Trade, Technology Adoption and the Rise of the Skill Premium in Mexico*

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ABSTRACT

This paper develops and estimates a structural model of trade and technology adoption with heterogeneous firms in a small open economy. In the model, monopolistically-competitive firms produce using two types of labor and face entry/exit, exporting and technology adoption decisions. The choice of technology affects the expected productivity realizations that a firm receives, with modern technologies producing high productivity draws at the expense of a higher per-period fixed cost of operation, in turn affecting the firm’s skill-intensity. Furthermore, the existence of a sunk cost of technology adoption makes the firm’s problem forward-looking. The model is estimated using a Simulated Method of Moments estimator, and fitted to the Mexican manufacturing sector after the trade liberalization reforms of 1985. Using the estimates of the structural model, I find that when import tariffs fall by 35 percent, the new steady state skill premium increases by 2.46 percent. When the sunk cost of technology adoption is also affected by the import tariff, the response of the skill premium increases to 4.2 percent

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1 Introduction

In the last two decades, middle-income developing countries have become more integrated with the world economy by slashing tariffs and scrapping quotas and other non-tariff barriers to trade. At the same time wage inequality within these countries has increased dramatically (Goldberg and Pavcnik, 2007, and Hanson and Harrison, 1999a document this relationship focusing mostly on the experience of Latin American countries). This fact is at variance with the prediction of the Stolper-Samuelson theorem which states that the real remuneration of unskilled workers should increase in countries relatively abundant in unskilled labor after opening up trade.

An alternative hypothesis suggested by Acemoglu (2002, 2003) is based on the stylized fact that firms in developing countries import a significant share of their machinery and equipment from skill-abundant developed countries (Eaton and Kortum, 2001). As the relative supply of skilled workers in developed countries (in particular in the US) has risen continuously since the 1970s, machinery and equipment (M&E) goods produced there have become more skill-complementary. When a developing country reduces its barriers to trade, it induces the adoption of skill-biased technology embodied in capital equipment. In this way, trade liberalization in an unskilled-labor abundant country can cause an increase in wage inequality. This paper explores the interplay between trade openness, technology adoption and the skill premium, estimating a structural dynamic model of an open economy with heterogeneous firms that make decisions about exporting, technology adoption and the skill intensity of their workforce. Using micro panel data from Mexico’s manufacturing sector I estimate the structural parameters that govern the technology adoption, skill intensity and export decisions for manufacturing firms. I then use my estimated model to quantify the impact of a unilateral trade liberalization on the skill premium. The work in this chapter is the first attempt to structurally estimate the impact that trade-induced technology adoption
has on wage inequality.¹

Using my econometric model I estimate the response of technology adoption and the skill premium to a unilateral trade liberalization of a similar magnitude to the one that took place in Mexico after 1985 (a 38% reduction in the price of the imported good in the model). I find that only a small fraction of plants in the middle of the productivity distribution find it profitable to switch from technology 1 to 2. When imports increase, the balanced trade condition implies that the value of exports increases in the same magnitude. The share of high-tech exporting firms in the economy rises from 29 to 32 percent, while firms in the lower tail of the productivity distribution contract (since they just serve the domestic market, and their sales have fallen) and become less skill-intensive or exit. Finally, firms that were using technology 2 before will see their total revenues fall, since the fall in their domestic profits exceeds the gain in foreign profits. Overall, the relative demand for skill increases producing an increase in the skill premium of around 2.4 percent. When I allow for the sunk cost of technology adoption to depend on import tariffs, the impact of trade liberalization on the skill premium is stronger, rising by 4.2 percent in the post-liberalization steady state.

My model builds on work by Hopenhayn (1992), Melitz (2003) and Yeaple (2005). The model is a dynamic model of industry evolution, where firms produce using skilled and unskilled labor, and are heterogeneous in their relative productivity of skilled labor. Productivity evolves according to an exogenous stochastic process, but unlike Hopenhayn (1992) or Melitz (2003) the mean of this process depends on the technology that a firm chooses to operate. Following Yeaple (2005) firms can choose between two technologies: a “traditional” technology characterized by high marginal costs, but low fixed costs (e.g. a traditional textile loom) and a “modern technology” that has low marginal costs but requires a high fixed cost of operation (e.g. a large-scale automatized sewing machine).² Higher productivity draws

¹Krusell et. al. (2000) study the role of falling prices of capital equipment in explaining the increase of wage inequality in the US using a structural estimation framework.
²My model is similar to Bustos (2005). In her model firms produce using two types of labor, and choose between two technologies characterized by the same trade-off between marginal and fixed cost. However, her
increase the relative marginal product of skilled labor, so firms substitute towards skilled labor\(^3\), becoming more skill-intensive as they grow. Only high-productivity firms (firms with sufficiently large sales) will find optimal to incur the higher per-period fixed cost of operating the modern technology. Hence, modern firms will be larger and more skill-intensive than firms using the traditional technology\(^4\).

Drawing from the literature on investment in physical capital, I assume that technology adoption is subject to sunk costs, which make firms adjust their technology infrequently. Thus the persistence of technology choice will be reflected in the skill mix that firms employ. Empirically, I identify plants that purchase imported machinery and equipment (M&E) as using the modern technology described above. Alvarez and Robertson (2004) using data from the 1995 National Survey of Employment, Salaries, Technology, and Training (ENESTYC) document that Mexican firms tend to adopt new advanced production technologies through imports rather than through R&D on-site.

Following Melitz (2003) I assume that exporting is costly. Firms selling abroad incur both a per-period fixed cost and an iceberg transport cost per unit of output. Hence, only high-productivity firms export. Trade liberalization will affect firms in different ways depending on the firm’s technology and productivity. A reduction on the variable cost of

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\(^3\)This is the case if skilled and unskilled labor are gross substitutes, that is when the elasticity of substitution between the two types of labor is greater than one

\(^4\)Doms et. al. (1997) observe a set of 17 advanced automation technologies used by manufacturing plants (i.e. numerically controlled machines, robots, programmable controllers, etc.) in a small set of industries (SICs 34-38) in the US. They find a monotonically increasing relationship between the number of technologies used in a plant and the education level of its workforce. They also find that in more technologically advanced plants, non-production workers’ share of employment and wage-bill are higher (controlling for size and capital-output ratio). Abowd et. al. (2007) find similar results for a broader sample of firms (including manufacturing, services, wholesale and retail trade) in the US. Fernandez (2001) studies in detail the retooling of a food processing plant in the Midwest. He finds that using a modern automated technology increased the complexity of tasks faced by production workers, and changed the composition of the production workforce in favor of high-skill occupations such as maintenance mechanics and electricians, which in turn commanded the largest increase in real wages, above those observed in the local labor market. For developing countries, Bustos (2005), Hanson and Harrison (1999a) and Pavcnik (2003) also find a positive correlation between the use of advanced technology (i.e. use of patents and licensing agreements, spending on computers and software) and skill intensity at the firm level.
trade will increase profits for existing and new exporters. If some of these firms were using the traditional technology previously, the higher volume of sales provides an incentive to incur the higher fixed cost of operation of the modern technology. As more productive firms expand, firms on the lower tail of the productivity distribution contract or exit the market altogether, reallocating workers across firms. These firms suffer a double whammy as import-competition shifts the demand from domestic to imported goods, and also because the increase in the relative demand for skilled workers pushes up the relative wage of skilled workers increasing costs for all firms.

Mexico is one the best case studies to understand the distributional effects of increased trade openness. Mexico went from being a very closed economy to become one of the most open countries in the world (trade as a fraction of GDP has increased from 20 percent in 1980 to 55 percent in 1995 and it has kept growing, up to 60 percent in 2006). At the same time, the skill premium, defined as the mean wage of skilled workers relative to the mean wage of unskilled workers increased by almost 30 percent between 1985 and 1994, remaining stable afterwards. These two trends are clearly depicted in Figure 1. To put it in perspective, it took more than twenty five years for a change of similar magnitude in the skill premium to take place in the United States.

A large body of literature has studied the relationship between wage inequality and trade openness from the perspective of the Hecksher-Ohlin-Samuelson (HOS) model and one of its main corollaries, the Stolper-Samuelson theorem (Esquivel and Rodríguez-López, 2003, Feliciano, 2001, Hanson and Harrison 1999b and Robertson, 2004 for the case of Mexico). However, these studies find a tenuous relationship between changes in trade barriers and wage inequality, since the correlation between changes in output prices and relative wages at the industry level is extremely low. Moreover, when ‘mandated wage’ equations (zero-profit

\footnote{The Stolper-Samuelson theorem predicts that changes in the relative price of final goods that take place after opening up to trade will shift production toward goods that use the country’s abundant factor more intensively. This in turn increases the relative demand for the abundant factor raising its real reward}
conditions derived from the HOS model) are fitted to the data, their estimates are very imprecise, grossly over-predict wage changes and have very low explanatory power. Other studies that have considered alternative hypotheses for the increase in wage inequality in Mexico include Feenstra and Hanson (1997) that examine the role of foreign direct investment, and Verhoogen (2008) which provides evidence that improved exporting opportunities increase within-industry wage dispersion due to product quality-upgrading at the plant level.

My model is related to a growing literature that studies the complementarities between investment and the decision to export at the firm level. These papers present evidence for several countries that suggests that exporting and productivity-enhancing investment are complementary actions for a firm. If trade openness does provide a strong incentive for firms to invest and absorb new technologies, then this channel might also be relevant to explain the rise of the skill premium observed in Mexico and other developing countries after they have liberalized their trade regimes.

