Trade Liberalization, Exports and Technology Upgrading:

Evidence on the Impact of MERCOSUR on Argentinean Firms

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Abstract

This paper studies the impact of a regional free trade agreement, MERCOSUR, on technology upgrading by Argentinean firms. To guide empirical work, I introduce technology choice in Melitz's (2003) model of trade with heterogeneous firms. The joint treatment of the technology adoption and exporting choices shows that the increase in revenues produced by trade integration can induce exporters to upgrade technology. An empirical test of the model reveals that firms in industries facing higher reductions in Brazil's tariffs increase their investment in technology faster. The effect of tariffs on entry in the export market and technology adoption is highest in the upper-middle range of the firm size distribution, as predicted by the model.

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1. Introduction

Trade liberalization can increase productivity by inducing a better allocation of production factors or the adoption of more advanced technologies. The recent trade literature [Melitz (2003), Bernard, Eaton, Jensen, and Kortum (2003), Pavcnik (2002) and Tybout (2003)] has emphasized the first channel: trade integration reallocates market shares towards exporters, the most productive firms, increasing aggregate productivity. In this paper I show that, in addition, the resulting increase in revenues can induce exporters to invest in new technologies.

I study the impact of a regional free trade agreement on technology upgrading by Argentinean firms. To guide empirical work, I introduce technology choice in a model of trade with heterogeneous firms. In the model, more productive firms make higher revenues, thus are the only ones that find paying the fixed costs to enter the export market profitable, like in Melitz's (2003). In addition, only the most productive firms adopt the most advanced technology. This is because the benefit of adoption is proportional to revenues, while its cost is fixed. In this setup, a bilateral reduction in tariffs increases export revenues more than it decreases domestic revenues, inducing more firms to adopt the new technology.

I test the model in the context of a regional trade liberalization episode: MERCOSUR. I directly estimate the impact of the reduction in Brazil's tariffs on entry in the export market and technology upgrading by Argentinean firms. Brazil's tariffs provide a good source of arguably exogenous variation, as they fell from an average of 29% in 1991 to zero in 1995, and varied extensibly across industries. Indeed, a look at the aggregate data suggests that MERCOSUR had a strong impact on Argentina's exports: between 1992 and 1996 exports to Brazil quadrupled while exports to the rest of the world increased only 60%.

The firm-level panel data set I analyze is uncommon in that it contains direct measures of *spending* in several dimensions of technology, namely computers, software, technology transfers, patents and innovation activities performed within the firm like R&D.[1] This permits to build a direct and comprehensive measure of investment in technology instead of relying on the estimation of residuals from the production function as proxies for the level of technology.

[1] In addition, the survey contains a series of questions asking whether the firm performed a certain category of innovation or improvement in products or production process during the period 1992-1996 that I use to perform robustness checks.

In a first analysis of the data I check whether the sorting pattern predicted by the model is consistent with the observed differences between exporters and non exporters operating in the same industry. In the model, underlying productivity differences produce a sorting of firms in three groups: the most productive firms both export and use the advanced technology, the intermediate group exports but still uses the old technology and the least productive firms use the old technology and serve only the domestic market. Indeed, in 1992 exporters had, on average, a higher level of spending in technology per worker than non exporters in the same industry. The model also predicts that during the liberalization period both old and new exporters upgrade technology faster than non exporters, which is confirmed by the data. In particular, new exporters were not more technology intensive than non exporters before liberalization, but upgrade technology faster as they enter the export market during the liberalization period.

The patterns in the data described above show that there is a coincidence between entry in the export market and technology upgrading but do not provide an answer to the question of whether trade liberalization induced firms to adopt new technologies. Indeed, both entry in the export market and technology upgrading could be caused by other economic reforms undertaken in the same period if these had heterogeneous effects on firms with different characteristics.[2] Then, a second step in the empirical analysis attempts to establish causality by linking exporting and technology adoption directly to the reduction in Brazil's tariffs for imports from Argentina. Note that this is a direct test of the model where both the decision to enter the export market and to adopt a new technology are endogenous, and thus a function of tariffs.

The model predicts that in industries where tariffs fall more, both the productivity cutoff to enter the export market and to adopt the new technology fall more. Then, to asses the impact of falling tariffs on the export decision I estimate the change in the probability that a firm enters the export market as a function of the change in Brazil's tariffs at the industry level. I find that firms in sectors with a higher reduction in tariffs are more likely to enter the export market. The average reduction in tariffs (24 percentage points) increases the probability to enter the export market by 10 to 12 percentage points.

[2] For example, capital account liberalization could have made credit available for middle sized firms allowing them to enter the export market and upgrade technology.

Next, to asses the impact of falling tariffs on the technology adoption decision I estimate the change in spending in technology[3] as a function of the change in tariffs. I find that firms increase their spending in technology faster in industries where tariffs fall more. The average reduction in Brazil's tariffs increases spending in technology by 0.20 to 0.28 log points. I find that the reduction in tariffs has a positive effect of the same magnitude on old and new exporters, as suggested by the within industry patterns in the data reported above.

Finally, I test the model's prediction that that the reduction in tariffs induces firms in the middle range of the productivity distribution to enter the export market and upgrade technology, but should not affect firms in the lower and upper ranges of the distribution. I find that the reduction in Brazil's tariffs had a stronger effect on both entry in the export market and technology upgrading in the 3rd quartile of the firm size distribution.[4] The estimated effects on the 3rd quartile are about double the size than the average effects for all firms reported above.

The empirical identification of the effect of falling export costs on entry in the export market and technology upgrading is based on a generalized differences and differences estimation, where the sources of variation are the changes in Brazil's tariffs for imports from Argentina across time (1996 - 1992) and across 4-digit-SIC industries. Note that, as MERCOSUR mandates that tariffs fall to zero in all industries, I relate *changes* in technology spending to the initial *level* of Brazil's tariffs. The focus on changes in technology differences out time-invariant industry characteristics that might be correlated with Brazil's tariffs. The use of the initial level of Brazil's tariffs minimizes reverse causality concerns. Still, a main potential problem is that other reforms carried out in the same period could have had heterogeneous effects on industries with different characteristics.[5] I address this concern by showing that results are robust to controls for industry trends at the 2-digit-SIC dissagregation level and the likely determinants of Brazilian trade policy: skill, capital intensity and the elasticity of demand of the industry at the 4-digit SIC dissagregation level.

[3] As measures technology I use spending in technology, spending in technology per worker and spending in technology over sales, all produce similar results.

[4] I use initial firm size measured as employment relative to the 4-digit-industry mean in 1992 as a proxy for productivity, as the survey does not provide for measures of value added nor a long enough series of investment that would permit to calculate productivity as a residual of an estimated production function.

[5] For example, capital account liberalization could have benefited capital-intensive industries disproportionately. If Brazil's trade policy was also targeting these industry characteristics, the estimates of the effects of tariffs might pick up the impact of this other policy.

The model developed in this paper builds on an extensive theoretical literature analyzing the effects of trade on technological change.[6] In particular, it was inspired by the insight that a reduction in trade costs increases the share of firms that export and use the most advanced technology in Yeaple (2005). The model I present differs from Yeaple's in that heterogeneity in exporting and technology choice is the result of ex-ante heterogeneity in productivity.[7] To my knowledge, the model presented in this paper is the first to show that when firms are heterogeneous the presence of fixed technology adoption costs implies that the trade-induced reallocations of market shares towards exporters can induce them to upgrade technology. This differential feature of the model is important to interpret the empirical findings reported above: the reduction in tariffs induced technology adoption mostly the 3rd quartile of the firm size distribution, and not only new exporters but also firms that were already exporting upgrade technology when variable trade costs fall.

The empirical work presented in this paper is related to the literature that analyzes the question of whether export market participation has a positive impact on productivity. The first studies by Clerides, Lach and Tybout (1998) for Colombia, Mexico and Morocco; and Bernard and Jensen (1999) for the U.S. find that exporters have higher productivity than non exporters, but this is because ex-ante more productive firms become exporters, while there are no effects of exporting on productivity. Instead, recent papers in this literature like Van Biesebroeck (2005) and De Loecker (2007) find increases in productivity after firms enter the export market in Ivory Coast and Slovenia, respectively. This paper differs from this literature in that the outcome of interest is technology instead of productivity; and that it analyzes the effect of bilateral trade liberalization on technology adoption, not the effect of exporting.

The focus on investment in technology as the outcome of interest has the advantage of isolating a particular mechanism through which firm-productivity can improve.[8] Earlier studies

[6] Grossman and Helpman (1991) provide a comprehensive analysis of the effects of economic integration on innovation and growth; Eaton and Kortum (2001) discuss the effect of lower barriers to trade on innovation, in particular, in their baseline model the effect of a bigger market size is counteracted by the increased competition with technologies embedded in imports, so that there is no effect of lower barriers to trade on innovation.

[7] In Yeaple (2005) all firms are ex-ante homogeneous, but in equilibrium all firms are indifferent between entering the export market and adopting the new technology or serving only the domestic market and remaining using the old technology.

[8] A similar approach was followed by Verhoogen (2008) who develops a model where increased trade with more developed countries increases production of high quality goods and tests it in the context of Mexico's 1994 devaluation. The mechanism generating quality upgrading in his model is the higher valuation for high quality goods

have often estimated productivity as a residual in the production function. These residuals not only capture differences in technical efficiency across firms but also differences in market power, factor market distortions, or changes in the product mix, as suggested by the recent work by Foster, Haltiwanger, and Syverson (2008), Hsieh and Klenow (2008) and Bernard, Redding and Schott (2008), respectively. More importantly, changes in technology not only affect productivity but can have implications for factor markets if new technologies use skilled labor more intensively. Indeed, several studies have documented increases in the relative demand for skill in developing countries during the trade liberalization period,[9] leaving the open question of whether skill-biased technological change might have been an endogenous response to trade liberalization. This paper provides evidence for a particular channel through which increased trade can induce firms to upgrade technology, namely increased export revenues.

The estimation of the impact of a reduction in a trading partner's tariffs on investment in technology instead of the effect of export market participation parallels the comparative static exercise that naturally emerges from a model where both the decision to export and adopt technology are endogenous, thus each variable is a direct function of tariffs. This exercise is aimed to address the policy question of what is the effect of a reduction in a trading partner's tariffs on technology investment, for which comparison of exporters and non exporters across time can only offer indirect evidence. Indeed, the finding that entry in the export market is not associated with increases in productivity in the absence of trade reforms can be explained by entry responding to temporary opportunities to sell in a foreign market. The opposite finding, even in the context of a trade reform, can't be fully attributed to it, specially in the context of simultaneous implementation of other market-oriented reforms that might have made it possible for some firms to invest in productivity improvements and thus enter the export market.

The empirical methodology implemented in this paper follows the literature measuring the effects of trade liberalization in economic outcomes through changes in tariffs.[10] The focus of

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of consumers in developed countries, the U.S. in this case. Instead, in this paper the analysis focuses on trade liberalization between two countries of a similar level of development, Argentina and Brazil, thus the mechanism generating technology upgrading is of a different nature: increased revenues for exporters to a country with identical homothetic preferences. Still, in the model technology upgrading can be interpreted alternatively as reducing marginal production costs or increasing quality.

[9] Goldberg and Pavcnik (2007) review and discuss these studies.

[10] This literature includes studies on the impact of trade liberalization in inequality like Attanasio, Goldberg and Pavcnik (2004) for Colombia, Topalova (2005) for India, and the study in the impact of trade liberalization in productivity in Colombia by Fernandes (2007).

most studies has been unilateral trade liberalizations while the analysis of regional or bilateral trade liberalizations are rare. The first study of the impact of a trading partner's reduction in tariffs using plant-level data was Trefler's (2004) analysis of the Canada-U.S. Free Trade Agreement. To my knowledge, this paper's analysis of MERCOSUR is the first study of the impact of a trading partner's reduction in tariffs for a developing country. Not surprisingly, the effects of trade on technology adoption seem to be different in this context. This can be seen by comparing the results presented here with those in a contemporaneous study of the Canada-U.S. Free Trade Agreement by Lileeva and Trefler (2007). Although the results are not directly comparable because the methodologies used are different, their finding that the reduction in U.S. tariffs only induced productivity increases in the least productive new entrants in the export market for the case of Canada contrasts with the findings for Argentina where the reduction in Brazil's tariffs induced technology upgrading mostly in the 3rd quartile of the firm-size distribution and not only in new but also in old exporters. As I discuss in the theoretical section of the paper, the result that old exporters upgrade technology when trade costs fall only obtains when the costs of technology adoption are high (relative to fixed exporting costs) which is more likely to be the case in developing countries.

The remaining of the paper is organized as follows. The next section presents the theoretical model and derives the empirical predictions on the effects of trade liberalization on entry in the export market and technology upgrading. Section 3 describes the trade liberalization episode and the data set. Section 4 presents the empirical strategy and tests the predictions of the model. Section 5 concludes.

2 Theory

This section develops a simple model of the decision to enter the export market and upgrade technology by heterogeneous firms. I consider the case of 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, and using a single factor of production, labor, as in Krugman (1979, 1980). Firms are heterogeneous in productivity, face fixed exporting costs as in Melitz (2003), and can choose to increase their productivity by paying a fixed technology adoption cost, as in Yeaple (2005).

2.1 Set up of the Model

I consider the simple case of two symmetric countries endowed with L units of labor used to produce differentiated products in a single industry. The symmetry assumption ensures that wages, which are the numeraire, and all aggregate variables are the same for both countries. I present the discussion from the point of view of the home country.

Entry

The supply side is characterized by monopolistic competition. Each variety is produced by a single firm, and there is free entry into the industry. Firms are heterogeneous in their productivity in the sense that marginal labor costs vary across firms using the same technology.[11] This idiosyncratic component of labor productivity is indexed by φ, that also indexes firms and varieties. To enter the industry in a given country, firms pay a fixed entry cost consisting of f_e units of labor. Entrants then and draw their productivity from a known cumulative distribution function $G(\varphi) = 1 - \varphi^{-k}$.

Technology

After observing their productivity firms decide whether to exit the market or stay and produce. Firms produce varieties using a technology that features a constant marginal cost and a fixed cost, both in terms of labor. Firms can choose to upgrade their technology in the following sense: by paying an additional fixed cost they can reduce their marginal cost of production. This can be represented as a choice between two different technologies *l* and *h*, where *h* features a higher fixed cost and a lower marginal cost. The resulting total cost functions under each technology are:

$$TC_l(q,\varphi) = \left(f + \frac{q}{\varphi} \right)$$

$$TC_h(q,\varphi) = \left(f\eta + \frac{q}{\gamma\varphi} \right)$$

Then, in this setup, there is a part of firm productivity that is the result of luck but firms can also take actions to increase their productivity. A simple interpretation would be that before entering an industry firms engage in product development, but the value of that product/its marginal production cost is revealed only after it has been developed and thus the cost of product

[11] Alternatively, heterogeneity in productivity can be interpreted as quality: more productive firms produce a good of higher quality, in the sense that consumers are willing to pay more for the same amount of the good.

development is sunk. At the production stage, firms can take actions to increase the quality of the product or further reduce its marginal cost, by paying a higher fixed production cost every period. Finally, in every period there is an exogenous probability of exit (δ).

Serving the Foreign Market

After entry, a firm can choose to export, in which case it must incur an additional fixed cost f_x. In addition, exported goods are subject to per-unit iceberg costs, so that τ units need to be shipped for 1 unit to make it to the foreign country.

Demand

Preferences across varieties have the standard CES form, with an elasticity of substitution $\sigma = 1/(1-\rho) > 1$. These preferences generate a demand function $q(\omega) = \frac{E}{P}\left(\frac{p(\omega)}{P}\right)^{-\sigma}$ for every variety ω, where $P = \left[\int_{\omega\in\Omega} p(\omega)^{1-\sigma} d\omega\right]^{\frac{1}{1-\sigma}}$ is the price index of the industry and E is the aggregate level of spending in the country.

2.2 Firm Behavior

Profit Maximization

Under CES preferences the profit maximizing price is a constant markup over marginal costs. Then, a firm with productivity φ using technology l charges the price $p_l^d(\varphi) = \frac{1}{\rho}\frac{1}{\varphi}$ in the domestic market and a higher price in the export market $p_l^x(\varphi) = \frac{1}{\rho}\frac{1}{\varphi}\tau$. If instead the firm uses technology h, it charges lower prices in both markets: $p_h^d(\varphi) = \frac{1}{\rho}\frac{1}{\varphi}\frac{1}{\gamma}$ and $p_h^x(\varphi) = \frac{1}{\rho}\frac{1}{\varphi}\frac{1}{\gamma}\tau$.

To make the joint decision of whether to enter the export market and whether to adopt technology h, firms compare the total profit of each of the four possible choices, which are described below.

