# The Impact of Trade Liberalization on Skill Upgrading Evidence from Argentina*

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**Abstract**

In this paper I study the effects of a regional free trade agreement on the demand for skill. I start by documenting a series of facts to shed light on the determinants of a steep increase in the relative demand of skilled labor in a panel of Argentinean industrial firms covering the trade liberalization period. First, this is not explained by labor reallocation across industries or firms but by skill upgrading within firms. Second, exporters upgrade skill faster than non exporters. Third, firms upgrading skill also upgrade technology. These findings are consistent with a model where a reduction in trading partner's tariffs induces the most productive firms (exporters) to adopt skill-intensive production technologies. Indeed, I find that the reduction in Brazil's tariffs induces the most productive Argentinean firms to upgrade skill, while the least productive ones downgrade. One third of the increase in the relative demand for skill can be attributed to the reduction in Brazil's tariffs.

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**Introduction**

During the last three decades, the integration of developing countries in the world economy has often coincided with increases in the skill premium [Goldberg and Pavcnik (2007)].[1] These trends are at odds with the predictions of the Heckscher-Ohlin trade model where trade opening in skill-scarce developing countries leads to a reduction in the skill premium. Thus, the recent literature has proposed several alternative mechanisms through which trade liberalization can increase the relative demand for skill in developing countries. In particular, the empirical finding that firms who export are more skill-intensive than non-exporters suggests that a bilateral trade liberalization can induce firms to upgrade skill. However, there is no direct empirical evidence documenting causal effects of a reduction in trading partner's tariffs on skill upgrading. In this paper I study a regional trade liberalization episode and show that a reduction in trading partner's tariffs induces the most productive firms (exporters) to upgrade skill while the least productive firms downgrade.

I analyze a panel of Argentinean manufacturing firms covering a regional trade liberalization period. The main advantage of this data set is that it includes information on the educational level of workers, while standard industry surveys only classify workers into production and non-production occupational categories. In a preliminary analysis of the data, I find that the relative employment of skilled labor (defined as college equivalents/high school and below) increased 16 percent in the period 1992-1996. Galiani and Sanguinetti (2003) report that during the same period the college wage premium increased 7 percentage points per year in the industrial sector. The simultaneous increase in relative prices and quantities of skilled labor indicates that the rise in the equilibrium relative employment of skilled labor must come from a demand shift.

To shed light on the possible causes of the increase in the aggregate demand for skill, I start by decomposing it in changes within and between industries.[2] This is important, as the increase in the relative demand for skill could result from reallocations of labor towards skill-intensive industries, as predicted by the H-O model. However, I find that the increase in the relative demand of skilled labor does not come from labor reallocation across sectors, nor across firms, but from skill upgrading within firms. A second alternative is that firms are outsourcing production activities to less skill-abundant countries to focus on non-production activities. Nevertheless, I find that most of the increase in the relative employment of skilled labor is explained by skill upgrading within production (P), non-production (NP) and R&D occupational categories, with reallocations of labor from P towards NP and R&D playing a minor role.

[1] See also Gindling and Robbins (2001) and Pavcnik (2003) on Chile; Galiani and Sanguinetti (2003) on Argentina, Attanasio Goldberg and Pavcnik (2004) on Colombia, Hanson and Harrison (1999) on Mexico, Topalova (2005) on India, Hsieh and Woo (2005) on Hong Kong.

[2] This paralells the analysis in Berman, Bound and Griliches (1994) for the U.S.

The finding that firms upgrade skill in a context of increasing skill premium suggests that firm-level skill demands are shifting out, that is, firms are changing the skill-intensity of their production technology. In addition, the data suggests that there is a strong association between export market participation and skill upgrading: before liberalization, exporters were more skill intensive than non-exporters; moreover, both continuing and new exporters upgrade skill faster during the liberalization period. These patterns, coupled with the fourfold increase in exports to Brazil during this period, suggest that the increase in the demand for skill could be partly due to the regional free trade agreement. However, it can also be a response to other reforms implemented during the same period. For example, capital account liberalization could have made credit available allowing some firms to invest, hire skilled workers and enter the export market. Thus, to isolate the causal effects of the regional trade liberalization, I directly estimate the effect of reductions in Brazil's tariffs on the skilled labor share of Argentinean firms.

To guide empirical work, I present a simple model that builds on work by Melitz (2003) and Yeaple (2005).[3] In the model, firms are heterogeneous in an underlying productivity parameter, and must incur fixed costs to enter the export market. In addition, firms can choose between two production technologies differing in their skill-intensity. The skill-intensive technology entails a lower marginal production cost, but a higher fixed cost. In equilibrium, firms sort into three groups: the most productive firms use the skill-intensive technology and export, the middle group exports but remains using the unskilled technology, and the least productive firms only serve the domestic market using the unskilled technology. A bilateral reduction in tariffs increases export revenues inducing firms in the upper-middle range of the productivity distribution to enter the export market and switch to the skill-intensive production technology. The trade-induced reallocations of market shares towards the most productive firms increase the relative demand for skilled labor and the skill premium. As a result, the least productive firms downgrade skill.

I test the model's predictions in the context of a regional free trade agreement, MERCOSUR. I exploit the differential reductions in Brazil's tariffs across industries to identify the causal effects of a reduction in trading partner's tariffs on the demand for skill. Brazil's tariff changes provide for a good source of arguably exogenous variation for the following reasons. Brazil's tariffs fall from an average of 29 percentage points in 1991 to zero in 1995. Thus, tariff changes are predetermined by their initial level, which varies extensively across industries. Note that as these are Brazilian most favored nation tariffs in 1991, their level is unlikely to be driven by Argentina's industry characteristics (Argentina's share of Brazil's trade was only 7.7 percent). In addition, Brazil's tariff

[3] The theoretical framework is also related to work by Acemoglu (1998, 2003), Thoening and Verdier (2003), Neary (2003), Ekholm and Midelfart (2005), and Gancia and Epifani (2006) who present models where trade induces firms to switch to skill-biased technologies.

structure in 1991 reflected a transition between the import substitution regime, which tended to protect unskilled-labor-intensive industries, and a new trade policy protecting some skill-intensive industries. As a result, the correlation between the initial level of Brazil's tariffs and an exogenous measure of industry skill intensity is very low (-0.002).

I find that the reduction in Brazil's tariffs induces Argentinean firms below median size to downgrade skill, while firms above median size upgrade, with finer partitions producing similar results.[4,5] The effect of Brazil's tariff reductions on the aggregate employment share of skilled labor is positive, because firms above the median have a larger weight on labor demand. The estimates imply that the average reduction in Brazil's tariffs during the period 1992-1996 (23 percentage points) explains one third of the increase in the aggregate employment share of skilled labor in the sample.[6] These estimates are robust to the inclusion of controls for industry trends and changes in Argentinean output and input tariffs with respect to Brazil and the rest of the world.[7]

The empirical findings outlined above can be rationalized by the model, as initial heterogeneity determines differential firm-level responses to tariff reductions. Consider first the finding that firms above median size upgrade skill faster in industries with bigger tariff reductions. This finding is consistent with the prediction that as tariff cuts reallocate market shares towards the most productive firms (exporters), they cross a size threshold above which skill-intensive production technologies are profitable. Second, take the finding that firms in the lower range of the firm-size distribution downgrade skill faster in industries with bigger reductions in Brazil's tariffs. This is consistent with the model's prediction that less productive firms operating in industries facing higher tariff cuts experience higher skill premium increases as skilled labor reallocates towards more productive firms within the same industry. Note that this finding suggests that there is limited skilled-labor mobility across industries, consistent with the evidence for other Latin American countries reviewed by Goldberg and Pavcnik (2007).

Next, I investigate the channel through which trading partner's tariff reductions increase the

[4] Note that when I test the model´s predictions I interact tariff changes with initial firm-size dummies instead of export status dummies. This is because in previous work I found that Mercosur tariff reductions had a strong impact on entry in the export market [Bustos (2011)]. Thus, export status after liberalization is not only endogenously determined with skill intensity in the model, but also positively correlated with the main source of exogenus variation: the change in Brazil´s tariffs, in the data. As a result, I treat changes and levels in export status as an outcome, like skill intensity. The explanatory variables are changes in tariffs and initial firm heterogeneity measured as relative firm size. Still, interactions of export status after liberalization and tariff changes produce the expected results: the reduction in Brazil´s tariffs induces non exporters to downgrade skill while exporters upgrade (Tables are available upon request).

[5] I measure firm size as employment in efficiency units relative to the mean in the corresponding 4-digit-industry. Results are robust to using firm sales as a measure of firm size instead (Tables are available upon request).

[6] More precisely, it explains 38% of the within firm component of the increase in the aggregate employment share of skilled labor in the sample.

[7] Argentinean import tariff changes do not have statistically significant effects on skill upgrading, possibly because Argentina's unilateral liberalization policies preceded this period, thus its initial m.f.n. tariffs where lower than in Brazil.

demand for skill. The model's prediction that bigger firms demand more skill results from the assumption that the skill-intensive technology entails higher fixed costs and lower marginal costs. Technologies can display this form for several reasons. For example, a higher scale of operations might make it optimal to add a layer of management [Caliendo and Rossi Hansberg (2011)]. In addition, an increase in scale can induce exporters to adopt technologies that entail fixed adoption costs [Lileeva and Trefler (2010), Bustos (2011)]. Alternatively, expansion into export markets can induce firms to upgrade skill through channels unrelated to increases in the scale of production. For example, firms might produce higher quality products for the export market, which requires more skilled workers [Verhoogen (2008)]. Finally, expansion into export markets can induce firms in the upper range of the productivity distribution to incur higher marketing costs as they serve more consumers [Arkolakis' (2010)]. As long as these market access tasks are skill-intensive this can lead to skill upgrading [Hsieh and Woo (2005), Matsuyama (2007)].[8]

The channels through which trading partner's tariff cuts can induce skill upgrading outlined above are not mutually exclusive. Thus, I attempt to assess their relative importance in three ways. First, I separate the skilled labor share in its production and non-production components. This allows me to evaluate the relative importance of skill upgrading in production and market access tasks. Second, I check whether the effect of tariffs on firm-level skill demands is strongest in the middle range of the firm-size distribution. This allows me to assess the importance of changes in the scale of production, which should not have an impact on the largest firms. Third, I check whether the reduction in tariffs had a stronger effect on other outcomes like spending in new technologies, process and product innovation in the same region of the firm size distribution. This permits to evaluate the importance of adoption of new production technologies and product innovation as channels through which tariff cuts induce skill upgrading.

I find that the effect of tariff reductions on skill intensity is mostly explained by changes in the skill intensity of production labor. The effect of tariffs on the skilled *production* labor share are strongest in the third quartile of the firm-size distribution, consistent with the idea that these firms cross a size threshold above which more skill-intensive production technologies are profitable as in models with fixed organizational or technology adoption costs. In previous work [Bustos (2011)] I found that the reduction in Brazil's tariffs induced firms in the third quartile of the firm size distribution to spend more in new technologies and engage in product and process innovation. Thus, the impact of tariff reductions on the skill intensity of production labor is likely mediated by the adoption of new production technologies and product innovation. This explanation is also consistent

[8] Matsuyama (2007) presents a model where international trade is more skill intensive than domestic trade because it requires expertise in international business and language skills. Hsieh and Woo (2005) provide evidence that international trade-related activities are more skill-intensive than manufacturing in Hong-Kong.

with the simple correlations in the data: firms upgrading skill faster also increase spending in technology faster and engage in more product innovation.

The effects of tariff reductions on *non-production* labor follows a different pattern. Tariff reductions have the strongest effect on the skill intensity of non-production labor for firms in the fourth quartile. This finding suggests that there are additional direct effects of tariff reductions on firm-level skill demands, not mediated by technology or product quality upgrading. The finding is consistent with skill-intensive market access costs increasing with the number of consumers served. Alternatively, it can respond to changes in the organization of firms that involve the incorporation of new layers of management.

**Related Literature**

The literature has proposed several channels through which trade liberalization can affect wage inequality in developing countries. Feenstra and Hanson (1996, 1997) develop and test a model that accounts for the simultaneous increase in the skill premium in developed and developing countries when they open up to trade in the presence of trade in intermediate inputs and capital movements. Goldberg and Pavcnik (2007) note that the increase in the skill premium in Latin American countries can be reconciled with the H-O framework if unskilled-labor-intensive industries were relatively more protected prior to liberalization, or if the countries also open up to trade with more unskilled-labor-abundant countries like China. Antras, Garicano and Rossi- Hansberg (2006) present a model where globalization leads to the formation of hierarchical teams across countries, leading to higher wage inequality in developing countries as higher ability workers form teams with managers in developed countries.

Recent theoretical papers study how trade liberalization can affect wages in the context of labor market frictions [Davis and Harrigan (2007), Egger and Kreickemeier (2009), Amiti and Davis (forthcoming), Helpman, Itskhoki and Redding (2010)]. The model presented in this paper instead focuses on how trade affects the returns to observable skills, namely education, in a neoclassical labor market. Other recent papers like Ohnsorge and Trefler (2007) and Costinot and Vogel (2009) study the effects of trade on wage inequality in competitive assignment models. Burstein and Vogel (2009) develop a model in which both comparative advantage and skill-biased technology shape the relationship between trade and wage inequality. The main differential feature of the model presented here is that firms can choose to switch to a skill-intensive technology; thus trade liberalization generates an upwards shift in firm-level skill demands. This generates an increase in the skill intensity of production within firms that upgrade technology, despite the increase in the skill premium.

My work builds on the empirical literature studying the effects of trade liberalization on wages through changes in tariffs [Attanasio, Goldberg and Pavcnik (2004), Topalova (2005), Amiti and Davis (forthcoming), Menezes-Filho and Muendler (2007), Galiani and Porto (2010)]. I see this paper as complementary to these studies as most of them focus on the effects of unilateral trade liberalizations. The few studies of the effects of bilateral liberalization [Trefler's (2004), Lileeva and Trefler's (2011) and Bustos (2011)] focus on the impact of trading partner's tariff reductions on productivity and technology adoption, not on the demand for skill.

My work is also related to empirical studies relating the expansion of export markets to the demand for skill and wages. Bernard and Jensen (1997) note that exporters are more skill-intensive than non-exporters in the U.S., thus a reallocation of market shares towards exporters can increase the demand for skill. Verhoogen (2008) proposes a model where increased trade with developed countries can induce exporters in developing countries to increase product quality and wages. He finds that a devaluation in Mexico induced the most productive firms to raise the export share of sales and wages relative to less productive plants. In further work, Frias, Kaplan and Verhoogen (2009) show that the increase in wages induced by the Mexican devaluation reflects changes in wage premia and not changes in the skill composition of the labor force. Instead, I find that a reduction in Brazil's tariffs induces the most productive firms to upgrade skill. I see these results as complementary, rather than contradictory: the difference in results might be due to the different nature of the shocks to the profitability of exports analyzed. A devaluation is likely to be perceived as more temporary than a regional trade liberalization. Thus, it can affect revenues and wages but is less likely to affect long-term investment decisions that affect the skill composition of workers.

Finally, the empirical work presented in this paper complements the findings on the effects of MERCOSUR on exports and investment in technology in Bustos (2011). The focus of this paper is instead understanding the causes of the increase in the demand for skill during this period. The model is similar to Bustos (2011) in that firms can choose to switch to a higher fixed cost but lower marginal cost technology. The difference is that here I consider an economy with two types of labor (skilled and unskilled) where the low marginal cost technology is skill-intensive. As a result, new testable predictions emerge: trade liberalization induces firms in the upper range of the productivity distribution to upgrade skill, but as the skill premium increases the least and most productive firms downgrade skill. The empirical work I present here focuses on testing these new predictions regarding skill intensity. To my knowledge, this is the first paper showing that a reduction in trading partner's tariffs induces firms above median size to upgrade skill. In addition, the finding that firms below median size downgrade skill is also new and highlights how the expansion of exporters can impact non-exporters through general equilibrium effects.

The next section describes the trade liberalization in Argentina and the data set. Section 2 provides preliminary empirical evidence on the increase in the relative demand for skill and describes broad patterns in the data that motivate the assumptions in the model. Section 3 develops the theoretical model and derives the empirical predictions on the effects of trade liberalization the demand for skill. Section 4 presents the empirical strategy and tests the predictions of the model. Section 5 concludes.

# 1 Context and Data

## 1.1 Trade Liberalization

At the beginning of the 1990's, Argentina undertook a broad reform program that included trade and capital account liberalization. Trade liberalization was implemented first through unilateral policies, and was later complemented by regional trade liberalization through the MERCOSUR treaty, and the multilateral negotiations of the General Agreement on Tariffs and Trade (GATT).

Trade liberalization started as a unilateral policy in 1988, as the result of negotiations started in the context of structural reforms supported by the World Bank. In March 1991 MERCOSUR, a regional free trade agreement, was signed between Argentina, Brazil, Paraguay, and Uruguay. The agreement established *generalized, linear and automatic* reductions in tariffs, and the adoption of a common external tariff with third countries. Tariff reductions were to be gradually implemented according to a timetable starting in December 1991 with the objective to achieve free trade within the region by the end of 1994. Finally, the Customs Union was established in 1995 with the adoption of a Common External Tariff (CET) [For a more detailed discussion of the regional and unilateral trade liberalization policies see Bustos (2011)].

During the period of implementation of MERCOSUR (1992-1996) Argentinean exports to Brazil quadrupled, while exports to the rest of the world only increased 60%. This might be related to deep reduction in Brazil's tariffs during this period. The average reduction in Brazil's tariffs in the period 1992-1996 is 24 p.p. These tariff reductions varied across industries, as initial m.f.n. tariffs were between 1 and 63 percentage points (Table A1 in the Appendix reports summary statistics for m.f.n. tariffs at the 4-digit-ISIC industry level of aggregation in the period under study).