The chapter is organized as follows: section 2 presents a succinct account of Mexico’s trade liberalization process, and a summary of previous research studying the evolution of wage inequality in Mexico. Section 3 presents the model and discusses its main implications. Section 4 describes the data used for the estimation, looks at the patterns of exporting and defines the proxy for technology adoption used in the estimation. Section 5 presents the estimation method, and discusses the resulting structural parameters. Section 6 presents the results of a counter-factual trade liberalization. Section 7 concludes and suggests avenues for

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6Attanasio et. al. (2004) and Hanson and Harrison (1999a, 1999b), argue that the increase in the skill premium can be explained using a HOS framework, since the industries that experienced the largest reductions in protection (and which should have experienced the largest changes in relative prices) were predominantly intensive in unskilled labor

7Aw et. al. (2007) find a positive and significant correlation between shocks that lead a firm to start exporting and shocks inducing investment in R&D/worker training in the Taiwanese electronics industry. Bustos (2005) finds that new exporters outspend existing exporters and domestic firms in technology-related investment in Argentina. Iacovone and Javorcik (2007) document a higher frequency of investment (in physical capital) spikes for Mexican manufacturing firms that will start exporting within the next two years, and Lileeva and Trefler (2007) find that Canadian plants that were induced to become exporters after the CUSFTA agreement increased their labor productivity and adoption of advanced manufacturing technologies.
future research. Appendix 7 provides a brief description of the computational algorithm used to compute the stationary equilibrium of the model in section 3, and Appendix 7 describes the data cleaning procedures.

2 Mexico in the 1980s

This section describes the main characteristics of the trade liberalization reform pursued by the Mexican government between 1985 and 1987. It also presents a brief account of the evolution of wage inequality in Mexico.

2.1 Mexico’s Trade Policy

Mexico, like many Latin American countries, pursued an import-substitution development strategy until the early 1980s. The level and scope of protection of domestic producers against foreign competition were very high even compared to other developing economies. Before the 1985 reform, 92 percent of domestic production was subject to import licenses, the maximum tariff was 100 percent ad-valorem and the production-weighted average tariff was 23.5 percent. At the beginning of the nineties, Mexico’s commercial regime was based on three main instruments: i) an ad-valorem tariff scheme, ii) official minimum prices for custom valuation, and iii) quantitative restrictions that included quotas and import licenses. There is a consensus that import licenses contributed the most to restrict trade flows (Kehoe, 1995, Ten Kate, 1992).

Following a spending spree in the late 1970s fueled by high oil prices and unrestricted bank lending, Mexico found itself in a dire situation as world interest rates began to increase, oil prices to tumble and credit to dry up. The balance-of-payments crisis that ensued led to a collapse of the peso, bank runs and a deep recession (Bergoing et. al., 2002, Lustig, 1998). Trade liberalization (apertura) marked the beginning of a series of structural reforms
carried by President Miguel de la Madrid intended to restore the growth of the Mexican economy. In July 1985, licenses for almost 3,600 tariff items were eliminated. The license coverage ratio fell from 92 to 47 percent between June and December of 1985. Initially, as import licenses were phased out, the government provided some compensation by increasing tariffs, so the average tariff went up from 23.5 to 28 percent during 1985. Furthermore, the government devalued the nominal exchange rate 20 percent, so the effective rate of protection was still relatively high during the early phase of the reform. In 1986 the maximum tariff rate was reduced to 50 percent, and a four-step calendar was announced that would result in a 0-30 percent tariff scale by October 1988. Moreover, in 1986 Mexico joined the General Agreement on Trade and Tariffs (GATT) deepening its commitment to market-oriented economic environment.

The trade liberalization reforms of the nineteen-eighties were concluded in 1987 with the enactment of the Economic Solidarity Pact (Pacto). The government, business organizations and labor unions agreed to speed up trade reform with the hope that stiffer competition from abroad would help to tame inflation. At the end of the year, the tariff structure was simplified from 16 tariff levels to 5, and a maximum tariff of 20 percent ad-valorem. At this point, the fraction of domestic output covered by import licenses was 23 percent, concentrated in a few key industries (such as petroleum refining, transport equipment and some agricultural commodities) and the production-weighted average tariff was 11 percent. The time path of reductions in tariffs and license coverage is illustrated in Figure 2. The process of trade liberalization was further deepened when Mexico jointly with the United States and Canada signed the North American Free Trade Agreement (NAFTA) in December of 1992 and coming into effect on January 1st of 1994.

The trade liberalization reforms had a huge impact on the pattern of trade of Mexico. First, the volume of trade has grown by leaps and bounds since 1985 and continues to do so, as seen in Figure 1. Second, the composition of exports changed radically as petroleum's
share of total exports fell from 75 percent in 1981 to 35 percent in 1990 as its relative price fell and manufactures increased their importance in total exports. Second, non-oil exports rose threefold from 5.5 to 16 billions of dollars between 1981 and 1990. Imports grew even more, as the real exchange rate depreciation of 1985-1986 was reversed after 1987 (Ten Kate, 1992). Finally, the importance of the United States as a trading partner became more pronounced as Mexico’s share of trade with the US rose from 56 percent in 1982 to 70 percent in 1992. This trend has continued after the implementation of NAFTA in 1994. As of 2006, exports to the US (including maquiladoras) account for 85 percent of all Mexican exports, while imports from the US constitute 51 percent of total imports (Banco de Mexico, 2007).

2.2 The Evolution of Wage Inequality in Mexico

Mexico is one of the least egalitarian countries in the world. Although its Gini coefficient fell consistently since the 1960s until the early eighties (Szekely, 1998), this pattern suddenly reversed after the debt crisis and the ensuing economic reforms. The Gini coefficient of wages increased from 0.43 in 1984 to 0.49 in 1992, a 13.9 percent increase in just eight years (Cortez, 2001). Other measures of dispersion show a similar pattern. Cragg and Eppelbaum (1996) report that the average real wage for individuals with some post-secondary schooling increased by almost 70 percent between 1987 and 1993, while for workers with some primary and some secondary schooling increased by 8 and 15 percent respectively. The ratio of non-production to production wages in manufacturing, another measure of skill premium, increased from 2.25 in 1988 to 2.75 in 1994 and 2.9 in 1996, remaining roughly constant afterwards. Thus by all accounts, a large and abrupt increase in wage inequality occurred in Mexico in the latter half on the eighties.

The fact that the large increase in the skill premium coincided with the trade liberaliza-

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8This pattern is observed all across the board. Esquivel and Rodríguez-López (2003) find that the skill premium increases for 46 out of 49 2-digit industries between 1988 and 1994. I observe the same pattern when comparing 1984 to 1990.
tion reforms has resulted in a large body of research that addresses possible linkages between increased trade openness and wage inequality in Mexico. At first glance, there is evidence suggesting trade has increased the skill premium. Feliciano (2001) finds that wage dispersion increased more in tradable (manufacturing) than non-tradable sectors (construction, services and government services) and also that changes in wages were more pronounced in industries that suffered the largest reductions in protection. However, trade liberalization was not the only major change taking place in this period. One of the most important components of the Pacto was a de-facto freeze of the minimum wage. This combined with an extensive privatization program and a substantial decline in unionization rates (Cortez, 2001) put downward pressure on real wages for workers in the lower end of the wage distribution, increasing wage inequality.

Employment appears to be much more stable than wages during this period. The employment share of manufacturing changed little during the period (on average 31%), and average hours for workers with different levels of education remained fairly constant as well (Feliciano, 2001), thus ruling out important shifts of employment out of the manufacturing sector as a determinant of the evolution of the skill premium. Sánchez-Paramo and Schady (2002) document a 34 percent increase in the relative supply of workers between 1987 and 1999. Implying that the relative demand for skilled workers had to increase more than the relative supply (this argument has been made before by Katz and Murphy, 1992 and Berman et. al., 1998 in support of skill-biased technical change explaining the increase of wage inequality in the US during the 1980s) to explain the increase in the skill premium. Cragg and Eppelbaum show that skill upgrading took place in both traded and non-traded sectors between 1987 and 1993 and that the returns to skill-intensive occupations such as professionals and administrators experienced the largest increases over the same period, while the wage premia for less educated occupations such as salespersons and transport workers experienced slower growth.
3 Model

In this section I develop a dynamic stochastic general equilibrium model of a small open economy in which firms make decisions regarding the adoption of new production technology and export participation. I will use the model to identify the impact of these decisions on the stationary equilibrium level of the skill premium (defined as the wage of skilled workers relative to unskilled workers) after a trade liberalization reform.

3.1 Preferences and Demand

Time is discrete and labeled $t = 0, 1, \ldots, \infty$. The economy is populated by a mass $L$ of individuals, a fraction $\lambda$ of which are skilled\(^9\). Each individual is endowed with one unit of time that is supplied inelastically. Individuals are risk-neutral and maximize the expected present discounted value of a consumption aggregate $C_t$,

$$E_0 \sum_{t=0}^{\infty} \beta^t C_t, \quad \beta \in (0, 1). \quad (1)$$

Individual income consists of labor income plus distributed profits from domestic firms. The consumption good is a CES aggregate of a continuum of domestically-produced varieties, $q_d(\omega)$ and a single imported variety, $q_f$,

$$C = \left( \int_{\omega \in \Omega} q_d(\omega)^\rho d\omega + q_f^\rho \right)^{\frac{1}{\rho}}, \quad \rho \in (0, 1), \quad \sigma_c \equiv 1/(1 - \rho). \quad (2)$$

where $\Omega$ denotes the set of domestically-produced goods. It is assumed that the elasticity of substitution among domestic varieties is the same as the elasticity of substitution between the foreign good and domestic goods. These preferences result in demand functions for

\(^9\)There are no productivity differences between skilled and unskilled workers. They simply are different factors of production (imperfect substitutes) from the perspective of firms.
variety $\omega$, and for the imported good of the form,

$$q_d(\omega) = \left( \frac{Y}{P} \right) \left( \frac{p_d(\omega)}{P} \right)^{-\sigma_c},$$

$$q_f = \left( \frac{Y}{P} \right) \left( \frac{p_f \tau_f}{P} \right)^{-\sigma_c},$$

where $Y$ is aggregate income, and $P$ is the ideal price index defined as,

$$P = \left[ \int_{\omega \in \Omega} p_d(\omega)^{1-\sigma_c} d\omega + (p_f \tau_f)^{1-\sigma_c} \right]^{\frac{1}{1-\sigma_c}}.$$  \hfill (4)

I assume that the economy is “small” with respect to the rest of the world in the following sense: consumers can buy the foreign good at a price $p_f \tau_f$, where $p_f$ is the world price of the good (which is set to be the numeraire) and $\tau_f > 1$ is an import tariff. Domestic producers in turn, face a foreign demand schedule $q_x(\omega) = A_x(p_x(\omega))^{-\sigma_c}$ for their variety, where $A_x$ is a parameter. Hence, this economy takes as given the price of imports and the demand schedules for its exports is the same as in Demidova and Rodríguez-Clare (2009).