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

$$\pi_l^d(\varphi) = \frac{1}{\sigma} E(P\rho)^{\sigma-1} \varphi^{\sigma-1} - f$$

Profits if only serving the domestic market and using technology *h*:

$$\pi_h^d(\varphi) = \frac{1}{\sigma} E(P\rho)^{\sigma-1} \varphi^{\sigma-1} \gamma^{\sigma-1} - f\eta$$

Profits if also exporting and using technology *l*:

$$\pi_l^x(\varphi) = \left(1+\tau^{1-\sigma}\right)\frac{1}{\sigma} E(P\rho)^{\sigma-1} \varphi^{\sigma-1} - f - f_x$$

Profits if also exporting and using technology *h*:

$$\pi_h^x(\varphi) = \left(1+\tau^{1-\sigma}\right)\frac{1}{\sigma} E(P\rho)^{\sigma-1} \varphi^{\sigma-1} \gamma^{\sigma-1} - f\eta - f_x$$

Note that the assumption that both countries are identical and trade costs are symmetric implies that the price index (P) and the expenditure level (E) in foreign are the same as at home. Exporting and technology choices are represented in Figure 1, where the four possible profits are depicted as a function of firm's productivity.[12] The equilibrium depicted is obtained when $\varphi^x < \varphi^h$, where φ^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 φ^h is defined as the level of productivity above which an exporter finds adoption of technology *h* profitable $[\pi_h^x(\varphi_h) = \pi_l^x(\varphi_h)]$. In Appendix A I show that in this equilibrium firms sort into four different groups: the least productive firms $\left(\varphi < \varphi^*\right)$ exit, the low productivity firms $\left(\varphi^* < \varphi < \varphi_x\right)$ only serve the domestic market and use technology l, the medium productivity firms $\left(\varphi_x < \varphi < \varphi_h\right)$ still use technology *l* but also export, and the most productive firms $\left(\varphi_h < \varphi\right)$ both export and use technology h.

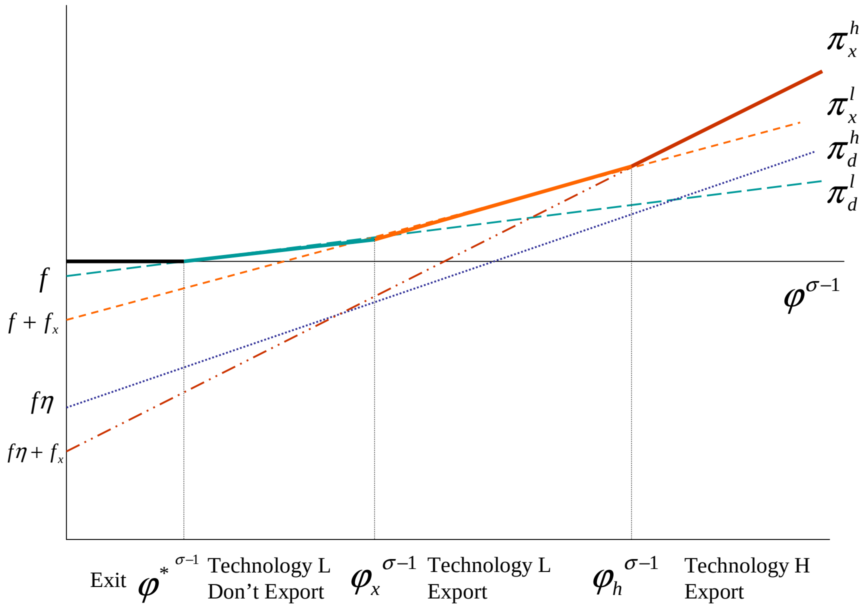
Note that in Figure 1 using technology h and only serving the domestic market is always dominated by some other choice. Note also that there is a range of productivity levels where exporting is profitable but adopting technology *h* is not, so that the marginal exporter uses technology *l*. I focus in this case $\left(\varphi^x < \varphi^h\right)$ in what follows and provide the necessary parameter

[12] More precisely a transformation of firm's productivity: $\varphi^{\sigma-1}$.

restrictions for this ordering of cutoffs to apply. The opposite case $\left(\varphi^x > \varphi^h\right)$ is one where the equilibrium features no exporters using the low technology, which is inconsistent with the empirical findings I report in the next section.

Figure 1

Exporting and Technology Choices



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 function of the exit cutoff, which I do next.

Exit

For the least productive firms profits are highest when using technology *l* and only serving the domestic market, then the exit cutoff φ^* is defined by:

$$\pi_l^d(\varphi^*) = 0 \Leftrightarrow \frac{1}{\sigma} E(P\rho)^{\sigma-1}\left(\varphi^*\right)^{\sigma-1} - f = 0 \tag{1}$$

Exporting

φ_x can be expressed as a function of φ^* by using $\pi_l^d(\varphi_x) = \pi_l^x(\varphi_x)$ and the zero profit condition for the marginal firm (eq. 1):

$$\varphi^x = \varphi^* \tau \left(\frac{f_x}{f}\right)^{\frac{1}{\sigma-1}} \tag{2}$$

note that as long as $\tau\left(\frac{f_x}{f}\right)^{\frac{1}{\sigma-1}} > 1$, $\varphi^x > \varphi^*$ thus only the most productive firms export.

Technology Choice

The marginal firm adopting technology h is an exporter, then the adoption cutoff (φ_h) is defined by:

$$\pi_h^x(\varphi_h) - \pi_l^x(\varphi_h) = 0 \quad \Leftrightarrow \left(\gamma^{\sigma-1} - 1\right)\left(1 + \tau^{1-\sigma}\right)\frac{1}{\sigma}E\left(P\rho\right)^{\sigma-1}\left(\varphi^h\right)^{\sigma-1} = f\left(\eta - 1\right)$$

The benefit of using technology h (the L.H.S. of the equation above) is that the firm makes higher revenues, as demand is elastic ($\sigma > 1$). The cost of using technology h (the R.H.S. of the equation above) is its higher fixed cost. Note that this cost is the same for all firms while the benefit is increasing in productivity. This is why technology choice is characterized by a cutoff productivity level φ_h above which all firms use technology h. Next, φ_h can be expressed as a function of φ^* by substituting the zero profit condition for the marginal firm (eq. 1) in the equation above:

$$\varphi^h = \varphi^* \frac{1}{\left(1 + \tau^{1-\sigma}\right)^{\frac{1}{\sigma-1}}}\left(\frac{\eta - 1}{\gamma^{\sigma-1} - 1}\right)^{\frac{1}{\sigma-1}} \tag{3}$$

Note that the share of active firms adopting technology h (that is $\left(\frac{\varphi^h}{\varphi^*}\right)^{-k}$) is higher the lower are variable trade costs. This is so because a reduction in trade costs increases the total revenues of exporters relative to those of the marginal firm which only serves the domestic market. By comparing equations (2) and (3) we can see that the parameter restriction required for $\varphi^h > \varphi^x$ is that technology adoption costs are high enough relative to fixed exporting costs:

$$\frac{\varphi^h}{\varphi^x} = \left(\frac{\tau^{1-\sigma}}{\left(1 + \tau^{1-\sigma}\right)}\frac{\frac{\eta-1}{\gamma^{\sigma-1}-1}}{\frac{f_x}{f}}\right)^{\frac{1}{\sigma-1}} > 1$$

2.3 Industry Equilibrium

The equilibrium price (P), number of firms (M) and the distribution of active firms' productivities in the economy are determined by the free entry condition. Free entry requires that the sunk entry cost equals the present value of expected profits:

$$f_e = \left[1 - G(\varphi^*)\right]\frac{1}{\delta}\bar{\pi} \tag{4}$$

where $1 - G(\varphi^*)$ is the probability of survival and $\bar{\pi}$ are per-period expected profits of surviving firms. $\bar{\pi} = \bar{\pi}_d + p_x \bar{\pi}_x$ where $\bar{\pi}_d$ are expected profits from domestic sales, $p_x = \frac{1-G(\varphi_x)}{1-G(\varphi^*)}$ is the probability of exporting and $\bar{\pi}_x$ are expected exporting profits. Then, to solve for the free entry condition (eq. 4) we need to solve for expected profits $\bar{\pi}$. The derivations are detailed in Appendix A:

$$\bar{\pi} = \left(\frac{\sigma - 1}{k - (\sigma - 1)}\right) f\Delta \tag{5}$$

$$\Delta = \left\{1 + \left(\tau\left(\frac{f_x}{f}\right)^{\frac{1}{\sigma-1}}\right)^{-k} \frac{f_x}{f} + \left[\left(\frac{\eta - 1}{\left(1 + \tau^{1-\sigma}\right)\left(\gamma^{\sigma-1} - 1\right)}\right)^{-\frac{k}{\sigma-1}} (\eta - 1)\right]\right\}$$

By substituting the solution for average profits (eq. 5) in the free entry condition (eq. 4) we can solve for the exit cutoff:

$$\varphi^* = \left[\frac{f}{\delta f_e}\left(\frac{\sigma - 1}{k - (\sigma - 1)}\right)\Delta\right]^{\frac{1}{k}} \tag{6}$$

By substituting the solution for the exit cutoff (eq. 6) in eqs. 2 and 3 a solution for the exporting and technology adoption cutoffs can be obtained:

$$\varphi^x = \left[\frac{f}{\delta f_e}\left(\frac{\sigma - 1}{k - (\sigma - 1)}\right)\right]^{\frac{1}{k}} \Delta^{\frac{1}{k}} \tau \left(\frac{f_x}{f}\right)^{\frac{1}{\sigma-1}} \tag{7}$$

$$\varphi^h = \left[\frac{f}{\delta f_e}\left(\frac{\sigma - 1}{k - (\sigma - 1)}\right)\right]^{\frac{1}{k}} \Delta^{\frac{1}{k}} \frac{1}{\left(1 + \tau^{1-\sigma}\right)^{\frac{1}{\sigma-1}}} \left(\frac{\eta - 1}{\gamma^{\sigma-1} - 1}\right)^{\frac{1}{\sigma-1}} \tag{8}$$

Finally, welfare is determined by the inverse of the price index, which can be obtained by substituting the exit cutoff (eq. 6) in the exit condition (eq. 1):

$$P = \frac{1}{\rho}\left(\frac{\sigma f}{L}\right)^{\frac{1}{\sigma-1}} \left[\frac{f}{\delta f_e}\left(\frac{\sigma - 1}{k - (\sigma - 1)}\right)\right]^{-\frac{1}{k}} \Delta^{-\frac{1}{k}} \tag{9}$$

Discussion

To interpret the solution for expected profits in eq. 5 note that $f\Delta$ can be written as:

$$f\Delta = f + p_x f_x + p_h\left(f_h - f\right)$$

where $p_x = \left(\frac{\varphi^x\left(\varphi^*\right)}{\varphi^*}\right)^{-k}$ and $p_h = \left(\frac{\varphi^h\left(\varphi^*\right)}{\varphi^*}\right)^{-k}$ are the fraction of surviving firms that export and adopt the high technology, respectively. Then, expected profits are proportional to expected fixed costs $\left(f\Delta\right)$. It is straightforward to show that in the simple case of a closed economy with only one technology the solution for expected profits is the same as in eq. 5 but with $\Delta = 1$. Then, expected profits are proportional to the variable profits of the marginal surviving firm, which must be equal to *f*. In the open economy, with probability p_x the firm becomes an exporter, and in that case expected profits are augmented in proportion to f_x, the variable exporting profits of the marginal exporter. Finally, with probability p_h the firm adopts the high technology, in which case expected profits are augmented in proportion to the variable adoption profits of the marginal adopters which are $\left(f_h - f\right)$. Note that as a reduction in variable trade costs increases the fraction of firms that export p_x and the fraction of firms adopting the high technology p_h,[13] expected profits increase.

2.4 Bilateral Trade Liberalization

In this section I analyze the impact of bilateral trade liberalization on entry in the export market and technology upgrading. I show that a reduction in trade costs increases export revenues, inducing more firms to enter the export market and upgrade technology. This increases expected profits, inducing more entry into the industry. Increased entry reduces the price index and thus firms only serving the domestic market loose revenues. As a result, the least productive firms make negative profits and exit.

More formally, I show in Appendix B that when variable trade costs (τ) fall:

1. *The fraction of surviving firms that export* $\left(\frac{\varphi_x\left(\varphi^*\right)}{\varphi^*}\right)^{-k}$ *and the fraction of surviving of firms that use technology h* $\left(\frac{\varphi_h\left(\varphi^*\right)}{\varphi^*}\right)^{-k}$ *increase*. This can be directly seen in eqs. (3) and (4).

[13] This can be directly seen in eqs. 2 and 3.

2. *Expected profits increase, that is* $\frac{\partial \bar{\pi}}{\partial \tau} < 0$

3. *The price index falls, that is* $\frac{\partial P}{\partial \tau} > 0$

4. *The exit productivity cutoff increases, that is* $\frac{\partial \varphi^*}{\partial \tau} < 0$.

5. *The productivity cutoff for exporting decreases, that is* $\frac{\partial \varphi_x}{\partial \tau} > 0$.

6. *The productivity cutoff for adopting technology h decreases (*$\frac{\partial \varphi_h}{\partial \tau} > 0$*), as long as not all firms export (* $\tau^{\sigma-1} f_x > f$ *).*

Discussion

The new result in the model is that the reduction in variable trade costs induces more firms to upgrade technology (Result 6). What makes adoption of the new technology profitable for the most productive exporters is the increase in total revenues.[14] Still, it is important to note that this is not a market size effect: an increase in market size as represented by an increase in *L* does not affect the technology adoption cutoff. Instead, the result is due to the asymmetric effect of trade liberalization in models of heterogeneous firms with fixed exporting costs: while firms serving only the domestic market loose revenues, exporters see their revenues increase.

Indeed, this result requires that domestic revenues fall less than export revenues increase. I show in Appendix C that this can never be the case when the marginal firm is an exporter. In that case, as τ falls free entry induces the price index to fall enough to make the profits of the marginal firm equal to zero. If this firm is an exporter, the price index falls enough to make the reduction in domestic profits completely offset the increase in export profits.

An alternative intuition for this result is that as countries engage in bilateral trade liberalization, firms loose domestic revenues because there are more foreign firms and increased foreign sales, but gain exporting revenues. The second effect dominates as long as exporters can serve the foreign market but face the entry of only a fraction of foreign firms.

[14] The benefit of technology adoption is proportional to revenues while its cost is fixed.

3 Context and Data

3.1 Trade Liberalization

In this section I describe the regional and unilateral trade liberalization policies undertaken in Argentina at the beginning of the 1990's. Although these policies had started to be discussed in the late 1980's, the depth and pace of the reforms implemented in 1991 were largely unexpected. The newly elected president had promised populist policies during the campaign, namely a widespread increase in wages, but his government implemented a set of market oriented reforms. Many observers believed that the newly built consensus for the reforms was largely due to the 1989 and 1990 hyperinflations, and the crisis in the socialist bloc. In particular, political arguments favoring MERCOSUR in Argentina and Brazil were based in the view that after the fall in the Berlin Wall the world would be organized in regional blocks, as the recent emergence of NAFTA and creation of the EU suggested.[15]

Argentina started reducing import tariffs with respect to the rest of the world before MERCOSUR was launched, in the context of debt-related negotiations with the World Bank and the IMF. Between October 1988 and October 1991 there were 11 major revisions of trade policy, often related to changes in macroeconomic policy aimed at controlling hyperinflation. By October 1991, the average nominal tariff was 12%, ranging from 0% to 35%, where rates were increasing in the value-added of production of each good. Manufactures were concentrated in the range of 5% to 22%. Almost all import licenses were eliminated, with the exception of the automobile industry. Finally, in October 1993 imports of new capital goods were exempted of tariffs.

MERCOSUR was established by Argentina, Brazil, Paraguay and Uruguay in March 1991. The agreement established *generalized, linear and automatic* reductions in tariffs, and the adoption of a common tariff with third countries. The tariff reductions were generalized in the sense that the same reduction relative to the m.f.n rates was to be applied to all goods. They were to be implemented gradually according to a semi-annual timetable starting by a 54% reduction in December 1991, and finishing at 100% in December 1994.[16] This new agreement

[15] For a discussion of the policy debates in Argentina and Brazil during the period of launching of MERCOSUR see Campbell, Rozemberg and Svarzman (1999).

[16] The timetable of reductions relative to m.f.n. rates was: 54% by December 1991, 61% by June 1992, 68% by December 1992, 75% by December 1993, 82% by December 1993, 89% by June 2004 and finally 100% by December 1994.

was in sharp contrast with the regional integration treaty signed in 1988, where reductions in tariffs were gradually negotiated sector by sector and free trade was to be achieved in 10 years.

The Customs Union was established in 1995 with the adoption of a Common External Tariff (CET), with an average level of 12%. Tariffs varied between 0 and 20% across industries. Inputs and materials had the lowest tariffs, followed by semi-finished industrial goods, capital and IT goods,[17] and final goods. There were exceptions to internal free trade for a limited number of products, special regimes for sugar and automobiles and some products faced tariff rates different from the CET.

MERCOSUR seems to have had a big impact on Argentinean exports. Between 1992 and 1996, exports to Brazil quadrupled, while exports to the rest of the world only increased 60%. As a result, growth in exports to Brazil explains 50% of the growth in total exports during this period. This might be related to deep reduction in Brazil's tariffs in this period. Table 1 reports summary statistics for m.f.n tariffs at the 4-digit-SIC industry level of aggregation in the period under study.[18] The first row reports the level of Brazil's m.f.n. tariffs in 1991 that are the baseline for the MERCOSUR tariff reductions that started in December 1991. The average reduction in Brazil's tariffs faced by Argentinean firms between December 1991 and December 1994 was 29 p.p. Also, tariff reductions varied extensibly across industries, as initial m.f.n tariffs varied between of 84 p.p. and 0 p.p.. As the panel of firms I analyze covers the period 1992-1996, I use the level of Brazil's m.f.n tariffs in 1992 as the baseline for the calculation of tariff reductions in the period 1992-1996. These are on average 24 p.p, slightly lower than 1991 tariffs but reflect a similar variation across industries, as their correlation is 0.97.