As Argentina's unilateral trade liberalization occurred before the period under study, between 1992 and 1996 Argentina's average import tariffs with respect to the rest of the world increased slightly (1 p.p.). Still, there were changes in tariffs in both directions, from -10 p.p. to 14 p.p. across 4-digit-ISIC industries, which were partly related to the convergence to the CET. Argentina's imports from Brazil grew at the same pace as imports from the rest of the world in the period under study (60%). This might be due to the fact that Argentina's unilateral liberalization preceded

MERCOSUR. Thus, the baseline for the reduction in Argentina's tariffs for imports from Brazil was only 13 percentage points on average. Still, there was significant variation in tariffs across 4-digit-ISIC industries, from 0 to 22 p.p. (See Appendix Table A1).[9]

*Brazil's Trade Policy*

The source of identification of the effect of tariff reductions on firm-level employment of skilled labor are differences across industries in the level of m.f.n. tariffs in Brazil in 1992. Thus, it is important to asses whether Brazil's trade policy is exogenous w.r.t. the outcome analyzed, skill intensity in Argentina.

Brazil implemented a program of unilateral trade liberalization between 1988 and 1994. Thus, Brazil's m.f.n. tariff rates in 1992 reflect a transition between import substitution policy and a new tariff structure protecting some skill-intensive industries. Possibly as a result, the correlation between Brazil's tariffs in 1992 and an exogenous measure of skill intensity of the industry is very low (-0.002). Still, the omission of industry characteristics that are correlated with Brazil's trade policy might induce biases in the estimation of the impact of the reduction in Brazil's tariffs on skill intensity. Thus, I perform robustness checks by including controls for 2-digit-ISIC-industry dummies that absorb part of the correlation between changes in tariffs and industry characteristics. In addition, I control for measures of capital, skill intensity and the elasticity of demand.

## 1.2 Data

### 1.2.1 Firm-Level Data

The data I analyze comes from the Encuesta Nacional de Innovación y Conducta Tecnológica de las Empresas Argentinas (ENIT) [National Survey on Innovation and Technological Behavior of Industrial Argentinean Firms] conducted by the Instituto Nacional de Estadística y Censos (INDEC), the Argentinean government statistical agency. The survey covers the period 1992-1996 and was conducted in 1997 over a sample of 1,639 industrial firms. The sample is representative of firms owning establishments with more than 10 employees, and is based on 1993 census data.[10] As the survey was conducted in 1997, it does not contain information on firms that were active in 1992 and exited afterwards. Thus, the data is not informative about changes in the skill composition of the industrial sector occurring through entry and exit. I focus my analysis on a balanced panel

[9] In addition, Table A1 reports average m.f.n. input tariffs for Argentina as these are used for robustness checks in the empirical analysis. The input tariff for each industry is computed as a weighted average of the tariffs of all inputs used, where the weights are based on the cost share of each input obtained from the input-output matrix of Argentina, as described in Bustos (2010). The baseline m.f.n rates for Argentina's input tariff reductions w.r.t Brazil were on average 11 p.p. in 1992.

[10] According to the census 15% of establishments had more than 10 employees, they represented 90,7% of the value of output, 90,9% of industrial value added, 87,9% of employment and 94,1% of the wage bill.

of 1,359 firms present both in 1992 and 1996 for which there is information on sales, employment and belong to 4-digit-ISIC industries with information on Brazil's tariffs.[11] The survey contains information on sales, exports, imports, employment by education and investment for the years 1992 and 1996 while information on spending in technology is available for all the years in the period 1992-1996.

As noted above, the initial year in the data is 1992 while the major trade liberalization measures were taken at the end of 1991. Still, the data for 1992 can be a good indication of the situation before liberalization started to have a considerable impact on exports and skill upgrading. This is because the instability of the previous period brought a high degree of uncertainty on whether the reforms taken at the end of 1991 would be permanent. For instance, industrial exports to Brazil only started growing in 1993. Similarly, many investment decisions are likely to have been delayed until the reform was perceived as permanent. Thus, when analyzing the data, I use 1992 as an indicator for the situation before liberalization had a significant impact, and 1993-1996 as the period after liberalization.

**Education Level of Workers** An important advantage of this survey over standard industrial surveys is that it contains direct information on the educational level of workers. Table 1.1 reports the change in employment by educational categories between 1992 and 1996. This change is ordered by skill, with employment of engineers growing 13.5% while employment of high school and primary school graduates fell 8.4%.

I aggregated workers into two skill categories to obtain a measure of the equilibrium relative demand for skill (S/U). Skilled workers (S) are college graduates plus technical education graduates converted to college equivalents.[12] Unskilled workers (U) are high school graduates and below converted to less than high school equivalents.[13] This aggregation scheme would provide for a

[11] I also trim the sample by excluding firms with changes in skilled labor ratios on the top and bottom percentiles, following a suggestion by Angrist and Krueger (1999).

[12] College graduates completed 5 to 6 years of education after high school, while technicians usually completed 2 to 3 years of education after high school.

[13] The survey classifies workers according to education but although it distinguishes between engineers, other college and technicians it does not distinguish within the categories of high school graduates and primary school graduates. These last two categories are pooled together for non-production and R&D workers and are divided into "skilled and specialized" and "unskilled" for production workers. As all the analysis in this paper is performed pooling high school and primary school workers into the unskilled labor category this does not present inconveniences, except that it affects the weighting of these types of workers to convert them in primary school equivalents. For this purpose workers have been assigned into one of these categories by assuming that the overall share of high school and primary school workers is the same as the one reported in the next wave of this survey (1998-2001) that does differentiate between these educational categories. Then, workers reported as high school or primary school workers in non-production and R&D are assigned in a fraction 0.46 to high school graduates. For production workers, "skilled and specialized" workers are also assigned in a fraction 0.46 to high school graduates while "unskilled" workers are assigned to primary school graduates. Alternative assignments or measures of the relative employment of skilled workers unweighted by skill premiums give similar results to the ones reported.

correct measure of the equilibrium relative demand for skill if workers within skill categories were perfect substitutes, and is a good approximation when the elasticity of substitution is higher within than across categories.[14] This seems to be a reasonable assumption, as the employment of college graduates and technicians increased by a similar amount (6,6%) while the employment of high school graduates and below fell (8.4%). The conversion of workers to college and less than high school equivalents was done using the 1992 educational wage premia.[15] Then, reported changes in the relative employment of skilled labor reflect changes in employment and not in wages. Overall, between 1992 and 1996, the relative employment of skilled labor increased by 16.1% in the balanced panel of 1359 firms (Table 1.2).

An alternative measure of the equilibrium relative demand for skill is the employment of share of skilled labor in efficiency units:

$$\frac{L_t^s}{L_t} = \frac{S_t w_{1992}}{S_t w_{1992} + U_t}$$

where t = 1992 , 1996 and $w_{1992}$ is the skill premium in 1992. Note that as skilled labor is weighted by the skill premium in 1992, changes in relative employment of skilled workers reflect changes in quantities of skilled and unskilled labor, and not changes in the skill premium. Overall, the employment share of skilled labor increased by 12.4% in the balanced panel of 1359 firms (Table 1.3). In what follows, I use the employment of share of skilled labor in efficiency units as a measure of skill intensity because this permits to perform the firm-level analysis on the full sample of firms. Instead, the relative employment of skilled workers (and its log) is not defined for some firms that have zero skilled or unskilled workers. Still, all the results in the paper are robust to using either measure of skill intensity.

The survey also classifies workers according to production (P), non-production (NP) and R&D occupational categories, which permits to investigate whether the increase in the relative demand of skilled labor came primarily from reallocations from production to non-production and R&D activities. Table 2 reports the skill intensity of each of these activities: non-production is around 2.3 times more skill-intensive than production, and R&D around 4.7 times more skill-intensive than production. This pattern is consistent with the findings in Berman, Bound and Griliches (1994) for the U.S. regarding the higher educational level of non-production relative to production workers. Most empirical studies using industry or firm-level data use production workers as a proxy for unskilled labor, and non-production workers as a proxy for skilled labor, given that the P/NP classification is the only one available in standard industry surveys and censuses. These

[14] For a thorough discussion about aggregation of labor categories see Katz and Author (1999).

[15] Estimated by mincerian regressions from Household Survey data in Sebastian Galiani and Guido Porto (forthcoming) and Leonardo Gasparini, Mariana Marchionni and Walter Sosa Escudero (2005).

studies capture primarily the reallocations from production to non-production labor, but miss skill upgrading within occupational categories, as I show in the next section.

**Spending on Technology** Firms can change their production technology in different ways: they can engage in internal R&D or adopt technologies developed elsewhere through the purchase of technology transfers and capital goods that embody new technologies. The survey contains information on several dimensions of spending on technology which permits to construct a comprehensive measure of spending on technology (ST) including: spending on computers and software; payments for technology transfers and patents; and spending on equipment, materials and labor related to innovation activities performed within the firm. In the survey innovation activities are defined as having the purpose of changing production processes, products, organizational forms or commercialization.

The survey contains information on ST for all years in the period 1992-1996, while information on all the rest of the variables (sales, exports, imports, employment by education, investment) is only available for the years 1992 and 1996. Thus, to obtain a measure of changes in technology in the period 1992-1996 I collapse the data in two sub-periods, one before (1992) and one after liberalization (1993-1996) and take first differences, as suggested by Marianne Bertrand, Esther Duflo, and Sendhil Mullainathan (2004).[16] Then, I define the change in ST in the liberalization period for firm i as:

$$\Delta \log ST_i = \frac{1}{4} \sum_{t=1993}^{1996} \log ST_{it} - \log ST_{i1992}.$$

The survey also contains a list of 9 yes/ no questions asking whether the firm performed a certain category of innovation or improvement in products or production process during the period 1992-1996. As an example, one of these categories is: "product differentiation" and another "machinery and equipment associated to new production process". I use this information to construct an innovation index equal to the fraction of categories for which the firm gave positive answers. A detailed description of the questions is contained in Bustos (2011).

Table A.2 in the Appendix contains summary statistics by export status for the main variables of interest for the initial year in the data, 1992.

[16] An alternative would be to only use the information in 1992 and 1996. I chose the first option to exploit all the available information, and also to minimize the number of observations with zero ST. The first alternative gives very similar results, although the standard errors are slightly bigger.

### 1.2.2 Industry-Level Data

In the empirical section I use controls for 4-digit-ISIC industry characteristics that might be correlated with changes in tariffs. First, average capital and skill intensity in the industry in the U.S. in the 1980's obtained from the National Bureau of Economic Research (NBER) productivity database.[17] I also use the elasticity of substitution in the industry as estimated by Broda and Weinstein (2006).

# 2 Preliminary Evidence

## 2.1 The Relative Demand for Skill

The coincidence of rising skill premia and increasing relative employment of skilled workers in the period 1992-1996 indicates that there must have been an outwards shift in the relative demand of skilled labor after trade liberalization.

Gasparini et al. (2002) report wage premia estimates from mincerian regressions using Household Survey data. They find that the college wage premium (the wage of college graduates relative to the wage of primary school graduates) rose 19.4% between 1992 and 1998, after falling 3.7% between 1986 and 1992. The high school wage premium rose much less (4.8%), and had been constant during the previous period. Estimates for the industrial sector in Galeani and Sanguinetti (2003) indicate that the college wage premium increased 7 percentage points per year during the 1990's, after being stable in the 1980's. They do not find any significant trend for the high school wage premium.

In the remaining of this section I analyze the changes in the relative employment of skilled and unskilled workers in the industrial sector.

*Decompositions of the Change in the Employment Share of Skilled Labor*

The increase in the aggregate relative demand for skilled labor could be mainly driven by factor reallocations towards skill-intensive sectors or firms, holding skill intensity within firms constant; or by increases in skill intensity within firms, holding the share of each firm in total factor demand constant. Assessing the relative importance of these two channels is a necessary step in the investigation of the causes of the increase in the aggregate demand for skill. This is because reallocations of factors across sectors or firms can be driven directly by trade liberalization, holding firm technology constant. Instead, within firm increases in skill intensity point towards changes in production

[17] Capital intensity is computed as CAP /EMP. CAP is the real capital stock in millions of 1987 dollars and EMP is the number of employees. Skill Intensity is computed as (EMP-PRODE)/ EMP. PRODE is the number of production workers in 1,000s. These variables are described in more detail in Bartelsman and Gray (1996).

technology. This is because firms who keep using the same (homotetic) production technology should decrease skill intensity in response to the increase in the skill premium documented above. Thus, the finding that within firm increases in skill intensity are important suggests that trade liberalization affects skill intensity through changes in production technology.

I perform three different decompositions of the increase in the aggregate employment of skilled labor: first between and within occupational categories (P, NP and R&D); second within and between sectors; third within and between firms.

To assess the importance of skill upgrading within occupational categories relative to reallocations from production to non-production and R&D, I perform the following decomposition of the change in the aggregate employment share of skilled labor from 1992 to 1996:

$$\Delta\left(\frac{L^s}{L}\right) = \sum_i \Delta\left(\frac{L_i}{L}\right)\overline{\left(\frac{L_i^s}{L_i}\right)} + \sum_i \overline{\left(\frac{L_i}{L}\right)}\Delta\left(\frac{L_i^s}{L_i}\right) \tag{1}$$

where $i =$ P, NP, R&D; $\frac{L_i}{L}$ is the share of labor (in efficiency units) employed in activity i; $\frac{L_i^s}{L_i}$ is skill intensity in category i; a bar over a term denotes a mean over time (1992 and 1996) and a $\Delta$ before a term denotes a change over time (from 1992 to 1996). The first term on the right reports the change in aggregate skill intensity attributable to shifts in employment shares between occupational categories holding skill intensity within categories constant. The second term reports the change in aggregate skill intensity attributable to changes in skill intensity within each occupational category.

Table 3 reports the between and within decompositions of the aggregate increase in skill intensity in the period 1992-1996. Of the 12.3 percent increase, only 2 points are explained by reallocations from production to non-production and R&D occupational categories, and 10.2 points correspond to skill upgrading within categories, of which 6.5 points correspond to production and 3.5 points to non-production. That most skill upgrading occurs within occupational categories suggests that studies using variation between these categories as proxies for skill upgrading might be missing an important part of it. In addition, it points towards changes in the production function within occupational categories, favoring the technological change over other explanations for skill upgrading that rely on reallocations of demand towards skill-intensive non-production activities due to outsourcing of production activities or the increasing importance of services over goods.

The relative importance of technological change versus market share or production factor reallocations can also be assessed by decomposing the aggregate increase in skill intensity in changes within and across industries. In this case the decomposition can also be described by equation (1) with $i$ denoting industry at 4-digit-ISIC classification. Table 4 reports the between and within industry decompositions of the aggregate increase in skill intensity in the period 1992-1996. Most of the 12.4 percent increase is explained by within-industry skill upgrading (11 points), the between component being small (1.5 points). Moreover, most of it is explained by skill upgrading within firms (10.6 points). There is one important caveat to take into account for interpretation of this evidence: the sample I analyze does not contain entry and exit, thus the reallocations across sectors and firms that occur through entry and exit are missed in these calculations.

That most skill upgrading occurred within 4-digit-ISIC industries is consistent with the findings for the U.S. [Berman, Bound and Griliches (1994)] and several Latin American countries [Goldberg and Pavcnik (2007)]. In addition, the finding that most of the increase in the relative demand for skill is explained by skill upgrading within firms points towards changes in production technology as the main cause of the increase in the relative demand of skilled labor. Thus, the next sections focus on investigating the effects of trade on skill upgrading through the technology adoption channel.

## 2.2 Technology and Skill Upgrading

In this subsection I investigate the relationship between technology and skill upgrading. I relate the change in the share of skilled labor between 1992 and 1996 to different measures of technology adoption. First, I estimate the following regression by OLS:

$$\Delta\left(\frac{L_i^s}{L_i}\right) = \alpha + \beta \Delta \log ST_i + \varepsilon_i \tag{2}$$

where i indexes firms and $\Delta$ denotes a change over time. This regression can only be run in the sub-sample of firms that have positive spending on technology in both sub-periods (880 out of 1359 firms), which is not representative as these firms tend to be bigger.[18] Thus, as a robustness check, I also estimate equation (2) using the product and process innovation indexes as these are available for a larger sub-sample of firms (1280 firms) that is representative in terms of size.

Estimation results are presented in Table 5. Column 1 shows that firms that increase spending in technology faster also upgrade skill faster. The estimated coefficient (0.544, t=3.32) implies that a one standard deviation increase in spending in technology is associated with a 0.62 percentage points increase in skill intensity, which represents 29% of the average increase for this sample. Column 2 shows that the estimated coefficient ($\beta$) is robust to the inclusion of 2-digit-ISIC industry dummies in the regression, which attempt to control for unobserved time-varying industry characteristics, like the speed of technological change. The product and process innovation indexes are also positively correlated with skill upgrading, as shown in columns 3 to 8.

[18] Only 14% of firms reporting a positive spending in technology belong to the first size quartile and 24% belong to the second. Thus, results might not be representative for firms below the median size.

The positive correlation between technology and skill upgrading reported in Table 5, suggests that new technologies are more skill-intensive.

### 2.3 Export Status and Skill Upgrading

In this section, I document systematic differences in skill intensity of both production and non-production labor between exporters and non exporters.

Table 6 reports the differences between firms that exported both in 1992 and 1996 (continuing exporters), firms that exported in 1996 but not in 1992 (new exporters), and firms that only serve the domestic market (non exporters). The continuing exporter and new exporter premia are estimated from a regression of the form

$$\ln Y_{ij} = \alpha + \alpha_{NE} NE_{ij} + \alpha_{EE} EE_{ij} + \alpha_{EN} EN_{ij} + I_j + \varepsilon_{ij}$$

where $i$ indexes firms, $j$ indexes industries (4-digit-SIC classification); $NE$ are new exporters, $EE$ are continuing exporters, $EN$ are firms that exported in 1992 but didn't in 1996,[19] and the reference category relative to which differences are estimated is non-exporters; $I_j$ are industry dummies, and Y is the firm characteristic for which the premia are estimated. Firm characteristics include the employment share of skilled labor and its disaggregation in production and non-production activities. In addition, the table reports differences in size and spending on technology per worker that reproduce the findings in Bustos (2011).