### 3.2 Production

Firms operate either a traditional or a modern technology. Let $k \in \{1, 2\}$ index the technology used by a firm, with $k = 1$ denoting the traditional technology and $k = 2$ the modern one. Technology $k$ requires a per-period fixed cost of operation $f_k$, denominated in terms of output. I assume that the fixed cost of operating the modern technology is higher than that of the traditional technology, so $f_1 < f_2$. This might reflect higher maintenance costs as the complexity of tasks that workers need to perform increases when using advanced technologies, as noted by Fernandez (2001). The only input in production is labor, skilled and
unskilled. Firms produce according to the following production function:

\[ q = \left[l^\alpha + (zh)^\alpha \right]^\frac{1}{\alpha}, \quad \sigma_p \equiv \frac{1}{1 - \alpha} > 0. \quad (5) \]

where \( l \) and \( h \) denote unskilled and skilled labor input employed by the firm, \( \sigma_p \) is the elasticity of substitution between skilled and unskilled labor, and \( z \) is a firm-specific, skill-biased productivity index. Firm’s productivity follows an AR(1) processes with a mean \( z_k \) that depends upon a firm’s technology choice,

\[ \log(z_{t+1}) = z_k + \phi \log(z_t) + \varepsilon_{t+1}, \quad \varepsilon_{t+1} \sim N(0, \sigma_\varepsilon^2), \quad (6) \]

\[ |\phi| \in (0, 1), \quad z_1 < z_2. \]

Technology 2 results in higher productivity realizations on average\(^{10}\), but requires a higher per-period fixed cost of use relative to technology 1. If a firm wants to start using a different technology, it needs to incur a sunk cost that reflects the costs of retooling and adopting the new productive process\(^{11}\).

This characterization of technology results in a trade-off for firms between marginal cost (which depends inversely on productivity) and the fixed cost of operating a given technology. The higher productivity realizations that come from using technology 2 will make a firm bigger (in terms of employment) and also more skill-intensive, provided that skilled and unskilled labor are gross substitutes (Doms et. al., 1997, Hanson and Harrison, 1999a and Pavcnik, 2003, among others, find a positive correlation between size and the employment share of non-production workers). How responsive is skill intensity to productivity shocks crucially depends on how substitutable skilled and unskilled workers are in production. If the

\(^{10}\)I assume that the persistence and variance of innovations are the same for both technologies.

\(^{11}\)This representation of the innovation decision is similar in spirit to the one used by Costantini and Melitz (2007) where firms face a one-time opportunity to obtain a high productivity draw which has long-lasting effects on productivity. On the other hand, in Atkenson and Burnstein (2007) firms repeatedly invest in R&D controlling the drift of a geometric Brownian motion process that governs productivity.
elasticity of substitution between the two types of labor is very high, even small productivity shocks will result in large changes in the relative demand for skilled workers at the firm level. At an aggregate level this will also imply that the skill premium will be highly responsive to aggregate shifts of the relative labor demand for skilled labor.

Firms are monopolistic competitors with market power in the good they sell but are price-takers in the labor market. Hence, the unit cost function for a firm is given by:

\[ mc = \left[ w_t^{1-\sigma_p} + \left( \frac{w_h}{z} \right)^{1-\sigma_p} \right]^{\frac{1}{1-\sigma_p}}, \]  

which is decreasing in firm-specific productivity, \( z \). The firm’s decision problem can be partitioned in a static profit maximization, in which a firm chooses its optimal price(s) to charge, labor input and whether or not to export. and a dynamic decision regarding technology adoption. I describe the static problem first. Figure 6 describes the sequence of actions that take place in the model.

**Static Problem**

Incumbent firms can sell their output at home or they can export it, although exporting is costly. A firm that in a given period decides to sell abroad faces two costs: 1) A (per-period) fixed cost \( f_x \) of participating in the export market (denominated in terms of output as in Yeaple (2005)) and 2) variable costs that take the form of iceberg transportation costs, so that for one unit of a good to arrive at its final destination, \( \tau_x > 1 \) units must be shipped. Since production exhibits constant-returns-to-scale, firms independently maximize the profits from domestic and foreign sales. Therefore, firms set their prices at the usual constant markup
over marginal cost

\[ p_d = \left( \frac{\sigma_c}{\sigma_c - 1} \right) mc, \quad (8) \]

\[ p_x = \tau_x p_d. \]

Every period a firm compares the potential profits from exporting with the participation cost in order to decide whether to export or not. Let \( \gamma \in \{0, 1\} \) denote the firm’s export decision, with \( \gamma = 1 \) meaning that the firm is exporting in the current period. The solution to this problem results in a cutoff rule for productivity, \( z_x \). Firms with current productivity above the cutoff will export. As soon as their productivity falls below \( z_x \), they stop servicing the foreign market. Hence, only the most productive firms will export. Given \( \gamma \), static profits net of exporting costs for Home firms are:

\[
\begin{align*}
\pi_d(k, z) &= YP^{\sigma_c - 1}\left[ \left( \frac{\sigma_c}{\sigma_c - 1} \right) mc(k, z) \right]^{1 - \sigma_c}, \\
\pi_x(k, z) &= A_x \left[ \left( \frac{\sigma_c}{\sigma_c - 1} \right) \tau_x mc(k, z) \right]^{1 - \sigma_c}, \\
\pi(k, z) &= \pi_d(k, z) + \max\left\{ \pi_x(k, z) - f_x mc(k, z), 0 \right\}.
\end{align*}
\]

Finally, the firm’s input demand is obtained by solving the following program taking the vector of wages \((w_l, w_h)\) as given

\[
\min_{l,h} w_l l(k, z) + w_h h(k, z) \quad (10)
\]

s.t.:

\[
[l^a + (zh)^a]^{\frac{1}{a}} = q_d(k, z) + \gamma(k, z)q_x(k, z).
\]
Dynamic Problem

A firm starts period $t$ with a given technology $k_t$, and a productivity level $z_{t-1}$, these are its state variables. At the beginning of the period, the firm draws $z_t$ and decides whether to continue producing or not (the scrap value of the firm is normalized to zero). Let $\chi(k, z) \in \{0, 1\}$ denote the exit policy rule, where $\chi(k, z) = 1$ denotes exit. An incumbent firm that stays in the market produces, decides whether to export or not, and finally chooses the technology that it will use in period $t + 1$. The dynamic programming problem of the firm is given by:

$$V(k, z) = \max \{0, V^C(k, z)\}.$$  \hfill (11)

$$V^C(k, z) = \max \left\{ \pi(k, z) - f_k mc(k, z) + \beta \int_{z'} Q_k(z, z') V(k, z') dz', \quad \pi(k, z) - [f_k + S_{\tilde{k}}] mc(k, z) + \beta \int_{z'} Q_{\tilde{k}}(z, z') V(\tilde{k}, z') dz' \right\}. \hfill (12)$$

where $S_{\tilde{k}}$ is the sunk cost that a firm has to pay when switching from technology $k$ to $\tilde{k}$ and $Q_k(z, z')$ is the transition density for productivity when using technology $k$. As I mentioned before, it is assumed that technology 2 requires a higher per-period fixed cost of operation than technology 1, that is $f_1 < f_2$. The solution to this problem produces two policy rules: for technology, $K(k, z) \in \{1, 2\}$, characterized by two productivity cutoffs, $z_{\text{out}} < z_{\text{in}}$ and exit, $\chi(k, z) \in \{0, 1\}$, which is also characterized by a productivity cutoff $z_{\text{exit}}(k)$, below which firms decide to exit the market. A firm currently using technology 1 will start using technology 2 if its current productivity draw exceeds $z_{\text{in}}$. However, a firm that already operates technology 2 will continue to use it even if its productivity falls below $z_{\text{in}}$, since it takes into account the option value of receiving higher productivity draws in the future without having to pay the adoption cost $S_2$.

\[12\text{In the estimation I assume that firms do not need to pay any adoption cost when switching from technology 2 to 1, that is, } S_1 = 0\]
Every period there is a continuum of ex-ante identical potential entrants. The only barrier to entry is a sunk entry cost $S_E$ (denominated in terms of output). When potential entrants pay the sunk entry cost, they draw their initial value of $z$ from a common distribution $G_E(z)$, which is assumed to be log-normal with mean, $\mu_E - \sigma^2_E/[2(1-\phi^2)]$, and variance, $\sigma^2_E/(1-\phi^2)$. The value of entry, net of entry costs is:

$$V^E = \int z V(1, z)dG_E(z) - mc(1, z)S_E. \quad (13)$$

I assume that all entrants start using technology 1, so they will be on average smaller than incumbent firms as empirical evidence suggests.