As m.f.n. tariffs in Argentina were already low before MERCOSUR was launched, the baseline for the reduction in Argentina's tariffs for imports from Brazil was only 13 percentage points on average (Table 1). Still, there was significant variation in tariffs across 4-digit-SIC

[17] According to Berlinski et al. (2006) the common external tariffs for capital goods (14%) and information technology and telecommunication (16%) were the most difficult to agree upon. Argentina favored low tariffs while Brazil wanted higher protection. Thus, national tariffs were to converge to the AEC by 2001 for capital goods and 2006 for IT goods, from above in the case of Brazil and from below in the case of Argentina.

[18] The source of the tariff data is UNCTAD-TRAINS. Tariffs for each 4-digit-SIC-industry are obtained as a weighted average of the 9-digit-HS-products within each 4-digit-SIC-industry, where the weights are given by imports of each product. Thus, when computing Brazil's m.f.n tariffs in 1992 weights for each product within a 4-digit industry are based on Argentina's exports to Brazil of that product in each year. An alternative is to obtain 4-digit-SIC-industry as simple averages of m.f.n tariffs for 9-digit-HS-products within each industry, but these give similar results as their correlation is 0.975.

industries, from 0 to 22 p.p. Surprisingly, imports from Brazil grew exactly at the same rate as imports from the rest of the world during this period (60%).

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 15 pp. across 4-digit-SIC industries. The modifications on import tariffs during this period are partly related to the convergence to the CET, that partly reflected the structure of protection in Brazil.[19]

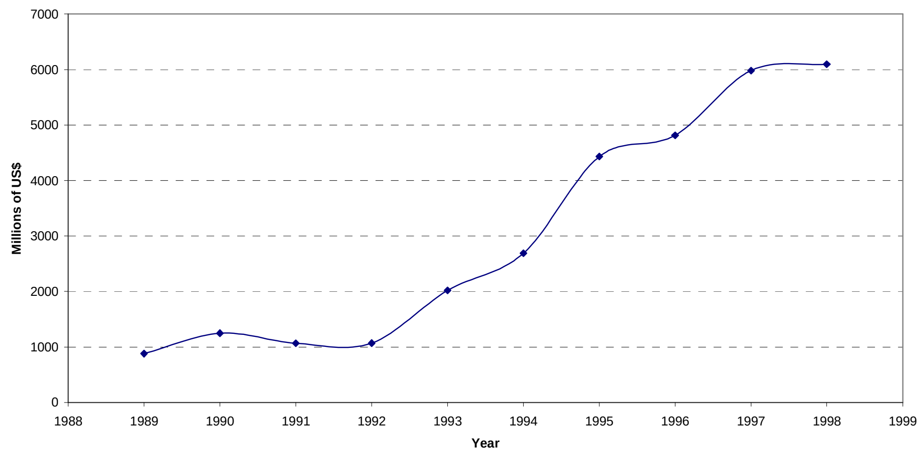
In addition, Table 1 reports average m.f.n. input tariffs for Argentina as these are used for robustness checks in the empirical analysis of the impact of Brazil's tariffs on entry in the export market and technology upgrading. The input tariff for each industry is computed as weighted average of the 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 Appendix D. The baseline m.f.n rates for Argentina's input tariff reductions w.r.t Brazil were smaller than the output tariffs reported above, with an average level of 11 p.p. in 1992. Similarly, the changes in Argentina's input tariffs w.r.t. the world were smaller than the output tariffs, ranging from -3 to 6 p.p.

Finally, an important point to note is that the start of MERCOSUR tariff reductions respect to m.f.n. rates, December 1991, just precedes the period under study 1992-1996. Still, exports seem to have reacted to tariff declines with a lag. The data on aggregate Argentinean industrial exports to Brazil shows that these started growing in 1993, as depicted in Figure 2. Thus, it is likely that the relevant overall tariff reductions in the period 1992-1996 are the full 100% reduction over m.f.n. rates between December 1991 and 1994 and not the 32% remaining reduction that occurred between December 1992 and 1994. Thus, in the empirical analysis I set the change in Brazil's tariffs w.r.t Argentina between 1992 and 1996 to minus the level of Brazil's m.f.n tariffs in 1992. Similarly, I set the change in Argentina's tariffs w.r.t Brazil between 1992 and 1996 to minus the level of Argentina's m.f.n tariffs in 1992. Note that the application of a 100% or 32% tariff reduction w.r.t. m.f.n tariffs in 1992 does not affect the estimation of the average impact of tariffs on entry in the export market or technology upgrading

[19] Berlinsky et al. (2006) and Chang and Winters (2002) provide a more detailed discussion of Argentina and Brazil's trade policy measures in the 1990's.

as in the first case the estimated coefficient is 0.32 times smaller but the average change in tariffs is (1/0.32) times bigger.[20] It does affect the interpretation of the results, though, as the implied responses of entry in the export market and spending in technology to a given tariff change are 0.32 times smaller when considering the full 100% reduction. Then, the reported estimates can be considered as a lower bound.

Figure 2
Exports from Brazil to Argentina 1989-1998
Sample of 104 industries with positive trade in 1992



Brazil's Trade Policy

As the source of identification of the effect of tariff reductions on entry in the export market and technology upgrading are the differences across industries in the level of m.f.n tariffs in Brazil in 1992, it is important to discuss Brazil's trade policy in more detail.

Like Argentina, Brazil implemented a program of unilateral trade liberalization between 1988 and 1994. Berlinski, Kume and Vaillant (2006) note that the tariff structure in 1988 was based on the tariffs implemented in 1957 under the import substitution policy. They argue that the first reforms implemented in 1988-89 did not have significant effects on the degree of protection of the domestic industry as NTBs, which were the main instrument of protection, were not modified. Instead, after a new government took power in march 1990 NTBs were eliminated

[20] For example, if the change in Brazil's tariffs is set to minus the level of m.f.n tariffs in 1992 multiplied by 0.32, estimated coefficients are 1/0.32 times bigger but then the average reduction in Brazil's tariffs in the period is 0.32 times smaller, thus the estimated effect of the average reduction of tariffs is the same.

and tariffs were reduced gradually according to a timetable ending in January 1994. The new tariffs would vary between 0 and 20%, except for a few goods facing 30-35% tariff rates.[21]

Brazil's m.f.n tariff rates in 1992 reflect a transition between the old and new tariff structure. As a result, they display tariff rates above 30 p.p. for some unskilled, labor-intensive industries protected under the import substitution policy like toys, textiles and rubber and also for skill-intensive industries that were protected under the new policy like domestic appliances, office accounting and computing and the car industry. Possibly as a result, the correlation between Brazil's tariffs in 1992 and an exogenous measure of skill intensity of the industry[22] is very low (-0.002). Instead, tariffs are negatively correlated with a measure of capital intensity (-0.21), suggesting that Brazil protected labor-intensive industries. As 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 entry in the export market and technology upgrading, I include in the regressions 2-digit-SIC-industry dummies that absorb part of the correlation between changes in tariffs and industry characteristics. After including 2-digit-SIC-industry dummies the correlation between capital intensity and tariffs falls to -0.06, although the correlation between tariffs and skill intensity increases to 0.06. Thus, in addition to including 2-digit-SIC-industry dummies I control for measures of capital, skill intensity and the elasticity of demand.[23]

3.2 Firm-Level Data

The data I analyze comes from the Survey on Technological Behavior of Industrial Argentinean Firms [Encuesta sobre la Conducta Tecnologica de las Empresas Industriales Argentinas (ETIA)] conducted by the National Institute of Census and Statistics in Argentina (INDEC). 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. Although according to the census only 15% of

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[21] According to Berlinski et al. (2006) the 0% tariffs corresponded to commodities and "exportables", 10% for agricultural products and their derivates, 10,15 and 20% for products using basic inputs with 0% tariffs and 20% for the rest of the products. The main exceptions to the general rule were IT goods with a 35% tariff, domestic appliances (30%) and the car industry (35% tariff).

[22] I use measures of average capital and skill intensity in the industry in the U.S. in the 1980's obtained from the NBER productivity database (see Appendix D for details).

[23] I use the elasticity of substitution in the industry as estimated by Broda and Weinstein (2006). The correlation of the elasticity of demand with tariffs is low: 0.05 and 0.06 with controls for 2-digit-SIC-industry dummies.

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.[24]

As the survey was conducted in 1997, it does not contain information on firms that were active in 1992 and exited afterwards. I focus my analysis on a balanced panel of 1,380 firms present both in 1992 and 1996 for which there is information on sales, employment and belong to 4-digit-SIC industries with information on Brazil's tariffs.

The survey contains information on several dimensions of spending on technology upgrading. Firms upgrade technology by performing various innovation activities like internal R&D, paying for technology transfers and buying capital goods that embody new technologies; and with different purposes like changing production processes, products, organizational forms or commercialization. I constructed a measure of spending on technology (ST) that includes the following: 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.[25]

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.

The survey also contains some binary measures of technology adoption: 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 Appendix D.

The main measure of technology I use in the empirical analysis is technology spending while the binary measures of technology are used to perform robustness checks. I think technology spending is a better measure of technology for two reasons. First, the information has

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[24] The sample is the same as the one used for the Encuesta Industrial Annual, the standard yearly industry survey used to compute Industrial GDP. A description of sampling methodology for Encuesta Industrial Annual by the National Statistics Office (INDEC) is available at www.indec.mecon.ar.

[25] Like R&D, adaptation of new products or production processes, technical assistance for production, engineering and industrial design, organization and commercialization.

a panel structure that can be used to control for unobserved firm and industry characteristics. Second, it is a more objective measure in the sense that it does not depend on the interpretation of what an improvement or innovation is.

Finally, another unusual feature of the survey is that it contains information on employment by education. I use this information to construct measures of employment in primary school equivalents, skill intensity and sales per worker as described in Appendix D.

Table D.1 in Appendix D contains summary statistics by export status for the main variables of interest for the initial year in the data, 1992.

3.3 Industry-Level Data

In the empirical section I use controls for 4-digit-SIC 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 NBER productivity database (see Appendix D for details). I also use the elasticity of substitution in the industry as estimated by Broda and Weinstein (2006). Finally, data on exports from Brazil to Argentina in the years 1992 and 1996 were obtained from the U.N. COMTRADE database. This information is aggregated at the 4-digit-SIC industry.

4 Empirics

In this section I test the predictions of the theoretical model developed in section 2. First, I check whether the sorting pattern of firms into exporting and technology use predicted by the model is consistent with the observed characteristics of exporters and non-exporters in the same 4-digit-SIC industry. Second, I test the main predictions of the model: that a reduction in variable trade costs causes entry in the export market and technology upgrading. To establish causality, I use the differential changes in Brazilian tariffs across 4-digit-SIC industries to show that firms are more likely to enter the export market and upgrade technology in industries where tariffs fell more.

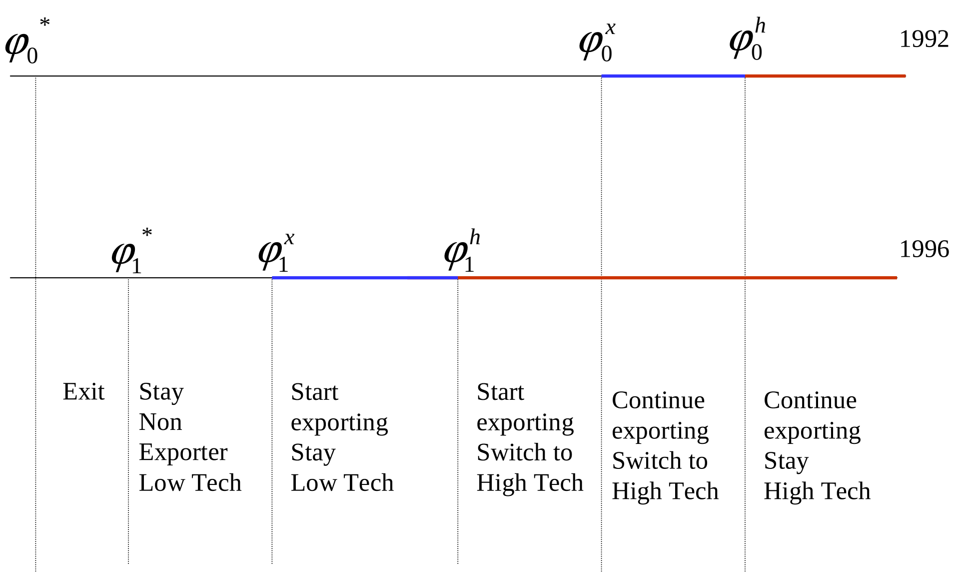
4.1 Within-Industry Patterns in the Data

In the model, 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, the medium productivity firms still use the low technology but also export, and the most productive firms both export and use the high technology. In this setting a reduction in variable trade costs increases exporting revenues inducing firms in the middle-range of the productivity distribution to enter the export market and upgrade technology.

Figure 3 illustrates the effects of trade liberalization for firms in each part of the productivity distribution. The upper line represents productivity cutoffs to adopt the high technology and to enter the export market before liberalization (φ_h^0, φ_x^0), while the lower line represents the cutoffs after liberalization (φ_h^1, φ_x^1). Within the group of firms that were already exporting before liberalization ($\varphi_x^0 < \varphi$) those in the upper range of productivity ($\varphi_h^0 < \varphi$) were already using technology *h*, while firms in the range $\varphi_x^0 < \varphi < \varphi_h^0$ adopt it only afterwards. Within the group of firms that enter the export market after liberalization ($\varphi_x^1 < \varphi < \varphi_x^0$), those in the upper range ($\varphi_h^1 < \varphi < \varphi_x^0$) enter the export market and adopt the new technology, while those in the lower range ($\varphi_x^1 < \varphi < \varphi_h^1$) enter the export market but keep the old technology.

Figure 3

Effect of Falling Variable Trade Costs



To check whether the sorting pattern depicted in figure 3 and the parameter restrictions required to obtain it are consistent with the data I divide firms into three groups: continuing exporters,[26] new exporters,[27] and never exporters[28] and compute differences in characteristics for firms operating within the same 4-digit-SIC industry.

Table 2 reports that, on average, continuing exporters have a 0.37 log points higher level of spending in technology per worker a than never exporters in 1992. This is consistent with at least a fraction of them already using the high technology before liberalization. Interestingly, they increase spending in technology 0.27 log points faster than never exporters during the liberalization period (1992-1996), which is consistent with a fraction of them adopting the high technology after liberalization.

Firms that would enter the export market after liberalization are not significantly more technology intensive than never exporters in 1992 (Table 2). In contrast, after liberalization these new exporters become more technology-intensive than firms that do not export, increasing their spending in technology per worker 0.34 log points faster between 1992 and 1996.

The patterns in the data described above show that there is a coincidence between entry in the export market and technology upgrading, but can't establish whether it is expanded export opportunities that cause technology adoption, vice versa, or whether both are caused by a third factor. Some alternative explanations for the results in Table 2 can be ruled out: as these are based on comparisons of exporters and non exporters within industries, they are robust to macroeconomic shocks that affect all firms equally (an example could be exchange rate appreciation) or to shocks that affect all firms within an industry (an example could be fast technological change in a particular industry). Still, the fact that within each sector exporters and new exporters are upgrading technology faster than other firms could reflect other shocks that affect middle and high productivity firms differentially. This is particularly plausible in a context where several reforms were implemented at the same time. For example, capital account liberalization, that could facilitate access to credit to finance technology upgrading and entry in foreign markets to medium and big firms but not to small firms in the presence of credit constraints. Then, the next step in the empirical analysis attempts to establish causality by linking

[26] Firms that were already exporting in 1992.
[27] Firms that export in 1996 but were not exporting in 1992.
[28] Firms that do not export in 1992 nor 1996.

exporting and technology adoption directly to the reduction in Brazil's tariffs for imports from Argentina.

4.2 The Impact of the Reduction in Brazil's Tariffs

4.2.1 Identification Strategy

Empirical identification of the effect of the fall in variable export costs on entry in the export market and technology upgrading by Argentinean firms is based on the differential reductions in Brazilian tariffs for imports from Argentina across 4-digit-SIC industries.

This source of identification has two features that make it likely to be exogenous with respect to the outcomes analyzed, *changes* in export status and *changes* in spending in technology between 1992 and 1996. First, the tariff reductions were programmed in 1991, and reach a level of zero for all industries[29] in 1995, thus *changes* in tariffs are predetermined by the 1991 m.f.n tariff *levels* in Brazil. Second, the 1991 m.f.n import tariffs of Brazil are the same for Argentina and the rest of the world thus they are unlikely to be targeted to industry characteristics particular to Argentina, whose share of Brazil's trade was only 7.7%.[30] As changes in tariffs are predetermined, they are unlikely to be driven by political pressures arising from the effects of liberalization in Brazil or Argentina, or by contemporaneous shocks to industrial performance. As they respond to Brazil's worldwide trade policy, it is also unlikely that results are driven by Brazilian tariffs being initially high in industries where Argentina has a comparative advantage.

Although the points above address the reverse causality problem, Brazil's initial tariff structure is certainly not random: as discussed above, Brazil's trade policy is correlated with some industry characteristics, and omitting them could be an important source of bias. Thus, I estimate all the equations in first differences, so that constant industry characteristics are differenced-out. Still, if industries with different initial characteristics are on different trends, Brazil's tariffs could be capturing some omitted industry-level -time-varying variable. I address this problem in two ways. First, I include in the differenced equations 2-digit-SIC-industry dummies that account for unobserved industry trends at broad sector levels like "Manufacture of

[29] Except for the automobile and sugar industries. In the results presented in this section, 1996 tariffs are still set to zero for these two industries, to avoid endogeneity problems in using the actual 1996 tariffs. As a robustness check, all the results presented in this section have been replicated for the sample of firms excluding these sectors.

