple relationship between M&E and skilled labour in order to keep the model more tractable.

in response to SBTC, they will increase their demand for skilled labour and capital by more. This pushes the low-productivity firms out of the domestic market and, as capital moves towards larger firms, the within-industry variance of the capital-labour ratio increases. Caselli (2010) extends this idea to show that trade policy can also affect the within-industry dispersion of the equipment-labour ratio, which is the basis of the empirical investigation in this paper. This implies that trade policy could have two effects on wages. The first effect is through changes in output prices and average productivity of firms, as identified by Bernard *et al.* (2007), which can be analysed with the use of tariff rates on final goods. The other effect is through changes in the demand for M&E and technologies, which tend to favour skilled labour and, thus, affect wages further. The second effect can be analysed with the use of tariff rates on inputs.

The identification strategy also relies on the use of the price of M&E in the US as an instrument for SBTC, following the arguments by Krusell *et al.* (2000) and Leonardi (2007). When the price of M&E decreases in the US exogenously, due for example to the information technology 'revolution', the same is likely to happen to the price of M&E in Mexico because it relies on imports of M&E from the US. In turn, the decrease in the price of M&E increases the demand for it and, assuming that M&E is more complementary with skilled than unskilled workers, leads to SBTC, not only in the US but in Mexico too. Moreover, this paper takes into account trade-induced SBTC by allowing the price of M&E in Mexico to be affected by trade policy. While Krusell *et al.* (2000) and Leonardi (2007) suggest the use of the price of M&E relative to the price of structures to identify SBTC, the model in Caselli (2010) makes use simply of the price of M&E. In the presence of inflation, the price of M&E needs to to be deflated by the consumer price index, which is the relative price of M&E used in this paper. This second measure of price for M&E is also preferred because it is the only one readily available for Mexico.

In order to implement an IV approach for SBTC, the instrument, i.e. the price of M&E, needs to be both informative and valid. For an instrument to be informative, what is required is that it is correlated with the endogenous variables. As will be seen in the next section, this is the case since regressions with fixed effects for the 46 3-digit manufacturing sectors show a statistically significant relationship between the relative price of M&E in the US and the relative price of M&E in Mexico and, in turn, between the predicted values of the latter and the within-industry variance in equipment-labour ratios. However, for the instrument to be valid, it must also be uncorrelated with the residual in the main equation determining wages. Not only does the theory suggests the validity of the instrument but it also seems unlikely that changes in the price of M&E in the US have any impact on wages in Mexico other than through changes in the price of M&E. Moreover, considering that Leonardi (2007) argued that it is a valid instrument for the within-industry variance of capital-labour ratios in US manufacturing, it is likely to be an even more valid instrument for the within-industry variance of equipment-labour ratios in Mexican manufacturing.

Two further assumptions are needed for the identification strategy to work, i.e. to identify the effects of openness and SBTC on real and relative wages by examining changes between industries over time. First, trade policy needs to be exogenous. As explained in section 2, it seems to be the case that the liberalisation process of the 1980s was caused by external factors following the 1982's debt crisis and its aim was to eliminate peaks in trade barriers and eventually to lower them in order to make them also more uniform. This meant that those sectors that were more protected saw the largest declines in tariffs (Goldberg and Pavcnik, 2007).

The second necessary assumption is that workers do not move freely across sectors and, if they do so, they tend to do so randomly, while they can still move across firms within the same sector. The reason why this assumption is needed is that otherwise workers would move to those industries where wages increase most, which would make it impossible to detect the effects of trade liberalisation and SBTC on wages since these effects are identified by changes at the industry level over time. There are several reasons why workers can move more easily across firms within industries than across industries. Labour legislation as well as housing and family ties can severely limit the possibility of labour mobility across sectors in the short and medium run (Goh and Javorcik, 2007). Even in the presence of these constraints, workers are still able to move across firms within industries if sectors are geographically clustered, since all firms belonging to any given industry are located close to each other, or if workers are required to have industry-specific skills, since it takes time and money to acquire the skills needed in a particular sector. The descriptive evidence provided in the previous section seems to confirm this short-run labour immobility as it shows that a high percentage of the changes in the relative demand for skilled labour are within industries rather than across them over the 1984-1990 period.

The identification strategy in this paper is based on an instrument, the relative price of M&E in the US, which varies across industries at 3-digit level, but is the same for all plants within an industry. The information available on tariff rates on final good and inputs is also such that these vary at the 3-digit industry level. This implies that it is natural to firstly analyse changes in relative and real wages at the 3-digit industry level using the instrumented within-industry variance of the equipment-labour ratio and tariff rates as controls. However, the paper also provides results based on regressing real and relative wages at the plant level on both plant- and industry-level variables. In these regressions, it is possible to study the impact of SBTC on wages by including both the instrumented within-industry variance of the equipment-labour ratio and more standard plant-level measures of SBTC, such as royalties paid on new technologies and M&E imports (see Chennells and Van Reenen, 1999). When using plant-level measures of SBTC, the fact that the unit of observation in the dataset is a plant rather than a firm poses problems of identification because firms may re-organise production among the plants they own.