### 3.3 Stationary Equilibrium Definition

A recursive competitive equilibrium for the model consists of a value function for firms $V^C(k, z)$, a list of decision rules for pricing $\{p_d(k, z), p_x(k, z)\}$, exporting $\gamma(k, z)$, labor demand $\{l(k, z), h(k, z)\}$, exit $\chi(k, z)$ and technology adoption $K(k, z)$; a post entry/exit distribution of firms across technologies and productivity $\mu(k, z)$ and a set of aggregate variables: aggregate income $Y$, ideal price index $P$, mass of incumbents $M$ and entrants $M_E$ and a vector of wages $\{w_l, w_h\}$ such that:

1. $V^C(k, z)$ solves the dynamic problem of the firm. Decision rules are optimal.

2. Labor demand equals labor supply for both types of workers

3. The flow of entrants balances the flow of exiting firms

4. Equilibrium good prices are consistent with the aggregate price index $P$

5. Aggregate income $Y$ equals aggregate profits plus total labor income

6. Free entry
Discussion

Several combinations of technology use and exporting status are possible depending on the relative position of the exporting and technology adoption cutoffs in the productivity distribution (for instance, if the productivity cutoff for exporting is too high, it might be the case that all firms that become exporters have first to adopt technology 2), which in turn depend on the relative size of the fixed costs of using each technology, the sunk cost of adopting technology 2 and the fixed cost of exporting. As firms with high productivity levels tend to export and use the modern technology, simulations of the model show that intermediate states such as exporting using technology 1 or not exporting using technology 2, tend not to be very persistent - firms quickly become high-tech exporters or low-tech domestic producers.

When the variable cost of trade that domestic firms face when selling abroad falls, sales for exporting firms (both existing and new) increase providing an incentive to adopt technology 2 as the higher fixed cost of operation can be spread over a higher volume of sales. In a stationary equilibrium with lower trade costs, the share of firms using the modern technology increases. Firms using technology 2 become larger and more skill-intensive at the expense of firms that use technology 1 which will contract or exit the market altogether.

If on the other hand what happens is that the economy pursues a unilateral trade liberalization, which reduces the price that consumers pay for imported goods, the demand for imports rises at the expense of the demand for domestic goods, reducing domestic profits for all local firms. Qualitatively, the response of firms will be similar as when exporting prospects improve: smaller, unskilled worker-intensive firms will contract and exit, while the most productive firms expand, as these firms reshuffle their sales from the domestic to the foreign market, thus maintaining the balanced trade condition. From an empirical perspective its important to notice the differences between the two scenarios, since in a large number
of cases, developing countries pursuing trade liberalization reforms do so in a unilateral fashion. In this case domestic exporters do not experience significant changes in the level of tariffs they face, since most of their exports are directed towards developed countries where tariffs are very low. This is certainly the case for Mexico\textsuperscript{13}, and for several Latin American countries as well. Quantitatively I find that since the response of exports is smaller after a unilateral liberalization, fewer firms adopt technology 2 and the skill premium rises by a smaller amount than in the first case.

4 Data

The data used in the paper comes from the Encuesta Industrial Anual (Annual Manufacturing Survey) produced by the Instituto Nacional de Estadísticas, Geografía, e Información (INEGI), the Mexican government statistical agency. After cleaning the data (the exact procedure is described in Appendix 7), I have a balanced panel of 1,913 plants for the period 1984-1990. For each plant I have information on the total number of obreros (blue-collar workers whose main activities include machine operation, production supervision, repair, maintenance and cleaning) and empleados (white-collar workers such as managers, administrators, professionals and salesmen), total number of hours worked for each type of worker, total remuneration, production, input use, investment in capital goods, including machinery and equipment imports, and exporting status (from 1986 onwards).

\textsuperscript{13}The NBER trade database shows that, from 1970 to 1992, Mexico’s annual average trade share with countries that were relatively skill abundant was greater than 90 percent throughout the period, including the United States and Canada (69 percent), Europe (16 percent), and Japan, Australia, and New Zealand (5 percent).
Exporting and Use of Imported Technology

Table 1 shows how export participation and the use of imported machinery and equipment (M&E) and materials experienced a dramatic increase over the second half of the 1980s. The patterns of openness for the manufacturing sector mirror the behavior of the aggregates for the whole economy shown in Figure 1. In 1986, 66 percent of the plants served only the domestic market and did not import any machinery and equipment, by the 1990, this group comprised 42 percent of the sample. At the same time, the number of plants that both export and use imported machinery doubled. The number of plants that export but do not import M&E increased by just 8 percent. Although the barriers faced by Mexican exporters were relatively low and did not change much during this period, one of the components of the macroeconomic stabilization program of 1985 was a 46 percent depreciation of the nominal exchange rate, which in turn resulted in depreciation of the real exchange rate of over one hundred percent, see Figure 3, providing a tremendous boost for exports\(^\text{14}\). At the same time, by the end of 1987 the price of machinery and equipment relative to consumer prices experienced a 30 percent fall which persisted until the Tequila crisis of 1994. This trend, which is presented in Figure 4, is very similar to what has been documented in the United States by Krusell et. al. (2000), but was also reinforced by a 55 percent tariff reduction.

As has been noted by the literature studying plant-level investment patterns (e.g Cooper and Haltiwanger, 2006), there is a great deal of inaction and spikes in investment rates: for 52 percent of the observations, the gross investment rate falls below 1 percent of the book value of capital stock, while at the same time, for 6 percent of plant-year observations an investment rate above 25 percent of the value of capital stock is observed. More importantly, 78 percent of these investment spikes involve the purchase of imported M&E. Hence, I identify a plant that starts importing machinery and equipment as adopting technology \(k = 2\) in the

\[^{14}\text{In fact, this real exchange rate depreciation, coupled with the very low price of oil prevailing in 1986 caused a sizeable reallocation towards manufacturing exports away from oil products.}\]
model\textsuperscript{15}. Similar definitions of technology adoption have also been used by Huggett and Ospina (2001) and Kasahara (2001).

**Relative Employment and Wages**

Table 3 shows the evolution of mean employment and hourly wages over the sample period. Between 1984 and 1990, the hourly remuneration for skilled workers increased by 20 percent, with most of the increase happening after 1988. Wages for unskilled workers fell by 7 percent over the same period. The two trends put together result in an increase in the skill premium of 31 percent in just six years, or a rate of growth of 4.6 percent per year, a dramatic rise in the skill premium. Importantly, the rise of the skill premium was not concentrated in a handful of industries, it took place across the board. The skill premium (measured as the ratio of the mean non-production worker wage relative to the mean production-worker wage) increased for 115 out 127 4-digit industries between 1984 and 1990, as show in Figure 7.

The pattern of employment is surprisingly stable during the period of study. In the sample, total employment increases by 17 percent, and white and blue-collar employment increase both by 13 percent. Mean employment share of non-production workers (a measure of skill intensity) remains stable at around 30 percent during the sample period. However, the wage-bill share of non-production workers increased by 15 percent.

Across the size distribution of plants, both exporters and plants importing M&E are about 18 percent more skill-intensive than domestic plants that do not use imported capital, this premium remains stable throughout the sample period for exporters while declining slightly for plants importing machinery. Moreover, similarly to the findings of Bustos (2005) and as predicted by the model in Section \textsuperscript{??}, new exporters show skill-upgrading before

\textsuperscript{15}Ideally knowing how important is imported M&E in the capital stock would allow me to better identify the plants that are using more advanced technologies, however this information is unavailable. Other indicators of use of advanced technology such as the use of advanced manufacturing technology and automatized processes are included in the ENESTYC survey which is available after 1992.
entering the export market\textsuperscript{16}, while the plants that stop exporting shift their employment towards non-skilled workers, as can be seen in Figure 5.

5 Estimation

The model presented in section 3 is estimated on a balanced panel of 1,913 Mexican manufacturing plants for the period 1984-1990, from the manufacturing survey described in section 4. I consider the period 1987-1990 as a post-liberalization stationary equilibrium of the model. The model is set to fit the size distribution of plants in the steady state with low import tariffs, since productivity differences are directly reflected in size (employment) differences. Other features that the model seeks to match are the frequency and intensity\textsuperscript{17} of exporting, use of imported technology, differences in skill intensity between exporting and non-exporting plants and the entry rates into exporting and use of imported technology\textsuperscript{18}.

The structural parameters of the model are estimated using a method of simulated moments (MSM) estimator. Given a vector of parameters $\theta$, the stationary equilibrium of the model is solved and policy rules for employment, exporting, exiting and technology adoption $\{l^*, h^*, \gamma^*, \chi^*, K^*\}$ are obtained. Using these policy rules, I simulate the behavior of a large number of plants, creating $S$\textsuperscript{19} simulated panel datasets $\{D_{it}(\theta)\}$. Taking averages over these simulations, I construct a vector of simulated moments,

$$\hat{m}(\theta) = \frac{1}{S} \sum_{s=1}^{S} m(D_{it}(\theta)). \quad (14)$$

\textsuperscript{16}Controlling for time and industry-specific variation and differences in capital stock.

\textsuperscript{17}Measured as the mean fraction of revenues accrued from exporting.

\textsuperscript{18}One problem that I face in the estimation is the fact that I do not observe entry and exit of plants in my sample. To circumvent this problem I used a dataset constructed by the Inter-American Development Bank from administrative records collected by the Instituto Mexicano del Seguro Social (IMSS) for the period 1994-2000. From this dataset, I obtain the relative sizes of entering and exiting plants as well as the mean entry rate used in the estimation.

\textsuperscript{19}The estimation procedure uses $S = 50$. 