[30] Argentina's share on Brazil's imports rose to 11.2% in 1995 when all tariffs were eliminated.

food products and beverages" (SIC 15) or "Manufacture of chemicals" (SIC 24). As tariffs vary at the 4-digit-level this means that I am comparing manufacturers of dairy products (SIC 1520) to macaroni producers (SIC 1544), but not to manufacturers of pharmaceuticals (SIC 2423) that are instead compared to producers of fertilizers (SIC 2412). Second, as there can still be important differences between producers of pharmaceuticals and of fertilizers, I include 4-digit-SIC-level controls for the industry characteristics that are likely to determine tariffs: the elasticity of demand, capital and skill intensity. These industry characteristics are measured with U.S. data to avoid endogeneity problems.

An additional issue concerning the use of Brazil's tariffs to measure the effect of expanded export opportunities on entry in the export market and technology upgrading is that they might be correlated with changes in Argentina's tariffs during this period, as long as the structure of protection was similar between the two countries in 1992. To address this concern I control for the change in Argentina's tariffs with respect to the world in the period 1992-1996, and alternatively for the change in Argentina's tariffs with respect to Brazil.[31] I control both for final goods tariffs and intermediate inputs tariffs.

Heterogeneous Effects

The sorting pattern of firms described in Figure 3 implies that the reduction in Brazil's tariffs should induce entry in the export market and technology upgrading for firms in the middle range of the productivity distribution. In particular, the model predicts that the reduction in tariffs would induce firms in the middle range of the productivity distribution to enter the export market, but should not affect firms in the lower and upper ranges of the distribution. Similarly, the reduction in tariffs should only induce firms in the middle range of the productivity distribution to upgrade technology. To study these heterogeneous effects, I use firm size relative to the 4-digit-SIC industry mean in 1992 as a proxy for initial productivity and divide firms into quartiles. Then, I analyze the effects of the reduction in Brazil's tariffs on each quartile of the firm size distribution.

Next I present the estimation of the effect tariff changes on entry in the export market and later the estimation for technology upgrading.

[31] An important point to note is that as Argentina's m.f.n tariffs with the rest of the world 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.

4.2.2 Entry in the Export Market

I estimate a linearized version of the entry in the export market choice described by equation (7). This linearization does not respect functional form thus estimation only attempts to recover the signs of the partial derivative of interest and to assess the economic significance of the estimated coefficients. To simplify the exposition, I first describe estimation of the average effect of a reduction in Brazil's tariffs on entry in the export market for all firms, and later analyze how this effect varies for firms in different quartiles of the size distribution.

I empirically analyze the entry in the export market decision using an index model:

$$EXP_{ijst} = \begin{Bmatrix} 1 & if\ \beta_{\tau}\tau_{jt} + \alpha_{st} + \alpha_{i} + \varepsilon_{ijst} > 0 \\ 0 & otherwise \end{Bmatrix} \tag{10}$$

where j indexes 4-digit-SIC industries; s indexes 2-digit-SIC industries; t indexes time, that is the years 1992 and 1996; i indexes firms; EXP_{isjt} is a dummy variable that takes the value of 1 if the firm exported in year t; τ_{jt} are Brazil's tariffs that vary across 4-digit-SIC industries and time; α_i are plant fixed effects that capture unobserved constant plant heterogeneity (φ), constant sector characteristics that affect the sector exporting cutoffs in the model (σ, k, f_x, f, η, γ) and also some other sector characteristics that although not included in the model might affect the exporting cutoffs (like factor intensity);[32] α_{st} are 2-digit-SIC industry dummies that capture variation across time in sector characteristics.

Equation (29) with plant fixed effects can't be consistently estimated by probit (incidental parameters problem), then I estimate it using the linear probability model:

$$EXP_{ijst} = \beta_{\tau^x}\tau^x_{jt} + \alpha_{st} + \alpha_i + \varepsilon_{ijst}$$

In this case, first differencing eliminates time-invariant plant and sector heterogeneity:

$$\Delta EXP_{ijs} = \beta_{\tau^x}\ \Delta\tau^x_j + \Delta\alpha_s + \Delta\varepsilon_{ij} \tag{11}$$

Estimation of equation (11) by OLS is reported in the first column of Panel A of Table 3, where the reported standard errors are clustered at the 4-digit-SIC industry level. The coefficient in the change in Brazil's tariffs (β_{τ^x}) is negative (-0.421) and significant (t = -5.01). The estimated

[32] Bernard, Redding and Schott (2007) develop a two factor, two sector and two country model of trade with heterogeneous firms and show that the cutoff for entry in the export market is closer to the exit cutoff in comparative advantage industries.

coefficient implies that the average reduction in Brazil's tariffs (24 percentage points) increases the probability of entry in the export market by 10 percentage points. Columns 2 to 8 assess the robustness of the baseline results to inclusion of controls, as described by the following equation:

$$\Delta EXP_{ijs} = \beta_{\tau^x}\ \Delta\tau_j^x + \beta_{\tau^m}\Delta\tau_j^m + \beta_z z_{ij1992} + \beta_c c_j + \Delta\alpha_s + \Delta\varepsilon_{ij} \tag{12}$$

where $\Delta\tau_j^m$ denotes changes in Argentina's import tariffs for outputs and inputs w.r.t. the world and Brazil; z_{ij1992} are firm characteristics in the initial year (1992) like size measured by the number of workers, sales per worker and skill intensity; and c_j are 4-digit-SIC industry characteristics like the elasticity of demand, skill and capital intensity in the U.S. Estimation of equation (12) is reported in columns (2) to (8) of Table 3, and although some of the firm and industry characteristics are highly significant, the coefficient on Brazil's tariffs is not significantly affected by their inclusion. The coefficients in the regressions including all controls (columns 5 and 8) are -0.472 (t=-4.87) and -0.533 (t=-3.78) and imply that the average drop in Brazil's tariffs (24 percentage points) increases the probability of entry in the export market by 11 to 12 percentage points.

A potential problem of the specification in equation (12) is that if there are sunk exporting costs, current export status might depend on lagged export status,[33] which in turn is likely to be negatively correlated with the initial level of Brazil's tariffs. This problem can't be solved by including lagged export status in the specification in first differences, as in that case export status in 1992 would be both part of the dependent variable and a regressor, thus necessary correlated with the error term.[34] Still, it is possible to estimate the equation in levels, including lagged export status as a regressor, as specified in the following equation:

$$EXP_{ijs1996} = \beta_{\tau^x}\Delta\tau_j^x + \delta\ EXP_{ij1992} + \alpha_s + \varepsilon_{ijs} \tag{13}$$

Unlike the first-difference specification, eq. (12) does not control for unobserved constant heterogeneity. Still, estimation of equation (13) is useful because first-difference and lagged-dependent-variable estimates have a bracketing property: if the first-difference specification in

[33] Roberts and Tybout (1997) and Bernard and Jensen (2004) find evidence of the existence of sunk exporting costs in Colombia and the U.S., respectively.

[34] An alternative solution to this problem that permits to control both for unobserved individual heterogeneity and lagged dependent variables is to run a specification in first differences and use further lags of the dependent variable as instruments, as proposed by Arellano and Bond (1991). I can't implement this solution because the panel I analyze only contains data for 1992 and 1996.

(12) is correct, then (13) will tend to underestimate the absolute value of β_{τ^x}, while if the lagged-dependent-variable specification in (13) is correct, then (12) will tend to overestimate the absolute value β_{τ^x}. This is because the initial level of Brazil's tariffs is negatively correlated with export status in 1992.[35] Panel B of Table 3 reports estimation of equation (13) where the estimated coefficient goes from -0.291 (t=4.09) in the baseline specification in Column 1 to 0.533 (t=3.78) in Column 9 where all controls are included. These estimates are 30% to 8% lower than the estimates in the first-differences specification, as expected. They are also less stable, possibly due to the omission of unobserved-time-invariant industry characteristics.

As a final check that the presence of sunk export costs are not creating a problem in the identification on the coefficient on Brazil's tariffs I estimate equation (13) restricted to firms that were not exporters in 1992. Panel C of Table 3 reports the estimation of equation (13) by OLS. The coefficient on the change in Brazil's tariffs is very similar to the one estimated in the firs-difference specification and significant [-0.446 (t=-3.20) and -0.605 (t=-2.99) in columns 5 and 8 where all controls are included], implying that the average reduction in tariffs increases the probability of entering the export market by 11 to 14.5 percentage points.[36]

A potential problem in the estimation of equation (13) restricted to non-exporters in 1992 is sample selection. The model predicts that in sectors where tariffs are higher the exporting cutoff is higher, thus it is likely that in sectors with high initial tariffs non exporters are more productive than in sectors with low initial tariffs, creating a positive correlation between Brazil's tariffs in 1992 and unobserved productivity, thus biasing downwards the coefficient on the change in tariffs. A simple way to asses whether this is a problem is to look at the correlation of tariffs with firm characteristics that are correlated with unobserved productivity like size and sales per worker in the sub sample of non exporters in 1992, and both are very low (-0.033 and 0.013). In addition, when these firm characteristics are included in the regressions the coefficient does not change (see Panel C , columns 1 and 2), thus sample selection does not seem to play an important role.

[35] For a discussion and a derivation of the biases in the first-difference and lagged-dependent-variable estimators see pages 243-247 in Angrist and Pischke (2008).

[36] Equation (13) can also be estimated by Probit as it does not contain firm fixed-effects. Probit estimation for both the full sample and the sample of non- exporters in 1992 produces very similar results as OLS, Tables reporting this estimations are available upon request.

Entry in the Export Market by Quartile of the Firm Size Distribution

The model predicts that reduction in Brazil's tariffs induces entry in the export market for firms in the middle range of the productivity distribution, but not for the least productive firms or the most productive firms who would export even in the presence of high tariffs. More precisely, the prediction is that the reduction in tariffs induces entry for firms who were below the exporting threshold before liberalization, but above afterwards. That is, those firms with productivity in the range $\varphi_x^1 < \varphi < \varphi_x^0$ in Figure 3. To test this prediction, I estimate the effect of the change in Brazil's tariffs on each quartile of the initial firm size distribution[37] through the following equation:

$$\Delta EXP_{ijs} = \sum_{r=1}^{4} \beta_{\tau^x}^r \left(\Delta \tau_j^x \times Q_{ij}^r\right) + \sum_{r=2}^{4} \alpha^r Q_{ij}^r + \Delta \alpha_s + \Delta \varepsilon_{ij} \qquad (14)$$

where r indexes each of the four quartiles of the size distribution and Q_{ij}^r are dummy variables taking the value of 1 when firm i belongs to quartile r. Estimation results are presented in columns 1 to 3 of Table 4. The effect of the reduction in Brazil's tariffs on the probability to enter the export market is around 2 times bigger in the 3rd quartile of the firm size distribution, where the point estimate is -0.735 (t= 4.45). Columns 4 to 6 present estimation of the equation in levels including lagged export status as a control. The point estimates of $\beta_{\tau^x}^r$ are smaller, but the same patter is observed: the estimate of $\beta_{\tau^x}^r$ is biggest in the 3rd quartile and precisely estimated ($\beta_{\tau^x}^3$ =-0.535, t= -3.56). Columns 7 to 9 report estimation of $\beta_{\tau^x}^r$ in the sample of non-exporters, with similar results as in the full sample ($\beta_{\tau^x}^3$ =-0.785, t= -3.31).

The effect of the reduction in tariffs on the rest of the quartiles is less precisely estimated. The coefficients are negative but not always statistically significant. Taken altogether the results suggest that some firms in the 1st, 2nd and 4th quartiles were induced to enter the export market

[37] As a proxy for initial productivity, I use initial firm size in terms of (log) employment in primary school equivalents relative to the 4-digit-industry average. I think that this is the best productivity proxy available in the data, as the survey does not provide information on value added, nor has a long enough series of investment to construct a good measure of the capital stock. Alternatively I used (log) domestic sales relative to the 4-digit-industry mean as a proxy for initial productivity, with similar but less precise results than the ones reported below. I prefer the employment measure because it reflects value-added better than sales, as long as there are differences in the level of vertical integration across firms.

by the reduction in Brazil's tariffs. This is not inconsistent with the model, as size is not a perfect measure of productivity and the exporting cutoffs might differ across industries.

The point estimate of $\beta^{3}_{\tau^{x}}$ in the baseline specifications (columns 1, 4 and 7) implies that the 24 p.p. reduction in Brazil's tariffs increases the probability to enter the export market by 0.18 to 0.13 p.p. for firms in the 3rd quartile of the size distribution. The finding that the reduction in Brazil's tariffs had a smaller impact on entry for firms in the top quartile of the size distribution suggests that most of them were above the threshold before (or regardless of) liberalization. Similarly, the lower induced entry for firms in the first and second quartile suggests that most of them were still below the threshold after liberalization. Thus, trade liberalization induced more entry in the export market for firms in the upper-middle range of the size distribution.

To assess the robustness of the baseline estimates of $\beta^{r}_{\tau^{x}}$ discussed above (Columns 1 , 4 and 7 of Table 4) I perform a similar series of checks as in the estimation of average industry-level effects of the reduction in Brazil's tariffs in Table 3. The remaining columns in Table 4 show that results are robust to the inclusion of changes in Argentina's import tariffs (for both output and inputs and w.r.t. the world and Brazil) and industry characteristics (capital, skill intensity and elasticity of demand).

4.2.3 Technology Adoption Decision

Spending in Technology

The technology adoption decision described in the model (equation 8) is binary. In the data, I observe a continuous measure of spending in technology and also some binary measures of product and process innovation. The technology spending measure has the advantage of having a panel structure that can be used to control for unobserved firm and industry characteristics but the disadvantage that only a sub-sample of firms has positive ST in 1992 and 1996. This sample is not representative for the smallest firms, while the binary measures of technology contained in the survey are available for a representative sample. I first analyze the ST measure and later I also discuss the binary innovation measures.

I first describe estimation of the average effect of a reduction in Brazil's tariffs on entry in the export market for all firms, and later analyze how this effect varies for firms in different quartiles of the size distribution. In the model, a firm is more likely to adopt technology *h* the lower is the threshold φ_h in its sector [equation (8)], and the higher is its own productivity (φ), then the level of spending in technology can be described by:

$$\log ST_{ijst} = \alpha_{st} + \alpha_i + \beta_{\tau^x}\ \tau^x_{jt} + \beta_{\tau^m}\ \tau^m_{jt} + \varepsilon_{ijst} \tag{15}$$

where τ^m denotes Argentina's import tariffs, as adoption of new technologies depends on both export market and domestic revenues. The survey has information on ST for all the years in the period 1992-1996. Still, as the variation across time in Brazil's tariffs is fully determined by their level in 1992, using the variation data for all the years after 1992 in the estimation of eq. (15) would induce serial correlation in the error terms. As a result, the standard error of the estimated coefficients would understate their standard deviation, as noted by Bertrand, Duflo, and Mullainathan (2004). Thus, instead of estimating equation (15) for all the available years, I use one their proposed solutions, namely to run the equation in first differences and set the level of ST after liberalization to the average level after 1992.[38] I thus estimate equation (15) in first differences:

$$\Delta \log ST_{ijs} = \Delta\alpha_s + \beta_{\tau^x}\Delta\tau^x_j + \beta_{\tau^m}\Delta\tau^m_j + \Delta\varepsilon_{ij} \tag{16}$$

where the change in ST in the liberalization period is:

$$\Delta \log ST_{ijs} = \frac{1}{4}\sum_{t=1993}^{1996} \log ST_{ijst} - \log ST_{ijs1992}$$

Estimation of equation (16) by OLS is reported in Table 5. The coefficient on the change in Brazil's tariffs is negative and significant in all specifications. The estimated coefficient in the baseline specification in column 1, where only the change in Brazil's tariffs is included as a regressor is -1.079 (t=3.08) and implies that the average reduction in Brazil's tariffs (24 percentage points) induces an increase in technology spending of 0.24 log points. The estimated coefficient is not affected by the inclusion of firm-level controls (Column 2) nor by the change in Argentina's output and input tariffs with respect to the world (Columns 3 to 5). Instead, the inclusion of the change in Argentina's output tariffs with respect to Brazil (Column 6) increases the coefficient to -1.436 (t=-3.21), possibly because these are correlated with Brazil's tariffs but had an effect of the opposite sign in technology adoption, although not statistically significant.

[38] 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.

Finally, the inclusion of the change in Argentina's input tariffs with respect to Brazil (Column 7) does not affect the estimated coefficient.

A further question is whether the reduction in Brazil's tariffs also increases the technology intensity of production, in the sense of increasing the ratio of spending in technology to labor. This is stronger evidence that firms are actually changing their production technology, instead of just expanding production by increasing the use of all factors proportionally. Table E.1 in Appendix E reports estimates of equation (16), replacing the growth in spending in technology by the growth in spending in technology per worker as the dependent variable. The estimates of $\alpha_{\tau x}$ are very similar to the ones reported in Table 5.[39]

An important caveat in the interpretation of the results presented in this section is that equation (16) can only be estimated on a sub-sample of firms that have positive ST in 1992 and 1993-1996, 894 out of the total of 1380 firms in the panel. Firms reporting a positive level of spending in technology tend to be bigger: only 14% of them belong to the first size quartile, while 33% belong to the fourth, as reported in Table D.2 in Appendix D. Thus, results might not be representative for the smallest firms. Instead, the binary measures of technology that I use to construct the innovation indexes are available for a bigger sub-sample of firms (1310 firms) that is representative in terms of size, as around 25% of firms in the sub-sample belong to each size quartile.