In 1992, exporters are 1.7 log points bigger than never exporters. More importantly, they have a 5.1 percentage points higher share of skilled labor, which reflects both higher skill intensity of production labor (1.84 p.p.) and non production labor (2.38 p.p.). In addition, they have a 0.34 log points higher level of spending in technology per worker. In contrast, firms that would enter the export market after trade liberalization, but still do not export in 1992, are only 1.08 log points bigger than never exporters and do not have a significantly higher share of skilled labor or spending in technology. Still, these firms upgrade technology and skill faster than never exporters as they enter the export market during the trade liberalization period, becoming thus more technology and skill intensive.

The patterns in the data reported in Table 6 suggest that exporting is associated with the use of a production function that is both more technology and skill intensive. In the following section I present a model that is consistent with these empirical patterns and generates some new predictions

[19] Only 28 out of 1516 firms are in this category, thus it is hard to interpret the coefficients on this group, specially because some of the zeros for 1996 could be imputed. I only include them as a control group.

regarding the impact of trade liberalization on firm-level skill demands.

# 3 Theory

In this section I present a simple model of trade with heterogeneous firms who decide whether to enter the export market and adopt a skill-intensive technology. I consider two symmetric countries engaging in bilateral trade liberalization. Each economy consists of a single monopolistically competitive industry where firms produce differentiated products under increasing returns to scale, as in Krugman (1979). Firms are heterogeneous in productivity and face fixed exporting costs as in Melitz (2003). In addition, firms can choose between two technologies, $h$ and $l$. Technology $h$ is more skill-intensive, has the advantage of a lower marginal production cost but entails higher fixed costs.

## 3.1 Setup of the Model

There are two identical countries. Each country is endowed with $\overline{S}$ units of skilled labor and $\overline{U}$ units of unskilled labor used to produce differentiated products in a single industry. I present the discussion from the point of view of the home country.

*Preferences*

Consumer preferences are defined over a continuum of horizontally-differentiated varieties within the industry. Preferences across varieties have the standard CES form, $U = \left[\int_0^M q(\omega)^{1-\sigma} d\omega\right]^{\frac{1}{1-\sigma}}$ with an elasticity of substitution $\sigma = 1/1-\rho > 1$.These preferences generate a demand function $q(\omega) = EP^{\sigma-1}p(\omega)^{-\sigma}$ for every variety $\omega$ where $p(\omega)$ is the price of each variety and $P = \left[\int_0^M p(i)^{1-\sigma} di\right]^{\frac{1}{1-\sigma}}$ is the price of the aggregate consumption good defined as $Q \equiv U$, $M$ is the number (measure) of existing varieties, and $E$ is the aggregate level of spending in the country.

*Entry*

Each variety is produced by a single firm. To enter the industry a firm pays a fixed cost of entry $f_e$ measured in units of the aggregate consumption good. The entrant then draws its productivity $\varphi$ from a known cumulative Pareto distribution $G(\varphi) = 1 - \varphi^{-k}$ with $k > 1$. Upon observing productivity, firms can decide to exit or stay and produce.

*Technology*

Firms can choose between two different production technologies $l$ and $h$. Production under technology $l$ entails a fixed cost $f$ in terms of the aggregate consumption good and constant marginal costs that reflect wage payments to skilled and unskilled labor. Total costs under technology $l$ can be described by:

$$TC_l(q,\varphi) = Pf + \frac{q}{\varphi} w_s^{\beta} w_u^{1-\beta}$$

where $w_s$ and $w_u$ are wages of skilled ($s$) and unskilled ($u$) workers, $q$ is the firm's output and $\beta \in (0,1)$. Firms have the option to adopt a skill-intensive technology $h$ which entails a higher fixed cost but can deliver lower marginal production costs if the equilibrium skill premium is not too high.[20] Total costs under technology $h$ can be described by:

$$TC_h(q,\varphi) = Pf\eta + \frac{q}{\gamma\varphi} w_s^{\alpha} w_u^{1-\alpha}$$

where $\eta > 1$, $\gamma > 1$, $\alpha \in (0,1)$ and $\alpha > \beta$.

*Serving The Foreign Market*

After learning $\varphi$ the firm decides whether to sell in the foreign market, which entails an additional per-period fixed cost of $f_x$ units of the aggregate consumption good. In addition, exported goods are subject to per-unit iceberg trade costs so that $\tau$ units need to be shipped for 1 unit to make it to the foreign country, with $\tau > 1$.

### 3.2 Firm Behavior

*Profit Maximization*

The profit maximizing price is a constant markup over marginal costs. Then, a firm with productivity $\varphi$ using technology $l$ charges the price $p_l^d(\varphi) = w_s^{\beta} w_u^{1-\beta}/(\rho\varphi)$ in the domestic market and a higher price $p_l^x(\varphi) = \tau p_l^d(\varphi)$ in the export market. If instead the firm uses technology $h$, it charges lower prices in both markets: $p_h^d(\varphi) = p_l^d(\varphi)/\lambda$ and $p_h^x(\varphi) = \tau p_l^d(\varphi)/\lambda$ where $\lambda \equiv \gamma / \left(\frac{w_s}{w_u}\right)^{\alpha-\beta}$ is the marginal cost advantage of the high technology.

Firms decide whether to export and adopt technology $h$ by comparing the profits obtained under each of the four possible choices, which are described below.

Profits if only serving the domestic market and using technology $l$ are:

$$\pi_l^d(\varphi) = \frac{r_l^d(\varphi)}{\sigma} - Pf \tag{3}$$

where $r_l^d(\varphi) = E\,(P\rho)^{\sigma-1}\left(w_s^{\beta} w_u^{1-\beta}\right)^{1-\sigma} \varphi^{\sigma-1}$ are revenues. Profits if only serving the domestic

[20] Parameter restrictions that ensure that this is the case are derived below.

market and using technology $h$ are:

$$\pi_h^d(\varphi) = \lambda^{\sigma-1}\frac{r_l^d(\varphi)}{\sigma} - Pf\eta \tag{4}$$

where I used that $r_h^d(\varphi) = \lambda^{\sigma-1} r_l^d(\varphi)$. Profits if exporting and using technology $l$ are:

$$\pi_l^x(\varphi) = \left(1+\tau^{1-\sigma}\right)\frac{r_l^d(\varphi)}{\sigma} - Pf - Pf_x \tag{5}$$

where I used that $r_l^x(\varphi) = \left(1+\tau^{1-\sigma}\right) r_l^d(\varphi)$.Note that the assumption that both countries are identical and trade costs are symmetric implies that the price index (P), wages ($w_s$ and $w_u$) and the expenditure level (E) are the same in home and foreign. Finally, profits if exporting and using technology $h$ are:

$$\pi_h^x(\varphi) = \lambda^{\sigma-1}\left(1+\tau^{1-\sigma}\right)\frac{r_l^d(\varphi)}{\sigma} - Pf\eta - Pf_x \tag{6}$$

where I used that $r_h^x(\varphi) = \lambda^{\sigma-1}\left(1+\tau^{1-\sigma}\right) r_l^d(\varphi)$.

Exporting and technology choices attaining the highest profits for each productivity level are represented in Figure 1. The equilibrium depicted obtains when $\varphi_x^* < \varphi_h^*$ where $\varphi_x^*$ is defined as the level of productivity above which a firm using technology $l$ finds exporting profitable $[\pi_l^d(\varphi_x^*) = \pi_l^x(\varphi_x^*)]$ and $\varphi_h^*$ is defined as the level of productivity above which an exporter finds adoption of technology $h$ profitable $[\pi_l^x(\varphi_h^*) = \pi_h^x(\varphi_h^*)]$. In Bustos (2010), I show that in this equilibrium firms sort into four different groups: the least productive firms ($\varphi < \varphi_d^*$) exit, the low productivity firms only serve the domestic market and use technology $l$ ($\varphi_d^* < \varphi < \varphi_x^*$), the medium productivity firms ($\varphi_x^* < \varphi < \varphi_h^*$) still use technology $l$ but also export, and the most productive firms both export and use technology $h$ ($\varphi_h^* < \varphi$) .Note that in this equilibrium using technology $h$ and only serving the domestic market is always dominated by some other choice. In addition, as there is a range of productivity levels where exporting is profitable but adopting technology $h$ is not, the marginal exporter uses technology $l$.In what follows I derive the conditions for this ordering of cutoffs ($\varphi_x^* < \varphi_h^*$) to be an equilibrium. The opposite case ($\varphi_h^* < \varphi_x^*$) is one where the equilibrium features no exporters using the low technology, which is inconsistent with the empirical findings I discuss in next section.

To solve for the industry equilibrium it is useful to state the conditions for exit, entry in the export market and technology adoption as a functions of the exit cutoff and the skill premium, which I do next.

*Exit*

For the least productive firms profits are highest when using technology $l$ and only serving the

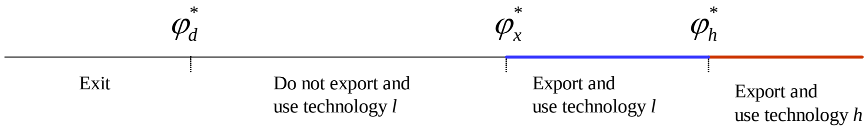


Figure 1: Export and Technology Choices

domestic market. Then, the exit cutoff ($\varphi_d^*$) is defined by:

$$\pi_l^d(\varphi_d^*) = 0 \Leftrightarrow \frac{r_l^d(\varphi_d^*)}{\sigma} - Pf = 0. \tag{7}$$

*Exporting*

The marginal exporter uses technology l, thus the exporting cutoff ($\varphi_x^*$) is defined by $\pi_l^d(\varphi_x^*) = \pi_l^x(\varphi_x^*)$ and can be expressed as a function of $\varphi_d^*$ using the zero profit condition for the marginal firm (equation 7):

$$\varphi_x^* = \varphi_d^* \tau \left(\frac{f_x}{f}\right)^{\frac{1}{\sigma-1}} \quad ; \tag{8}$$

note that as long as $\tau \left(f_x/f\right)^{\frac{1}{\sigma-1}} > 1$, $\varphi_x^* > \varphi_d^*$.Thus, only the most productive firms export. In addition, the fraction of firms that export, defined as $p_x \equiv \left(\frac{\varphi_x^*}{\varphi_d^*}\right)^{-k}$, is only a function of parameters, thus it is independent of the equilibrium skill premium. This is because the marginal exporter uses the same technology as the marginal firm in the industry.

*Technology Choice*

The marginal firm adopting technology $h$ is an exporter, then the adoption cutoff ($\varphi_h^*$) is defined by $\pi_h^x(\varphi_h^*) = \pi_l^x(\varphi_h^*)$. By comparing $\pi_l^x(\varphi)$ and $\pi_h^x(\varphi)$, as described in equations 5 and 6, one can see that the benefit of technology adoption is a proportional increase in variable profits by a factor $\lambda^{\sigma-1}$ where $\lambda \equiv \frac{\gamma}{\left(\frac{w_S}{w_U}\right)^{(\alpha-\beta)}}$ represents the marginal cost advantage of technology $h$. This benefit of adopting technology $h$ is increasing in revenues, while its cost $[Pf\,(\eta-1)]$ is fixed. Thus, adoption is characterized by a productivity cutoff $\varphi_h^*$ above which all firms use technology $h$. $\varphi_h^*$ can be expressed as a function of $\varphi_d^*$ by using the zero profit condition for the marginal firm (equation 7):

$$\varphi_h^* = \varphi_d^* \left[\frac{\eta - 1}{\left(1+\tau^{1-\sigma}\right)\left[\lambda^{\sigma-1} - 1\right]}\right]^{\frac{1}{\sigma-1}}. \tag{9}$$

Note that the fraction of firms adopting technology $h$,defined as $p_h \equiv \left(\frac{\varphi_h^*}{\varphi_d^*}\right)^{-k}$, is a function of parameters and the skill premium. This is because technology $h$ uses skilled-labor more intensively, thus its marginal cost advantage ($\lambda$) is decreasing in the skill premium. Then, the fraction of firms adopting the high technology ($p_h$) is a decreasing function of the skill premium.

## 3.3 Equilibrium

The industry equilibrium can be characterized by the skill premium, $\left(\frac{w_s}{w_u}\right)^*$, and the exit cutoff, $\varphi_d^*$.This is because all remaining endogenous variables can be written as functions of these two variables and parameters. In this section, I show that $\left(\frac{w_s}{w_u}\right)^*$ and $\varphi_d^*$ are determined by the labor market clearing and free entry conditions. These two conditions can be solved for sequentially: first, we find the skill premium that clears the labor market; second, we use the solution for $\left(\frac{w_s}{w_u}\right)^*$and the free entry condition to find the equilibrium exit cutoff.

### 3.3.1 *Labor Market*

The equilibrium skill premium is determined by equating the relative supply of skilled labor $\left(\frac{\overline{S}}{\overline{U}}\right)$ to the aggregate relative demand for skill $\left[\left(\frac{S}{U}\right)^D\right]$. To find the labor market equilibrium, it is useful to decompose the aggregate demand for skill in the demand of high technology firms and low technology firms, as follows: $S = S_l + S_h$, where:

$$S_l = \int_{\varphi_d^*}^{\varphi_x^*} s_l^d(\varphi)\frac{g(\varphi)}{1-G(\varphi_d^*)}d\varphi + \int_{\varphi_x^*}^{\varphi_h^*} s_l^x(\varphi)\frac{g(\varphi)}{1-G(\varphi_d^*)}d\varphi \quad \text{and} \quad S_h = \int_{\varphi_h}^{\infty} s_h(\varphi)\frac{g(\varphi)}{1-G(\varphi^*)}d\varphi;$$

$s_l^d(\varphi)$, $s_l^x(\varphi)$, and $s_h(\varphi)$ are labor demands for each of the three types of firms described in Figure 1. Analogous definitions apply to $U = U_l + U_h$.

We can derive firm-level labor demands for skilled and unskilled labor using the total cost functions for each type of firm, as detailed in the Appendix. The resulting firm-level relative demands for skill are independent of a firm's output level (and productivity) once it's technology choice is accounted for:

$$\frac{s_l^d(\varphi)}{u_l^d(\varphi)} = \frac{s_l^x(\varphi)}{u_l^x(\varphi)} = \left(\frac{s}{u}\right)_l = \frac{\beta}{1-\beta}\frac{w_u}{w_s} \quad \text{and} \quad \frac{s_h(\varphi)}{u_h(\varphi)} = \left(\frac{s}{u}\right)_h = \frac{\alpha}{1-\alpha}\frac{w_u}{w_s}.$$

This implies that the aggregate relative demand for skill of firms using the high technology is simply $\frac{S_h}{U_h} = \left(\frac{s}{u}\right)_h$ and for low technology firms: $\frac{S_l}{U_l} = \left(\frac{s}{u}\right)_l$. Thus, the aggregate relative demand for skill can be written as a weighted average of the (firm-level) relative demands for skill of high and low technology firms, where the weights are given by their employment share of unskilled labor:

$$\left(\frac{S}{U}\right)^D = \frac{S^h + S^l}{U^h + U^l} = \frac{S^h}{U^h}\frac{U^h}{U} + \frac{S^h}{U^h}\frac{U^l}{U} = \left(\frac{s}{u}\right)_h \frac{U^h}{U} + \left(\frac{s}{u}\right)_l \frac{U^l}{U}. \tag{10}$$

This representation of the relative demand for skill is similar to the standard 2x2x2 H-O model. The only difference is that here $h$ and $l$ do not represent different industries producing goods with inherently different technologies, but groups of firms choosing different production technologies within the same industry.

In the Appendix I show that the employment ratio of low and high technology firms $\frac{U_l}{U_h}$ is proportional to their revenue ratio $\frac{U_l}{U_h} = \frac{(1-\beta)}{(1-\alpha)} \frac{R_l}{R_h}$. Then, after substituting for $\left(\frac{s}{u}\right)_h$ and $\left(\frac{s}{u}\right)_l$ in 10 and some algebra, the relative demand for skill can be written as a function of the skill premium and the aggregate relative revenues of low and high technology firms $\frac{R_l}{R_h}$:

$$\left(\frac{S}{U}\right)^D = \frac{w_u}{w_s}\left\{\frac{\beta}{1-\beta} + \left(\frac{\alpha}{1-\alpha} - \frac{\beta}{1-\beta}\right)\frac{1}{1+\frac{(1-\beta)}{(1-\alpha)}\frac{R_l}{R_h}}\right\} \tag{11}$$

where

$$\frac{R_l}{R_h} = \frac{1}{\lambda^{\sigma-1}(1+\tau^{1-\sigma})}\left\{\left[\left(\frac{\varphi_h^*}{\varphi_d^*}\right)^{k-(\sigma-1)} - 1\right] + \tau^{1-\sigma}\left[\left(\frac{\varphi_h^*}{\varphi_x^*}\right)^{k-(\sigma-1)} - 1\right]\right\} \tag{12}$$

*Equilibrium Skill Premium*

The equilibrium skill premium is only determined by the labor market equilibrium condition $\frac{\overline{S}}{\overline{U}} = \left(\frac{S}{U}\right)^D$, independently of the exit cutoff. This is because $\lambda$, $\frac{\varphi_h^*}{\varphi_d^*}$ and $\frac{\varphi_h^*}{\varphi_x^*}$ are only functions of the skill premium and parameters (see equations 8 and 9). Thus, the relative demand for skill described in equations 11 and 12 is only a function of parameters and the skill premium. The equilibrium in the labor market is represented in Figure 2 where $RD_h$ and $RD_l$ represent the relative demand for skill of high and low technology firms, respectively (i.e. $\frac{w_s}{w_u} = \frac{\alpha}{1-\alpha}\left(\frac{s}{u}\right)_h$ and $\frac{w_s}{w_u} = \frac{\beta}{1-\beta}\left(\frac{s}{u}\right)_l$). $RD$ represents their weighted average, where weights are given by employment shares, or relative revenues (i.e. the inverse of $\left(\frac{S}{U}\right)^D$).