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The estimated vector of parameters minimizes the log-differences between a set of simulated and sample moments:

$$\hat{\theta} = \arg \min_{\theta \in \Theta} \Psi = (\log(\hat{m}(\theta)) - \log(m))'[(1 + 1/S)\hat{\Sigma}]^{-1}(\log(\hat{m}(\theta)) - \log(m)).$$

(15)

where $m$ is the vector of moments calculated directly from the data, and $\hat{\Sigma}$ is the estimated optimal weighting matrix\(^{20}\). The objective function results from a complicated dynamic programming problem, hence is not smooth and presents multiple local minima. In order to deal with these issues, I use a stochastic pattern search algorithm to solve the problem in equation 15, and use several initial values for the estimated parameters.

There is a set of parameters that are determined out of the estimation routine. The discount factor $\beta$ is set equal to 0.939 to match the average real interest rate\(^{21}\) for the period 1982-2006, of 6.46 percent. The fraction of skilled workers in the economy is set equal to the mean share of non-production employment, 0.311. Given the CES demand system used, the ratio of domestic revenues to total variable cost is constant across firms, and equal to the markup charged by firms. The mean of this ratio for the post-liberalization period is 1.379, which implies a demand elasticity $\sigma_c = 3.634$. The price of the imported good faced by consumers $\tau_f$ is set to 1.05. The variable cost of exporting for Mexican firms is set to match the average U.S. tariff on dutiable goods imported from Mexico, 5 percent. Table 4 summarizes the parameter values fixed outside the estimation. Finally, the size of the economy $L$ is normalized to 1,000.

This leaves the following 12 parameters to be estimated by MSM:

$$\theta \equiv \{z_1, z_2, \phi, \sigma_\varepsilon^2, f_1, f_2, S_2, A_x, f_x, \mu_E, S_E, \sigma_p\}.$$  

(16)

\(^{20}\)The details on how the optimal weighting matrix is estimated can be found on Appendix 7.

\(^{21}\)Based on Certificados de la Tesorería de la Federación a 28 días, CETES bonds.
Where \((z_1, z_2, \phi, \sigma^2)\) determine the stochastic process for firm-specific productivity, \((f_1, f_2, S_2)\) are the fixed cost of operating and adopting each technology, \(A_x\) is the size of the foreign market, \(f_x\) is the fixed cost of participating in the export market in each period, and \(\sigma_p\) is the elasticity of substitution between skilled and unskilled labor.

Table 5 reports the moments used in the estimation. The parameters governing the decision to export \((A_x, f_x)\) are pinned down by the frequency and intensity of exporting: a larger foreign market induces more firms to export, and also leads exporters to sell a larger share of their output abroad. A higher \(f_x\) on the other hand reduces the number of firms engaged in exporting activities, but increases the share of exports in total revenues as the fewer firms that find profitable to export will seek to spread the large fixed cost over a larger volume of sales.

The second set of moments is based on the size distribution of plants in the post-liberalization steady state. In the model, all productivity differences are reflected in size (employment) differences. Fixed costs \(f_k\) and and the intercepts of the productivity processes, \(z_k\) determine the average size of incumbent firms, since higher fixed costs and higher productivity realizations result in larger firms in equilibrium. The difference between \(z_1\) and \(z_2\) and \(f_1\) and \(f_2\) are determined by the premium in skill-intensity and size between exporting and non-exporting plants (due to selection effects the largest firms become exporters), as well as by the share of firms importing M&E in steady state.

The elasticity of substitution between skilled (non-production) and unskilled (production) workers determines the responsiveness of skill-intensity to productivity innovations, given that labor supply is fixed in the model. If \(\sigma_p\) is large, firms that draw good productivity shocks become very large and highly skill-intensive, while firms that suffer bad draws will shrink and employ a large share of unskilled workers. Matching the share of plants in different size bins, and the employment dispersion helps me to identify \(\sigma_p\). The relative size of entrants and the mean entry rate (which is identical to the exit rate in the stationary equilibrium)
determine $\mu_E$ and $S_E$.

A set of dynamic moments allows me to identify the root of the auto-regressive process governing productivity which in turn will affect the persistence of skill-intensity, which is very high in the data. If productivity is highly persistent, in my model this would result in a highly persistent skill-intensity across firms (for a given elasticity of substitution), with large changes taking place only when firms switch technology. The dispersion of the size distribution helps me to identify the variance of productivity shocks. Finally, the sunk cost of adopting technology 2 is identified by the share of firms importing technology in the cross-section and the average rate at which plants start importing M&E.

**Point Estimates**

Table 6 reports the point estimates produced by the model. All the parameters with the exception of the elasticity of substitution are statistically significant. The elasticity of substitution between skilled and unskilled workers is estimated to be 1.41, although is not very precisely estimated as the other parameters in the model, it falls in middle of the range of estimates obtained for the US (between 1 and 2.2) estimated from macroeconomic data, and is very close to the preferred estimate found by Katz and Murphy (1992), 1.42.

The difference on average productivity for the two technologies is statistically significant. Plants that become sufficiently productive to start operating the modern technology become significantly bigger and more skill-intensive. On average, plants using technology 2 are 82 times larger than their counterparts using the high-marginal cost technology, and account for most of the dispersion of the size distribution.

The fixed cost of operation accounts on average for 33 percent of total labor cost. Although there are no other studies that estimate these fixed costs to compare the plausibility of the estimates, Costantini and Melitz (2007) calibrate the fixed cost of operation in their
model so that plants devote 20 percent of their labor cost to overhead, assuming that all non-production workers are devoted to overhead, based on results from Bustos (2005). Exporters pay on average 5 percent of their foreign revenues as a per-period cost to serve the world market. However, since the fixed cost of exporting is denominated in units of output, the smaller new exporters pay on average 11 percent of their exporting revenues.

Given the estimated size of the foreign market and the fixed cost of exporting and using technology 2, a firm that breaks into world markets adopts the modern technology immediately. Iacovone and Javorcik (2007) present evidence of frequent investment spikes and skill upgrading for plants that will start exporting in the next two years in the Mexican manufacturing sector. The implication in terms of the labor force composition is that for the plants that start importing M&E, their skill-intensity almost doubles on impact.

Firms that decide to start using technology 2 in the next period incur an adoption cost equivalent to twice their current revenues at the time of switching. Since plants that start using the modern technology always start exporting at the same time, they become 6 times bigger in terms of employment with total revenue 60 times larger on impact.\footnote{By the construction of the model, all exporting firms sell the same share of output in foreign markets, about 21 percent in the benchmark estimation. Therefore, all new exporters experience a great boost to their total revenues upon entry.}

Table 7 shows how the model fits the data. The overall difference between the empirical and simulated moments is about 0.09 log-points, and in fact, this difference for several moments is smaller than 5 percent. The model does a good job matching several features of the size distribution of Mexican manufacturing plants. In particular, the overall mean of the size distribution, the share of exporters and their export and skill-intensity closely fit the data. The simulated size distribution is also very close to the data, although the model slightly overestimates the share of large plants.

The main shortcoming of the model is its inability to match the dispersion of the size distribution and the size premium of exporters. As pointed out by Armenter and Koren
(2009) models with fixed costs to export have a very hard time matching both the share of exporting plants and the relative size of exporters. Since only one third of the plants in the sample export, the sizeable fixed cost needed to match this moment results in exporters that are too large. In the data, exporters are about twice as big as non-exporters, while in the simulated model they are 82 times larger. Figure 8 depicts the enormous export size premium of exporters that the model generates. This mismatch is also manifested in the skill intensity premium for exporters, since in the model there is a monotonic relationship between size and skill intensity. Although the skill intensity for exporters is closely fitted, non-exporting plants are 58 percent less skill-intensive than in the data. In a similar fashion, the combination of high fixed costs of using the modern technology and fixed costs to participate in the export market that are necessary to match the share of these type of plants in the data, result in an extremely high dispersion of size in the simulated model, almost six times larger than in the data. The fact that the only source of uncertainty in the model is idiosyncratic productivity, which at the same time is highly persistent, contributes to this discrepancy.

Looking at the dynamic moments, the high persistence of the stochastic process for productivity allows me to match the high persistence of exporting status and skill-intensity across firms quite closely. The lower predicted persistence and higher entry rate into exporting reflect the fact there are no sunk costs to enter foreign markets. There is no option value of staying a exporter when productivity falls below the level that induced the firm to start exporting.

The high fixed costs of using the modern technology and exporting together with the highly persistent productivity process produce a size distribution with a relatively high mean size (311 workers) and a high share of small plants (about 71 percent of plants have 30 workers or less). Almost all large plants are high-tech exporters and the majority of plants are non-exporters and new entrants (which by assumption enter the market using technology
1) which face a high probability of exiting the market soon\textsuperscript{23}.

6 Trade Liberalization

Using the estimates from the previous section, I perform a counterfactual analysis and ask what would happen to technology adoption and the skill premium in a high import tariff stationary equilibrium. Comparing this situation with the post-liberalization benchmark allows me to gauge at the contribution to the rise of skill premium of trade-induced skill-biased technology adoption.

In order to capture the experience of Mexico in the second half of the 1980s, I consider a pre-liberalization scenario in which import tariffs are 38\% higher than in the post-liberalization benchmark, so $\tau_f$ increases from 1.05 to 1.55, while the iceberg transportation cost faced by Mexican exporters remains the same. The results of this experiment are presented in Table 8. This increase in $\tau_f$ is bigger than the change in the production-weighted average tariff for manufacturing imports that took place after liberalization, but intends to take into consideration the broad licensing requirements that were in place at the time, which are considered the most binding barrier to trade.

A unilateral trade liberalization has a direct effect on the aggregate price index, which falls 21\% percent. This has a negative effect on domestic profits and aggregate income which falls by 16\% percent, resulting in a decrease in the average plant size of about one percent. After a unilateral trade liberalization, the equilibrium mass of firms in the market falls by approximately 2\% percent. Exit takes place at the lower end of the productivity distribution and workers employed on these firms reallocate to larger and more skill-intensive firms, a pro-competitive effect.