Binary Measures of Technology

In this section I analyze alternative measures of technology. I use a set of questions on improvements in products and production process to construct indexes for the fraction of questions in each category and overall that were answered positively by the firm.

Table 6 reports OLS estimates of equation (16), replacing the change in spending in technology by indexes of innovation as a dependent variable. The coefficient on the change in Brazil's tariffs is negative and significant for all and each type of innovation. Consistent with the results presented in the previous section, the estimated coefficient is sensitive to the inclusion of the change in Argentina's tariffs with respect to Brazil as a control, changing from -0.30 (t=3.35) to -0.40 (t=3.42) (columns 2 and 3). It is possible that this is due to the reduction in Argentina's output tariffs having an effect of innovation of the opposite sign, although the estimate is only

[39] Similar results are also obtained when the outcome variable is the ratio of spending in technology to sales.

marginally significant (Column 3). The estimated coefficient in column 2 implies that the average reduction in Brazil's tariffs induces an increase of 0,07 in the innovations index, which is 19% of the average innovation index (0,38). As the index is constructed as the fraction of yes/no questions about product and process innovation to which the firm gave a positive answer, the result can be interpreted as 19% increase in the fraction of questions about innovation answered positively by the firm. The effect of a reduction in Brazil's tariffs is of similar magnitude when the innovation index is disaggregated in product and process innovations.

Technology Adoption by Quartile of the Firm Size Distribution

The model predicts that reduction in Brazil's tariffs induces technology adoption for firms in the middle range of the productivity distribution, but not for the least productive firms who do not export nor the most productive firms who already adopted the high technology. More precisely, the prediction is that the reduction in tariffs induces technology upgrading for firms who were below the technology adoption threshold before liberalization, but above afterwards. That is, those firms with productivity in the range $\varphi_h^1 < \varphi < \varphi_h^0$ in Figure 3. To test this prediction, I estimate the effect of the change in Brazil's tariffs on each quartile of the initial firm size distribution[40] through the following equation:

$$\Delta \log ST_{ijs} = \sum_{r=1}^{4} \beta_{\tau^x}^r \left(\Delta \tau_j^x \times Q_{ij}^r \right) + \sum_{r=2}^{4} \alpha^r Q_{ij}^r + \beta_{\tau^m} \Delta \tau_j^m + \Delta \alpha_s + \Delta \varepsilon_{ij} \tag{17}$$

where r indexes each of the four quartiles of the size distribution and Q_{ij}^r are dummy variables taking the value of 1 when firm i belongs to quartile r. Estimation results are presented in Table 7 for both spending in technology and the innovation index. The reduction in tariffs induces a statistically significant increase in spending in technology only in the third quartile of the size distribution, where the estimated coefficient is -2.184 (t=3.57) (column 1). The point estimate is double the size than the estimated average effect for all firms in Table 5, and more than double the estimated coefficient for the other three quartiles of the size distribution. The results on the

[40] As a proxy for initial productivity, I use initial firm size in terms of (log) employment in efficiency units relative to the 4-digit-industry average. I think that this is the best productivity proxy available in the data, as the survey does not provide information on value added, nor has a long enough series of investment to construct a good measure of the capital stock. Alternatively I used (log) domestic sales relative to the 4-digit-industry mean as a proxy for initial productivity, with similar but less precise results than the ones reported below. I prefer the employment measure because it reflects value-added better than sales, as long as there are differences in the level of vertical integration across firms.

innovation index parallel the findings with the ST measure: the reduction in tariffs induces a statistically significant increase in innovation only in the third quartile of the size distribution, where the point estimate of $\beta^{r}_{\tau^{x}}$ is -0.385 (t=2.92), as reported in column 4.

The effect of the reduction in tariffs on the rest of the quartiles is less precisely estimated. The coefficients are negative but not statistically significant, thus it is possible that some firms in the 1^{st}, 2^{nd} and 4^{th} quartiles were induced to upgrade technology by the reduction in Brazil's tariffs. This is not inconsistent with the model, as size is not a perfect measure of productivity and the technology adoption cutoffs might differ across industries.

The point estimate of $\beta^{3}_{\tau^{x}}$ implies that the 24 p.p. reduction in Brazil's tariffs induces firms in the third quartile of the size distribution to increase their spending in technology an average of 0.52 log points. The finding that firms in the top quartile of the size distribution did not increase ST in response to the reduction in tariffs suggests that they were above the threshold before, or regardless of, liberalization. Similarly, the lower and not statistically significant increase in spending in technology for firms in the second quartile suggests that they were still below the threshold after liberalization. Thus, trade liberalization induced technology upgrading for firms in the upper-middle range of the size distribution.

To assess the robustness of the baseline estimates of $\beta^{r}_{\tau^{x}}$ discussed above (Columns 1 and 4 of Table 7) I perform a similar series of checks as in the estimation of average industry-level effects of the reduction in Brazil's tariffs in Tables 5 and 6. Columns 1-6 in Table 7 show that results are robust to the inclusion of changes in Argentina's import tariffs (for both output and inputs and w.r.t. the world and Brazil) and industry characteristics (capital, skill intensity and elasticity of demand).[41]

To assess whether firms increased the technology intensity of production, I estimate eq. 17 replacing the outcome of interest by spending in technology per worker. The results parallel the findings with the ST measure: the reduction in tariffs induces a statistically significant increase

[41] As a further robustness check interactions between changes in Argentina's import tariffs with firm size quartiles were included as controls in the estimation of equation 17. Alternatively, a set of interactions between industry characteristics and firm size quartiles are also included as controls. The estimated coefficient of the effect of Brazil's tariffs on ST and innovation in the 3^{rd} quartile of the firm size distribution is not affected by the inclusion of these controls, and is always significant at 1% confidence level. Tables reporting this estimation are available upon request.

in spending in technology only in the third quartile of the size distribution, where the estimated coefficient is -2.124 (t=3.76) (column 1, Table E.3 in Appendix E).

Finally, to assess whether the reduction in Brazil's tariffs affected both product and process innovation, I estimate equation 17 separately for each type of innovation index. I obtain similar results as the ones reported above with the aggregate index, as reported in Columns 4-9 of Table E.3 in Appendix E.

4.2.4 Mechanism

In this section I discuss how the evidence provided so far relates to the mechanism emphasized in the theoretical model, namely that trade liberalization generates an increase in revenues for exporters making it profitable for them to adopt the high technology. Finally, I provide evidence that the reduction in Brazil's tariffs increased export sales to Brazil, and the reduction in Argentina's tariffs w.r.t. Brazil reduced domestic sales.

Technology Upgrading by Export Status

The finding that the reduction in tariffs induces an increase in Spending in Technology on the 3rd quartile of the firm size distribution is consistent with the theoretical prediction that only firms who are induced to cross a size threshold by the increase in export sales upgrade technology. To explore this issue further, I split the sample of firms in two on the basis of initial export status and show that the reduction in Brazil's tariffs induced technology upgrading in both sub-samples. This implies that firms that were already exporting in 1992 are induced to upgrade technology by the reduction in Brazil's tariffs, which is consistent with technology upgrading being driven by the increase in revenues. If technology upgrading was driven by the mere act of exporting, Brazil's tariffs would impact technology spending only through their induced entry in the export market.

I estimate the effect of the reduction in Brazil's tariffs on ST and the innovation indices for two sub-samples of firms, the ones that did not export in 1992 and the ones that did. The model predicts that both groups upgrade technology if the ordering of cutoffs is $\varphi_x^1 < \varphi_H^1 < \varphi_x^0 < \varphi_H^0$, as depicted in Figure 3. Estimation results when the outcome of interest is ST are reported in Table 8, where Panel A reports the estimation the sub-sample of firms that did not export in 1992 and Panel B for the sub-sample of firms that exported in 1992. The coefficient is similar to the one estimated for the full sample, and significant in almost all specifications. These findings are consistent with the within-industry patterns in the data presented in Table 2, namely that both continuing exporters and new entrants in the export market increase ST faster than non exporters in the same 4-digit industry. Finally, Table 9 reports the estimation of the impact of Brazil's tariffs when the outcome of interest are the product and process innovation indexes, with similar results in both sub-samples.

Exports to Brazil

In this section I report evidence using COMTRADE data on exports from Argentina to Brazil at the 4-digit-SIC-industry level of aggregation that has information on export sales by destination. The analysis of export sales at the firm-level did not produce consistent results, possibly because the data combines all destinations.[42] The main differences between the industry-level and firm-level data on exports are that industry-level data is reported by destination, reflects the universe of exports instead of a sample, and changes in export sales at the industry level not only capture the changes in sales of continuing exporters but also of new exporters.

Table 10.1 reports estimation results of the effect of the reduction in Brazil's tariffs on (log) exports to Brazil. As the number of observations is smaller than with the firm-level data, I try to assess the robustness of the estimates by reporting results with and without 2-digit-SIC industry dummies, and report both O.L.S. and I.V estimates. The I.V. estimates use Brazil's tariffs in 1991 to instrument for Brazil's tariffs in 1992 in an attempt to correct for measurement error in Brazil's tariffs. As industry-level tariffs are computed as averages of product-level tariffs, zero or small trade in some products in a given year can produce inaccurate measures of industry-level tariffs. Panel A reports O.L.S estimates. The point estimate of the effect of Brazil's tariffs on exports is negative, and statistically significant in all columns except in column 3 where controls for changes in Argentina's tariffs w.r.t Brazil and 2-digit-SIC industry dummies are included in the regression. Panel B reports I.V. estimates, where both the magnitude of the coefficient increases and standard errors fall, suggesting that measurement

[42] The estimated coefficients for the impact of the reduction in Brazil's tariffs on the change in (log) export sales at the firm-level are not significant nor robust, in the sense that the point estimates vary between 1.429 and 0.16 depending on the combination of controls. In addition, they have the wrong sign. To check whether this instability is due to the fact that the distribution of the dependent variable is very disperse, I dropped the observations in the top and bottom deciles. The coefficients become all negative and stable between -0.471 and -0.252 but still not statistically significant.

error in tariffs might produce attenuation bias in the O.L.S. results. Finally, Table 10.2 reports the first stage of the I.V. estimates.

Overall, the industry-level data estimates suggest that the reduction in Brazil's tariffs had a sizable impact on export sales: the 0.24 p.p. reduction in tariffs increased export sales by 0.68 to 0.84 log points, according to the O.L.S and I.V. baseline estimates reported in column 1, where 2-digit-SIC dummies are included.

Domestic Sales

The model predicts that domestic sales decline with tariff declines. The mapping of this prediction to the data is not straightforward, as the model considers a fully symmetric case where changes in tariffs are the same for both countries.[43] Thus, the model does not differentiate between Brazil's and Argentina's tariffs. The empirical evidence suggests that the reduction in Argentina's tariffs w.r.t. Brazil reduced domestic sales, while the reduction in Brazil's tariffs did not have a significant effect.

Table 11.1 reports estimation of the impact of the reduction in Argentina's tariffs w.r.t. Brazil on domestic sales. The point estimate in the baseline specification in column 1 is 1.431 (t=2.61), and implies that the 13 p.p. reduction in Argentina's tariffs reduced domestic sales by 0.19 log points. The point estimate is robust to the inclusion of controls for changes in Argentina's input tariffs w.r.t. Brazil and industry characteristics (Columns 2 and 4), falls slightly to 1.153 (t=2.20) when changes in Brazil's tariffs are included in the regression (Column 5) and becomes insignificant when in addition controls for industry or firm characteristics are included as controls (Columns 6 and 7). The evidence is thus not conclusive but suggestive that the reduction in Argentina's tariffs w.r.t. Brazil reduced domestic sales.

Table 11.2 reports estimation of the effect of other changes in tariffs on domestic sales. Unlike the change in Argentina's tariffs w.r.t. Brazil, changes in Argentina's output and input tariffs w.r.t. the world did not have a statistically significant effect on domestic sales. This might be due to the fact that the changes in Argentina's tariffs w.r.t the world were smaller, as

[43] The reason for considering the symmetric case is to obtain a closed-form solution for the model in general equilibrium, that is, allowing for the free entry of firms. This is important, as it highlights that trade liberalization has an impact on technology adoption only when not all firms export, as if all firms exported the increased revenues produced by tariff reductions would induce entry until revenues fall to their initial level, as indicated in the theory section.

unilateral trade liberalization took place before 1992. Finally, changes in Brazil's tariffs w.r.t Argentina did not have a statistically significant effect on domestic sales.

5 Concluding Remarks

The evidence reported in this paper suggests that expanded export opportunities can have a positive effect on firm performance. The evidence is consistent with falling trading partner's tariffs increasing revenues for exporters and making adoption of new technologies profitable for more firms. The finding that falling trading partner's tariffs induce firms to take actions that can increase their productivity suggests that the cross-sectional differences between exporters and non exporters are not completely explained by selection of the most productive firms into the export market, but are partly induced by participation in export markets. Then, trade policies oriented to facilitate access to foreign markets, like multilateral trade liberalizations, can have a positive effect on firm-level performance.

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Table 1: Brazil and Argentina's m.f.n Tariffs

	Average	St. 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	0.15	104
Inputs	0.01	0.02	-0.03	0.06	101

Note: Tariffs expressed in percentage points. Industries refer to 4-digit-SIC Industries with available tariff data. The source of the tariff data is UNCTAD-TRAINS. Tariffs for each 4-digit-SIC-industry are obtained as a weighted average of the 9-digit-HS-products within each 4-digit-SIC-industry, where the weights are given by imports of each product. For example, when computing Brazil's m.f.n tariffs in 1992 weights for each product within a 4-digit-SIC industry are based on Argentina's exports to Brazil of that product in each year.

Table 2: Differences between exporters and non exporters

	Levels in 1992		Changes 1992-1996		
	Continuing Exporters	New Exporters	Continuing Exporters	New Exporters	Number of Firms
<u>Firm Characteristic</u>					
Sales	1.82	1.06	0.18	0.25	1380
	[0.086]***	[0.099]***	[0.038]***	[0.046]***	
Employment	1.52	0.86	0.02	0.18	1380
	[0.072]***	[0.084]***	[0.025]	[0.033]***	
Spending in Technology	0.37	0.21	0.27	0.34	894
per worker	[0.145]**	[0.168]	[0.103]***	[0.116]***	
Skill Intensity	6.49	1.88	1.22	1.27	1380
	[1.099]***	[1.071]*	[0.374]***	[0.461]***	

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 industries (four digit SIC classification); *NE* are new exporters (231 firms), *EE* are continuing exporters (556 firms), *EN* are firms that exported in 1992 but didn't in 1996 (27 firms) and the reference category relative to which differences are estimated is non exporters (566 firms); *I* are industry dummies, and *Y* is the firm characteristic for which the differences are estimated.