Note that the aggregate relative demand for skill is decreasing in the skill premium: $\frac{\partial\left(\frac{S}{U}\right)^D}{\partial\frac{w_s}{w_u}} < 0$. This is the result of two reinforcing effects. First, firm-level relative demands for skill $\left(\frac{s}{u}\right)_l$ and $\left(\frac{s}{u}\right)_h$ are downwards sloping. Second, the share of workers employed (or revenues produced) by low technology firms rises when the skill premium increases, because their marginal cost disadvantage is decreasing in the skill premium.

As $\left(\frac{S}{U}\right)^D$ is downwards sloping and $\frac{\overline{S}}{\overline{U}}$ is vertical, there is one and only one equilibrium skill premium $\left(\frac{w_s}{w_u}\right)^*$ at which $\left(\frac{S}{U}\right)^D = \frac{\overline{S}}{\overline{U}}$. In the Appendix I show that this equilibrium, where $\varphi_x^* < \varphi_h^*$, only obtains when the relative supply of skill belongs to an interval $\left(\left(\frac{\overline{S}}{\overline{U}}\right)^{\min}, \left(\frac{\overline{S}}{\overline{U}}\right)^{\max}\right)$. The intuition for this restriction on $\frac{\overline{S}}{\overline{U}}$ is that if the relative supply of skill is very high, then the skill premium is low and the cost advantage of technology $h$ is high enough that all exporters adopt it, thus $\varphi_h^* \leq \varphi_x^*$. In contrast, if the relative supply of skill is too low, the skill premium is too high, thus the new technology does not provide a marginal cost advantage and no firm adopts it.

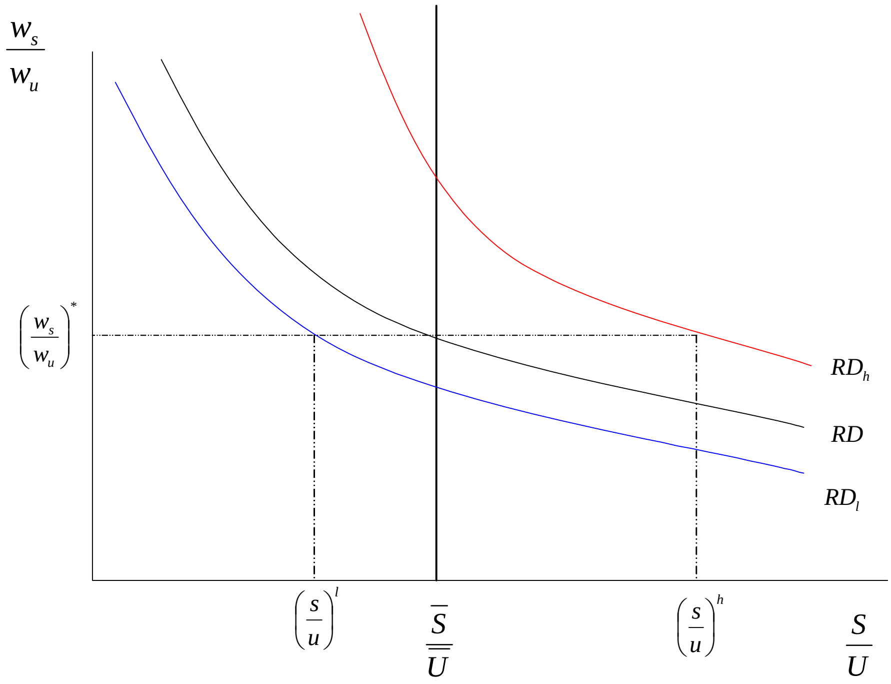


Figure 2: Labor Market Equilibrium

### 3.3.2 *Free Entry*

In an equilibrium with positive entry, the free entry condition must hold. This condition requires that the expected value of entry equals the sunk entry cost:

$$Pf_e = [1 - G(\varphi_d^*)] \frac{1}{\delta} \overline{\pi} \tag{13}$$

where $1 - G(\varphi_d^*)$ is the probability of survival and $\overline{\pi}$ are per period expected profits of surviving firms: $\overline{\pi} = \overline{\pi}_l^d + p_x \overline{\pi}_l^x + p_h \overline{\pi}_h^x$ where $\overline{\pi}_l^d$ are expected profits for surviving firms that do not export, $p_x$ is the fraction of surviving firms that export but use the low technology, $\overline{\pi}_l^x$ are their expected profits, and $p_h$ is the fraction of surviving firms that export but use the high technology and $\overline{\pi}_h^x$ are their expected profits. In the Appendix I show that this condition can be written as:

$$f\left[\left(\frac{\tilde{\varphi}_d}{\varphi_d^*}\right)^{\sigma-1} - 1\right] + p_x f_x \left[\left(\frac{\tilde{\varphi}_x}{\varphi_x^*}\right)^{\sigma-1} - 1\right] + p_h f(\eta - 1)\left[\left(\frac{\tilde{\varphi}_h}{\varphi_h^*}\right)^{\sigma-1} - 1\right] = \frac{f_e \delta}{[1 - G(\varphi_d^*)]}$$

where: $\tilde{\varphi}_i = \left(\int_{\varphi_i^* < \varphi} \varphi^{\sigma-1} \frac{g(\varphi)}{1 - G(\varphi_i^*)} d\varphi\right)^{\frac{1}{\sigma-1}}$ .The free entry condition can be further simplified if $G(\varphi)$ is a Pareto distribution with shape parameter k, in which case a solution for the exit cutoff can be obtained:

$$\varphi_d^* = \Psi \left[ f + p_x f_x + p_h (\eta - 1) f \right]^{\frac{1}{k}} \tag{14}$$

where

$$\Psi = \left[ \left( \frac{\sigma - 1}{k - \sigma + 1} \right) \frac{1}{\delta f_e} \right]^{\frac{1}{k}}.$$

$$p^x = \left( \frac{\varphi_x}{\varphi^*} \right)^{-k} = \tau \left( \frac{f_x}{f} \right)^{-\frac{k}{\sigma-1}} \tag{15}$$

$$p^h = \left( \frac{\varphi_h}{\varphi^*} \right)^{-k} = \left[ \frac{\eta - 1}{(1 + \tau^{1-\sigma}) \left[ \lambda^{\sigma-1} - 1 \right]} \right]^{-\frac{k}{\sigma-1}} \tag{16}$$

Note that the exit cutoff $\varphi_d^*$, as expressed in equation 14, is a function of parameters and the equilibrium skill premium, as $p^x$is only a function of parameters and $p^h$ is a function of both parameters and the skill premium. Then, the solution for equilibrium exit cutoff can be obtained by plugging in the solution for the equilibrium skill premium obtained above in equation 16. Note that the exit cutoff is negatively related to the equilibrium skill premium: an increase in the skill premium reduces the marginal cost advantage of the high technology ($\lambda$), which reduces the fraction of firms adopting it ($p_h$). As a result expected profits fall, thus the probability of successful entry must increase and the exit cutoff decreases.

## 3.4 Trade Liberalization

In this section I describe the effects of a bilateral trade liberalization where both countries reduce tariffs simultaneously.

**Proposition 1**. A reduction in variable trade costs ($\tau$):

(a) increases the equilibrium skill premium$\frac{\partial \left( \frac{w_s}{w_u} \right)^*}{\partial \tau} < 0$,

(b) reallocates market shares towards high technology firms $\frac{\partial \left( \frac{R_h}{R_l} \right)^*}{\partial \tau} < 0$,

(c) increases the share of exporters $\frac{\partial p^x}{\partial \tau} < 0$ and high technology firms $\frac{\partial p^h}{\partial \tau} < 0$,

(d) increases the exit productivity cutoff $\frac{\partial \varphi_d^*}{\partial \tau} < 0$

(e) reduces the export productivity cutoff $\frac{\partial \varphi_x^*}{\partial \tau} > 0$ and the technology adoption cutoff $\frac{\partial \varphi_x^*}{\partial \tau} > 0$.

Proof: see Appendix.

*Discussion and testable implications*

To analyze the effects of trade liberalization on the skill premium it suffices to consider its effects on the labor market equilibrium condition. A reduction in variable trade costs reallocates market shares from low to high technology firms, which shifts out the relative demand for skill, as shown in Figure 3. This results in an increase in the skill premium, which reestablishes equilibrium as it

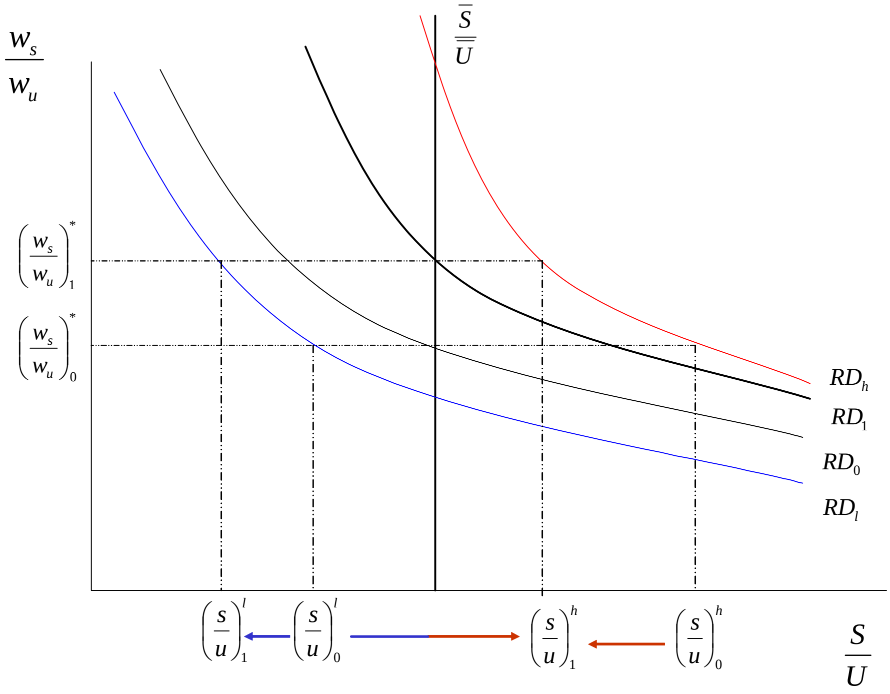


Figure 3: Effects of Trade Liberalization on Labor Market Equilibrium ($\tau_1 < \tau_0$)

induces both high and low technology firms to use a less skill-intensive production technique. In addition, as trade liberalization increases export revenues, it makes technology adoption more profitable, inducing some firms to adopt the high technology. This is because the benefit of adoption is proportional to revenues, while its cost is fixed. The effects of trade liberalization on the export and technology adoption decisions are represented in Figure 4. The upper line represents productivity cutoffs to adopt the high technology and to enter the export market before liberalization $(\varphi_x^0, \varphi_h^0)$, while the lower line represents the cutoffs after liberalization $(\varphi_x^1, \varphi_h^1)$. Note that the least productive firms, who continue using the low technology $(\varphi < \varphi_h^1)$, respond to the increase in the skill premium by reducing their skill demand, as shown in Figure 3. Similarly, the most productive firms, who continue using the high technology $(\varphi_h^0 < \varphi)$, also reduce their their skill demand. In contrast, firms in the middle range of the productivity distribution $(\varphi_h^1 < \varphi < \varphi_h^0)$, increase their skill demand as they adopt the high technology.

# 4 Empirics

In this section, I start by documenting that the cross-sectional patterns in the data are consistent with the model. Next, I test the model's predictions regarding the effect of trade liberalization on skill upgrading.

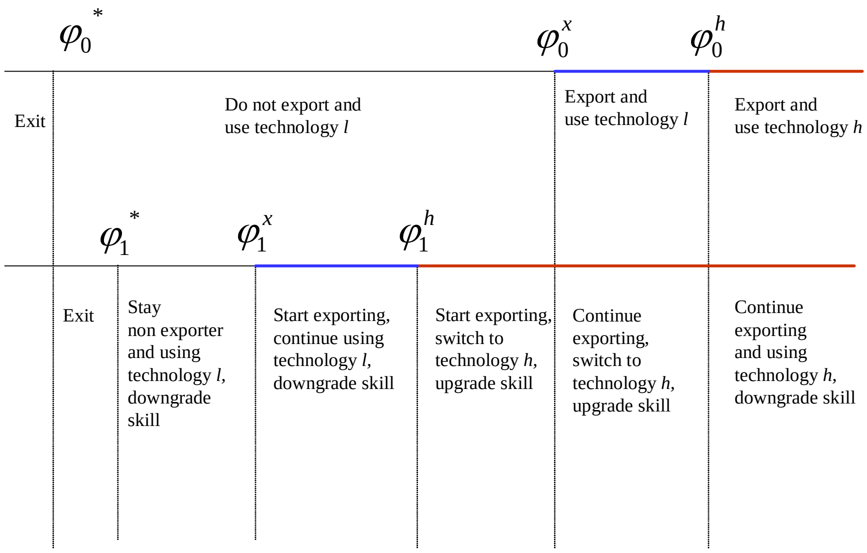


Figure 4: Effects of Trade Liberalization on Export and Technology Cutoffs ($\tau_1 < \tau_0$)

### 4.1 Cross Sectional Patterns in the Data

The model predicts that underlying productivity differences produce a sorting of firms into three groups: the low productivity firms only serve the domestic market and use the low technology ($\varphi_d^* < \varphi < \varphi_x^*$), the medium productivity firms still use the low technology but also export ($\varphi_x^* < \varphi < \varphi_h^*$), and the most productive firms both export and use the high technology ($\varphi_h^* < \varphi$) (see Figure 1). In this section I attempt to asses the approximate location of these cutoffs by looking for sizable differences in the share of exporters, skill and technology intensity across the firm-size distribution. Note that as there are several sources of heterogeneity other than productivity in the data, the exact location of the export and technology adoption cutoffs is likely to vary across industries or firms. [21] Thus, I just document how the average probability to export and skill intensity vary with firm size. I estimate the average differences in these outcomes for each quartile

[21] For example, the exporting and technology adoption productivity cutoffs ($\varphi_x^*$ and $\varphi_h^*$) are likely to differ across industries with different factor intensity as in Bernard, Redding and Schott (2007). In addition, there can be other sources of heterogeneity across firms, like differences in fixed export costs, that affect export status but do not necessarily translate into size differences. Finally, firm size is an imprefect measure of productivity.

of the initial firm-size distribution[22] w.r.t. the first quartile, through the following equation:

$$Y_{ij1996} = \sum_{r=2}^{4} \delta^r Q^r_{ij1992} + \alpha_j + \varepsilon_{ij} \tag{17}$$

where $i$ indexes firms, $j$ indexes 4-digit-ISIC industries, $Y_{ij1996}$ are firm characteristics in 1996 (export status, skill intensity and spending in technology per worker), $Q^r_{ij1992}$ are dummy variables taking the value of 1 when firm $i$ belongs to quartile $r$ of the firm-size distribution in 1992,[23] and $\alpha_j$ are 4-digit-ISIC industry dummies. Thus, $\delta^r$ corresponds to the differences in average outcomes for a firm in quartile $r$ relative to a firm in the first quartile.

Table 7 reports estimation of equation (17). The probability of exporting and the skilled labor share increase with firm size, which is consistent with the model. Note that the skilled *production* labor share is higher in the third and fourth quartiles than in the first two, which suggests that firms above median size are, on average, above the productivity cutoff to use technology $h$ after liberalization ($\varphi^1_h$ in Figure 4).

## 4.2 The Effect of Brazil's Tariffs

Tariff reductions can increase the demand for skill through the mechanism highlighted in the model, namely increased export revenues inducing firms to cross a size threshold above which skill-intensive production technologies are profitable, or other channels related to the expansion of exports but not necessarily to changes in production technology. Thus, in this section I focus on identifying the causal effects of trading partner's tariff reductions on the demand for skill, regardless of the mechanism at work. In next section, I conduct a more detailed analysis of the data to understand the importance of the mechanism emphasized by the model and identify other possible mechanisms at work.

### 4.2.1 Identification of causal effects of Brazil's tariff reductions

I estimate the effects of tariffs on the skilled labor share separately for different quantiles of the firm-size distribution. In this section I start by reporting the results obtained when dividing firms in only two groups: below and above median size. Finer partitions provide similar point estimates

[22] As a proxy for unobserved productivity, I use initial firm size in terms of (log) employment in less than high school equivalents relative to the 4-digit-industry average, as detailed in the Appendix. Alternatively I used (log) domestic sales relative to the 4-digit-industry mean as a proxy for initial productivity, with similar results than the ones reported below. I prefer the employment measure because it reflects value-added better than sales.

[23] Outcomes in 1996 are related to measures if firm size in 1992 to avoid simultaneity problems. These are particularly important for the skilled labor share and spending in technology per worker measures, as both have employment as a denominator, which is the same variable used to measure firm size. Then, relating 1996 outcomes to 1996 firm size would lead to a negative bias on the coefficient of firm-size if there is measurement error in employment.

but bigger standard errors, as there are on average 14 firms per industry. The median is a useful cutoff to identify the causal effects of tariff reductions on skill upgrading because 76% of the firms above the median size export while only 38% of the firms below median size do. Thus, we expect the reduction in Brazil's tariffs to have a direct effect on firms above median size, while the rest are mostly affected by general equilibrium changes in the skill premium.[24]

I estimate the effects of the reduction in Brazil's tariffs on firms below and above median size through the following equation:

$$\Delta\left(\frac{L_{ij}^{s}}{L_{ij}}\right)=\alpha+\beta\Delta\tau_{j}+\delta\left(\Delta\tau_{j}\times Big_{ij}\right)+\gamma Big_{ij}+\Delta\varepsilon_{ij} \tag{18}$$

where $i$ denotes firms, $j$ denotes 4-digit-ISIC industries; $\Delta\tau_j$ is the change in Brazil's tariffs during the period 1992-1996, which is given by minus its initial-level; and $Big_{ij}$ is a dummy variable taking the value of 1 when firms are above median size.