\textsuperscript{23}In fact, contrary to the findings of the empirical literature on industry evolution, the model generates exiting plants that are slightly bigger than new entrants. The size difference between the two is not statistically significant.
Notwithstanding the reduction in domestic profits, the balanced trade condition implies that as the value of imports increases, so does the value of exports. The productivity cutoff to start exporting falls, thus increasing the share of exporting plants by 12 percent when import competition is more intense. With the entry of these relatively smaller firms, exporters as a group become on average smaller and less skill-intensive, by 12 and 3 percent, respectively. New exporters also start importing M&E, although the increase is smaller than in the number of firms exporting, since a small fraction of firms in the high-tariff equilibrium import M&E but only serve the domestic market. All of these become high-tech exporters after trade liberalization.

The main difference in the size distribution of firms when import tariffs falls occurs in the middle, as the new users of modern technology shift towards the right of the size distribution, as seen in Figure 9. This is a similar result to the findings of Lileeva and Trefler (2007), who show that only Canadian firms with moderate pre-CUSFTA value-added per worker experienced significant gains in productivity as a result of productivity-enhancing investment activities.

Overall, a unilateral trade liberalization decreases profits for a large number of firms in the economy, therefore, the use of modern technology increases by just one percentage point. This modest increase in turn, results in a 2.46 percent rise of the skill premium, far from what is observed in the data. Allowing the sunk cost of technology adoption to be affected by the import tariff (i.e. purchasing a foreign piece of equipment subject to an import tariff, resulting in a technology adoption cost \( \tau_f S_2 \)) produces similar results qualitatively. From a quantitative standpoint the change in number of exporters and high-tech firms is larger relative to the benchmark experiment, producing a stronger response of the skill premium, which now rises by 4.2 percent. This is my preferred specification, since it takes into account the contribution of changes in trade policy in the price of imported machinery and equipment described in section 4. In this case, the stronger response of technology
adoption to trade liberalization results in an increase in the skill premium of about one-sixth of the total magnitude observed in the data, a significant quantitative contribution for just this one channel. As mentioned in the introduction, this is the first attempt to quantify how important the complementarity between exporting and investing in productivity-enhancing technologies for understanding changes in wage inequality.

As mentioned in Sections 2.1 and 2.2, Mexican policymakers pursued drastic policy changes additionally to liberalizing the trade regime, that might have had an important impact in shaping factor remunerations and inequality. For instance, changes in labor market institutions have been argued to have depressed the relative demand for unskilled labor. Through the Pacto the Mexican government aggressively pursued a de-indexation of the minimum wage aimed at containing inflation. At the same time, the political power of national unions waned, and with it their ability to influence industry wage agreements in detriment of production workers’ wages. One would expect these institutional changes to compress the bottom of the wage distribution, however, Cortez (2001) finds that wage inequality remained stable among workers with low educational attainment, while growing substantially among college-educated workers. This happened primarily due to a large rise in the return to higher education in the midst of a period of significant educational expansion as noted in Section 2.2, which gives support to the adoption of skill-biased technology as a quantitatively important channel affecting the patterns of the skill premium. Furthermore, Cortez (2001) shows that the minimum wage is just binding for agriculture, not services or manufacturing. Thus, the de-indexation of minimum wages should not be as important in explaining the changes in wage inequality in the manufacturing sector.
7 Concluding Remarks

This chapter presents a structural empirical model of trade and technology adoption with heterogeneous firms aimed at understanding the extraordinary rise of the skill premium in Mexico after the inception of an ambitious trade liberalization process. Several mechanisms have been proposed that link changes in the degree of trade openness to changes in wage inequality but with limited success. This paper studies the hypothesis that trade-induced adoption of skill-intensive technologies could be behind the increase in inequality. Previous research has lent support to this view by finding that new exporters exhibit higher rates of investment than domestic firms and continuing exporters and also that they are the ones that benefit the most in terms of productivity change. My model does a good job matching several key characteristics of the Mexican manufacturing sector, and produces sensible estimates of the parameters that govern technology adoption. The results of my estimation suggest that the import-competition effect result from trade liberalization does not provide a sufficiently large push of the relative demand for skilled labor to explain the rise of the skill premium that we observed in Mexico since the mid 1980s.

Future work on the impact of trade openness on wage inequality would benefit greatly from using data from the National Survey of Employment, Salaries, Technology, and Training (ENESTYC) to construct more refined measurements of advanced manufacturing technology utilization. This would enable researchers to better identify how the labor force composition of a firm changes when specific technologies are introduced in the workplace. Another interesting area for future research is the transitional dynamics of wage inequality after trade liberalizations. Work on this area should aim to explain why the skill premium increase so rapidly after Mexico joined the GATT while remaining stable when it joined NAFTA and its volume of trade almost tripled. Understanding the evolution of wage inequality is particularly interesting since similar patterns are observed in other countries such as Argentina, Chile
and Colombia. Structural empirical models of these dynamics should help to further our understanding of the factors determining wage inequality.
References


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[34] Iacovone, Leonardo and Beata S. Javorcik (2007): “Preparation to Export”, mimeo World Bank


[40] Lileeva, Alla and Daniel Trefler (2007): “Improved Access to Foreign Markets Raises Plant-level Productivity... for Some Plants” mimeo University of Toronto


Journal of Development Economics 71: 311-328

Mexico” Journal of International Economics 64: 387-409

[46] Székely, Miguel, The Economics of Poverty, Inequality and Wealth Accumulation in

and Vector Autoregressions” Economics Letters 20: 177-181

Lessons from Experience” World Development 20: 659-672

sions of Efficiency Change in Mexican Manufacturing Industries” Journal of Interna-
tional Economics 39: 53-78

 Manufacturing Sector” Quarterly Journal of Economics 123: 489-530

and Wages” Journal of International Economics 65: 1-20
Appendix A: Computational Algorithm

This section describes the computational algorithm used to compute the stationary equilibrium of my model.

(i) Let $\theta$ denotes the vector of parameters to be estimated, and $\theta_{ne}$ the vector of parameters calibrated outside the model.

$$\theta = [z_1, z_2, \phi, \sigma^2, f_1, f_2, S, A_x, f_x, \mu_E, S_E, \sigma_p]_{12 \times 1},$$

$$\theta_{ne} = [\beta, \lambda, \sigma_c, L, \tau_f, \tau_x]_{6 \times 1}.$$

Let $\theta^0$ be the initial guess for the estimated parameters.

(ii) The state variables for a firm are: 1) technology $k \in \{1, 2\}$ and 2) the idiosyncratic productivity index, $z^k$. I assume that $z^k$ can take values in a grid $Z^k \equiv \{z^k_1, \ldots, z^k_N\}$. The stochastic process for the idiosyncratic productivity shock is approximated using the method proposed by Tauchen (1986). This produces two sets of grids $Z^1 \equiv \{z^1_1, \ldots, z^1_N\}$ and $Z^2 \equiv \{z^2_1, \ldots, z^2_N\}$ and associated transition matrices $Q_1(z, z')$ and $Q_2(z, z')$, with $N = 100$.

(iii) Given an initial guess for the aggregate macroeconomic variables in the model,

$$X \equiv [P, Y, M, w_l, w_h],$$

firms solve their static problem choosing optimal prices in each market (domestic and foreign), labor demand for each type of worker and whether to export or not, and static profits $\pi(k, z)$ are calculated.

(iv) Running through all points in the state space $i_k = 1, 2$ and $i_z = 1, \ldots, N$ solve the firm’s dynamic programming problem using value function iteration. Iterate over equation (12) until $\|v^\ell - v^{\ell-1}\| < \text{tol}$, where $\ell$ indexes iterations over the value function, and $\text{tol} = 1e-4$ is the convergence criterion. This step yields a value function $v(k, z)$, a policy rule for technology adoption $K(k, z)$, and a policy rule for exiting, $\chi(k, z)$.

(v) Given the policy functions for technology adoption and exiting, and the transition matrix for productivity, construct a transition matrix $P$ of size $(2N \times 2N)$ that gives the conditional probability of visiting state $(i_k', i_z')$ next period for incumbent firms with current state is $(i_k, i_z)$. Finally, compute the invariant distribution associated with $P$, $\tilde{\mu}(k, z)$.

(vi) Define $M_E$ as the mass of potential entrants that can start producing in a given period. In a stationary equilibrium, the flow of successful entrants should exactly balance the flow of exiting firms. Given the distribution of incumbents $\tilde{\mu}(k, z)$, we can solve for $M_E$:

$$M_E = \frac{M\tilde{\mu}(k, z)'\chi(k, z)}{G_E(z)'(1 - \chi(1, z))}.$$  

(A.3)
and we can also define the post entry/exit distribution of firms across technologies and productivity, \( \mu(k, z) \):

\[
\mu(k, z) = \bar{\mu}(k, z)'(1 - \chi(k, z)) + \left( \frac{M_E}{M} \right) G_E(z)'(1 - \chi(k, z)). \tag{A.4}
\]

(vii) Compute the market clearing conditions: 1) labor market clearing, 2) consistency of the aggregate price index, 3) consistency of aggregate income, 4) net value of entry equal to zero, and 5) balanced trade:

\[
\begin{align*}
\frac{h(k, z)}{l(k, z)} - \frac{\lambda}{(1 - \lambda)} &= 0, \tag{Labor Market Clearing} \\
\frac{1}{1 - \sigma_c} P = &\left[ M\mu(k, z)' p_d(k, z)^{1-\sigma_c} + \tau_f^{1-\sigma_c} \right] &\tag{Aggregate Price Index} \\
Y = M\mu(k, z)' \pi(k, z) + L[\lambda w_h + (1 - \lambda) w_l], &\tag{Aggregate Income} \\
G_E(z)' v(1, z) - mc(k, z) S_E = 0, &\tag{Free Entry} \\
M\mu(k, z)' [\gamma(k, z) r_x(k, z)] - Y \left( \frac{\tau_f}{P} \right)^{1-\sigma_c} = 0. \tag{Balanced Trade}
\end{align*}
\]

a vector \( X^* \equiv [P^*, Y^*, M^*, w^*_l, w^*_h] \) that solves the system of equations defined above characterizes the stationary equilibrium of this economy. In the computer code, the function \texttt{mktclear} receives as inputs the vector of initial parameters \( \theta^0 \), and the initial guess for the macroeconomic variables \( X \). The program solves the static and dynamic problems of the firm, finds the stationary distribution of the economy, and produces the vector of market clearing conditions, \( \Phi \), such that \( X^* = \operatorname{arg\,min} \| \Phi(X) \| \).