At the industry level, the set of equations to be estimated is:

$$\ln q_{i,t} = \alpha_0 + \alpha_1 \ln z_{i,t} + \alpha_2 \ln(1 + n_{i,t}) + y_t + \mu_i + \upsilon_{i,t} \qquad (3)$$

$$\ln c_{i,t} = \beta_0 + \beta_1 \ln \hat{q}_{i,t} + y_t + \nu_i + \upsilon_{i,t} \qquad (4)$$

$$\omega_{i,t} = \gamma_0 + \gamma_1 o_{i,t} + \gamma_2 \ln \hat{c}_{i,t} + \gamma_3 h_{i,t} + \gamma_4 u_{i,t} + y_t + \eta_i + \epsilon_{i,t}, \qquad (5)$$

where $\omega_{i,t} = \frac{w_{s,i,t}}{\bar{p}_{s,t}} \frac{\bar{p}_{u,t}}{w_{u,i,t}}$. The last equation (5) differs slightly when applied to the real wages of skilled and unskilled workers:

$$rw_{j,i,t} = \gamma_0 + \gamma_1 o_{i,t} + \gamma_2 \ln \hat{c}_{i,t} + \gamma_3 h_{i,t} + \gamma_4 u_{i,t} + y_t + \eta_i + \epsilon_{i,t}, \qquad (6)$$

where $rw_{j,i,t} = \frac{w_{j,i,t}}{\bar{p}_{j,t}}$.

In this econometric model, the first two stages (equations (3) and (4)) are based on regressing the within-industry variance of the equipment-labour ratio, c, which is the proxy for SBTC, on the predicted values obtained from a regression of the relative price of M&E in Mexico, q, on the relative price of M&E in the US, z, and on the tariff rates on inputs, n. The variables in these regressions are in natural logs since the first equation follows from $q = z \cdot (1+n)$, which is easily transformed into $\ln q = \ln z + \ln(1 + n)$. In the last stage, an unlogged specification seems to fit the data best.

In the industry-level panel regressions, the dependent variables in the last stage (equations (5) and (6)) are the ratio of skilled to unskilled wages, $\omega_{i,t}$, and real wages of both skilled and unskilled workers, $w_{j,i,t}/\bar{p}_{j,t}$ for $j = s, u$, where s denotes skilled workers, u unskilled workers, i industries (*ramas*) and t year.

The independent variables in the last stage are trade liberalisation, o, measured by sector-specific production-weighted average tariff rates on final goods, and SBTC, c, proxied by the predicted intra-industry dispersion of the equipment-labour ratio for industry i at time t. This is obtained from the predicted values of the second stage regression.

Other controls need to be included in the analysis, which may also have differing effects depending on whether skilled or unskilled wages are analysed. Goh and Javorcik (2007) show the importance of including an indicator of the amount of competition among firms in a specific sector, as measured by the normalised Herfindahl-Hirschman Index, h. It is arguable that, in a specific-factors model, where one or both types of labour are imperfectly mobile across sectors, firms that have large market power in a specific sector might also have large market power in the acquisition of the specific inputs required for that sector, such as specific labour, with a direct effect on wages. It is also likely that this effect will be influenced by the bargaining power that workers have in that sector, which can be measured by the degree of unionisation in each sector, u, because any monopoly rent will need to be shared between a firm and its workers, which will have an effect on wages. The degree of unionisation is also a proxy for labour market conditions and the possible difficulties in hiring and firing workers, which also have a direct effect on wages (Fairris and Levine, 2004). All regressions include time dummies to control for economy-wide changes that also have affected wages. Among these economy-wide changes there are not only exchange rate movements and minimum wage legislation, but also additional effects of trade liberalisation and SBTC that cannot be identified using the present strategy due to some labour mobility. Therefore, the effects of trade liberalisation and SBTC found in the next section are likely to be a lower bound.

The above set of equations will be estimated by means of two-stage least squares (i.e. predicted values from the initial stage are used as regressors in the following stage instead of the actual values of the endogenous variables) extended to traditional panel data estimators, such as pooled OLS, random effects and fixed effects.

At the firm level, the following equations are estimated for relative and real wages:

$$\omega_{k,i,t} = \gamma_0 + \gamma_1\omega_{k,i,t-1} + \gamma_2 \ln \hat{c}_{k,i,t} + \gamma_3 o_{i,t} + \gamma_4 l_{i,t} + \gamma_5 m_{k,i,t} + y_t + \eta_k + \epsilon_{k,t} \quad (7)$$

$$rw_{k,j,i,t} = \gamma_0 + \gamma_1 rw_{k,j,i,t-1} + \gamma_2 \ln \hat{c}_{k,i,t} + \gamma_3 o_{i,t} + \gamma_4 l_{i,t} + \gamma_5 m_{k,i,t} + y_t + \eta_k + \epsilon_{k,t}. \quad (8)$$

In these firm-level panel regressions, the dependent variables are the same as in the industry-level regressions. As mentioned earlier, these regressions use additional measures for SBTC, c. The industry-level proxy for SBTC will be the within-industry variance of the equipment-labour ratio, while the firm-level proxies for SBTC will be royalties paid on new technologies and M&E imports. The within-industry variance of the equipment-labour ratio is obtained from the predicted values of the first two stages as with the industry-level panel regressions.