Equation (18) exploits the differential changes in Brazil's tariffs across 4-digit-ISIC industries to identify the causal effect of a reduction in trade costs on skill intensity. These tariff changes are likely to be exogenous with respect to the outcome analyzed, the change in skill intensity between 1992 and 1996, because they are predetermined by the 1991 m.f.n. tariff *levels* in Brazil.[25] Thus, tariff changes can't be driven by contemporaneous political pressures or shocks to industrial performance. In addition, as 1991 m.f.n. tariffs respond to Brazil's worldwide trade policy, they are unlikely to be targeted to Argentina's comparative advantage.[26] Still, Brazil's initial tariff structure is correlated with some industry characteristics and omitting them could be an important source of bias. This is why I estimate equation (18) in first differences so that constant industry characteristics are differenced-out. Still, if industries with different initial characteristics were on different trends, Brazil's tariffs could capture some omitted industry-level-time-varying variable. I address this problem by including in the differenced equations 2-digit-ISIC-industry dummies and 4-digit-ISIC-industry-level controls for industry characteristics that are likely to influence trade policy like the elasticity of demand, capital and skill intensity.[27]

[24] Note that when I test the model's predictions I interact tariff changes with initial firm-size dummies instead of export status dummies. This is because in previous work I found that Mercosur tariff reductions had a strong impact on entry in the export market [Bustos (2011)]. Thus, export status after liberalization is not only endogenously determined with skill intensity in the model, but also positively correlated with the main source of exogenus variation: the change in Brazil´s tariffs, in the data. As a result, I treat changes and levels in export status as an outcome, like skill intensity. The explanatory variables are changes in tariffs and initial firm heterogeneity measured as relative firm size. Still, interactions of export status after liberalization and tariff changes produce the expected results: the reduction in Brazil´s tariffs induces non exporters to downgrade skill while exporters upgrade (Tables are available upon request).

[25] As discussed in section 1.1. tariff reductions were programmed in 1991, and reach a level of zero for all industries in 1995. For a more detailed discussion of the implementation of MERCOSUR see Bustos (forthcoming).

[26] Argentina's share on Brazil's trade was only 7.7% in 1991.

[27] These industry characteristics are measured with U.S. data to avoid endogeneity problems.

An additional issue is that Brazil's tariffs might be correlated with changes in Argentina's tariffs during this period if both countries had a similar structure of protection. To address this concern I control for the change in Argentina's tariffs with respect to the world and Brazil for both final goods and intermediate inputs.[28]

#### 4.2.2 Results

Estimation results indicate that firms above median size were induced to upgrade skill by the reduction in Brazil's tariffs, while firms below median size were induced to downgrade skill. Estimation of equation (18) is reported in Table 8 where Column 1 includes no controls while the rest of the columns add the controls described in the previous sub-section. The first row reports estimation of $\beta$ which measures the average effect of Brazil's tariffs on the skilled labor share for firms below median size. The second row reports $\delta$, which measures the differential effect of Brazil's tariffs on the skilled labor share of firms above median size (the total effect for this group is $\beta + \delta$). The estimated coefficients in the baseline specification,[29] reported in column (2), are $\beta$ = 3.999 (t =2.47) and $\delta$ = -8.654 (t=3.36). These coefficients imply that the average reduction in Brazil's tariffs (23 percentage points) induced an 8% reduction in the average skilled labor share for firms below median size and a 6% increase for firms above median size. Another way of reading the results is that in a sector with the average reduction in Brazil's tariffs, big firms increased the skilled labor share 1.98 percentage points faster than small firms. This amounts to a 35% increase in the skill intensity gap between big and small firms.

The rest of he columns in Table 8 show that estimation results are robust to the inclusion of changes in Argentina's output and input tariffs w.r.t. the world and Brazil and 4-digit-ISIC industry characteristics. Results are also robust to including interactions of all these industry-level variables with the dummy variable indicating whether a firm is above median size ($Big_{ij}$). Finally, column (8) shows that the result that firms above median size upgrade skill faster in industries with bigger reductions in tariffs is robust to the inclusion of 4-digit-ISIC industry dummies.

I performed some additional robustness checks for the results reported in Table 8. First, I estimated an equation similar to (18) but instead of using a dummy variable indicating firm size, I directly interacted the change in tariffs with firm-size, as reported in Appendix Table A.3. The

[28] As Argentina's m.f.n tariffs in 1992 were the basis for MERCOSUR tariff reductions, it is hard to distinguish the effect of the reduction of tariffs with respect to Brazil from changes of tariffs with respect to the rest of the world, thus I control for them separately.

[29] The baseline or preferred specification is the one that includes controls for 2-digit-ISIC industry dummies. This is because it controls for differential industry trends at the 2-digit aggregation level, and does not include changes (or levels) of Argentina's tariffs which are more likley to be endogenous to Argentina's industry characteristics than the initial level of Brazil's tariffs.

estimated coefficients on the change in Brazil's tariffs and firm-size imply that effect of tariff reductions changes sign around the median, confirming the results reported in Table 8. Finally, I also estimated equation (18) replacing the outcome of interest for the log ratio of skilled to unskilled labor, obtaining very similar results not reported in the paper but available upon request.

### 4.2.3 Mechanism

In this section, I investigate the mechanisms through which the reduction in Brazil's tariffs induced skill upgrading. For this purpose, I separate the skilled labor share in its production ($p$) and non-production ($np$) components, as follows: $\frac{L^s}{L} = \frac{L^{s,p}}{L} + \frac{L^{s,np}}{L}$.[30] This allows me to evaluate the relative importance of skill upgrading in production and market access tasks.

*Skill in Production and Non-production Activities*

I estimate the effects of the reduction in Brazil's tariffs on skill upgrading for each quartile of the firm-size distribution through the following equation:

$$\Delta\left(\frac{L^s_{ij}}{L_{ij}}\right) = \alpha + \beta\Delta\tau_j + \sum_{r=3,4}\delta^r\left(\Delta\tau_j \times Q^r_{ij}\right) + \sum_{r=3,4}\gamma^r Q^r_{ij} + \Delta\varepsilon_{ij} \qquad (19)$$

where $Q^r_{ij}$ are dummy variables taking the value of 1 when firm $i$ belongs to quartile $r$ of the firm size distribution in 1992. Table 9 reports results from estimation of equation (19). In Panel A the outcome is the skilled labor share, as in Table 8. Panels B and C report results for the skilled production and non-production labor shares separately. Panel A confirms the results reported in the previous section: firms below median size downgrade skill and firms below upgrade, with effects on the third and fourth quartiles being of similar size. In Panel B, where the outcome is the skilled production labor share, the reported coefficient on the change in Brazil's tariffs ($\beta$) is always positive [$\beta$ = 3.03 (t=2.66) in Panel B column 2] and significantly different from zero. Thus, the reduction in Brazil's tariffs induced firms below median size to reduce the skilled production labor share. The reported coefficients on the interaction between Brazil's tariffs and the third and fourth size quartiles ($\delta^3$ and $\delta^4$) measure the differential effect of the change in Brazil's tariffs on these quartiles relative to firms below median size. This difference is always negative and statistically significant [$\delta^3$= -7.34 (t=3.06) and $\delta^4$= -4.86 (t=2.75) in Panel B column 2]. Note that the point estimate for the fourth quartile is smaller than for the third, although the difference is not statistically

[30] Note that a more detailed analysis would be possible by writing the skilled production labor share as $\frac{L^{s,p}}{L} = \frac{L^{s,p}}{L^p}\frac{L^p}{L}$ where $L^p$ is total employment in production. This would permit to analyze the skill intensity of production $\left(\frac{L^{s,p}}{L^p}\right)$ separately from the employment share of production $\left(\frac{L^p}{L}\right)$. Unfortunately, estimates of the effects of tariffs are not precise at this finer level of dissagregation. Thus, in what follows I discuss the effects on the skilled production labor share $\left(\frac{L^{s,p}}{L}\right)$.

significant. Panel C reports estimation of the effect of tariffs on the skilled-non production labor share. The only robust result in Panel C is that in sectors where Brazil's tariffs fall, firms in the 4th quartile upgrade skill faster than firms below median size. This difference is always negative and statistically significant [$\delta^4$ = -2.99 (t=1.97) in Panel Column 2]. The point estimate on firms below median size ($\beta$) is positive but only statistically significant when the change in Argentina's tariffs w.r.t. Brazil is included as a control.

Taken altogether, the results reported in Table 9 indicate that the effect of the reduction in Brazil's tariffs induced firms below median size to reduce skill intensity in production activities. In turn, firms in the third quartile of the firm size distribution were induced to upgrade skill in production activities. Finally, tariff reductions also induced firms in the fourth quartile to upgrade skill overall, although with a relative stronger emphasis on non-production activities.

*Discussion*

The model's predictions are consistent with the firm-level responses to trade liberalization reported above. First, as trade liberalization increases the equilibrium skill premium, the model predicts that firms still using technology $l$ ($\varphi < \varphi_h^1$) downgrade skill. This consistent with the data, as firms below median size downgrade skill faster in industries where tariffs fall more. Second, the finding that the effect of Brazil's tariffs on the skilled production labor share is stronger in the third than in the fourth quartile is consistent with the model's prediction that reductions in trade costs induce firms in the upper-middle range of the productivity distribution ($\varphi_h^1 < \varphi < \varphi_h^0$) to switch to a more skill-intensive production technology. Finally, the model also predicts that the most productive firms that were already using the high technology before liberalization ($\varphi_h^0 < \varphi$) downgrade skill when faced with increases in the skill premium (see Figure 4). I did not find support for this prediction in the data, as finer partitions of the upper-range of the firm-size distribution tend to produce imprecise estimates. This suggests that there were very few firms above $\varphi_h^0$ before liberalization. Taken together, the findings suggest that the effect of tariffs on the skill intensity of non production labor are strongest in the upper-middle range of the firm-size distribution which suggests that tariff reductions induced firms to cross a size threshold above which more skill-intensive technologies are profitable. This is consistent with mechanisms that stress changes in the scale of production, as this should not have an impact on the largest firms. For example, a higher scale of operations might make it optimal to add a layer of management [Caliendo and Rossi Hansberg (2011) propose a model where ]. Alternatively, an increase in scale can induce exporters to adopt technologies that entail fixed adoption costs [Lileeva and Trefler (2010)] Bustos (2011)]. Indeed in Bustos (2011) I report that firms in the third quartile respond to tariff cuts by increasing spending in technology, suggesting that this group of firms was below $\varphi_h^0$ before liberalization but above $\varphi_h^1$ afterwards. [31] In turn, firms in the fourth quartile increase spending in technology 55% faster than firms in the first and second quartiles during the liberalization period which suggests that many of them were below the adoption cutoff before liberalization, but above afterwards.

Finally, firms in the fourth quartile respond to tariff cuts by increasing the skilled non-production labor share (Table 9, Panel C) which is unrelated to changes in production technology. As 86% of firms in the fourth quartile export after liberalization, this finding suggests that entry or expansion of sales in export markets per se induces firms to upgrade skill, which would be consistent with models where foreign market access costs are more skill intensive than domestic market access costs.

#### 4.2.4 Aggregation

In this section I use the estimates of the effects of tariffs on firm's skilled labor shares to calculate how much of the aggregate increase in the employment share of skilled workers can be explained by the reduction in Brazil's tariffs. For this purpose, I use the total effects of tariff reductions on skill intensity reported in Table 8. Thus, the results should be interpreted as the overall effect of Brazil's tariff reductions regardless of the mechanism at work.

The main challenge in obtaining an aggregate estimate is that firms below and above median size behave differently, thus we need to weight their impact on the aggregate demand by their employment share. I implemented this calculation through the following formula:

$$\sum_i \Delta\left(\frac{L_i^s}{L_i}\right) = \left[\frac{1}{n_P}\sum_{i\in P}\Delta\left(\frac{L_i^s}{L_i}\right)\right]\frac{\sum_{i\in P} L_i}{L} + \left[\frac{1}{n_B}\sum_{i\in B}\Delta\left(\frac{L_i^s}{L_i}\right)\right]\frac{\sum_{i\in B} L_i}{L}$$

where $P$ and $B$ denote the sets of firms below and above median size, respectively. Next I use the baseline estimated average effect of Brazil's tariffs on small firms [$\beta$ as reported in Column 2 of Table (8)] to approximate the predicted average increase in the skilled labor share for small firms, as follows: $\sum_{i\in P}\frac{1}{n_P}\Delta\left(\frac{L_i^s}{L_i}\right) \simeq \beta\sum_i \frac{1}{n_P}\Delta\tau$. In turn, $\sum_{i\in P}\frac{L_i}{L}$ is approximated by the initial share of total employment of small firms. Analogous approximations are used for the terms corresponding to the set of big firms.

I find that the reduction in Brazil's tariffs can explain approximately 32% of the total increase in the skilled labor employment share, which is 2.6 percentage points in the period 1992-1996 (see Table 1.2). The contribution of small firms to the change in the skilled labor share is -0.11 percentage points, as the initial employment share of small firms is 0.12, and their average change in the skilled labor share induced by tariff cuts is -0.91 percentage points (3.999 $\times$ -0.23). The

[31] I summarize these findings in Appendix Table A4.

contribution of big firms to the change in the skilled labor share is 0.93 percentage points, as their initial employment share is 0.88, and their average change in the skilled labor share induced by tariff cuts is 1.06 percentage points ( -4.655 $\times$ -0.23).

# 5 Conclusion

The findings reported in this paper suggest that firms can respond to trade liberalization by increasing the skill intensity of production technology. This implies that trade can have a role in explaining not only the increases in the relative demand for skill that are driven by reallocations of labor towards skill-intensive sectors or firms, but also increases in skill intensity within firms. This can substantially increase the estimates of the aggregate effects of trade liberalization on the skill premium, specially in developing countries where several studies document little reallocation of labor across sectors.

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**Theory Appendix**

This appendix contains the derivations of expressions in the theory section of the paper and the proof of proposition 1.

**Labor Market Equilibrium**

*Derivation of firm-level labor demands*

Firm-level labor demands can be obtained by differentiating their total cost functions w.r.t. wages (Shepard's lemma ).There are three firm types in equilibrium: firms that only serve the domestic market, firms that export but use the low technology and firms that export and use the high technology. Total costs for the first type are:

$$TC_l^d \left[q_l^d(\varphi), w_s, w_u\right] = Pf + \frac{q_l^d(\varphi)}{\varphi} w_s^{\beta} w_u^{1-\beta}$$

where $q_l^d(\varphi) = EP^{\sigma-1} (\rho\varphi)^{\sigma} \left(w_s^{\beta} w_u^{1-\beta}\right)^{-\sigma}$.We can obtain the demand for skilled and unskilled labor differentiating the total cost function w.r.t. wages:

$$\frac{\partial TC_l^d \left[q_l^d(\varphi), w_s, w_u\right]}{\partial w_s} = s_l^d(\varphi) = \beta \frac{q_l^d(\varphi)}{\varphi} \left(\frac{w_s}{w_u}\right)^{\beta-1}$$
$$\frac{\partial TC_l^d \left[q_l^d(\varphi), w_s, w_u\right]}{\partial w_u} = u_l^d(\varphi) = (1-\beta) \frac{q_l^d(\varphi)}{\varphi} \left(\frac{w_s}{w_u}\right)^{\beta}$$

Labor demands for the remaining two types of firms can be obtained in a similar way. Total costs for firms that export but use the low technology are:

$$TC_l^x \left[q_l^d(\varphi), q_l^x(\varphi), w_s, w_u\right] = Pf + Pf_x + \frac{q_l^d(\varphi)}{\varphi} w_s^{\beta} w_u^{1-\beta} + \frac{q_l^x(\varphi)}{\varphi} w_s^{\beta} w_u^{1-\beta} \tau$$

Using Shepard's lemma and $q_l^x(\varphi) = \tau^{-\sigma} q_l^d(\varphi)$ we obtain $s_l^x(\varphi) = s_l^d(\varphi)(1+\tau^{1-\sigma})$ and $u_l^x(\varphi) = u_l^d(\varphi)(1+\tau^{1-\sigma})$. Total costs for firms that export and use the high technology are :

$$TC_h \left[q_h^d(\varphi), q_h^x(\varphi), w_s, w_u\right] = Pf\eta + Pf_x + \frac{q_h^d(\varphi)}{\gamma\varphi} w_s^{\alpha} w_u^{1-\alpha} + \frac{q_h^x(\varphi)}{\gamma\varphi} w_s^{\alpha} w_u^{1-\alpha} \tau$$

where $q_h^d(\varphi) = EP^{\sigma-1} (\rho\gamma\varphi)^{\sigma} \left(w_s^{\alpha} w_u^{1-\alpha}\right)^{-\sigma}$.Again, using Shepard's lemma and $q_h^x(\varphi) = \tau^{-\sigma} q_h^d(\varphi)$ we obtain:

$$s_h(\varphi) = \alpha \frac{q_h^d(\varphi)}{\gamma\varphi} \left(\frac{w_s}{w_u}\right)^{\alpha-1} (1+\tau^{1-\sigma})$$
$$u_h(\varphi) = (1-\alpha) \frac{q_h^d(\varphi)}{\gamma\varphi} \left(\frac{w_s}{w_u}\right)^{\alpha} (1+\tau^{1-\sigma})$$

*Derivations for aggregate demand for skill*

In this section I provide some details on the derivations required to obtain equations 11 and 12.