(viii) Armed with the policy rules for labor demand, exporting, technology choice, entry and exit, generate \( S = 50 \) simulated panels of firms. Starting with a given number of incumbent firms, \( N_{inc} = 200 \), with \( N_{ent} = (M_E/M) N_{inc} \) potential entrants every period. Using these simulations, compute a vector of simulated moments (averaged across simulations), of size \( r > 12 \) (the number of parameters to estimate) and minimize the loss function 15 with respect to \( \theta \).

(ix) The limiting distribution of \( \hat{\theta} \) is given by:

\[
\sqrt{T}(\hat{\theta} - \theta_0) \to \mathcal{N}(0, V). \tag{A.5}
\]

where \( V = (\hat{D}\hat{\Sigma}^{-1}\hat{D}')^{-1} \) and \( \hat{D} \) is the \((12 \times r)\) Jacobian matrix,
\[
\dot{D} = \frac{\partial g(D_{it}, \hat{\theta})}{\partial \theta} \equiv \begin{pmatrix}
\frac{\partial g_1(Z, \hat{\theta})}{\partial \theta_1} & \frac{\partial g_2(Z, \hat{\theta})}{\partial \theta_1} & \cdots & \frac{\partial g_r(Z, \hat{\theta})}{\partial \theta_1} \\
\frac{\partial g_1(Z, \hat{\theta})}{\partial \theta_2} & \frac{\partial g_2(Z, \hat{\theta})}{\partial \theta_2} & \cdots & \frac{\partial g_r(Z, \hat{\theta})}{\partial \theta_2} \\
\vdots & \vdots & \ddots & \vdots \\
\frac{\partial g_1(Z, \hat{\theta})}{\partial \theta_{12}} & \frac{\partial g_2(Z, \hat{\theta})}{\partial \theta_{12}} & \cdots & \frac{\partial g_r(Z, \hat{\theta})}{\partial \theta_{12}}
\end{pmatrix}.
\] 

(A.6)

where \( T \) is the sample size, and \( g(D_{it}, \hat{\theta}) \) is the difference between the mean vector of simulated moments and the sample moments:

\[
g(D_{it}, \hat{\theta}) = \log \left( \frac{1}{S} \sum_{s=1}^{S} m(D_{it}^s(\hat{\theta})) \right) - \log \left( \frac{1}{T} \sum_{t=1}^{T} m(D_{it}) \right).
\] 

(A.7)

Finally, \( \hat{\Sigma}^{-1} \), the optimal weighting matrix, is estimated by bootstrapping the moments directly from the data. The data is re-sampled 1,000 times, and for each sample the vector of moments \( m \) is calculated to produce the estimated variance-covariance matrix.
Appendix B: Encuesta Industrial Anual: Cleaning Procedure

The Encuesta Industrial Anual (Annual Manufacturing Survey) is produced by the Instituto Nacional de Estadísticas, Geografía, e Información (INEGI), the Mexican government statistical agency. The data contains information on 3,218 manufacturing plants for the period 1984-1990 (for a total of 22,526 plant-year observations) and it is by design a balanced panel that covers roughly 80 percent of cumulative value-added. The sample design is deterministic. Plants with more than 100 employees are included automatically. Plants are ranked according to total value of production and are added to the sample until the set of the selected plants covers approximately 85 percent of the respective class’s (4-digit industry) output value. Furthermore, whenever the normal sampling procedure implies that more than 120 plants need to be surveyed to reach the 85 percent threshold, the number of plants surveyed is kept to a maximum of 120; on the other hand if the 85 percent threshold is reached by covering less than 15 plants, then all the plants are included. For more information about the Encuesta Industrial Anual see Iacovone (2008).

The survey contains information on inputs used by manufacturing plants (labor split into production and non-production workers, raw materials, intermediate inputs, energy consumption), and output indicators such as value of production, value of sales, inventory, revenues derived from industrial services like maquila and non-industrial services. The original sample did not have information on the value of imported materials or machinery and equipment and export revenues. However from 1986 onwards this information is available following a World Bank project aimed at collecting exporting information for plants covered by the EIA. The cleaning procedure for the sample follows Grether (1996):

1. An observation is eliminated if one of the following variables is non-positive: total employment, number of non-production workers, number of production workers, total wage-bill, value-added and gross value of output. This resulted in the elimination of 1,550 plant-year observations.

2. Elimination of odd observations: observations for which the annual growth rate of total employment was above 300 percent on absolute value; annual growth rate of total remuneration above 1,000 percent in absolute value; annual growth rate of total value of production above 1,000 percent in absolute value; annual growth rate of energy consumption above 2,500 percent in absolute value and annual growth rate of expenditure on materials above 2,500 percent in absolute value. This resulted in the elimination of 5,973 plant-year observations.

3. Elimination of incomplete series: plants that were discarded in at least one year for the reasons mentioned above were discarded for all the other years as well. This resulted in the elimination of 39 plant-year observations.

\[\text{value-added} = \text{value-added} + \text{income from maquila services} - \text{expenditure on maquiladora services}\]
in the elimination of 848 plant-year observations.

4. Entry and exit: Some plants are recorded as entrants or exiters even though the sample is supposed to be closed. This resulted in the elimination of 317 plant-year observations.

5. Maquila plants: Plants for which revenues from maquila services were more than 10 percent of total revenues. This resulted in the elimination of 447 plant-year observations.

The final sample contained 13,391 observations, that is, 1,913 per year.
Table 1: Trade Openness at the Plant Level

<table>
<thead>
<tr>
<th></th>
<th>1986</th>
<th>1990</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraction of exporting plants</td>
<td>22.8</td>
<td>35.9</td>
<td>57.4</td>
</tr>
<tr>
<td>Mean exports/sales</td>
<td>24.7</td>
<td>26.8</td>
<td>8.5</td>
</tr>
<tr>
<td>Fraction of plants importing M&amp;E</td>
<td>22.6</td>
<td>37.3</td>
<td>64.9</td>
</tr>
<tr>
<td>Expenditure in imported M&amp;E$^a$</td>
<td>5.3</td>
<td>9.9</td>
<td>85.5</td>
</tr>
<tr>
<td>Fraction of plants importing materials</td>
<td>33.5</td>
<td>50.6</td>
<td>51.1</td>
</tr>
<tr>
<td>Expenditure in imported materials$^b$</td>
<td>8.0</td>
<td>12.9</td>
<td>60.8</td>
</tr>
</tbody>
</table>

$^a$As a fraction of total expenditure in Machinery and Equipment  
$^b$As a fraction of total expenditure in materials

Own calculations. Source: *Encuesta Industrial Anual* (Annual Manufacturing Survey), Mexico, 1984-1990, INEGI.

Table 2: Exporting and Use of Imported Machinery and Equipment at the Plant Level

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>65.52</td>
<td>11.38</td>
<td>11.89</td>
<td>11.21</td>
</tr>
<tr>
<td>1987</td>
<td>60.59</td>
<td>11.27</td>
<td>15.46</td>
<td>12.68</td>
</tr>
<tr>
<td>1988</td>
<td>54.76</td>
<td>13.76</td>
<td>14.16</td>
<td>17.33</td>
</tr>
<tr>
<td>1989</td>
<td>48.64</td>
<td>17.50</td>
<td>13.08</td>
<td>20.78</td>
</tr>
<tr>
<td>1990</td>
<td>42.87</td>
<td>21.23</td>
<td>12.80</td>
<td>23.10</td>
</tr>
</tbody>
</table>

Own calculations. Source: *Encuesta Industrial Anual* (Annual Manufacturing Survey), Mexico, 1984-1990, INEGI.
Table 3: Employment and Relative Wages

<table>
<thead>
<tr>
<th></th>
<th>1984</th>
<th>1990</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Employment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>201.8</td>
<td>228.9</td>
<td>13.4</td>
</tr>
<tr>
<td>Non-production</td>
<td>86.7</td>
<td>98.4</td>
<td>13.4</td>
</tr>
<tr>
<td><strong>Hourly wages</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production</td>
<td>28.7</td>
<td>26.7</td>
<td>-6.8</td>
</tr>
<tr>
<td>Non-production</td>
<td>56.1</td>
<td>67.5</td>
<td>20.2</td>
</tr>
<tr>
<td><strong>Skill premium</strong></td>
<td>2.10</td>
<td>2.76</td>
<td>31.4</td>
</tr>
</tbody>
</table>

Own calculations. Source: *Encuesta Industrial Anual* (Annual Manufacturing Survey), Mexico, 1984-1990, INEGI.