Tariff rates on final goods, o, account for trade liberalisation in the same way as in the industry-level regressions. The other industry-level regressors (l), i.e. the normalised Herfindahl-Hirschman Index and the degree of unionisation, are also included in these regressions. Regarding firm-level controls (m) to be included, the literature review by Chennells and Van Reenen (1999) suggests several variables. These will be the lagged dependent variable, dummies for firms' size based on total employment, the ratio of total capital to labour, the share of output of each firm in its 3-digit industry and the value of exports. Including the lagged dependent variable means that traditional panel data estimators are subject to dynamic panel bias (Roodman, 2009). Given that the number of observations is large, the preferred estimator at the firm level is system GMM.[7]

6 Econometric analysis

6.1 Results at the industry level

Table 7 reports the results for equations (3)-(5). The first three columns report the results of regressions using the basic POLS estimator while the last three report the IV-FE regressions. The first set of regressions is reported to provide

[7] The number of groups in the industry-level regressions is only 46, which is too small for system GMM to give consistent estimates and, therefore, it is not used in the industry-level analysis.

a baseline even though these estimates are inconsistent. The Hausman IV test always rejects the null hypothesis, which implies that the IV estimator is consistent. The AR test and the Cragg-Donald statistic show that there should not be an issue of weak instruments, although the Cragg-Donald statistic is slightly lower than the conventionally accepted value of 10. The Breusch-Pagan LM test rejects the null hypothesis of no serial correlation, implying that IV-RE is preferred to IV-POLS. However, the IV-RE estimator, whose results are not reported, also appears inconsistent since the Hausman FE test rejects the null hypothesis that the coefficients of IV-RE and IV-FE are similar. Therefore, the following discussion of the results is based on the results from the IV-FE regressions, which seem most likely to yield consistent estimates.

The coefficients for the IV-FE regressions reported in columns 4-6 are significant as a whole, as evidenced by the F statistics. In the first stage, the dependent variable is the relative price of M&E in Mexico. As can be seen in column 4, both the relative price of M&E in the US and tariff rates on inputs have a positive and significant effect on the price in Mexico. This is consistent with both intuition and theory given that most of the technology in Mexico either comes from the US in the form of imported M&E or is produced locally based on the design of models from the US. The size of the coefficients is easily interpretable since these regressions include two-way fixed effects and all the variables are in natural logs. If the relative price of M&E in the US decreased by about 1 percent or tariff rates on inputs went down by about 4 percent, the relative price of M&E in Mexico would also decrease by approximately 1 percent.

In the second stage, the dependent variable is the within-industry variance of the equipment-labour ratio, a proxy for SBTC. Column 5 shows that the predicted

Table 7: The effects of trade and SBTC on wage inequality at industry level

Dep. var.	$\ln pmex$	$\ln varel$	ws/wu	$\ln pmex$	$\ln varel$	ws/wu
Estimator	POLS	POLS	POLS	FE	IV-FE	IV-FE
$\ln pus$	-0.10			1.06		
	(0.14)			(0.35)***		
$\ln(1 + tari)$	0.30			0.25		
	(0.13)**			(0.11)**		
$\ln pmex$		-2.62			-9.53	
		(1.17)**			(2.85)***	
$\ln varel$			-0.02			0.15
			(0.01)**			(0.08)*
$taro$			0.36			-0.41
			(0.19)*			(0.11)***
$nhhi$			-0.53			0.69
			(0.15)***			(0.34)**
$union$			0.73			0.07
			(0.14)***			(0.35)
$constant$	-0.09	-11.34	1.99	-0.30	-11.89	3.95
	(0.03)***	(0.29)***	(0.51)***	(0.07)***	(0.24)***	(0.97)***
Year dummies	yes	yes	yes	yes	yes	yes
No. obs.	276	276	276	276	276	276
R^2	0.34	0.02	0.45	0.25	0.04	0.19
F statistics	32.76***	0.94	21.59***	106.42***	3.22***	117.44***
Breusch-Pagan test				454.98***	594.20***	372.39***
Hausman (FE test)				4.48	0.01	14069.9***
Hausman (IV test)					45.93***	254.16***
AR Wald test (χ^2)					13.84***	3.79**
Cragg-Donald stat.					7.40	8.37

Notes: Robust standard errors are shown in parenthesis. One, two and three asterisks indicate coefficients significantly different from zero at 10%, 5% and 1% level respectively.