Step1. First I show that $\frac{U_l}{U_h} = \frac{(1-\beta)}{(1-\alpha)}\frac{R_l}{R_h}$ where

$$\frac{R_l}{R_h} = \frac{\int_{\varphi_d^*}^{\varphi_x^*} r_l^d(\varphi)\frac{g(\varphi)}{1-G(\varphi_d^*)}d\varphi + \int_{\varphi_x^*}^{\varphi_h^*} r_l^x(\varphi)\frac{g(\varphi)}{1-G(\varphi_d^*)}d\varphi}{\int_{\varphi_h^*}^{\infty} r_h(\varphi)\frac{g(\varphi)}{1-G(\varphi_d^*)}d\varphi} \tag{20}$$

$$\frac{U_l}{U_h} = \frac{\int_{\varphi_d^*}^{\varphi_x^*} u_l^d(\varphi)\frac{g(\varphi)}{1-G(\varphi_d^*)}d\varphi + \int_{\varphi_x^*}^{\varphi_h^*} u_l^x(\varphi)\frac{g(\varphi)}{1-G(\varphi_d^*)}d\varphi}{\int_{\varphi_h^*}^{\infty} u_h(\varphi)\frac{g(\varphi)}{1-G(\varphi_d^*)}d\varphi}$$

Start by using the solutions for $u_l^d(\varphi)$, $u_l^x(\varphi)$ and $u_h(\varphi)$ given above and noting that:

$$\begin{aligned}
u_l^d(\varphi) &= \frac{\rho}{w_u}(1-\beta)\,r_l^d(\varphi) \\
u_l^x(\varphi) &= \frac{\rho}{w_u}(1-\beta)\,(1+\tau^{1-\sigma})r_l^d(\varphi) \\
u_h(\varphi) &= \frac{\rho}{w_u}(1-\alpha)\,\lambda^{\sigma-1}\left(1+\tau^{1-\sigma}\right)r_l^d(\varphi).
\end{aligned}$$

Next, substitute the expressions just above on $\frac{U_l}{U_h}$ to obtain:

$$\frac{U_l}{U_h} = \frac{(1-\beta)}{(1-\alpha)}\frac{\int_{\varphi_d}^{\varphi_x} r_l^d(\varphi)\frac{g(\varphi)}{1-G(\varphi^*)}d\varphi + \left(1+\tau^{1-\sigma}\right)\int_{\varphi_x}^{\varphi_h} r_l^d(\varphi)\frac{g(\varphi)}{1-G(\varphi^*)}d\varphi}{\lambda^{\sigma-1}\left(1+\tau^{1-\sigma}\right)\int_{\varphi_h}^{\infty} r_l^d(\varphi)\frac{g(\varphi)}{1-G(\varphi^*)}d\varphi} = \frac{(1-\beta)}{(1-\alpha)}\frac{R_l}{R_h}$$

where the last equality used that $r_l^x(\varphi) = \left(1+\tau^{1-\sigma}\right)r_l^d(\varphi)$ and $r_h(\varphi) = \lambda^{\sigma-1}\left(1+\tau^{1-\sigma}\right)r_l^d(\varphi)$.

Step 2. Second, I derive equation 12. Start from equation 20 and substitute $r_l^x(\varphi) = \left(1+\tau^{1-\sigma}\right)r_l^d(\varphi)$, $r_h(\varphi) = \lambda^{\sigma-1}\left(1+\tau^{1-\sigma}\right)r_l^d(\varphi)$. Next, use the zero profit condition (equation 7) to substitute $r_l^d(\varphi) = \sigma P f\left(\frac{\varphi}{\varphi_d^*}\right)^{\sigma-1}$ and obtain:

$$\frac{R_l}{R_h} = \frac{1}{\lambda^{\sigma-1}\left(1+\tau^{1-\sigma}\right)}\frac{\int_{\varphi_d^*}^{\varphi_h^*}\varphi^{\sigma-1}g(\varphi)d\varphi + \tau^{1-\sigma}\int_{\varphi_x^*}^{\varphi_h^*}\varphi^{\sigma-1}g(\varphi)d\varphi}{\int_{\varphi_h^*}^{\infty}\varphi^{\sigma-1}g(\varphi)d\varphi}$$

Next, use $g(\varphi) = k\varphi^{-k-1}$ to get:

$$
\begin{aligned}
\frac{R_l}{R_h} &= \frac{1}{\lambda^{\sigma-1}\left(1+\tau^{1-\sigma}\right)}\left\{\frac{\left|\frac{k}{-k+\sigma-1}\varphi^{-k+\sigma-1}\right|_{\varphi_d^*}^{\varphi_h^*}}{\left|\frac{k}{-k+\sigma-1}\varphi^{-k+\sigma-1}\right|_{\varphi_h^*}^{\infty}}+\tau^{1-\sigma}\frac{\left|\frac{k}{-k+\sigma-1}\varphi^{-k+\sigma-1}\right|_{\varphi_x^*}^{\varphi_h^*}}{\left|\frac{k}{-k+\sigma-1}\varphi^{-k+\sigma-1}\right|_{\varphi_h^*}^{\infty}}\right\} \\
&= \frac{1}{\lambda^{\sigma-1}\left(1+\tau^{1-\sigma}\right)}\left\{\left[\left(\frac{\varphi_d^*}{\varphi_h^*}\right)^{-k+\sigma-1}-1\right]+\tau^{1-\sigma}\left[\left(\frac{\varphi_x^*}{\varphi_h^*}\right)^{-k+\sigma-1}-1\right]\right\}
\end{aligned}
$$

*Equilibrium Skill Premium*

*Existence and Uniqueness*

There is one and only one equilibrium skill premium $\left(\frac{w_s}{w_u}\right)^*$ at which $\left(\frac{S}{U}\right)^D=\frac{\overline{S}}{\overline{U}}$ if the relative supply of skill belongs to an interval $\left(\left(\frac{\overline{S}}{\overline{U}}\right)^{\min},\left(\frac{\overline{S}}{\overline{U}}\right)^{\max}\right)$

**Proof**

1. The aggregate relative demand for skill $\left(\frac{S}{U}\right)^D$ is decreasing in the skill premium $\frac{\partial\left(\frac{S}{U}\right)^D}{\partial\frac{w_s}{w_u}}<0$. This can be seen from equation 11 where the first term on the right is $\frac{1}{\frac{w_s}{w_u}}$ and the second term in brackets is also decreasing in the skill premium because $\frac{\partial\frac{R_l}{R_h}}{\partial\frac{w_s}{w_u}}>0$, as shown below.

To see that $\frac{\partial\frac{R_l}{R_h}}{\partial\frac{w_s}{w_u}}>0$, note that the first term of $\frac{R_l}{R_h}$, as described by equation 12, is increasing in the skill premium because $\frac{\partial\lambda}{\partial\frac{w_s}{w_u}}<0$.The second term is also increasing in the skill premium because the share of firms adopting the high technology is decreasing in the skill premium, thus $\partial\frac{\varphi_h^*}{\varphi_x^*}/\partial\frac{w_s}{w_u}>0$ and $\partial\frac{\varphi_h^*}{\varphi_d^*}/\partial\frac{w_s}{w_u}>0$ (see equations 8 and 9).

2. Equations 8 and 9 imply that $\varphi^h>\varphi^x$ is an equilibrium only if the equilibrium skill premium is not too low, as otherwise all exporters would adopt the high technology. In addition, for technology adoption to be profitable for some firms, we need $\lambda>1$.These two conditions imply that the equilibrium skill premium $\left(\frac{w_s}{w_u}\right)^*$ must satisfy the following condition:

$$
\gamma^{\frac{1}{\alpha-\beta}}\equiv\left(\frac{w_s}{w_u}\right)^{\max}>\left(\frac{w_s}{w_u}\right)^*>\left(\frac{w_s}{w_u}\right)^{\min}\equiv\left\{\gamma\left[\frac{\tau^{1-\sigma}}{\left(1+\tau^{1-\sigma}\right)}\frac{\eta-1}{\frac{f_x}{f}}+1\right]^{-\frac{1}{\sigma-1}}\right\}^{\frac{1}{\alpha-\beta}}.
$$

This condition implies that, for $\left(\frac{w_s}{w_u}\right)^*$ to be an equilibrium, the relative supply of skill must belong to the interval $\left(\left(\frac{\overline{S}}{\overline{U}}\right)^{\min},\left(\frac{\overline{S}}{\overline{U}}\right)^{\max}\right)$ which can be obtained by plugging in $\left(\frac{w_s}{w_u}\right)^{\max}$ and $\left(\frac{w_s}{w_u}\right)^{\min}$ in the relative demand for skill (equation 11).

3. As the relative demand for skill is decreasing in $\frac{w_s}{w_u}$ on $\left(\left(\frac{w_s}{w_u}\right)^{\min},\left(\frac{w_s}{w_u}\right)^{\max}\right)$ and the relative supply of skill is vertical, there is one and only one equilibrium skill premium $\left(\frac{w_s}{w_u}\right)^*$ at

which $\left(\frac{S}{U}\right)^{D} = \frac{\overline{S}}{U}$ if $\frac{\overline{S}}{U} \in \left(\left(\frac{\overline{S}}{U}\right)^{\min}, \left(\frac{\overline{S}}{U}\right)^{\max}\right)$.

**Free Entry**

In this section I show how to obtain the solution for the exit cutoff stated in equation 14 from the free entry condition $Pf_e = [1 - G(\varphi_d^*)] \frac{1}{\delta}\overline{\pi}$, where $\overline{\pi} = \overline{\pi}_l^d + p_x \overline{\pi}_l^x + p_h \overline{\pi}_h^x$ and:

$$\overline{\pi}_l^d = \int_{\varphi_d^*}^{\varphi_x^*} \pi_l^d(\varphi) \frac{g(\varphi)}{1 - G(\varphi_d^*)}$$
$$\overline{\pi}_l^x = \int_{\varphi_x^*}^{\varphi_h^*} \pi_l^x(\varphi) \frac{g(\varphi)}{1 - G(\varphi_x^*)}$$
$$\overline{\pi}_l^d = \int_{\varphi_h^*}^{\infty} \pi_h^x(\varphi) \frac{g(\varphi)}{1 - G(\varphi^*)}$$

$$p^x = \frac{1 - G(\varphi^x)}{1 - G(\varphi^*)}$$
$$p^h = \frac{1 - G(\varphi^h)}{1 - G(\varphi^*)}$$

Using the expression for profits given in equations 3, 5 and 6, expected profits can be written as:

$$\overline{\pi} = \frac{\overline{r}}{\sigma} - Pf - p_x P f_x - p_h P f(\eta - 1) \tag{A1}$$

where $\overline{r}$ are expected revenues of surviving firms:

$$\overline{r} = \int_{\varphi_d^*}^{\varphi_x^*} r_l^d(\varphi) \frac{g(\varphi)}{1 - G(\varphi_d^*)} d\varphi + \int_{\varphi_x^*}^{\varphi_h^*} r_l^x(\varphi) \frac{g(\varphi)}{1 - G(\varphi_d^*)} d\varphi + \int_{\varphi_h^*}^{\infty} r_h(\varphi) \frac{g(\varphi)}{1 - G(\varphi_d^*)} d\varphi$$

which after substituting for $r_l^x(\varphi) = \left(1 + \tau^{1-\sigma}\right) r_l^d(\varphi)$ and $r_h(\varphi) = \lambda^{\sigma-1}\left(1 + \tau^{1-\sigma}\right) r_l^d(\varphi)$.can be rearranged to the following expression:

$$\begin{aligned}\overline{r} \quad = \quad & \int_{\varphi_d^*}^{\varphi_x^*} r_l^d(\varphi) \frac{g(\varphi)}{1 - G(\varphi^*)} d\varphi + \tau^{1-\sigma} \int_{\varphi_x^*}^{\infty} r_l^d(\varphi) \frac{g(\varphi)}{1 - G(\varphi^*)} d\varphi \\ & + \left(\lambda^{\sigma-1} - 1\right)\left(1 + \tau^{1-\sigma}\right) \int_{\varphi_h^*}^{\infty} r_l^d(\varphi) \frac{g(\varphi)}{1 - G(\varphi^*)} d\varphi.\end{aligned}$$

Next, using the zero profit condition (equation 7), we can use $r_l^d(\varphi) = \sigma P f \left(\frac{\varphi}{\varphi^*}\right)^{\sigma-1}$ and rearrange terms to get:

$$\overline{r} = \sigma P f \left(\frac{\tilde{\varphi}_d}{\varphi_d}\right)^{\sigma-1} + p_x \sigma P f_x \left(\frac{\tilde{\varphi}_x}{\varphi_x}\right)^{\sigma-1} + p_h \sigma P f(\eta - 1) \left(\frac{\tilde{\varphi}_h}{\varphi_h}\right)^{\sigma-1},$$

where: $\tilde{\varphi}_i = \left(\int_{\varphi_i^*<\varphi} \varphi^{\sigma-1} \frac{g(\varphi)}{1-G(\varphi_i^*)} d\varphi\right)^{\frac{1}{\sigma-1}}$. Next, we can substitute $\overline{r}$ in equation A1 to obtain expected profits:

$$\overline{\pi} = Pf\left[\left(\frac{\tilde{\varphi}_d}{\varphi_d^*}\right)^{\sigma-1} - 1\right] + p_x P f_x \left[\left(\frac{\tilde{\varphi}_x}{\varphi_d^*}\right)^{\sigma-1} - 1\right] + p_h P f\left(\eta - 1\right)\left[\left(\frac{\tilde{\varphi}_h}{\varphi_d^*}\right)^{\sigma-1} - 1\right].$$

Finally, substitute the expression above on the free entry condition (equation 13) to obtain:

$$f\left[\left(\frac{\tilde{\varphi}_d}{\varphi_d^*}\right)^{\sigma-1} - 1\right] + p_x f_x \left[\left(\frac{\tilde{\varphi}_x}{\varphi_x^*}\right)^{\sigma-1} - 1\right] + p_h f\left(\eta - 1\right)\left[\left(\frac{\tilde{\varphi}_h}{\varphi_h^*}\right)^{\sigma-1} - 1\right] = \frac{f_e \delta}{\left[1 - G\left(\varphi_d^*\right)\right]}.$$

To simplify the free entry condition further, we can use the fact that under a Pareto distribution with shape parameter k: $\left(\frac{\tilde{\varphi}_i}{\varphi_i^*}\right)^{\sigma-1} = \int_{\varphi_i^*<\varphi} \left(\frac{\varphi}{\varphi_i^*}\right)^{\sigma-1} \frac{g(\varphi)}{1-G(\varphi_i^*)} = \frac{k}{k-(\sigma-1)}$ for $i = d, x, h$, to obtain:

$$\left(\frac{\sigma - 1}{k - \sigma + 1}\right)\left[f + p_x f_x + p_h f\left(\eta - 1\right)\right] = \delta f_e \varphi_d^k \tag{A2}$$

from which the solution for the exit cutoff given in equation 14 is obtained.

**Derivations for section 3.4 Trade Liberalization**

*Proof of Proposition 1.*

(a) A reduction in variable trade cots increases the equilibrium skill premium: $\frac{\partial \frac{w_s}{w_u}^*}{\partial \tau} < 0$.

To analyze the effects of trade liberalization on the skill premium it suffices to consider its effects on the labor market equilibrium condition. For a given skill premium, the only component of the relative demand for skill that is affected by trade costs are the relative revenues of low and high technology firms $\left(\frac{R_l}{R_h}\right)$(see equation 11).Thus, trade liberalization increases the demand for skill only if it reallocates market shares from low to high technology firms. Note that this does not immediately follow from the reallocation of market shares towards exporters because there are both low and high technology exporters $\left(\frac{R_l}{R_h} = \frac{R_l^d + R_l^x}{R_h}\right)$. Still, if firm-productivity follows a Pareto distribution we can show that, for a given skill premium, a reduction in tariffs increases the relative revenues of high technology firms: $\frac{\partial \frac{R_l}{R_h}\left(\frac{w_s}{w_u}\right)}{\partial \tau} > 0$

Step 1. Proof that $\frac{\partial \frac{R_l}{R_h}\left(\frac{w_s}{w_u}\right)}{\partial \tau} > 0$:

To see this, it is useful to rewrite $\frac{R_l}{R_h}$ as:[32]

$$\frac{R_l}{R_h} = \frac{1 - \lambda^{1-\sigma}}{\eta - 1}\left(\frac{1 + p_x \frac{f_x}{f}}{p_h}\right) - \lambda^{1-\sigma}.$$

[32] The steps required to obtain this expression for $\frac{R_l}{R_h}$ are similar to the ones followed above to obtain expected profits. Detailed derivations are available upon request.

Note that, as we are calculating the derivative of $\frac{R_l}{R_h}$ w.r.t. $\tau$ for a given skill premium, $\lambda$ is constant. Then, $sign\left(\frac{\partial\frac{R_l}{R_h}}{\partial\tau}\right) = sign\left\{\frac{\partial\left[\frac{1}{p_h}(1+p_x\frac{f_x}{f})\right]}{\partial\tau}\right\}$ because $\frac{1-\lambda^{1-\sigma}}{\eta-1} > 0$ as $\lambda > 1$, $\sigma > 1$ and $\eta > 1$.Then, substituting $p_x$ and $p_h$ by their solutions in equations 15 and 16 and rearranging we get:

$$\frac{1}{p_h}(1+p_x\frac{f_x}{f}) = \left[\frac{\eta-1}{\lambda^{\sigma-1}-1}\right]\left\{\left(1+\tau^{1-\sigma}\right)^{-\frac{k}{\sigma-1}}\left[1+\tau^{-k}\left(\frac{f_x}{f}\right)^{1-\frac{k}{\sigma-1}}\right]\right\} \tag{21}$$

As $\left[\frac{\eta-1}{\lambda^{\sigma-1}-1}\right]^{\frac{k}{\sigma-1}} > 0$, the sign of $\frac{\partial\left[\frac{1}{p_h}(1+p_x\frac{f_x}{f})\right]}{\partial\tau}$ is the same as the sign of the the derivative of the second term in the R.H.S. of equation 21, which for convenience I name $\Upsilon$. Then, differentiate $\Upsilon$ w.r.t. $\tau$ to obtain

$$\frac{\partial\Upsilon}{\partial\tau} = k\left(1+\tau^{1-\sigma}\right)^{-\frac{k}{\sigma-1}-1}\tau^{-\sigma}\left[1+\tau^{-k}\left(\frac{f_x}{f}\right)^{1-\frac{k}{\sigma-1}}\right] + \left(1+\tau^{1-\sigma}\right)^{-\frac{k}{\sigma-1}}\left[-k\tau^{-k-1}\left(\frac{f_x}{f}\right)^{1-\frac{k}{\sigma-1}}\right].$$

After some algebra, one can show that $\frac{\partial\Upsilon}{\partial\tau} > 0$ iff $\tau\left(\frac{f_x}{f}\right)^{\frac{1}{\sigma-1}} > 1$, that is, if not all firms export.