Table 3: Entry in the Export Market

	1	2	3	4	5	6	7	8
Panel A: Full Sample. Dependent variable: change in export status 1996-1992								
Change in Brazil's tariffs	-0.421	-0.417	-0.406	-0.342	-0.472	-0.325	-0.362	-0.533
	[0.084]***	[0.080]***	[0.083]***	[0.108]***	[0.097]***	[0.091]***	[0.093]***	[0.141]***
Change in Arg.'s tariffs w.r.t. world								
Outputs			0.172	0.118	-0.091			
			[0.408]	[0.383]	[0.317]			
Inputs				1.108	1.554			
				[0.880]	[0.689]**			
Change in Arg.'s tariffs w.r.t. Brazil								
Outputs						-0.507	-0.780	-0.269
						[0.331]	[0.300]**	[0.344]
Inputs							1.213	0.701
							[0.599]**	[0.524]
Firm-level controls								
Log (Employment$_{1992}$)		0.014	0.014	0.013	0.013	0.013	0.011	0.013
		[0.010]	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]	[0.010]
Log (Sales per worker$_{1992}$)		0.037	0.037	0.038	0.041	0.037	0.035	0.037
		[0.014]***	[0.014]**	[0.015]**	[0.014]***	[0.014]**	[0.014]**	[0.014]***
Skill Intensity$_{1992}$		-0.155	-0.155	-0.149	-0.107	-0.140	-0.120	-0.098
		[0.069]**	[0.069]**	[0.070]**	[0.071]	[0.071]*	[0.073]	[0.073]
Industry-level controls								
Demand elasticity					0.017			0.016
					[0.006]***			[0.006]***
U.S. Capital intensity					-0.049			-0.045
					[0.027]*			[0.030]
U.S. Skill intensity					-0.159			-0.127
					[0.057]***			[0.068]*
2-digit-SIC industry dummies								
Observations	1380	1380	1380	1348	1348	1374	1342	1342
R-squared	0.03	0.04	0.04	0.04	0.05	0.04	0.04	0.05
Panel B: Full Sample. Dependent variable: export status in 1996								
Change in Brazil's tariffs	-0.291	-0.286	-0.271	-0.199	-0.321	-0.262	-0.281	-0.490
	[0.071]***	[0.077]***	[0.073]***	[0.084]**	[0.102]***	[0.101]**	[0.111]**	[0.144]***
Export status in 1992	0.642	0.543	0.542	0.544	0.546	0.542	0.545	0.544
	[0.023]***	[0.028]***	[0.028]***	[0.028]***	[0.028]***	[0.028]***	[0.029]***	[0.028]***
R-squared	0.46	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Remaining controls and number of observations are the same as in the corresponding column in Panel A								
Panel C: Sample of non exporters in 1992. Dependent variable: export status in 1996								
Change in Brazil's tariffs	-0.411	-0.447	-0.446	-0.288	-0.446	-0.330	-0.357	-0.605
	[0.108]***	[0.123]***	[0.122]***	[0.125]**	[0.139]***	[0.150]**	[0.175]**	[0.202]***
Observations	797	797	797	781	781	797	781	781
R-squared	0.04	0.16	0.16	0.16	0.17	0.16	0.16	0.17
Controls are the same as in the corresponding column in Panel A								

Notes: standard errors are clustered at the 4-digit-SIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4: Entry in the Export Market by Quartile of the Firm Size Distribution

Dependent variable indicated in columns

	Full Sample						Sample of non-exporters in 1992		
	Change in Export Status 1996-1992			Export Status in 1996			Export Status in 1996		
	1	2	3	4	5	6	7	8	9
<u>Change in Brazil's tariffs</u>									
* First Size Quartile	-0.328	-0.392	-0.438	-0.125	-0.157	-0.290	-0.358	-0.373	-0.435
	[0.184]*	[0.189]**	[0.198]**	[0.169]	[0.179]	[0.189]	[0.180]**	[0.203]*	[0.224]*
* Second Size Quartile	-0.325	-0.372	-0.408	-0.142	-0.166	-0.299	-0.249	-0.250	-0.306
	[0.147]**	[0.194]*	[0.220]*	[0.175]	[0.211]	[0.229]	[0.233]	[0.261]	[0.281]
* Third Size Quartile	-0.735	-0.806	-0.848	-0.535	-0.570	-0.696	-0.785	-0.731	-0.798
	[0.165]***	[0.153]***	[0.201]***	[0.150]***	[0.152]***	[0.195]***	[0.237]***	[0.242]***	[0.283]***
* Fourth Size Quartile	-0.346	-0.421	-0.469	-0.290	-0.338	-0.473	-0.317	-0.348	-0.399
	[0.174]**	[0.177]**	[0.203]**	[0.118]**	[0.144]**	[0.163]***	[0.350]	[0.385]	[0.377]
<u>Change in Arg.'s tariffs w.r.t. world</u>									
Outputs		-0.008			0.214			-0.014	
		[0.346]			[0.317]			[0.489]	
Inputs		1.363			1.330			2.640	
		[0.699]*			[0.575]**			[0.936]***	
<u>Change in Arg.'s tariffs w.r.t. Brazil</u>									-0.729
Outputs			-0.415			-0.021			[0.452]
			[0.354]			[0.377]			1.150
Inputs			0.977			0.711			[1.210]
			[0.537]*			[0.695]			
<u>Firm-level controls</u>									
Second Size Quartile	0.051	0.052	0.056	0.115	0.113	0.114	0.146	0.149	0.153
	[0.059]	[0.060]	[0.061]	[0.058]*	[0.059]*	[0.060]*	[0.079]*	[0.082]*	[0.084]*
Third Size Quartile	-0.030	-0.036	-0.035	0.108	0.102	0.104	0.130	0.153	0.149
	[0.059]	[0.060]	[0.060]	[0.062]*	[0.063]	[0.064]	[0.083]	[0.087]*	[0.087]*
Fourth Size Quartile	0.057	0.047	0.047	0.244	0.231	0.232	0.451	0.443	0.446
	[0.072]	[0.073]	[0.073]	[0.069]***	[0.070]***	[0.070]***	[0.121]***	[0.121]***	[0.121]***
Export Status in 1992				0.553	0.558	0.557			
				[0.027]***	[0.027]***	[0.028]***			
<u>Industry-level controls</u>									
Demand elasticity		0.015	0.014		0.002	0.003		0.003	0.003
		[0.006]**	[0.006]**		[0.007]	[0.007]		[0.011]	[0.012]
U.S. Capital intensity		-0.045	-0.041		-0.005	-0.003		0.058	0.077
		[0.027]*	[0.030]		[0.024]	[0.025]		[0.042]	[0.048]
U.S. Skill intensity		-0.166	-0.127		-0.156	-0.143		-0.227	-0.149
		[0.060]***	[0.070]*		[0.059]***	[0.063]**		[0.073]***	[0.081]*
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes	Yes			
Observations	1380	1348	1342	1380	1348	1342	797	781	781
R-squared	0.03	0.05	0.05	0.50	0.50	0.50	0.15	0.16	0.16

Notes: standard errors are clustered at the 4-digit-SIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%.

Table 5: Technology Adoption

Dependent variable: change in log (spending in technology)

	1	2	3	4	5	6	7	8
Change in Brazil's tariffs	-1.079	-1.076	-1.033	-1.063	-0.921	-1.436	-1.435	-1.448
	[0.350]***	[0.346]***	[0.319]***	[0.334]***	[0.383]**	[0.447]***	[0.483]***	[0.643]**
<u>Change in Arg.'s tariffs w.r.t. world</u>								
Outputs			0.635	0.717	0.760			
			[1.073]	[1.099]	[1.153]			
Inputs				-0.863	-0.995			
				[3.229]	[3.031]			
<u>Change in Arg.'s tariffs w.r.t. Brazil</u>								
Outputs						2.050	2.250	2.534
						[1.323]	[1.370]	[1.883]
Inputs							-0.351	-0.728
							[2.788]	[3.037]
<u>Firm-level controls</u>								
Log (Employment$_{1992}$)		0.102	0.103	0.108	0.108	0.106	0.112	0.113
		[0.030]***	[0.031]***	[0.031]***	[0.031]***	[0.030]***	[0.031]***	[0.031]***
Log (Sales per worker$_{1992}$)		0.554	0.557	0.519	0.496	0.572	0.550	0.516
		[0.291]*	[0.291]*	[0.299]*	[0.293]*	[0.288]*	[0.291]*	[0.277]*
Log (Sales per worker$_{1992}$)^2		-0.066	-0.067	-0.063	-0.058	-0.069	-0.066	-0.060
		[0.034]*	[0.034]*	[0.034]*	[0.034]*	[0.034]**	[0.034]*	[0.032]*
Skill Intensity$_{1992}$		0.477	0.473	0.446	0.458	0.416	0.380	0.413
		[0.228]**	[0.228]**	[0.230]*	[0.231]*	[0.229]*	[0.233]	[0.231]*
<u>Industry-level controls</u>								
Demand elasticity					0.023			0.031
					[0.022]			[0.024]
U.S. Capital intensity					-0.228			-0.239
					[0.088]**			[0.092]**
U.S. Skill intensity					0.241			0.065
					[0.168]			[0.222]
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	894	894	894	872	872	892	870	870
R-squared	0.03	0.05	0.05	0.05	0.06	0.05	0.05	0.06

Notes: standard errors are clustered at the 4-digit-SIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%.

Table 6: Product and Process Innovation

Dependent variable indicated in columns

	All Improvements			Improvements in Products			Production Process Improvements		
	1	2	3	4	5	6	7	8	9
Change in Brazil's tariffs	-0.236	-0.302	-0.400	-0.293	-0.348	-0.438	-0.183	-0.266	-0.358
	[0.104]**	[0.090]***	[0.117]***	[0.116]**	[0.098]***	[0.116]***	[0.100]*	[0.094]***	[0.127]***
<u>Change in Arg.'s tariffs w.r.t. world</u>									
Outputs		-0.184			-0.155			-0.238	
		[0.251]			[0.264]			[0.275]	
Inputs		0.261			0.102			0.389	
		[0.619]			[0.740]			[0.572]	
<u>Change in Arg.'s tariffs w.r.t. Brazil</u>									
Outputs			0.526			0.622			0.336
			[0.308]*			[0.335]*			[0.326]
Inputs			-0.254			-0.577			0.196
			[0.554]			[0.578]			[0.587]
<u>Firm-level controls</u>									
Log (Employment$_{1992}$)	0.083	0.084	0.086	0.075	0.077	0.080	0.090	0.090	0.092
	[0.006]***	[0.006]***	[0.006]***	[0.007]***	[0.007]***	[0.007]***	[0.007]***	[0.007]***	[0.007]***
Log (Sales per worker$_{1992}$)	0.050	0.053	0.050	0.051	0.055	0.052	0.048	0.049	0.046
	[0.011]***	[0.010]***	[0.010]***	[0.012]***	[0.011]***	[0.010]***	[0.012]***	[0.011]***	[0.011]***
Skill Intensity$_{1992}$	0.200	0.222	0.211	0.217	0.233	0.219	0.189	0.219	0.212
	[0.051]***	[0.056]***	[0.056]***	[0.057]***	[0.061]***	[0.061]***	[0.053]***	[0.058]***	[0.058]***
<u>Industry-level controls</u>									
Demand elasticity		0.003	0.003		0.000	0.001		0.005	0.004
		[0.005]	[0.005]		[0.005]	[0.005]		[0.005]	[0.005]
U.S. Capital intensity		-0.057	-0.058		-0.082	-0.085		-0.029	-0.028
		[0.021]***	[0.021]***		[0.021]***	[0.021]***		[0.024]	[0.025]
U.S. Skill intensity		-0.072	-0.101		-0.051	-0.086		-0.102	-0.118
		[0.048]	[0.049]**		[0.052]	[0.049]*		[0.049]**	[0.051]**
2-digit-SIC industry dummies									
Observations	1301	1269	1263	1312	1280	1274	1319	1287	1281
R-squared	0.24	0.25	0.26	0.22	0.24	0.24	0.22	0.23	0.23

Notes: standard errors are clustered at the 4-digit-SIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%.

Table 7: Heterogeneous Effects on Technology Adoption

Dependent variable indicated in columns

	Change in Spending in Technology 1996-1992			Product and Process Innovation		
	1	2	3	4	5	6
Change in Brazil's tariffs						
* First Size Quartile	-0.888	-0.726	-1.254	-0.037	-0.072	-0.159
	[0.606]	[0.569]	[0.758]	[0.115]	[0.113]	[0.142]
* Second Size Quartile	-0.829	-0.633	-1.155	-0.200	-0.228	-0.326
	[0.569]	[0.632]	[0.830]	[0.150]	[0.145]	[0.163]**
* Third Size Quartile	-2.184	-1.990	-2.505	-0.385	-0.429	-0.491
	[0.612]***	[0.628]***	[0.887]***	[0.132]***	[0.145]***	[0.168]***
* Fourth Size Quartile	-0.314	-0.079	-0.596	-0.168	-0.206	-0.294
	[0.545]	[0.566]	[0.781]	[0.127]	[0.129]	[0.152]*
Change in Arg.'s tariffs w.r.t. World						
Outputs		0.895			-0.022	
		[1.146]			[0.286]	
Inputs		-1.404			-0.023	
		[2.953]			[0.577]	
Change in Arg.'s tariffs w.r.t. Brazil						
Outputs			2.350			0.294
			[1.851]			[0.283]
Inputs			-0.313			0.251
			[3.169]			[0.699]
Firm-level controls						
Second Size Quartile	-0.011	-0.046	-0.047	0.086	0.086	0.082
	[0.233]	[0.233]	[0.236]	[0.038]**	[0.037]**	[0.037]**
Third Size Quartile	0.009	0.015	0.019	0.110	0.105	0.114
	[0.212]	[0.219]	[0.219]	[0.047]**	[0.048]**	[0.049]**
Fourth Size Quartile	0.420	0.435	0.438	0.269	0.266	0.268
	[0.217]*	[0.222]*	[0.222]*	[0.041]***	[0.041]***	[0.041]***
Industry-level controls						
Demand elasticity		0.020	0.027		-0.002	-0.002
		[0.022]	[0.024]		[0.006]	[0.006]
U.S. Capital intensity		-0.193	-0.206		-0.020	-0.021
		[0.088]**	[0.095]**		[0.024]	[0.023]
U.S. Skill intensity		0.306	0.128		-0.037	-0.061
		[0.170]*	[0.226]		[0.052]	[0.054]
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	894	872	870	1301	1269	1263
R-squared	0.05	0.06	0.06	0.20	0.20	0.21

Notes: standard errors are clustered at the 4-digit-SIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%.

Table 8: Technology Adoption by initial Export Status

Dependent variable: change in log (spending in technology) 1996-1992

	1	2	3	4	5	6	7	8
Panel A: Sample of non-exporters in 1992								
Change in Brazil's tariffs	-1.073	-1.255	-1.312	-1.119	-0.992	-1.587	-1.871	-1.788
	[0.520]**	[0.513]**	[0.494]***	[0.434]**	[0.458]**	[0.682]**	[0.763]**	[0.947]*
Panel B: Sample of exporters in 1992								
Change in Brazil's tariffs	-1.116	-1.041	-0.895	-1.105	-0.974	-1.343	-1.012	-1.149
	[0.382]***	[0.380]***	[0.409]**	[0.404]***	[0.524]*	[0.485]***	[0.555]*	[0.787]
Controls								
Change in Arg.'s tariffs w.r.t. world								
Outputs			Yes	Yes	Yes			
Inputs				Yes	Yes			
Change in Arg.'s tariffs w.r.t. Brazil								
Outputs						Yes	Yes	Yes
Inputs							Yes	Yes
Firm-level controls		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-level controls					Yes			Yes
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: standard errors are clustered at the 4-digit-SIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%. Number of observations in Panel A is 417 or 407 when input tariffs are included as controls. Number of observations in Panel B is 477 in columns 1 to 3, 465 in columns 4 and 6, 475 in column 6 and 463 in columns 7 and 8.

Table 9: Product and Process Innovation by initial Export Status

Dependent variable indicated in columns

	All Improvements			Improvements in Products			Production Process Improvements		
	1	2	3	4	5	6	7	8	9
Panel A: Sample of non-exporters in 1992									
Change in Brazil's tariffs	-0.181	-0.290	-0.370	-0.221	-0.326	-0.405	-0.146	-0.265	-0.336
	[0.118]	[0.100]***	[0.126]***	[0.126]*	[0.112]***	[0.126]***	[0.116]	[0.099]***	[0.138]**
Panel B: Sample of exporters in 1992	-0.324	-0.321	-0.412	-0.402	-0.378	-0.454	-0.246	-0.273	-0.363
Change in Brazil's tariffs	[0.130]**	[0.141]**	[0.184]**	[0.159]**	[0.151]**	[0.204]**	[0.121]**	[0.149]*	[0.181]**
Controls									
Change in Arg.'s tariffs w.r.t. world		Yes			Yes			Yes	
Change in Arg.'s tariffs w.r.t. Brazil			Yes			Yes			Yes
Firm-level controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-level controls		Yes	Yes		Yes	Yes		Yes	Yes
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: standard errors are clustered at the 4-digit-SIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%. Number of observations in Panel A is 741 in column 1, 725 columns 2, and 3, 747 in column 4, 731 in columns 5 and 6, 753 in column 7 and 737 in columns 8 and 9.