values for the relative price of M&E in Mexico from the first stage have a negative and significant effect on this variance and that its size is such that a decrease of 1 percent in the relative price of M&E leads to an increase in the within-industry variance of the equipment-labour ratio by 9.5 percent. This is consistent with the model of Caselli (2010) where it is argued that as the price of M&E decreases, due to exogenous technical progress abroad or a decline in tariffs, the demand for M&E by more efficient increases and, due to its complementarity, so does the relative demand for skilled workers. This shows up in the data as an increase in the within-industry variance of the equipment-labour ratio, which is used as a proxy for SBTC

In the last stage, the ratio of skilled to unskilled wages (wi) is regressed on tariff rates on final goods and the predicted values from the second stage, which represent SBTC, as well as other regressors to control for other industry characteristics. Column 6 shows that both SBTC and trade liberalisation, i.e. lower output tariffs, have a positive and significant effect on the skill premium. The significant sign on the trade liberalisation variable implies that workers' wages are, at least partially, determined at the industry level and do not tend to equalise across sectors, as under perfect labour mobility. Thus, a specific-factors model of trade fits the data better, possibly due to the short-run nature of the dataset. On the other hand, the fact that the sign is negative implies that skilled workers gained relative to unskilled workers following the trade liberalisation. This is possibly due to the fact that Mexico was skill abundant relative to the world average during this period, but it is also likely that trade liberalisation increased the relative demand for skilled workers through rises in productivity, especially in more efficient and skill-intensive firms.

In terms of the size of the effect, it is possible to calculate the "direct" effect of trade liberalisation through a decrease in tariff rates on final goods by 20 percentage points, the "induced SBTC" effect through a decrease in tariff rates on inputs by 11 percentage points, which together match the extent of trade liberalisation occurred in Mexico between 1985 and 1990, and the effect of exogenous SBTC measured by the decrease by 0.006 points in the relative price of M&E in the US. The combined effect of these three shocks can explain about one quarter of the 0.7 points by which the skill premium increased during this period. While most of the overall effect is due to exogenous and trade-induced SBTC, trade liberalisation for final goods also plays a role. These results confirm the theoretical findings in Caselli (2010).

Regarding the other controls, a decrease in overall competition, i.e. an increase in the HHI, seems to have increased wage inequality, although by a small amount. Finally, the year dummies, also contribute significantly to the large increase in the skill premium since they show that relative wages on average increased by 0.5 points between 1985 and 1990. This may be due, among other things, to the decrease in the real value of the minimum wage (Bosch and Manacorda, 2010). However, it may also be due to the additional effects of trade liberalisation and SBTC that cannot be identified using the present strategy due to some labour mobility. Therefore, trade liberalisation and SBTC are likely to have contributed to more than one quarter of the increase in the skill premium observed in Mexico during 1984-1990.

Table 8 reports the results of the regressions for skilled and unskilled real wages. In these regressions, equation (5) is replaced by equation (6) in the last stage and thus only the estimates from the last stage are reported. Two interesting results are revealed by these regressions. First, the instrumented within-industry variance in the equipment-labour ratio is significant only in the equation for skilled wages – and it is the only significant variable besides the year dummies. Therefore, SBTC has a positive effect on skilled wages as it leads to higher demand for skilled workers.

Second, it seems that this econometric model cannot explain changes in unskilled wages over this period, since only the year dummies are significant in the

Table 8: The effects of trade and SBTC on skilled and unskilled wages at industry level

Dep. var.	*ws*	*ws*	*wu*	*wu*
Estimator	POLS	IV-FE	POLS	IV-FE
$\ln varel$	2.92	10.81	2.01	-1.62
	(0.97)***	(6.06)*	(0.43)**	(2.27)
taro	15.61	-0.59	2.10	1.07
	(15.81)	(9.75)	(7.32)	(2.86)
nhhi	-29.72	4.09	-2.50	-14.77
	(13.59)**	(22.84)	(5.55)	(9.03)
union	65.22	30.34	15.16	1.36
	(15.98)***	(23.63)	(7.16)**	(9.35)
constant	116.99	208.76	73.31	34.22
	(13.91)***	(69.32)***	(6.36)***	(25.97)
Year dummies	yes	yes	yes	yes
No. obs.	276	276	276	276
R^2	0.27	0.10	0.30	0.17
F statistics	9.51***	29.10***	15.62***	54.06***
Breusch-Pagan LM test		503.92***		539.71***
Hausman (FE test)		238.03***		12.96***
Hausman (IV test)		21.71***		0.25
AR Wald test		4.53**		0.32
Cragg-Donald statistic		8.37		8.37

Notes: Robust standard errors are shown in parenthesis. One, two and three asterisks indicate coefficients significantly different from zero at 10%, 5% and 1% level respectively.

last regression as they show a decrease in average unskilled real wages during 1985-1990. This could be due to the fact that while skilled workers do not move perfectly across sectors (one of the assumptions necessary for the identification strategy used here) because they possess both general and sector-specific skills, unskilled workers are more mobile across sectors. Therefore, differences in unskilled real wages across sectors simply reflect some constant compensating differentials, while changes over time reflect economy-wide trends that are picked up by time dummies. This is consistent with the previous evidence pointing towards a specific-factor model. It also seems to be consistent with some of the findings by Cragg and Epelbaum (1996).