Step 2. We just established that reduction in trade costs increases the relative revenues of high-technology firms, for a given skill premium $\frac{\partial\frac{R_l}{R_h}\left(\frac{w_s}{w_u}\right)}{\partial\tau} > 0$. Then, when trade costs fall the relative demand for skill depicted in Figure 2 shifts out which results in a higher equilibrium skill premium because the relative supply of skill is vertical.

(b) A reduction in trade costs increases the equilibrium relative revenues of high-technology firms: $\frac{\partial\left(\frac{R_h}{R_l}\right)^*}{\partial\tau} < 0$.

To see this, differentiate w.r.t. $\tau$ the labor market equilibrium condition, $\frac{\overline{S}}{\overline{U}} = \frac{S}{U}^D\left(\frac{w_s}{w_u}^*, \frac{R_h}{R_l}^*\right)$, where the relative demand for skill is described by equation 11:

$$\frac{d\frac{S}{U}^D\left(\frac{w_s}{w_u}^*, \frac{R_h}{R_l}^*\right)}{d\tau} = \frac{\partial\frac{S}{U}^D\left(\frac{w_s}{w_u}^*, \frac{R_h}{R_l}^*\right)}{\partial\frac{w_s}{w_u}^*}\frac{\partial\frac{w_s}{w_u}^*}{\partial\tau} + \frac{\partial\frac{S}{U}^D\left(\frac{w_s}{w_u}^*, \frac{R_h}{R_l}^*\right)}{\partial\frac{R_h}{R_l}^*}\frac{\partial\frac{R_h}{R_l}^*}{\partial\tau} = 0.$$

Note that as $\frac{\partial\frac{S}{U}^D\left(\frac{w_s}{w_u}^*, \frac{R_h}{R_l}^*\right)}{\partial\frac{w_s}{w_u}^*} < 0$ and $\frac{\partial\frac{w_s}{w_u}^*}{\partial\tau} < 0$, the second term on the R.H.S. must be negative. But $\frac{\partial\frac{S}{U}^D\left(\frac{w_s}{w_u}^*, \frac{R_h}{R_l}^*\right)}{\partial\frac{R_h}{R_l}^*} > 0$ then, $\frac{\partial\frac{R_h}{R_l}^*}{\partial\tau} < 0$.

(c) A reduction in trade costs increases:

-The share of exporters, $\frac{\partial p^x}{\partial\tau} < 0$.This can be directly seen on equation 15.

-The share of high technology firms, $\frac{\partial p^h}{\partial\tau} < 0$.

$\tau$ has a direct negative effect on the solution for $p^h$ described in equation 16 but an indirect positive effect through $\lambda$. This is because the reduction in tariffs increases the skill premium reducing the cost advantage of high technology firms. Still, we can show that the direct effect must dominate.

To see this, suppose it was not the case. Then, $p^h$ falls as trade costs fall: $\frac{\partial p^h}{\partial \tau} \geq 0$. But we show below that this implies that the relative revenues of high technology firms fall, $\frac{\partial \frac{R_h}{R_l}^*}{\partial \tau} \geq 0$, which is a contradiction.

To see that $\frac{\partial p^h}{\partial \tau} \geq 0$ implies $\frac{\partial \frac{R_h}{R_l}^*}{\partial \tau} \geq 0$ start from the expression for relative revenues in equation 12. Next, multiply and divide its R.H.S. by $\frac{\eta-1}{\lambda^{\sigma-1}-1}$ and use $\frac{\varphi_h}{\varphi^*} = \left(\frac{\eta-1}{(1+\tau^{1-\sigma})(\lambda^{\sigma-1}-1)}\right)^{\frac{1}{\sigma-1}}$ to obtain:

$$\left(\frac{R_l}{R_h}\right)^* = \frac{1}{\eta-1}\frac{\lambda^{\sigma-1}-1}{\lambda^{\sigma-1}}\left(\frac{\varphi_h}{\varphi_d}\right)^{\sigma-1}\left\{\left[\left(\frac{\varphi_h}{\varphi_d}\right)^{k-(\sigma-1)}-1\right]+\tau^{1-\sigma}\left[\left(\frac{\varphi_h}{\varphi_x}\right)^{k-(\sigma-1)}-1\right]\right\}.$$

Note that if $\frac{\partial p^h}{\partial \tau} \geq 0$ all terms in the R.H.S. of the equation above increase as trade costs fall. This is because: $\frac{w_s}{w_u}$ increases, then $\lambda$ falls and thus $\frac{\lambda^{\sigma-1}-1}{\lambda^{\sigma-1}}$ increases; as $p^h$ falls $\frac{\varphi_h}{\varphi_d}$ increases, thus $\left(\frac{\varphi_h}{\varphi_d}\right)^{\sigma-1}$ and $\left[\left(\frac{\varphi_h}{\varphi_d}\right)^{k-(\sigma-1)}-1\right]$ increase; finally, as $p^x$ increases $\frac{\varphi_x}{\varphi_d}$ falls, thus $\frac{\varphi_h}{\varphi_x} = \frac{\varphi_h/\varphi_d}{\varphi_x/\varphi_d}$ increases. Then, $\left(\frac{R_l}{R_h}\right)^*$ must increase as trade costs fall: $\frac{\partial\left(\frac{R_h}{R_l}\right)^*}{\partial \tau} \geq 0$, but this contradicts point (b) just above.

(d) A reduction in variable trade costs increases the exit productivity cutoff$\frac{\partial \varphi_d^*}{\partial \tau} < 0$,

Proof: Suppose that the opposite is true, $\varphi_d^*$ falls as trade costs fall. Then, the solution for $\varphi_d^*$ described in equation 14 implies that expected fixed costs, given by $f + p_x \frac{f_x}{f} + p_h(\eta-1)$ must fall. But as the fraction of exporters $p_x$ increases when trade costs fall (see equation 15) this implies that the fraction of firms using the high technology $p_h$ must fall, which contradicts point (c) above.

(e) A reduction in variable trade costs reduces the export and the technology cutoffs.

-Export cutoff: $\frac{\partial \varphi_x^*}{\partial \tau} > 0$

To see this, start from the definition of $\varphi_x^*$ as a function of $\varphi_d^*$ given in equation 8. Use $p_x = \left(\frac{\varphi_x^*}{\varphi_d^*}\right)^{-k}$ and the solution for $\varphi_d^*$ in equation 14 to get:

$$\varphi_x^* = \Psi\left[\frac{1}{p^x}f + f_x + \frac{p^h}{p^x}(\eta-1)f\right]^{\frac{1}{k}}.$$

Note that $\frac{p_x}{p_h} = \left[\frac{\tau^{1-\sigma}}{1+\tau^{1-\sigma}}\frac{f}{f_x}\frac{\eta-1}{[\lambda^{\sigma-1}-1]}\right]^{\frac{k}{\sigma-1}}$ increases when $\tau$ falls because $\frac{\tau^{1-\sigma}}{1+\tau^{1-\sigma}}$ increases and $\lambda$ falls. Then, as $p^x$ and $\frac{p_x}{p_h}$ increase when $\tau$ falls, $\varphi_x^*$ must fall.

-Technology Cutoff: $\frac{\partial \varphi_h^*}{\partial \tau} > 0$

To see this, start from the definition of $\varphi_h^*$ as a function of $\varphi_d^*$ given in equation 9. Use $p_h =$

$\left(\frac{\varphi_h^*}{\varphi_d^*}\right)^{-k}$ and the solution for $\varphi_d^*$ in equation 14 to get:

$$\varphi_h^* = \Psi \left[ \frac{1}{p^h} f + \frac{p^x}{p^h} f_x + (\eta - 1) f \right]^{\frac{1}{k}}$$

The equation above implies that $sign\left(\frac{\partial \varphi_h^*}{\partial \tau}\right) = sign\left\{\frac{\partial\left[\frac{1}{p_h}(1+p_x\frac{f_x}{f})\right]}{\partial \tau}\right\} > 0$. Where the last inequality is a necessary condition for $\frac{\partial\left(\frac{R_l}{R_h}\right)^*}{\partial \tau} > 0$, which we proved to be the case in point b) above. To see this, note that relative revenues of low technology firms can be written as:

$$\left(\frac{R_l}{R_h}\right)^* = \frac{1}{\eta - 1} \frac{\lambda^{\sigma-1} - 1}{\lambda^{\sigma-1}} \left[ \frac{1 + p_x \frac{f_x}{f}}{p_h} - 1 \right]$$

Then, as $\tau$ falls, $\frac{w_s}{w_u}$ increases, $\lambda$ falls, $\frac{\lambda^{\sigma-1}-1}{\lambda^{\sigma-1}}$ increases, but then $\left(\frac{1+p_x\frac{f_x}{f}}{p_h}\right)$ must fall so that that relative revenues of low technology firms fall in equilibrium. Then, $\frac{\partial\left[\frac{1}{p_h}(1+p_x\frac{f_x}{f})\right]}{\partial \tau} > 0$, thus $\frac{\partial \varphi_h^*}{\partial \tau} > 0$.

**Table 1.1**
**Employment by Education**

| | 1992 | 1996 | Percent Change |
|---|---|---|---|
| Educational Categories | | | |
| Engineers | 7,416 | 8,414 | 0.135 |
| Other college | 13,318 | 13,680 | 0.027 |
| Technicians | 21,623 | 23,050 | 0.066 |
| High school graduates and below | 272,077 | 249,307 | -0.084 |
| Total | 314,434 | 294,451 | -0.064 |

Note: This table reports the total number of employees in the ENIT Balanced Panel of 1359 Firms

**Table 1.2**
**Relative Employment of Skilled Workers**

| | 1992 | 1996 | Percent Change |
|---|---|---|---|
| College equivalents (*S*) | 38,271 | 40,788 | 0.066 |
| Less than high school equivalents (*U*) | 300,240 | 275,556 | -0.082 |
| Skilled/Unskilled (*S/U)* | 0.127 | 0.148 | 0.161 |

Note: This table reports the total number of skilled workers (college plus technicians) and unskilled workers (high school plus primary school and below) expressed as less than high school equivalents by weighting them by the corresponding 1992 returns to education.

**Table 1.3**
**Employment Share of Skilled Workers in Efficiency Units**

| | 1992 | 1996 | Percent Change |
|---|---|---|---|
| Employment of skilled workers ($S \cdot w$) | 77,078 | 82,148 | 0.066 |
| Total employment ($S w + U$) | 377,317 | 357,703 | -0.052 |
| Employment share of skilled workers $S \cdot w /(S w + U)$ | 0.204 | 0.230 | 0.124 |

Note: This table reports the total number of skilled workers (college plus technicians) and unskilled workers (high school plus primary school and below) expressed as primary school equivalents by weighting them by the corresponding 1992 returns to education. Same sample of firms as Tables 1.1 and 1.2.

**Table 2**
**Employment Share of Skilled Workers by Occupational Category**

| | 1992 | 1996 | Percent Change |
|---|---|---|---|
| Production | 0.156 | 0.177 | 0.129 |
| Non production | 0.364 | 0.393 | 0.079 |
| R&D | 0.735 | 0.759 | 0.033 |
| Total | 0.221 | 0.248 | 0.123 |

Note: Same sample of firms as Table 1.3. Totals differ because there is a default category of workers unclassified by occupation which is not included in Table 2.

**Table 3**
**Decomposition of the change in the Employment Share of Skilled Labor by Occupational Category**

| | Within | Between | Total |
|---|---|---|---|
| Production | 0.065 | -0.011 | 0.054 |
| Non production | 0.035 | 0.019 | 0.054 |
| R&D | 0.002 | 0.013 | 0.015 |
| Total | 0.102 | 0.020 | 0.123 |

Note: Same sample of firms as Table 1.3. Totals differ because there is a default category of workers unclassified by occupation which is not included in Table 3.

**Table 4**
**Decomposition of the change in the Employment Share of Skilled Labor by Sectors and Firms**

| | Within | Between | Total |
|---|---|---|---|
| Industries at 2-digit-ISIC | 0.111 | 0.014 | 0.124 |
| Industries at 4-digit-ISIC | 0.110 | 0.015 | 0.124 |
| Firms | 0.106 | 0.019 | 0.124 |

Note: Same sample of firms as Table 1.3.

**Table 5**
**Technology and Skill Upgrading**
Dependent variable: change (Δ) in employment share of skilled labor

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Δ log (Spending in Technology) | 0.544 | 0.531 | | | | | | |
| | [0.164]*** | [0.162]*** | | | | | | |
| Product and process innovation index | | | 1.448 | 1.071 | | | | |
| | | | [0.486]*** | [0.503]** | | | | |
| Product innovation index | | | | | 1.483 | 1.185 | | |
| | | | | | [0.462]*** | [0.483]** | | |
| Process innovation index | | | | | | | 1.120 | 0.764 |
| | | | | | | | [0.449]** | [0.461]* |
| 2-digit-ISIC-Industry dummies | | Yes | | Yes | | Yes | | Yes |
| Observations | 880 | 880 | 1280 | 1280 | 1291 | 1291 | 1298 | 1298 |
| R-squared | 0.01 | 0.04 | 0.01 | 0.04 | 0.01 | 0.04 | 0.00 | 0.04 |

Note: Robust standard errors in brackets. * indicates significant at 10%; ** significant at 5%; *** significant at 1%

**Table 6**
**Export Status and Skill Upgrading**

| | Levels in 1992 | | Changes 1992-1996 | | |
|---|---|---|---|---|---|
| | Continuing Exporters | New Exporters | Continuing Exporters | New Exporters | Number of Firms |
| Firm Characteristic | | | | | |
| Sales | 1.795 | 1.078 | 0.178 | 0.241 | 1359 |
| | [0.090]*** | [0.103]*** | [0.040]*** | [0.049]*** | |
| Employment | 1.530 | 0.917 | 0.015 | 0.158 | 1359 |
| | [0.075]*** | [0.087]*** | [0.026] | [0.034]*** | |
| Skilled Labor Share | 5.113 | 1.316 | 1.375 | 1.569 | 1359 |
| | [1.043]*** | [1.100] | [0.354]*** | [0.437]*** | |
| Skilled Production Labor Share | 1.839 | 0.301 | 0.629 | 0.585 | 1359 |
| | [0.688]*** | [0.682] | [0.299]** | [0.297]** | |
| Skilled Non Production Labor Share | 2.377 | 0.589 | 0.747 | 0.632 | 1359 |
| | [0.658]*** | [0.667] | [0.281]*** | [0.269]** | |
| Spending in Technology per worker | 0.516 | 0.087 | 0.183 | 0.211 | 1359 |
| | [0.161]*** | [0.102] | [0.133] | [0.069]*** | |
| Spending in Technology per worker (logs) | 0.343 | 0.191 | 0.292 | 0.393 | 880 |
| | [0.151]** | [0.176] | [0.106]*** | [0.118]*** | |

Note: Robust Standard Errors in Brackets. * indicates significant at 10%; ** significant at 5%; *** significant at 1%. Exporter premia are estimated from a regression of the form: $ln\ Y_{ij} = \alpha_1\ NE_{ij} + \alpha_2\ EE_{ij} + \alpha_3\ EN_{ij} + I_j + \varepsilon_{ij}$ where $i$ indexes firms, $j$ indexes 4-digit-ISIC industries; *NE* are new exporters (226 firms), *EE* are continuing exporters ( 552 firms), *EN* are firms that exported in 1992 but didn't in 1996 (25 firms) and the reference category relative to which differences are estimated is non exporters (556 firms); *I* are industry dummies, and *Y* is the firm characteristic for which the differences are estimated.

**Table 7**
**Cross Sectional Patterns in the Data**

| | Export Status | Skill Intensity | | | Technology | | | |
|---|---|---|---|---|---|---|---|---|
| | | Skilled Labor share | Skilled Production Labor share | Skilled Non Production Labor share | Spending in Technology per worker | Spending in Technology per worker (in logs) | Product Innovation Index | Process Innovation Index |
| 2nd size quartile | 0.215 | 5.193 | 2.369 | 2.277 | 0.128 | 0.088 | 0.109 | 0.140 |
| | [0.035]*** | [1.146]*** | [0.749]*** | [0.695]*** | [0.156] | [0.156] | [0.022]*** | [0.025]*** |
| 3rd size quartile | 0.389 | 6.684 | 3.875 | 2.423 | 0.304 | 0.503 | 0.163 | 0.199 |
| | [0.033]*** | [1.182]*** | [0.801]*** | [0.646]*** | [0.139]** | [0.147]*** | [0.022]*** | [0.024]*** |
| 4th size quartile | 0.576 | 10.383 | 5.216 | 4.346 | 0.591 | 0.940 | 0.283 | 0.323 |
| | [0.030]*** | [1.169]*** | [0.799]*** | [0.680]*** | [0.131]*** | [0.145]*** | [0.023]*** | [0.024]*** |
| 4-digit-ISIC industry dummies | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 1359 | 1359 | 1359 | 1359 | 1359 | 1132 | 1291 | 1298 |
| Average 1st size quartile | 0.274 | 11.319 | 5.881 | 4.467 | 0.410 | -1.900 | 0.226 | 0.225 |
| | [0.024] | [0.872] | [0.547] | [0.457] | [0.093] | [0.113] | [0.014] | [0.016] |

Notes: robust standard errors in brackets. * indicates significant at 10%; ** significant at 5%; *** significant at 1%. Coefficients report differences in 1996 outcomes (indicated in columns) of firms belonging to the quartiles indicated in each row w.r.t. firms belonging to the first size quartile. The bottom two rows of the table report the mean of each outcome for firms in the first quartile, as reference. Firm size is measured as the (log) number of employees in efficiency units relative to the 4-digit-ISIC industry mean for the initial year in the sample, 1992.