Table 10.1: Export Sales to Brazil

Dependent variable: change in (log) export sales 1992-1996

	1	2	3	4	5	6
Panel A: OLS						
Change in Brazil's tariffs	-2.836	-3.587	-2.402	-3.113	-2.654	-2.291
	[1.560]*	[1.353]***	[1.622]	[1.325]**	[1.214]**	[1.325]*
Change in Arg.'s tariffs w.r.t. world						
Outputs		0.820			3.734	
		[3.281]			[3.380]	
Inputs		-14.102			3.193	
		[12.612]			[9.810]	
Change in Arg.'s tariffs w.r.t. Brazil						
Outputs			-3.168			-2.689
			[4.385]			[4.348]
Inputs			-4.580			3.317
			[11.270]			[6.463]
Industry-level controls						
Demand elasticity		0.072	0.072		-0.095	-0.095
		[0.081]	[0.088]		[0.074]	[0.073]
U.S. Capital intensity		-0.286	-0.351		-0.284	-0.128
		[0.343]	[0.309]		[0.218]	[0.201]
U.S. Skill intensity		-1.227	-1.330		-1.287	-1.110
		[0.770]	[0.871]		[0.612]**	[0.648]*
2-digit-SIC industry dummies	Yes	Yes	Yes	No	No	No
Observations	100	97	96	100	97	96
R-squared	0.39	0.45	0.45	0.07	0.19	0.17
Panel B: IV						
Change in Brazil's tariffs	-3.513	-4.227	-3.129	-3.911	-3.376	-3.242
	[1.448]**	[1.288]***	[1.411]**	[1.339]***	[1.270]***	[1.341]**
Change in Arg.'s tariffs w.r.t. world						
Outputs		0.506			3.639	
		[2.855]			[3.312]	
Inputs		-15.351			2.111	
		[10.948]			[9.482]	
Change in Arg.'s tariffs w.r.t. Brazil						
Outputs			-2.403			-1.515
			[3.646]			[4.127]
Inputs			-3.812			3.337
			[9.310]			[6.200]
Industry-level controls						
Demand elasticity		0.080	0.077		-0.095	-0.100
		[0.069]	[0.074]		[0.076]	[0.075]
U.S. Capital intensity		-0.285	-0.343		-0.250	-0.120
		[0.293]	[0.262]		[0.215]	[0.201]
U.S. Skill intensity		-1.263	-1.401		-1.300	-1.195
		[0.651]*	[0.739]*		[0.591]**	[0.625]*
2-digit-SIC industry dummies	Yes	Yes	Yes	No	No	No
Observations	100	97	96	100	97	96
R-squared	0.39	0.45	0.45	0.07	0.19	0.16

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

Table 10.2: Export Sales to Brazil , First Stage for I.V. Estimates

Dependent variable: Change in Brazil's tariffs 1992-1996

	1	2	3	4	5	6
Brazil's tariffs 1991	-0.774	-0.761	-0.747	-0.763	-0.765	-0.744
	[0.035]***	[0.041]***	[0.038]***	[0.026]***	[0.029]***	[0.032]***
Change in Arg.'s tariffs w.r.t. world						
Outputs		-0.064			0.039	
		[0.099]			[0.076]	
Inputs		-0.163			0.176	
		[0.345]			[0.244]	
Change in Arg.'s tariffs w.r.t. Brazil						
Outputs			0.192			0.154
			[0.125]			[0.109]
Inputs			-0.164			-0.068
			[0.254]			[0.147]
Industry-level controls						
Demand elasticity		0.002	0.001		-0.002	-0.002
		[0.002]	[0.002]		[0.001]	[0.002]
U.S. Capital intensity		0.006	0.005		0.005	0.003
		[0.010]	[0.009]		[0.005]	[0.006]
U.S. Skill intensity		-0.011	-0.022		-0.011	-0.016
		[0.015]	[0.016]		[0.012]	[0.012]
2-digit-SIC industry dummies	Yes	Yes	Yes	No	No	No
Observations	100	97	96	100	97	96
R-squared	0.95	0.95	0.95	0.94	0.94	0.94

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

Table 11.1: Domestic Sales, Effect of Argentina's Tariff Reductions w.r.t Brazil

Dependent variable: change in log (domestic sales) 1996-1992

	1	2	3	4	5	6	7
<u>Change in Arg.'s tariffs w.r.t. Brazil</u>							
Outputs	1.431	1.520	1.082	1.421	1.153	0.767	0.893
	[0.547]**	[0.565]***	[0.527]**	[0.524]***	[0.523]**	[0.550]	[0.649]
Inputs		-0.598	-0.131	-0.444		-0.634	-0.819
		[1.508]	[1.349]	[1.251]		[1.246]	[1.196]
<u>Change in Brazil's tariffs</u>					0.180	0.268	0.351
					[0.249]	[0.211]	[0.260]
<u>Firm-level controls</u>							
Log ($Employment_{1992}$)			0.616			0.621	
			[0.114]***			[0.115]***	
Skill $Intensity_{1992}$			-0.010			-0.011	
			[0.014]			[0.014]	
<u>Industry-level controls</u>							
Demand elasticity				0.005			0.005
				[0.015]			[0.016]
U.S. Capital intensity				0.113			0.112
				[0.051]**			[0.051]**
U.S. Skill intensity				0.000			0.078
				[0.090]			[0.116]
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1374	1342	1342	1342	1374	1342	1342
R-squared	0.06	0.06	0.08	0.07	0.06	0.09	0.07

Notes: standard errors are clustered at the 4-digit-SIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%.

Table 11.2: Domestic Sales, Effect of other Tariff Reductions

Dependent variable: change in log (domestic sales) 1996-1992

	1	2	3	4	5
Change in Brazil's tariffs	1.065				
	[1.444]				
<u>Change in Arg.'s tariffs w.r.t. Brazil</u>					
Inputs		0.382			
		[0.245]			
<u>Change in Arg.'s tariffs w.r.t. the world</u>					
Outputs			-0.816		-1.078
			[0.736]		[0.724]
Inputs				1.799	2.150
				[1.484]	[1.591]
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes
Observations	1348	1380	1380	1348	1348
R-squared	0.06	0.06	0.06	0.06	0.06

Notes: standard errors are clustered at the 4-digit-SIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%.

Appendices for

Trade Liberalization, Exports and Technology Upgrading:

Evidence in the Impact of MERCOSUR on Argentinean Firms

Paula Bustos

August 2009

This document contains Theory Appendices A, B and C and Data Appendices D and E.

Appendix A: Theoretical Model, Industry Equilibrium

A.1 Proof that the sorting of firms in technology and exporting choices are the ones described in Figure 1

To solve for the optimal exporting and technology choices as a function of productivity I split the productivity space in segments where exporting dominates non exporting regardless of technology choice and vice versa, based on the following propositions:

Proposition 1 If a firm finds exporting profitable under technology *l*, then that firm also finds exporting profitable under technology *h*:

$$\pi_l^x(\varphi) > \pi_l^d(\varphi) \Rightarrow \pi_h^x(\varphi) > \pi_h^d(\varphi)$$

Proof

$$\pi_l^x(\varphi) > \pi_l^d(\varphi) \Rightarrow \tau^{1-\sigma}\frac{1}{\sigma}E(P\rho)^{\sigma-1}\varphi^{\sigma-1} > f_x \Rightarrow$$

$$\tau^{1-\sigma}\frac{1}{\sigma}E(P\rho)^{\sigma-1}\varphi^{\sigma-1}\gamma^{\sigma-1} > f_x \Rightarrow \pi_h^x(\varphi) > \pi_h^d(\varphi)$$

Then, if φ^x is defined as the level of productivity above which a firm using technology *l* finds exporting profitable [$\pi_l^d(\varphi_x) = \pi_l^x(\varphi_x)$], Proposition 1 implies that all firms with $\varphi > \varphi_x$ export, regradless of technology choice.

Proposition 2 If a firm finds does not find technology *h* profitable when exporting, that same firm does not find technology *h* profitable when only serving the domestic market:

$$\pi_l^x(\varphi) > \pi_h^x(\varphi) \Rightarrow \pi_l^d(\varphi) > \pi_h^d(\varphi)$$

Proof

$$\pi_l^x(\varphi) > \pi_h^x(\varphi) \Rightarrow \left(1+\tau^{1-\sigma}\right)\frac{1}{\sigma}E(P\rho)^{\sigma-1}\varphi^{\sigma-1}\left(\gamma^{\sigma-1}-1\right) < f(\eta-1) \Rightarrow$$
$$\frac{1}{\sigma}E(P\rho)^{\sigma-1}\varphi^{\sigma-1}\left(\gamma^{\sigma-1}-1\right) < f(\eta-1) \Rightarrow \pi_l^d(\varphi) > \pi_h^d(\varphi)$$

Then, if φ^h is defined as the level of productivity above which an exporter finds adoption of technology h profitable [$\pi_h^x(\varphi_h) = \pi_l^x(\varphi_h)$], Proposition 2 implies that all firms with $\varphi < \varphi^h$ use technology *l*, regardless of export status.

There are two possible configurations for the technology and export status decisions:

1. $\varphi^x < \varphi^h$

In this case, propositions 1 and 2 imply that firms in the range

- $\varphi^* < \varphi < \varphi_x$ only serve the domestic market and use technology l
- $\varphi_x < \varphi < \varphi_h$ use technology l but also export
- $\varphi_h < \varphi$ both export and use technology h

2. $\varphi^h < \varphi^x$

In this case there are two possible situations:

2.a. The marginal firm using technology *h* is only serving the domestic market. Thus, in equilibrium there are firms only serving the domestic market and using technology *l*, firms only serving the domestic market and using technology *h*, and exporters using technology *h.* That is, there are no exporters using technology *l*.

2.b The marginal firm using technology *h* is an exporter. In equilibrium there are only domestic firms using the low technology and exporters using the high technology. That is, in this case there are no exporters using technology *l* either.

A.2 Solution for expected profits $\bar{\pi}$

To solve for expected profits, first note that they can be expressed as:

$$\bar{\pi} = \bar{\pi}_d(\tilde{\varphi}_d) + p_x\bar{\pi}_x(\tilde{\varphi}_x)$$

where $\bar{\pi}_d(\tilde{\varphi}_d)$ are expected profits from domestic sales:

$$\bar{\pi}_d = \frac{1}{\sigma} E(P\rho)^{\sigma-1} \tilde{\varphi}_d^{\;\sigma-1} - f - f(\eta-1)\frac{1-G(\varphi^h)}{1-G(\varphi^*)} \qquad \text{(A.1)}$$

and $\tilde{\varphi}_d$ is the expected productivity level of home surviving firms:

$$\tilde{\varphi}_d = \left(\int_{\varphi^*<\varphi<\varphi_h} (\varphi)^{\sigma-1} \frac{g(\varphi)}{1-G(\varphi^*)} d\varphi + \int_{\varphi_h<\varphi} \gamma^{\sigma-1} (\varphi)^{\sigma-1} \frac{g(\varphi)}{1-G(\varphi^*)} d\varphi \right)^{\frac{1}{\sigma-1}}$$

$p_x = \frac{1-G(\varphi_x)}{1-G(\varphi^*)}$ is the probability of exporting and $\bar{\pi}_x(\tilde{\varphi}_x)$ are expected exporting profits:

$$\bar{\pi}_x(\tilde{\varphi}_x) = \frac{1}{\sigma} E(P\rho)^{\sigma-1} \tau^{1-\sigma} \left[\tilde{\varphi}_x(\varphi^*) \right]^{\sigma-1} - f_x$$

and $\tilde{\varphi}_x$ is the expected productivity level of home firms that export:

$$\tilde{\varphi}_x = \left[\int_{\varphi_x<\varphi<\varphi_h} (\varphi)^{\sigma-1} g(\varphi) d\varphi + \int_{\varphi_h<\varphi} \gamma^{\sigma-1} (\varphi)^{\sigma-1} g(\varphi) d\varphi \right]^{\frac{1}{\sigma-1}}$$

I first express $\bar{\pi}$ as a function of the exit cutoff. $\bar{\pi}_d(\tilde{\varphi}_d)$ can be written as a function of the exit cutoff substituting for the solution for $\varphi^h(\varphi^*)$ (eq. 3) in eq. (A.1) and using the zero profit condition for the marginal firm (eq. 1) to eliminate the aggregate variables (E and P) in eq. (A.1). $\bar{\pi}_x(\tilde{\varphi}_x)$ can also be written as a function of the exit cutoff by substituting for the solution for $\varphi^x(\varphi^*)$ and $\varphi^h(\varphi^*)$ (eqs. 2 and 3) in the definition of $\tilde{\varphi}_x$ to obtain $\tilde{\varphi}_x(\varphi^*)$ and also using the zero profit condition for the marginal firm in the foreign country (that is identical to the one at home (eq. 1) because of the symmetry assumption) to eliminate the aggregate variables (E and P). After some algebra, the solution for expected profits is (5).

Appendix B: Theoretical Model, Comparative Statics

B.1 Proof that $\frac{\partial \bar{\pi}}{\partial \tau} < 0$: note that $\frac{\partial \bar{\pi}}{\partial \tau} = \left(\frac{\sigma - 1}{k - (\sigma - 1)}\right) f \frac{\partial \Delta}{\partial \tau} < 0$ because $\sigma > 1$, $k > (\sigma - 1)$

and $\frac{\partial \Delta}{\partial \tau} = -k\tau^{-k-1}\left(\frac{f_x}{f}\right)^{\frac{-k}{\sigma-1}} \frac{f_x}{f} - k\left(1 + \tau^{1-\sigma}\right)^{\frac{k}{\sigma-1}-1} \tau^{-\sigma}\left(\frac{\eta - 1}{\left(\gamma^{\sigma-1} - 1\right)}\right)^{-\frac{k}{\sigma-1}} (\eta - 1) < 0$.

B.2 That $\frac{\partial P}{\partial \tau} > 0$ can be seen from equation (9) where the sign of $\frac{\partial P}{\partial \tau}$ is the opposite of the sign of $\frac{\partial \Delta}{\partial \tau}$.

B.3 That $\frac{\partial \varphi^*}{\partial \tau} < 0$ can be seen from equation (6) where the sign of $\frac{\partial \varphi^*}{\partial \tau}$ is the same as the sign of $\frac{\partial \Delta_t}{\partial \tau}$.

B.4 Proof that $\frac{\partial \varphi_x}{\partial \tau} > 0$: differentiate equation (7) w.r.t. τ

$$\frac{\partial \varphi^x}{\partial \tau} = \left[\frac{f}{\delta f_e}\left(\frac{\sigma - 1}{k - (\sigma - 1)}\right)\right]^{\frac{1}{k}} \left(\frac{f_x}{f}\right)^{\frac{1}{\sigma-1}} \frac{\partial\left(\Delta_t^{\frac{1}{k}}\tau\right)}{\partial \tau}$$

then, as $\sigma > 1$ and $k > (\sigma - 1)$, it is sufficient to consider the sign of the last term. As

$$\Delta_t^{\frac{1}{k}}\tau = \left\{\tau^k + \left(\left(\frac{f_x}{f}\right)^{\frac{1}{\sigma-1}}\right)^{-k} \frac{f_x}{f} + \tau^k\left(1 + \tau^{1-\sigma}\right)^{\frac{k}{\sigma-1}}\left[\left(\frac{\eta - 1}{\left(\gamma^{\sigma-1} - 1\right)}\right)^{-\frac{k}{\sigma-1}} (\eta - 1)\right]\right\}^{\frac{1}{k}}$$

the last term is:

$$\frac{\partial\left(\Delta_t^{\frac{1}{k}}\tau\right)}{\partial \tau} = \frac{1}{k}\left(\Delta_t^{\frac{1}{k}}\tau\right)^{\frac{1}{k}-1}\left\{k\tau^{k-1} + A\left[\left(\frac{\eta - 1}{\left(\gamma^{\sigma-1} - 1\right)}\right)^{-\frac{k}{\sigma-1}} (\eta - 1)\right]\right\} \tag{B.1}$$

where

$$A = k\tau^{k-1}\left(1 + \tau^{1-\sigma}\right)^{\frac{k}{\sigma-1}} - \tau^k k\left(1 + \tau^{1-\sigma}\right)^{\frac{k}{\sigma-1}-1}\tau^{-\sigma} > 0$$

because:

$$A > 0 \Leftrightarrow k\tau^{k-1}\left(1 + \tau^{1-\sigma}\right)^{\frac{k}{\sigma-1}} > \tau^k k\left(1 + \tau^{1-\sigma}\right)^{\frac{k}{\sigma-1}-1}\tau^{-\sigma} \Leftrightarrow 1 > \frac{\tau^{1-\sigma}}{\left(1 + \tau^{1-\sigma}\right)}$$

Then, as all terms in equation (B.1) are positive, $\frac{\partial\left(\Delta_t^{\frac{1}{k}}\tau\right)}{\partial \tau} > 0$, and then $\frac{\partial \varphi_x}{\partial \tau} > 0$.

B.5 Proof that $\frac{\partial \varphi_h}{\partial \tau} > 0$: first, note that as $k > 0$, $sign \frac{\partial \varphi_h}{\partial \tau} = sign \frac{\partial\left[(\varphi_h)^k\right]}{\partial \tau}$

$$(\varphi_h)^k = \left[\frac{f}{\delta f_e}\left(\frac{\sigma-1}{k-(\sigma-1)}\right)\right]\left(\frac{\eta-1}{\gamma^{\sigma-1}-1}\right)^{\frac{k}{\sigma-1}} \Delta_t\left(1+\tau^{1-\sigma}\right)^{-\frac{k}{\sigma-1}}$$

$$\frac{\partial\left[(\varphi_h)^k\right]}{\partial\tau} = \left[\frac{f}{\delta f_e}\left(\frac{\sigma-1}{k-(\sigma-1)}\right)\right]\left(\frac{\eta-1}{\gamma^{\sigma-1}-1}\right)^{\frac{k}{\sigma-1}} \frac{\partial\left[\Delta_t\left(1+\tau^{1-\sigma}\right)^{-\frac{k}{\sigma-1}}\right]}{\partial\tau}$$

Then, it is sufficient to consider the sign of the derivative of the last term w.r.t. τ , where the last term is:

$$\Delta_t\left(1+\tau^{1-\sigma}\right)^{-\frac{k}{\sigma-1}} = \left\{\left(1+\tau^{1-\sigma}\right)^{-\frac{k}{\sigma-1}} + \left(1+\tau^{1-\sigma}\right)^{-\frac{k}{\sigma-1}}\tau^{-k}\frac{f_x}{f}^{\frac{\sigma-1-k}{\sigma-1}} + \left[\left(\frac{\eta-1}{\left(\gamma^{\sigma-1}-1\right)}\right)^{-\frac{k}{\sigma-1}}(\eta-1)\right]\right\}$$

Then,

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

As $k\left(1+\tau^{1-\sigma}\right)^{-\frac{k}{\sigma-1}} > 0$, then the sign of $\frac{\partial\left[\Delta_t\left(1+\tau^{1-\sigma}\right)^{-\frac{k}{\sigma-1}}\right]}{\partial\tau}$ is the same as the sign of the last term: which I show below is > 0 as long as $\tau^{\sigma-1} f_x > f$ which will be the case if trade costs are such that not all firms export:

$$\left(1+\tau^{1-\sigma}\right)^{-1}\tau^{-\sigma}\left(1+\tau^{-k}\frac{f_x}{f}^{\frac{\sigma-1-k}{\sigma-1}}\right) - \tau^{-k-1}\frac{f_x}{f}^{\frac{\sigma-1-k}{\sigma-1}} > 0 \Leftrightarrow$$

$$1+\tau^{-k}\frac{f_x}{f}^{\frac{\sigma-1-k}{\sigma-1}} > \left(1+\tau^{1-\sigma}\right)\tau^{\sigma-k-1}\frac{f_x}{f}^{\frac{\sigma-1-k}{\sigma-1}} \Leftrightarrow$$

$$1+\tau^{-k}\frac{f_x}{f}^{\frac{\sigma-1-k}{\sigma-1}} > \tau^{\sigma-k-1}\frac{f_x}{f}^{\frac{\sigma-1-k}{\sigma-1}} + \tau^{-k}\frac{f_x}{f}^{\frac{\sigma-1-k}{\sigma-1}} \Leftrightarrow$$

$$1 > \frac{1}{\tau^{k-(\sigma-1)}}\frac{f}{f_x}^{\frac{k-(\sigma-1)}{\sigma-1}} \Leftrightarrow$$

$$\tau^{\sigma-1} f_x > f$$

Appendix C: Theoretical Model, The Case Where All Firms Export

Suppose the marginal firm is an exporter. In this case φ^* would be defined by:

$$\pi_l^x(\varphi^*) = 0 \Leftrightarrow \left(1+\tau^{1-\sigma}\right)\frac{1}{\sigma}E(P\rho)^{\sigma-1}\left(\varphi^*\right)^{\sigma-1} - f - f_x = 0 \qquad \text{(C.1)}$$

Then, the technology adoption cutoff would be

$$\varphi^h = \varphi^*\left(\frac{\eta-1}{\gamma^{\sigma-1}-1}\right)^{\frac{1}{\sigma-1}}$$

and expected profits would be

$$\bar{\pi}_t = \left(\frac{\sigma-1}{k-(\sigma-1)}\right)\left[f + f_x + \left(\left(\frac{\eta-1}{\gamma^{\sigma-1}-1}\right)^{\frac{1}{\sigma-1}}\right)^{-k}(f_h - f)\right]$$

Then, a reduction in τ would not affect expected profits, thus the exit cutoff would also remain unaffected. As a result, as can be seen in eq. (C.1) the price level would fall in such a way to offset the increase in revenues produced by the fall in τ, then the benefit of technology adoption (that is proportional to revenues) would not increase. The reason why this does not happen when not all firms export is that the reduction in τ produces an advantage for the more productive firms relative to the marginal firm, thus its positive impact on revenues is not offset by free entry.