6.2 Results at the firm level

Having analysed the effects of SBTC and trade liberalisation on relative and real wages at the industry level, the following section moves on to the econometric analysis at the firm level. The sample used is smaller because information on exports and M&E imports are only available from 1986 onwards, but additional regressions that exclude these variables and include a larger sample do not show any qualitative difference in the results. Table 9 shows five regressions where the dependent variable is the skill premium at the firm level. Three different proxies for SBTC are used, i.e. the instrumented within-industry variance of the equipment-labour ratio, royalties paid on technology and M&E imports. Tariff rates on final goods at the industry level are also included. The other controls are divided between firm-level and industry-level variables. The estimator applied in all the regressions is system GMM, and thus the only difference among these regressions are the variables used to proxy for SBTC.

The Wald tests show that all regressions are significant as a whole, while the AR(1) and AR(2), the Arellano-Bond tests for serial correlation of the residuals, detect only first order serial correlation and reject the hypothesis of higher-order serial correlation. The Sargan test of overidentifying restrictions, which is not reported, is failed. It tests the overall validity of the GMM instruments where the null hypothesis is that the instruments are uncorrelated with some set of residuals. In all the regressions, the null hypothesis is always rejected. However the failure of this test is not worrisome, as noted by Meschi *et al.* (2009), because it is prone to weakness (Roodman, 2009) and it tends to become more significant as the number of observations grows large (Meschi *et al.*, 2009), as in this analysis.

Table 9: The effects of trade and SBTC on wage inequality at firm level

Dep. var.	*ws/wu*	*ws/wu*	*ws/wu*	*ws/wu*	*ws/wu*
SBTC proxies					
ln *varel*	0.02			0.02	0.02
	(0.01)***			(0.01)***	(0.01)***
royalties		0.06		0.07	0.07
		(0.03)*		(0.03)**	(0.03)**
eimp			0.02		0.02
			(0.01)		(0.01)
Firm-level variables					
$wi(-1)$	0.72	0.72	0.72	0.72	0.72
	(0.01)***	(0.01)***	(0.01)***	(0.01)***	(0.01)***
size (10-49 workers)	0.14	0.09	0.10	0.14	0.14
	(0.10)	(0.10)	(0.10)	(0.10)	(0.10)
size (50-99 workers)	0.31	0.31	0.32	0.31	0.31
	(0.09)***	(0.09)***	(0.09)***	(0.09)***	(0.09)***
size ($\geq$ 100 workers)	0.40	0.45	0.44	0.40	0.40
	(0.09)***	(0.09)***	(0.09)***	(0.09)***	(0.09)***
kl	0.79	0.81	0.98	0.64	0.66
	(0.57)	(0.57)	(0.57)*	(0.57)	(0.57)
soutput	0.50	0.23	0.18	0.51	0.50
	(0.35)	(0.36)	(0.36)	(0.35)	(0.34)
exports	-0.00	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Industry-level variables					
taro	-0.09	-0.12	-0.12	-0.09	-0.09
	(0.07)	(0.07)*	(0.07)*	(0.07)	(0.07)
nhhi	-0.18	0.59	0.55	-0.19	-0.17
	(0.28)	(0.33)*	(0.33)*	(0.28)	(0.28)
union	-0.05	0.14	0.12	-0.03	-0.02
	(0.09)	(0.12)	(0.12)	(0.09)	(0.09)
constant	0.81	0.52	0.53	0.80	0.79
	(0.12)***	(0.10)***	(0.10)***	(0.12)***	(0.12)***
Year dummies	yes	yes	yes	yes	yes
No. obs.	10070	10070	10070	10070	10070
Wald test	8418.35***	8456.13***	8352.84***	8544.27***	8559.31***
AR(1)	-28.61***	-28.31***	-28.47***	-28.53***	-28.55***
AR(2)	-1.19	-1.18	-1.19	-1.16	-1.14

Notes: The dependent variable is the skill premium in all regressions. Robust standard errors are shown in parenthesis. One, two and three asterisks indicate coefficients significantly different from zero at 10%, 5% and 1% level respectively.

The first three rows show the coefficients on the variables that proxy SBTC. In the three regressions where it is included, the log of the within-industry variance of the equipment-labour ratio is always positive and significant, which confirms the industry-level result that SBTC leads to an increase in the skill premium, although the magnitude of the coefficient is now smaller. Royalties paid for the use of licensed technologies are also always positive and significant, although only at the 10% level when they are included on their own. The magnitude is such that an increase in royalties spending by one standard deviation in 1990 increases the skill premium by 0.02. While this may seem small, it is important to notice that the difference between minimum and maximum spending on royalties is about 30 standard deviations. Both the log of the within-industry variance of the equipment-labour ratio and spending on royalties remain positive and significant when added together and in conjunction with M&E imports, which have a positive sign but are never significant. This indicates that firms in industries in which the relative price of M&E has decreased pay higher relative skilled wages, as in Caselli (2010), but within all industries firms that spend more on technology also pay even higher relative skilled wages. This seems to show that spending on M&E and spending on royalties for the use of licensed technologies are ways to invest in different types of technology. The next set of regressions, with skilled and unskilled wages as dependent variables, sheds more light on this issue.