Table 4: Calibrated Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>Discount factor</td>
<td>0.939</td>
</tr>
<tr>
<td>$\sigma_c$</td>
<td>Elasticity of substitution, consumption</td>
<td>3.634</td>
</tr>
<tr>
<td>$\tau_f$</td>
<td>Post-liberalization import tariff</td>
<td>1.05</td>
</tr>
<tr>
<td>$\tau_x$</td>
<td>Export tariff</td>
<td>1.05</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>Share of skilled workers</td>
<td>0.311</td>
</tr>
<tr>
<td>$L$</td>
<td>Size of Labor force</td>
<td>1,000</td>
</tr>
</tbody>
</table>
Table 5: Moments used for Estimation (Data)

<table>
<thead>
<tr>
<th>Post-Liberalization (1987-1990)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean fraction of exporting firms</td>
<td>0.317</td>
</tr>
<tr>
<td>Mean exports/sales ratio</td>
<td>0.213</td>
</tr>
<tr>
<td>Std. skill share of employment</td>
<td>0.175</td>
</tr>
<tr>
<td>Mean skill share, exporters</td>
<td>0.347</td>
</tr>
<tr>
<td>Mean entry rate</td>
<td>0.110</td>
</tr>
<tr>
<td>Mean total employment</td>
<td>311.76</td>
</tr>
<tr>
<td>Std total employment</td>
<td>461.70</td>
</tr>
<tr>
<td>Mean total employment, entrants</td>
<td>17.85</td>
</tr>
<tr>
<td>Mean total employment, exiters</td>
<td>15.564</td>
</tr>
<tr>
<td>Mean fraction of firms using foreign technology</td>
<td>0.222</td>
</tr>
<tr>
<td>Mean total employment, exporters</td>
<td>504.93</td>
</tr>
<tr>
<td>Correlation(export$<em>t$, export$</em>{t-1}$)</td>
<td>0.862</td>
</tr>
<tr>
<td>Correlation (skill share$<em>t$, skill share$</em>{t-1}$)</td>
<td>0.937</td>
</tr>
<tr>
<td>Mean adoption rate imported technology</td>
<td>0.053</td>
</tr>
<tr>
<td>Mean entry rate into exporting</td>
<td>0.039</td>
</tr>
<tr>
<td>Fraction of plants with 0-30 employees</td>
<td>0.713</td>
</tr>
<tr>
<td>Fraction of plants with 30-100 employees</td>
<td>0.209</td>
</tr>
<tr>
<td>Fraction of plants with 100-500 employees</td>
<td>0.051</td>
</tr>
</tbody>
</table>

### Table 6: Parameter Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Point Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean productivity tech. 1 ($\bar{z}_1$)</td>
<td>0.050</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
</tr>
<tr>
<td>Mean productivity tech. 2 ($\bar{z}_2$)</td>
<td>0.109</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
</tr>
<tr>
<td>Root productivity process ($\phi$)</td>
<td>0.952</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
</tr>
<tr>
<td>Variance productivity innovations ($\sigma^2_\epsilon$)</td>
<td>0.278</td>
</tr>
<tr>
<td></td>
<td>(0.073)</td>
</tr>
<tr>
<td>Fixed cost of using tech. 1 ($f_1$)</td>
<td>91.409</td>
</tr>
<tr>
<td></td>
<td>(2.354)</td>
</tr>
<tr>
<td>Fixed cost of using tech. 2 ($f_2$)</td>
<td>568.53</td>
</tr>
<tr>
<td></td>
<td>(30.242)</td>
</tr>
<tr>
<td>Sunk cost of adopting tech. 2 ($S$)</td>
<td>65.093</td>
</tr>
<tr>
<td></td>
<td>(14.881)</td>
</tr>
<tr>
<td>Foreign market size ($A_x$)</td>
<td>910.23</td>
</tr>
<tr>
<td></td>
<td>(0.892)</td>
</tr>
<tr>
<td>Fixed cost of exporting ($f_x$)</td>
<td>48.726</td>
</tr>
<tr>
<td></td>
<td>(0.045)</td>
</tr>
<tr>
<td>Mean productivity, entrants ($\mu_E$)</td>
<td>1.226</td>
</tr>
<tr>
<td></td>
<td>(0.0187)</td>
</tr>
<tr>
<td>Sunk cost of entry ($S_E$)</td>
<td>4.234</td>
</tr>
<tr>
<td></td>
<td>(1.555)</td>
</tr>
<tr>
<td>Elasticity of substitution ($\sigma_p$) in production</td>
<td>1.410</td>
</tr>
<tr>
<td></td>
<td>(0.952)</td>
</tr>
<tr>
<td>Value objective function ($\Psi$)</td>
<td>0.0926</td>
</tr>
</tbody>
</table>

Standard errors in parenthesis.
### Table 7: Goodness of Fit

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of exporting plants</td>
<td>0.317</td>
<td><strong>0.327</strong></td>
<td>0.014</td>
</tr>
<tr>
<td>Mean exports/sales ratio</td>
<td>0.213</td>
<td><strong>0.223</strong></td>
<td>0.018</td>
</tr>
<tr>
<td>Std. skill share of employment</td>
<td>0.175</td>
<td><strong>0.120</strong></td>
<td>0.164</td>
</tr>
<tr>
<td>Skill share, exporters</td>
<td>0.347</td>
<td><strong>0.345</strong></td>
<td>0.002</td>
</tr>
<tr>
<td>Mean entry rate</td>
<td>0.110</td>
<td><strong>0.005</strong></td>
<td>1.280</td>
</tr>
<tr>
<td>Mean total employment</td>
<td>311.76</td>
<td><strong>380.81</strong></td>
<td>0.087</td>
</tr>
<tr>
<td>Std. log(total employment)</td>
<td>461.70</td>
<td><strong>2,548.45</strong></td>
<td>0.742</td>
</tr>
<tr>
<td>Mean total employment, entrants</td>
<td>17.85</td>
<td><strong>19.17</strong></td>
<td>0.030</td>
</tr>
<tr>
<td>Mean total employment, exiters</td>
<td>15.564</td>
<td><strong>21.54</strong></td>
<td>0.141</td>
</tr>
<tr>
<td>Share of plants using imported M&amp;E</td>
<td>0.222</td>
<td><strong>0.327</strong></td>
<td>0.169</td>
</tr>
<tr>
<td>Mean total employment, exporters</td>
<td>504.93</td>
<td><strong>1,111.76</strong></td>
<td>0.343</td>
</tr>
<tr>
<td>Corr. (export&lt;sub&gt;t&lt;/sub&gt;, export&lt;sub&gt;t-1&lt;/sub&gt;)</td>
<td>0.862</td>
<td><strong>0.785</strong></td>
<td>0.046</td>
</tr>
<tr>
<td>Corr. (skill share&lt;sub&gt;t&lt;/sub&gt;, skill share&lt;sub&gt;t-1&lt;/sub&gt;)</td>
<td>0.937</td>
<td><strong>0.908</strong></td>
<td>0.041</td>
</tr>
<tr>
<td>Mean adoption rate imported M&amp;E</td>
<td>0.039</td>
<td><strong>0.043</strong></td>
<td>0.084</td>
</tr>
<tr>
<td>Mean entry rate into exporting</td>
<td>0.033</td>
<td><strong>0.043</strong></td>
<td>0.047</td>
</tr>
<tr>
<td>Share of plants with 0-30 employees</td>
<td>0.713</td>
<td><strong>0.708</strong></td>
<td>0.003</td>
</tr>
<tr>
<td>Share of plants with 30-100 employees</td>
<td>0.209</td>
<td><strong>0.140</strong></td>
<td>0.172</td>
</tr>
<tr>
<td>Share of plants with 100-500 employees</td>
<td>0.051</td>
<td><strong>0.086</strong></td>
<td>0.229</td>
</tr>
</tbody>
</table>

### Table 8: Unilateral Trade Liberalization

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Benchmark</th>
<th>High tariff</th>
<th>High tariff affecting S₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate income (Y)</td>
<td>100</td>
<td>116.10</td>
<td>118.02</td>
</tr>
<tr>
<td>Price index (P)</td>
<td>100</td>
<td>120.91</td>
<td>124.10</td>
</tr>
<tr>
<td>Price of foreign consumption good (τ_f)</td>
<td>105</td>
<td>155</td>
<td>155</td>
</tr>
<tr>
<td>Mass of incumbent firms (M)</td>
<td>100</td>
<td>101.23</td>
<td>102.50</td>
</tr>
<tr>
<td>Skill premium (w_h/w_l)</td>
<td>6.871</td>
<td>6.701</td>
<td>6.584</td>
</tr>
<tr>
<td>Share of plants using imported M&amp;E</td>
<td>0.329</td>
<td>0.319</td>
<td>0.274</td>
</tr>
<tr>
<td>Share of exporting plants</td>
<td>0.329</td>
<td>0.292</td>
<td>0.262</td>
</tr>
</tbody>
</table>
Figure 1: Trade Volume and the Rise of the Skill Premium in Mexico

Source: World Bank WDI and INEGI. Exports and imports of manufacturing goods. Skill premium is defined as the mean ratio of non-production to production wages across 2-digit industries.
Figure 2: Protection Measures for Manufacturing during the 1980s (1-digit Industries)

Source: Lustig (1998)
Figure 3: Real Exchange Rate Mexico 1980-1990

Source: Banco de México.
Figure 4: Relative Price of Machinery and Equipment

Source: INEGI.
The figure depicts the residual of regressing the share of non-production employment at the plant level on the log of capital stock, time and 4-digit industry-specific dummies around entry into the export market.
New entrants pay an entry fee
draw $z$ from a distribution $G(z)$
using technology 1

Incumbent’s state
is $(z_{t-1}, k_t)$

Draw $z_t$

Choose $l_t$, $h_t$, and $\gamma_t$

Choose $k_{t+1}$

Exit
Figure 7: Skill Premium Across 4-digit Industries

Own calculations. Mean wage of non-production workers relative to mean wage of production workers by 4-digit industry. Source: *Encuesta Industrial Anual* (Annual Manufacturing Survey), Mexico, 1984-1990, INEGI.
Figure 8: Size Distribution by Exporting Status
Figure 9: Size Distribution after Trade Liberalization

\[ \tau_f = 1.55 \]
\[ \tau_f = 1.05 \]