**Table 8**
**Effect of Brazil's Tariff Reductions on Skill Upgrading**

Dependent variable: Skilled Labor Share

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Change in Brazil's tariffs | 4.885 | 3.999 | 4.905 | 5.791 | 6.246 | 6.019 | |
| | [1.947]** | [1.621]** | [1.835]*** | [1.923]*** | [1.775]*** | [1.927]*** | |
| × Above median size | -8.141 | -8.654 | -8.713 | -10.181 | -8.621 | -7.840 | -7.944 |
| | [2.617]*** | [2.576]*** | [2.609]*** | [2.849]*** | [2.536]*** | [2.699]*** | [2.123]*** |
| Above median size | -1.274 | -1.504 | -1.504 | -8.081 | -1.486 | -7.543 | -1.324 |
| | [0.742]* | [0.731]** | [0.745]** | [3.880]** | [0.734]** | [3.914]* | [0.603]** |
| Change in Arg.'s output tariffs w.r.t. World | | | 3.029 | 3.988 | | | |
| | | | [5.597] | [7.619] | | | |
| × Above median size | | | | -2.744 | | | |
| | | | | [10.540] | | | |
| Change in Arg.'s input tariffs w.r.t. World | | | 5.737 | 9.517 | | | |
| | | | [11.870] | [17.215] | | | |
| × Above median size | | | | -5.290 | | | |
| | | | | [22.763] | | | |
| Change in Arg.'s output tariffs w.r.t. Brazil | | | | | 1.578 | 7.539 | |
| | | | | | [4.510] | [7.169] | |
| × Above median size | | | | | | -13.628 | |
| | | | | | | [10.794] | |
| Change in Arg.'s input tariffs w.r.t. Brazil | | | | | -29.081 | -35.965 | |
| | | | | | [9.369]*** | [11.364]*** | |
| × Above median size | | | | | | 16.643 | |
| | | | | | | [14.439] | |
| Demand elasticity | | | 0.136 | 0.157 | 0.199 | 0.254 | |
| | | | [0.085] | [0.106] | [0.079]** | [0.111]** | |
| × Above median size | | | | -0.039 | | -0.103 | |
| | | | | [0.149] | | [0.167] | |
| U.S. Capital intensity | | | -0.169 | -0.739 | -0.295 | -0.968 | |
| | | | [0.477] | [0.499] | [0.401] | [0.513]* | |
| × Above median size | | | | 1.107 | | 1.315 | |
| | | | | [0.664]* | | [0.740]* | |
| U.S. Skill intensity | | | 0.644 | 1.373 | 0.684 | 1.157 | |
| | | | [0.606] | [0.808]* | [0.694] | [0.816] | |
| × Above median size | | | | -1.487 | | -0.886 | |
| | | | | [1.058] | | [1.111] | |
| 2-digit-ISIC industry dummies | | Yes | Yes | Yes | Yes | Yes | |
| 4-digit-ISIC industry dummies | | | | | | | Yes |
| Observations | 1359 | 1359 | 1327 | 1327 | 1321 | 1321 | 1359 |
| R-squared | 0.01 | 0.05 | 0.05 | 0.05 | 0.05 | 0.06 | 0.10 |

Notes: standard errors are clustered at the 4-digit-ISIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%. Firm size is measured as the (log) number of employees measured in efficiency units relative to the 4-digit-SIC mean.

**Table 9**
**Effect of Brazil's Tariff Reductions on Skill Upgrading in Production and Non-production Activities**

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Panel A: dependent variable is Skilled Labor Share** | | | | | |
| Change in Brazil's tariffs | 4.885 | 4.001 | 4.902 | 6.287 | |
| | [1.949]** | [1.623]** | [1.825]*** | [1.782]*** | |
| × 3rd size quartile | -8.315 | -9.013 | -9.064 | -8.887 | -8.292 |
| | [3.346]** | [3.340]*** | [3.399]*** | [3.265]*** | [3.007]*** |
| × 4th size quartile | -7.863 | -8.160 | -8.245 | -8.244 | -7.445 |
| | [2.706]*** | [2.645]*** | [2.668]*** | [2.652]*** | [2.349]*** |
| 3rd size quartile | -1.435 | -1.764 | -1.749 | -1.723 | -1.622 |
| | [0.866] | [0.871]** | [0.893]* | [0.875]* | [0.795]** |
| 4th size quartile | -1.085 | -1.208 | -1.231 | -1.224 | -0.994 |
| | [0.812] | [0.785] | [0.795] | [0.790] | [0.677] |
| Change in Arg.'s output tariffs w.r.t. World | | | 2.855 | | |
| | | | [5.619] | | |
| Change in Arg.'s input tariffs w.r.t. World | | | 5.635 | | |
| | | | [11.834] | | |
| Change in Arg.'s output tariffs w.r.t. Brazil | | | | 1.463 | |
| | | | | [4.542] | |
| Change in Arg.'s input tariffs w.r.t. Brazil | | | | -29.039 | |
| | | | | [9.451]*** | |
| **Panel B: dependent variable is Skilled Production Labor Share** | | | | | |
| Change in Brazil's tariffs | 3.645 | 3.032 | 3.298 | 3.303 | |
| | [1.434]** | [1.140]*** | [1.362]** | [1.429]** | |
| × 3rd size quartile | -7.128 | -7.341 | -7.370 | -7.171 | -6.874 |
| | [2.611]*** | [2.399]*** | [2.443]*** | [2.350]*** | [2.250]*** |
| × 4th size quartile | -4.539 | -4.856 | -4.992 | -5.050 | -4.532 |
| | [1.839]** | [1.766]*** | [1.782]*** | [1.754]*** | [1.584]*** |
| 3rd size quartile | -1.309 | -1.457 | -1.458 | -1.417 | -1.327 |
| | [0.667]* | [0.647]** | [0.661]** | [0.642]** | [0.615]** |
| 4th size quartile | -1.041 | -1.108 | -1.152 | -1.164 | -0.956 |
| | [0.556]* | [0.533]** | [0.536]** | [0.523]** | [0.466]** |
| Change in Arg.'s output tariffs w.r.t. World | | | 2.340 | | |
| | | | [3.399] | | |
| Change in Arg.'s input tariffs w.r.t. World | | | 5.109 | | |
| | | | [6.932] | | |
| Change in Arg.'s output tariffs w.r.t. Brazil | | | | 5.942 | |
| | | | | [3.462]* | |
| Change in Arg.'s input tariffs w.r.t. Brazil | | | | -24.284 | |
| | | | | [7.945]*** | |
| **Panel C: dependent variable is Skilled Non- Production Labor Share** | | | | | |
| Change in Brazil's tariffs | 0.862 | 0.884 | 1.595 | 2.957 | |
| | [1.065] | [0.825] | [1.031] | [1.321]** | |
| × 3rd size quartile | -1.403 | -1.646 | -1.757 | -1.756 | -1.409 |
| | [1.600] | [1.598] | [1.606] | [1.571] | [1.699] |
| × 4th size quartile | -2.879 | -2.998 | -2.988 | -2.921 | -2.746 |
| | [1.529]* | [1.521]* | [1.538]* | [1.532]* | [1.520]* |
| 3rd size quartile | -0.059 | -0.176 | -0.208 | -0.218 | -0.160 |
| | [0.412] | [0.397] | [0.405] | [0.406] | [0.453] |
| 4th size quartile | -0.044 | -0.105 | -0.099 | -0.078 | -0.062 |
| | [0.437] | [0.428] | [0.436] | [0.437] | [0.431] |
| Change in Arg.'s output tariffs w.r.t. World | | | 0.236 | | |
| | | | [3.825] | | |
| Change in Arg.'s input tariffs w.r.t. World | | | 1.411 | | |
| | | | [6.203] | | |
| Change in Arg.'s output tariffs w.r.t. Brazil | | | | -3.999 | |
| | | | | [3.808] | |
| Change in Arg.'s input tariffs w.r.t. Brazil | | | | -6.418 | |
| | | | | [6.099] | |
| **Additional controls** | | | | | |
| 4-digit-ISIC industry characteristics | | | Yes | Yes | |
| 2-digit-ISIC industry dummies | | Yes | Yes | Yes | |
| 4-digit-ISIC industry dummies | | | | | Yes |
| Observations | 1359 | 1359 | 1327 | 1321 | 1359 |

Notes: standard errors are clustered at the 4-digit-ISIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%. Firm size is measured as the (log) number of employees measured in efficiency units relative to the 4-digit-SIC mean.

# Data Appendix

This appendix contains supplementary tables A1 to A4.

**Table A1**
**Brazil and Argentina's m.f.n Tariffs**

| | Average | Standard Deviation | Minimum | Maximum | Industries |
|---|---|---|---|---|---|
| Brazil's m.f.n. tariffs in 1991 | 0.29 | 0.17 | 0.00 | 0.84 | 101 |
| Brazil's m.f.n. tariffs in 1992 | 0.24 | 0.13 | 0.00 | 0.63 | 104 |
| | | | | | |
| <u>Argentina's m.f.n tariffs in 1992</u> | | | | | |
| Outputs | 0.13 | 0.06 | 0.00 | 0.22 | 102 |
| Inputs | 0.11 | 0.03 | 0.01 | 0.17 | 101 |
| | | | | | |
| <u>Change in Arg.'s tariffs w.r.t. the world 1992-1996</u> | | | | | |
| Outputs | 0.01 | 0.05 | -0.10 | 0.14 | 104 |
| Inputs | 0.01 | 0.02 | -0.03 | 0.06 | 101 |

Note: Industries refer to 4-digit-ISIC industries with available tariff data.

**Table A.2**
**Summary Statistics**
**ETIA Panel, Year 1992.**

| | Non-exporters | Exporters | All | Observations |
|---|---|---|---|---|
| Employment | 122.573 | 378.825 | 231.372 | 1359 |
| | [9.102] | [25.070] | [12.346] | |
| Employment in efficiency units | 142.404 | 460.931 | 277.643 | 1359 |
| | [10.149] | [31.169] | [15.077] | |
| Sales | 9,606.65 | 40,710.27 | 22,812.53 | 1359 |
| | [689.557] | [4,555.679] | [2,017.160] | |
| Skill intensity | 11.782 | 19.289 | 14.969 | 1359 |
| | [0.547] | [0.716] | [0.449] | |
| Spending in technology per worker | 0.306 | 0.856 | 0.539 | 1359 |
| | [0.036] | [0.112] | [0.052] | |
| Investment in capital goods per worker | 3.312 | 3.506 | 3.394 | 1359 |
| | [0.848] | [0.459] | [0.525] | |
| Spending in technology per worker / ST>0 | 0.563 | 1.042 | 0.816 | 899 |
| | [0.063] | [0.134] | [0.077] | |
| Investment in capital goods per worker / I>0 | 5.138 | 4.162 | 4.659 | 990 |
| | [1.309] | [0.540] | [0.717] | |
| Index of product and process innovation | 0.316 | 0.467 | 0.381 | 1280 |
| | [0.011] | [0.013] | [0.009] | |
| Index of product innovation | 0.305 | 0.449 | 0.367 | 1291 |
| | [0.011] | [0.013] | [0.009] | |
| Index of production process innovation | 0.327 | 0.485 | 0.395 | 1298 |
| | [0.012] | [0.014] | [0.009] | |
| Export share of sales/ Exports >0 | | 0.16 | | 577 |
| | | [0.010] | | |

Notes: Standard errors of means in parentheses. Employment in number of workers, employment in primary school equivalents in number of less than complete high school workers, sales in thousands of 1992 pesos (exchange rate: 1 peso / US$ 1), spending in technology per worker and investment in capital goods per worker in thousands of 1992 pesos per worker in efficiency units. Further detail on dataset and variable definitions in section 1.2.1 of text.

**Table A.3**
**Effect of Brazil's Tariff Reductions on Skill Upgrading**

Dependent variable: Skilled Labor Share

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Change in Brazil's tariffs | 0.763 | 14.664 | 14.696 | 14.856 | 16.468 | 15.622 | 13.516 | |
| | [1.310] | [4.975]*** | [4.490]*** | [4.627]*** | [5.466]*** | [4.306]*** | [5.295]** | |
| × Firm size | | -2.867 | -3.050 | -2.938 | -3.289 | -2.865 | -2.363 | -2.842 |
| | | [0.888]*** | [0.842]*** | [0.849]*** | [1.009]*** | [0.843]*** | [1.069]** | [0.848]*** |
| Firm size | 0.355 | -0.311 | -0.406 | -0.381 | -1.580 | -0.355 | -1.398 | -0.365 |
| | [0.137]** | [0.286] | [0.277] | [0.283] | [1.601] | [0.281] | [1.558] | [0.253] |
| Change in Arg.'s output tariffs w.r.t. World | | | | 1.813 | 6.760 | | | |
| | | | | [5.671] | [20.244] | | | |
| × Firm size | | | | | -1.211 | | | |
| | | | | | [4.218] | | | |
| Change in Arg.'s input tariffs w.r.t. World | | | | 5.341 | 9.199 | | | |
| | | | | [12.195] | [47.446] | | | |
| × Firm size | | | | | -0.759 | | | |
| | | | | | [8.341] | | | |
| Change in Arg.'s output tariffs w.r.t. Brazil | | | | | | 2.854 | 24.446 | |
| | | | | | | [4.472] | [19.559] | |
| × Firm size | | | | | | | -5.027 | |
| | | | | | | | [4.294] | |
| Change in Arg.'s input tariffs w.r.t. Brazil | | | | | | -28.602 | -49.583 | |
| | | | | | | [9.384]*** | [31.027] | |
| × Firm size | | | | | | | 4.849 | |
| | | | | | | | [6.180] | |
| Demand elasticity | | | | 0.108 | 0.149 | 0.169 | 0.350 | |
| | | | | [0.088] | [0.252] | [0.084]** | [0.277] | |
| × Firm size | | | | | -0.008 | | -0.038 | |
| | | | | | [0.052] | | [0.055] | |
| U.S. Capital intensity | | | | -0.154 | -1.110 | -0.289 | -1.544 | |
| | | | | [0.499] | [1.326] | [0.430] | [1.449] | |
| × Firm size | | | | | 0.187 | | 0.250 | |
| | | | | | [0.245] | | [0.275] | |
| U.S. Skill intensity | | | | 0.511 | 1.973 | 0.458 | 0.906 | |
| | | | | [0.621] | [2.788] | [0.701] | [2.464] | |
| × Firm size | | | | | -0.304 | | -0.069 | |
| | | | | | [0.542] | | [0.498] | |
| 2-digit-ISIC industry dummies | | | Yes | Yes | Yes | Yes | Yes | |
| 4-digit-ISIC industry dummies | | | | | | | | Yes |
| Observations | 1359 | 1359 | 1359 | 1327 | 1327 | 1321 | 1321 | 1359 |
| R-squared | 0.01 | 0.02 | 0.05 | 0.05 | 0.05 | 0.05 | 0.06 | 0.10 |

Notes: standard errors are clustered at the 4-digit-ISIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%. Firm size is measured as the (log) number of employees measured in efficiency units.

**Table A.4**
**Effect of Brazil's Tariff Reductions on Entry in the Export Market and Technology Adoption**

Dependent variable indicated in column headings.

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| | Entry in The Export Market | Export Status in 1996 | Spending in Technology per worker | Spending in Technology per worker (in logs) | Spending in Technology (in logs) | Product and Process Innovation |
| Change in Brazil's tariffs | | | | | | |
| × 1st or 2nd size quartiles | -0.301 | -0.111 | -0.589 | -0.812 | -0.794 | -0.117 |
| | [0.124]** | [0.129] | [0.412] | [0.499] | [0.491] | [0.114] |
| × 3rd size quartile | -0.756 | -0.555 | -1.924 | -2.246 | -2.342 | -0.336 |
| | [0.173]*** | [0.157]*** | [0.577]*** | [0.589]*** | [0.615]*** | [0.135]** |
| × 4th size quartile | -0.351 | -0.291 | -0.470 | -0.376 | -0.402 | -0.183 |
| | [0.174]** | [0.111]*** | [0.291] | [0.530] | [0.534] | [0.132] |
| 3rd size quartile | -0.061 | 0.043 | -0.016 | 0.073 | -0.019 | 0.083 |
| | [0.049] | [0.051] | [0.193] | [0.196] | [0.193] | [0.039]** |
| 4th size quartile | 0.029 | 0.186 | 0.386 | 0.552 | 0.385 | 0.224 |
| | [0.066] | [0.059]*** | [0.181]** | [0.166]*** | [0.179]** | [0.036]*** |
| Export Status in 1992 | | 0.566 | | | | |
| | | [0.026]*** | | | | |
| Observations | 1359 | 1359 | 1359 | 880 | 880 | 1280 |

Notes: standard errors are clustered at the 4-digit-ISIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%. Firm size is measured as the (log) number of employees measured in efficiency units relative to the 4-digit-ISIC industry mean. Results presented in this table summarize the findings reported in Bustos (forthcoming).