Regarding the other variables, the lagged skill premium is always positive and significant and the size dummies indicate that larger firms pay higher relative skilled wages, even after controlling for the capital-labour ratio, the share of output in the 3-digit industry and exports. Of the industry-level variables, only the tariff rate on final goods is significant, although only at the 10% level and only in those specifications where the log of the within-industry variance of the equipment-labour ratio is not included. The sign is always negative, which agrees with the results at the industry level that liberalisation of tariff rates on final goods leads to an increase in the skill premium.

Table 10 shows six regressions, in which the dependent variable is either real skilled wages (first three columns) or real unskilled wages (last three columns). As with the regressions for the skill premium, each regression includes one of three different proxies for SBTC and tariff rates on final goods at the industry level as well as all other firm- and industry-level controls. In all the regressions, the estimator used is system GMM.

The Wald tests show that all regressions are significant as a whole. In the first three regressions, in which the dependent variable is real skilled wages, the AR(1) and AR(2) tests detect only first-order serial correlation and reject the hypothesis of serial correlation of higher order. In the last three regressions, in which the dependent variable is real unskilled wages, these tests detect both first- and second-order serial correlation, but reject serial correlation of higher order. Hence, the system GMM estimator was implemented by using second, third and fourth lags of the dependent variable as instruments (Meschi *et al.*, 2009). The Sargan test of overidentifying restrictions is always rejected, but, as argued in the discussion of the regressions for the skill premium, the failure of this test is not worrisome.

Starting from the regressions for real skilled wages, the variables proxying for SBTC are all positive and significant, which confirm the findings in the industry-level regressions. In particular, firms that import M&E also pay higher real skilled wages, which can be caused by the fact that skilled workers and M&E are complementary in production, as in the model of Caselli (2010). However, the size of the effect is much smaller than in the case of spending on royalties, possibly

Table 10: The effects of trade and SBTC on skilled and unskilled wages at firm level

Dep. var.	*ws*	*ws*	*ws*	*wu*	*wu*	*wu*
SBTC proxies						
$\ln varel$	0.80			-0.70		
	(0.24)***			(0.10)***		
royalties		23.22			6.87	
		(1.32)***			(0.55)***	
eimp			1.13			-2.06
			(0.51)**			(0.41)***
Firm-level variables						
$ws(-1)$	0.10	0.11	0.10			
	(0.00)***	(0.00)***	(0.00)***			
$wu(-1)$				0.11	0.11	0.11
				(0.00)***	(0.00)***	(0.00)***
size (10-49 *l*)	21.71	21.45	21.26	3.00	5.48	4.68
	(3.71)***	(3.72)***	(3.71)***	(2.01)	(2.01)***	(2.02)**
size (50-99 *l*)	34.43	33.82	33.82	-1.54	-0.71	-1.15
	(3.59)***	(3.60)***	(3.59)***	(1.98)	(1.97)	(1.98)
size ($\geq$ 100 *l*)	45.35	45.24	44.93	5.65	2.59	3.24
	(3.54)***	(3.54)***	(3.53)***	(1.89)***	(1.89)	(1.90)*
kl	219.22	218.30	230.74	101.67	104.45	106.69
	(22.22)***	(22.15)***	(22.02)***	(9.15)***	(9.06)***	(9.17)***
soutput	261.22	257.45	275.23	69.69	80.15	86.32
	(15.59)***	(15.35)***	(15.27)***	(5.21)***	(5.21)***	(5.19)***
exports	0.49	0.34	0.47	0.38	0.32	0.36
	(0.05)***	(0.05)***	(0.05)***	(0.02)***	(0.02)***	(0.02)***
Industry-level variables						
taro	-28.46	-26.71	-27.68	-18.38	-15.90	-16.35
	(2.64)***	(2.62)***	(2.62)***	(1.12)***	(1.12)***	(1.13)***
nhhi	-78.83	-82.12	-83.30	0.21	-31.93	-27.10
	(6.08)***	(5.96)***	(5.98)***	(4.80)	(5.51)***	(5.51)***
union	68.18	66.96	68.15	24.89	8.00	8.87
	(2.57)***	(2.56)***	(2.55)***	(1.64)***	(2.24)***	(2.27)***
constant	65.47	56.17	56.64	26.60	41.28	40.87
	(4.42)***	(3.51)***	(3.50)***	(2.26)***	(1.97)***	(1.99)***
Year dummies	yes	yes	yes	yes	yes	yes
No. obs.	10070	10070	1070	10070	10070	10070
Wald test	6075.96***	6737.60***	6285.58***	4922.47***	4355.90***	4108.63***
AR(1)	-21.11***	-21.28***	-21.17***	-19.49***	-19.62***	-19.93***
AR(2)	-0.81	-0.62	-0.80	-2.71***	-2.73***	-2.52***

Notes: Robust standard errors are shown in parenthesis. One, two and three asterisks indicate coefficients significantly different from zero at 10%, 5% and 1% level respectively.

highlighting the fact that imported M&E does not take into account that firms can purchase M&E from other domestic firms acting as importers or from domestic producers copying foreign or imported designs.