Appendix D: Data Description

D.1 Methodology used to compute input tariffs

I computed input tariffs for each 4-digit-SIC industry in a similar way as in Amiti and Konings (2007). The Input tariff for each industry is computed as weighted average of the tariffs of all inputs used, where the weights are based on the cost share of each input, according to the following formula:

$$input\ tariff_{jt} = \sum_i w_{ij} \times tariff_{it} \qquad \text{where} \qquad w_{ij} = \frac{a_{ij}}{\sum_i a_{ij}} \tag{D.1}$$

where j indexes the 4-digit-SIC industry for which the input tariffs is computed; i indexes the 4-digit-SIC industry producing the input, and t indexes time. w_{ij} denote the cost share of each input i in the production of output j, and a_{ij} is total expenditure in input i by industry j. These expenditure shares include both domestic and imported inputs, as the objective is to assign the relevant input tariff to each industry based on the inputs used, irrespective of whether these are imported or not.

I obtained data on a_{ij} directly from the "Use Matrix at Buyer Prices" computed by the National Institute of Census and Statistics (INDEC) of Argentina for the year 1997.[1] This is the closest year to the period under study (1992-1996) with available data, as the previous matrix was elaborated in 1973. The columns of the matrix correspond to economic *activities* demanding inputs and the rows to the cost of the inputs (*products*) demanded. For the industrial sector there are a total of 79 activities and 115 products (inputs) classified according to an ad-hoc classification (MIPAr97) that follows very closely the 4-digit-SIC industry classification.

To calculate input tariffs according to formula (D.1) I constructed a correspondence between the MIPAr97 classification for products and the 4-digit-SIC classification.[2] The construction of the correspondence was straightforward as most MIPAr97 products had a single match and a few matched to more than one 4-digit-SIC industry. In those cases I computed the product tariff as a weighted average of the tariffs of each of the 4-digit-SIC-industry tariffs where weights were given by imports. With this information I applied formula (D.1) to find the input tariff corresponding to each MIPAr97 activity.

[1] The data and description of the methodology used to compute the matrices are available on INDEC's website: http://www.indec.mecon.ar/principal.asp?id_tema=621.

[2] The MIPAr97 classification is in Spanish and I matched it to the 4-digit-SIC classification in English. When in doubt about the translation of some product or activity I used the translations available in the United Nations Classifications Registry online http://unstats.un.org/unsd/cr/registry/default.asp.

Next, to match the input tariff corresponding to each MIPAr97 activity to the firm-level dataset I constructed a correspondence between the MIPAr97 activity classification and the 4-digit-SIC classification. The construction of this correspondence was also straightforward as the majority of MIPAr97 activities had a single match and some matched to more than one 4-digit-SIC industry, in which case I assigned the same input tariff to both.

D.2 Discrete Measures of Technology Adoption

The survey (ETIA) includes the following 9 YES/NO questions referring to improvements and innovations achieved between 1992 and 1996:

Improvements in Products

1. Technological improvement of existing products
2. New product because of advances in scientific-technological basis
3. New product because of new production process
4. New product because of employment of new raw materials or intermediates
5. Product differentiation

Improvements in Production Process

1. Technological improvement of existing process for the same product
2. New process associated to advances in scientific-technological basis
3. New production process for new product
4. Machinery and equipment associated to new processes

D.3 Measures of Employment in Primary School Equivalents and Skill Intensity

I aggregated workers into two skill categories. Skilled workers (*S*) are college graduates plus tertiary education graduates converted to college equivalents.[3] Unskilled workers (*U*) are primary school graduates plus high school graduates converted to primary school equivalents.[4] The

[3] College graduates completed 5 to 6 years of education after high school, while tertiary graduates completed 3 years of education after high school.

[4] The survey classifies workers according to education but although it distinguishes between engineers, other college and tertiary degrees 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

conversion of workers to college and primary school equivalents was done using the 1992 industrial sector wage premia.[5] Employment in primary school equivalents is computed as: $L_t = S_t \; (w_s / w_u)_{1992} + U_t$ where t=1992, 1996.

Skill intensity is measured as the share of skilled labor in employment in primary school equivalents:

$$\left(\frac{L_s}{L}\right)_t = \frac{S_t \; (w_s / w_u)_{1992}}{S_t \; (w_s / w_u)_{1992} + U_t}$$

where t = 1992 , 1996. As skilled labor is weighted by the skill premium in 1992, changes in this share only reflect changes in quantities of skilled and unskilled labor, and not changes in the skill premium.

D.4 Proxy for Initial Productivity

In the model heterogeneity is given by labor productivity holding technology constant (φ), which is not observable in the data. The information in the survey does not allow to estimate a measure of productivity by inference from the residual in the production function because it lacks information on value added and a long-enough series of investment to construct a measure of the capital stock. As a proxy for initial productivity, I use initial firm size in terms of (log) employment in primary school equivalents relative to the 4-digit-industry average. Alternatively (log) domestic sales relative to the 4-digit-industry could be used as a proxy for initial productivity. I prefer the employment measure because it reflects value-added better than sales, as long as there are differences in the level of vertical integration across firms.

D.5 Sector-level measures of capital and skill intensity in the U.S. from the NBER productivity database.

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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.

[5] Estimated by mincerian equations from Household Survey data in Galeani and Sanguinetti (2003) and Gasparini et al. (2002).

Average capital and skill intensity in the industry in the U.S. in the 1980's obtained from the NBER productivity database. The measure of capital intensity is capital (real equipment plus real structures) per worker, although other measures like only real equipment capital per worker, or capital over value added provide similar results. The measure of skill intensity is the ratio of non-production to production workers in the industry, although the relative wage share of non-production workers was also used providing similar results.

Table D.1

Summary Statistics

ETIA Panel, Year 1992.

	Non-exporters	Exporters	All	Observations
Employment	122.571	376.237	229.736	1380
	[8.949]	[24.839]	[12.17]	
Employment in primary school equivalents	147.380	477.154	286.698	1380
	[10.249]	[32.253]	[15.48]	
Sales	9,609.766	40,385.240	22,611.288	1380
	[678.182]	[4,510.816]	[1,987.16]	
Skill intensity	0.125	0.202	0.158	1380
	[0.006]	[0.007]	[0.005]	
Spending in technology per worker	0.303	0.820	0.521	1380
	[0.035]	[0.105]	[0.049]	
Investment in capital goods per worker	3.202	3.358	3.268	1380
	[0.806]	[0.432]	[0.500]	
Spending in technology per worker / ST>0	0.557	0.998	0.788	913
	[0.061]	[0.127]	[0.073]	
Investment in capital goods per worker / I>0	4.965	3.987	4.487	1005
	[1.243]	[0.508]	[0.682]	
Index of all improvements	0.38	0.529	0.443	1264
	[0.011]	[0.012]	[0.008]	
Index of product improvements	0.306	0.449	0.368	1312
	[0.011]	[0.013]	[0.009]	
Index of production process improvements	0.327	0.482	0.394	1319
	[0.012]	[0.014]	[0.009]	
Export share of sales/ Exports >0		0.159		583
		[0.010]		

Notes: Standard errors of means in parentheses. Employment in number of workers, employment in primary school equivalents in number of primary 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 3.2 of text and Appendix D.

Table D.2 : Firms per Quartile of the Firm Size Distribution in 1992

Quartile	Full Sample	Sample with data on innovation index	Simple with positive ST in 1992-1996
Panel A: Number of firms in the sample per size quartile			
1	346	329	126
2	339	318	210
3	350	329	264
4	345	325	294
Total	1380	1301	894
Panel B: Percent of total observations in the sample			
1	0.25	0.25	0.14
2	0.25	0.24	0.23
3	0.25	0.25	0.30
4	0.25	0.25	0.33
Total	1.00	1.00	1.00

Note: The measure of firm size used to define quartiles is employment in primary school equivalents relative to the 4-digit-SIC Industry mean in 1992.

Appendix E: Suplementary Tables

Table E.1: Spending in Technology per worker

Dependent variable: change in log (spending in technology per worker) 1996-1992

	1	2	3	4	5	6	7	8
Change in Brazil's tariffs	-1.066	-1.038	-0.934	-1.021	-0.854	-1.310	-1.271	-1.213
	[0.333]***	[0.334]***	[0.312]***	[0.293]***	[0.335]**	[0.448]***	[0.505]**	[0.658]*
<u>Change in Arg.'s tariffs w.r.t. world</u>								
Outputs			1.520	1.669	1.794			
			[1.006]	[1.027]	[1.062]*			
Inputs				-1.981	-2.358			
				[2.490]	[2.613]			
<u>Change in Arg.'s tariffs w.r.t. Brazil</u>								
Outputs						1.550	1.941	1.955
						[1.244]	[1.277]	[1.824]
Inputs							-1.264	-1.407
							[2.741]	[3.021]
<u>Firm-level controls</u>								
Log (Employment$_{1992}$)		0.196	0.197	0.204	0.203	0.197	0.206	0.206
		[0.031]***	[0.031]***	[0.032]***	[0.031]***	[0.031]***	[0.032]***	[0.032]***
Log (Sales per worker$_{1992}$)		0.535	0.543	0.502	0.494	0.559	0.548	0.536
		[0.228]**	[0.228]**	[0.245]**	[0.243]**	[0.226]**	[0.229]**	[0.225]**
Log (Sales per worker$_{1992}$)^2		-0.075	-0.077	-0.072	-0.070	-0.078	-0.077	-0.074
		[0.026]***	[0.026]***	[0.028]**	[0.028]**	[0.026]***	[0.027]***	[0.026]***
Skill Intensity$_{1992}$		0.194	0.184	0.148	0.136	0.149	0.091	0.103
		[0.214]	[0.213]	[0.213]	[0.216]	[0.219]	[0.220]	[0.220]
<u>Industry-level controls</u>								
Demand elasticity					0.009			0.023
					[0.026]			[0.027]
U.S. Capital intensity					-0.131			-0.144
					[0.088]			[0.090]
U.S. Skill intensity					0.262			0.100
					[0.162]			[0.228]
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	894	894	894	872	872	892	870	870
R-squared	0.04	0.09	0.09	0.09	0.09	0.09	0.09	0.09

Notes: standard errors are clustered at the 4-digit-SIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%.

Table E.2: Spending in Technology per worker by initial Export Status

Dependent variable: change in log (spending in technology per worker) 1996-1992

	1	2	3	4	5	6	7	8
<u>Panel A: Sample of non-exporters in 1992</u>								
Change in Brazil's tariffs	-0.911	-1.011	-0.914	-0.930	-0.830	-1.332	-1.519	-1.459
	[0.530]*	[0.493]**	[0.464]*	[0.410]**	[0.427]*	[0.664]**	[0.762]**	[0.933]
<u>Panel B: Sample of exporters in 1992</u>								
Change in Brazil's tariffs	-1.199	-1.093	-0.950	-1.134	-0.960	-1.268	-1.022	-1.009
	[0.351]***	[0.360]***	[0.391]**	[0.364]***	[0.451]**	[0.473]***	[0.588]*	[0.802]
<u>Controls</u>								
<u>Change in Arg.'s tariffs w.r.t. world</u>								
Outputs			Yes	Yes	Yes			
Inputs				Yes	Yes			
<u>Change in Arg.'s tariffs w.r.t. Brazil</u>								
Outputs						Yes	Yes	Yes
Inputs							Yes	Yes
Firm-level controls		Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-level controls					Yes			Yes
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: standard errors are clustered at the 4-digit-SIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%. Number of observations in Panel A is 417 or 407 when input tariffs are included as controls. Number of observations in Panel B is 477 in columns 1 to 3, 465 in columns 4 and 6, 475 in column 6 and 463 in columns 7 and 8.

Table E.3: Technology Adoption by Quartile of the Firm Size Distribution
Alternative Measures of Technology Adoption: Spending in Technology per worker, Product and Process Innovation

Dependent variable indicated in columns

	Change in Spending in Technology per worker 1996-1992			Product Innovation Index			Process Innovation Index		
	1	2	3	4	5	6	7	8	9
Change in Brazil's tariffs									
* First Size Quartile	-0.720	-0.561	-0.853	-0.042	-0.074	-0.157	-0.026	-0.072	-0.153
	[0.651]	[0.598]	[0.819]	[0.104]	[0.109]	[0.129]	[0.137]	[0.134]	[0.168]
* Second Size Quartile	-0.843	-0.650	-0.876	-0.280	-0.286	-0.380	-0.144	-0.200	-0.289
	[0.547]	[0.590]	[0.837]	[0.170]	[0.161]*	[0.171]**	[0.141]	[0.140]	[0.165]*
* Third Size Quartile	-2.124	-1.917	-2.179	-0.483	-0.521	-0.579	-0.283	-0.341	-0.399
	[0.565]***	[0.597]***	[0.898]**	[0.128]***	[0.143]***	[0.162]***	[0.160]*	[0.168]**	[0.191]**
* Fourth Size Quartile	-0.304	-0.077	-0.314	-0.221	-0.250	-0.333	-0.115	-0.170	-0.250
	[0.530]	[0.547]	[0.807]	[0.151]	[0.152]	[0.163]**	[0.122]	[0.127]	[0.157]
Change in Arg.'s tariffs w.r.t. World									
Outputs		1.669			0.016			-0.086	
		[1.082]			[0.291]			[0.312]	
Inputs		-2.663			-0.195			0.126	
		[2.632]			[0.668]			[0.591]	
Change in Arg.'s tariffs w.r.t. Brazil									
Outputs			1.122			0.426			0.112
			[1.817]			[0.302]			[0.304]
Inputs			-0.310			-0.118			0.667
			[3.200]			[0.687]			[0.749]
Firm-level controls									
Second Size Quartile	0.119	0.098	0.120	0.047	0.053	0.049	0.112	0.106	0.102
	[0.237]	[0.237]	[0.240]	[0.038]	[0.038]	[0.038]	[0.046]**	[0.045]**	[0.045]**
Third Size Quartile	0.177	0.204	0.212	0.062	0.059	0.067	0.158	0.150	0.159
	[0.213]	[0.220]	[0.221]	[0.044]	[0.044]	[0.044]	[0.058]***	[0.058]**	[0.060]***
Fourth Size Quartile	0.668	0.699	0.713	0.236	0.236	0.237	0.300	0.293	0.295
	[0.208]***	[0.212]***	[0.212]***	[0.044]***	[0.044]***	[0.043]***	[0.047]***	[0.047]***	[0.047]***
Industry-level controls									
Demand elasticity		0.004	0.014		-0.005	-0.004		-0.000	-0.002
		[0.023]	[0.026]		[0.006]	[0.006]		[0.007]	[0.007]
U.S. Capital intensity		-0.124	-0.137		-0.046	-0.049		0.008	0.008
		[0.087]	[0.096]		[0.025]*	[0.023]**		[0.026]	[0.026]
U.S. Skill intensity		0.312	0.188		-0.015	-0.048		-0.066	-0.078
		[0.163]*	[0.233]		[0.054]	[0.054]		[0.053]	[0.056]
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	894	872	870	1312	1280	1274	1319	1287	1281
R-squared	0.08	0.09	0.09	0.18	0.19	0.19	0.18	0.19	0.19

Notes: standard errors are clustered at the 4-digit-SIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%.