An interesting pattern can be observed in the regressions for real unskilled wages. While all coefficients are significant, those on the log of the within-industry variance of the equipment-labour ratio and on M&E imports are negative and that on spending on royalties for technology licenses is positive. Combined with the other results, this seems to suggest that M&E and royalties for technology licenses represent spending on different types of technology. In particular, M&E seems to be a technology that is complementary with skilled labour and a substitute for unskilled labour. Expenses on royalties seem to be a technology that is either complementary with both, although to different degrees, or more generally that increases the productivity of both types of labour.

Regarding the "direct" effect of trade liberalisation, firms in industries that face a larger decrease in tariff rates on final goods pay higher real skilled and unskilled wages, although the size of the coefficient is statistically larger for real skilled wages. This is consistent with the hypothesis that in this period Mexico was relatively skill abundant and, therefore, skilled workers would be favoured by a trade liberalisation. Moreover, it agrees with the hypothesis that trade liberalisation increases firms' average productivity, which favours all workers, although particularly skilled workers.

The other variables suggest that, as predicted, it is important to add lagged dependent variables for both skilled and unskilled wages. Larger firms pay higher real skilled wages, but the evidence is less clear-cut for real unskilled wages. The reason could be that unskilled workers have lower bargaining power as they can be more easily replaced. Firms with more capital per worker, that have a larger share of output in their 3-digit industry and that export also pay higher real skilled and unskilled wages.

6.3 Robustness checks

This section presents some robustness checks for the results presented above. Examining figure 3 discussed above and figures 4 and 5 in the Appendix, there are a few observations that are more likely to have contributed to the increase in the dispersion of wages across sectors. However, eliminating these few odd observations does not alter the results significantly. More worrisome is the possibility that wages at the sectoral level changed mainly due to a few outlier firms. In order to investigate the potential role of within-sector wage dispersion across firms, table 11 shows the same type of regressions already presented in tables 7 and 8, but it takes the median wage for each sector rather than the mean wage since the median is not affected by outliers. The table only shows the estimates of the last-stage regressions using fixed effects.

None of the signs of the coefficients change, compared to those estimated using mean sectoral wages, but there are still a few notable differences. While SBTC has a larger positive and significant effect on relative skilled wages, it no longer affects real skilled wages. On the other hand, the coefficient on tariff rates on final goods is still negative in the regression for relative wages although not significant, but it now becomes significant in the regression for real skilled wages. As before, SBTC and trade liberalisation do not seem to affect real unskilled wages, while less competition and more unionisation appear to have a significant effect. Even though the results confirm partially the role that SBTC and trade liberalisation

Table 11: The effects of trade and SBTC on median relative and real wages at industry level

Dep. var.	*ws/wu*	*ws*	*wu*
ln *varel*	0.21	0.08	-0.82
	(0.09)**	(5.61)	(2.12)
taro	-0.13	-13.67	0.94
	(0.12)	(7.07)**	(2.67)
nhhi	0.17	23.42	-94.05
	(0.37)	(22.33)	(8.45)***
union	0.33	7.85	18.37
	(0.38)	(23.14)	(8.75)**
constant	4.35	104.30	42.42
	(1.05)***	(64.25)	(24.30)*
Year dummies	yes	yes	yes
No. obs.	276	276	276
R^2	0.18	0.05	0.10
F statistics	65.21***	18.48***	72.16***

Notes: Robust standard errors are shown in parenthesis. One, two and three asterisks indicate coefficients significantly different from zero at 10%, 5% and 1% level respectively.

had in wage determination in Mexico during 1984-1990, they also show that these shocks had non-trivial effects on the dispersion of wages within each sector, as pointed out by Leonardi (2007).

With regard to different specifications, the results are not altered much when the last-stage regressions are estimated in logs. In none of the regressions estimated in the previous section is there a change in the signs of the coefficient when switching between the logged and unlogged specifications. In the logged specification, however, the coefficient on tariff rates on final goods in the last stage of the wage inequality regression is not significantly different from zero, while it is significantly different from zero in the unlogged specification.

The results provided are also robust to the use of different regressors. In particular, the estimates do not change significantly when the price of M&E relative to the price of structures is used instead of the price of M&E relative to the consumer price index for both the US and Mexico.

However, results at the industry level change when a different proxy for SBTC is used, as in the firm-level regressions, with the caveat that these additional regressions can only describe correlations and not causal relationships because both M&E imports and royalties spending for the use of licensed technologies are endogenous at the industry level. While M&E imports are not significant in any of the regressions and their inclusion does not alter the other estimates, the inclusion of royalties spending for technology licenses makes insignificant the estimate of the predicted values of the within-industry variance of the equipment-labour ratio. The coefficient on royalties is positive and significant in all the regressions (both for relative wages and for real wages), implying that sectors that spend more on technology upgrading tend to pay higher wages, especially to skilled workers. This confirms the firm-level findings that royalties for technology licenses represent a type of technology upgrading that is either complementary with both types of labour, although to different degrees, or more generally increases the productivity of both types. However, at sectoral level, it is not possible to distinguish this type of technology upgrading from that represented by M&E spending, which is expected to be complementary with skilled labour and a substitute for unskilled labour.

7 Conclusion

This paper analyses and quantifies the effects of SBTC, both exogenous and trade-induced, and of liberalisation of trade in final goods using firm-level data in Mexican manufacturing from 1984 to 1990. In order to produce consistent estimates and to avoid possible endogeneity problems, it builds an identification strategy based on the model of Caselli (2010). The effect of both exogenous and trade-induced SBTC on wages, and especially on wage inequality, appears substantial. The regressions show that trade liberalisation and changes in the relative price of equipment in the US, which induce exogenous SBTC in Mexico, can explain about one quarter of the increase in the skill premium during the period considered and that most of this effect is due to SBTC, although trade liberalisation for final goods also plays a non-trivial role.

The evidence presented is, therefore, consistent with the idea that as the price of equipment decreases, due to exogenous technical progress abroad or a decline in tariffs, the demand for it increases and, due to complementarity, so does the relative demand for skilled workers. These results are confirmed when the regressions are run at the firm level and use different firm-level proxies for SBTC. The pattern of absolute changes in real skilled wages can also be explained by SBTC and trade liberalisation, while the decrease in unskilled wages during this period can be explained mainly by SBTC, though in some specifications also by trade liberalisation. The evidence points towards a specific-factors model in which skilled workers have both general and sector-specific skills.

The recent increase in economic research on trade-induced SBTC has been confined mainly to theoretical work, with the exception of Bustos (2009) for the case of Argentina and Meschi *et al.* (2009) for the case of Turkey. It is hoped that the present study of wages in Mexican manufacturing to be followed by empirical studies of other developing countries in order to learn more about the channels through which exogenous and trade-induced SBTC works.

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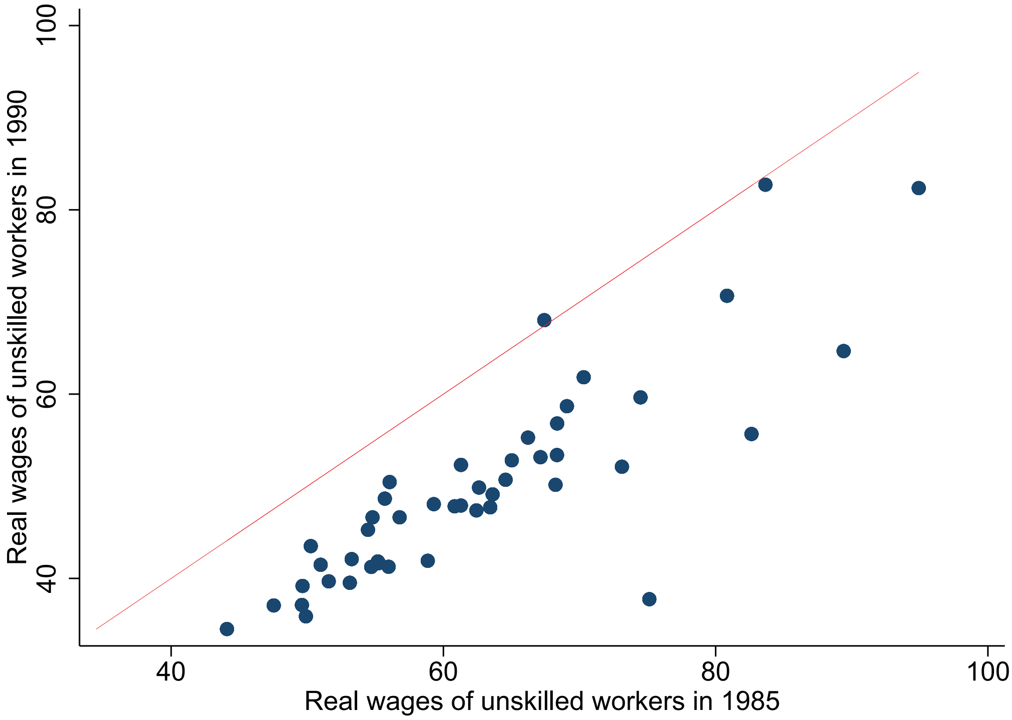
Appendix

A Additional figures

Figure 4: Real skilled wages at the 3-digit industry level in 1985 and 1990

Source: Own calculations based on *Encuesta Industrial Anual*, 1984-1990, INEGI.

Figure 5: Real unskilled wages at the 3-digit industry level in 1985 and 1990



Source: Own calculations based on *Encuesta Industrial Anual*, 1984-1990, INEGI.