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 import tariffs increase their investment in technology faster and exporters upgrade technology faster than other firms in the same industry.

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.

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[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 falls 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 13 percentage points.

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[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.

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.[4] 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.

The model developed in this paper builds on an extensive theoretical literature analyzing the effects of trade on technological change.[5] 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

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[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] 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.

[5] 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.

exporting and technology choice is the result of ex-ante heterogeneity in productivity.[6] 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: 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.[7] Earlier studies 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

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[6] 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.

[7] 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 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 symmetric country. Indeed, in the model technology upgrading can be interpreted alternatively as reducing marginal production costs or increasing quality.

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,[8] 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. As such, it is a first step towards the study of the effects of trade liberalization on the relative demand for skill.

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.[9] The focus of 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.

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

[9] 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).

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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 finding that the reduction in Brazil's tariffs induced technology upgrading not only in new but also in old exporters in Argentina, presumably the most productive firms. 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 an economy consisting 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). I first present the closed economy model to later use it as a benchmark for the open economy where two symmetric countries trade.

In the model, firms can enter the industry by paying a fixed entry cost, after which their productivity is revealed. Heterogeneity in productivity can be interpreted in two ways: first, more productive firms have a lower marginal production cost in the sense that they produce more output per unit of labor; second, 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. Up to this point the setup is identical to Melitz (2003), but in addition, after observing their productivity, firms

can choose to pay a fixed cost to adopt a new technology that produces a proportional reduction in their marginal cost (or a proportional increase in the quality of the good).

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 cost of product 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.

2.1 Closed Economy

2.1.1 Set up of the Model

Demand

There is a representative consumer with CES preferences over a continuum of varieties of a good:

$$U = \left[\int_{\omega \in \Omega} q(\omega)^\rho \, d\omega \right]^{\frac{1}{\rho}} \qquad 0 < \rho < 1$$

Consumers maximize utility subject to the budget constraint: $\int_{\omega \in \Omega} p(\omega)q(\omega)d\omega = E$. Then,

demand for a particular variety is $q(\omega) = \dfrac{E}{P}\left(\dfrac{p(\omega)}{P} \right)^{-\sigma}$ where $\sigma = \dfrac{1}{1-\rho} > 1$ is the constant

elasticity of substitution and

$$P = \left[\int_{\omega \in \Omega} p(\omega)^{1-\sigma} \, d\omega \right]^{\frac{1}{1-\sigma}} \tag{1}$$

Supply

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 produce varieties using a technology that features a constant marginal cost and a fixed cost, both in terms of labor. Firms are heterogeneous in their productivity in the sense that marginal labor costs varies across firms using the same technology. This idiosyncratic component of labor productivity is indexed by φ, that also indexes firms and varieties. 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:

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

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

(2)

where $\eta > 1$ and $\gamma > 1$.

Entry and Timing

Before starting to produce a given variety firms face uncertainty regarding their productivity level (φ). Upon entry they pay a fixed entry cost consisting of f_e units of labor, and draw their productivity from a known cumulative distribution function $G(\varphi) = 1 - \varphi^{-k}$. After observing their productivity they decide whether to exit the market or start producing with one of the technologies in equation (2). Finally, in every period there is an exogenous probability of exit (δ).

2.1.2 Firm Behavior

After observing their productivity (φ) firms calculate the price that attains the maximum profits under each technology. Then, they choose the technology that attains higher profits. If profits are negative under the best technology choice, they exit.

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 $p_l(\varphi) = \frac{1}{\rho}\frac{1}{\varphi}$ and sells $q_l(\varphi) = EP^{\sigma-1}(\rho\varphi)^\sigma$. If instead the firm uses technology h, it charges a lower price $p_h(\varphi) = \frac{1}{\rho}\frac{1}{\varphi}\frac{1}{\gamma}$ and sells more: $q_h(\varphi) = EP^{\sigma-1}(\rho\varphi)^\sigma\gamma^\sigma$. Then, the maximum profits under technologies l and h are:

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

(3)

$$\pi_h(\varphi) = \frac{1}{\sigma} E(P\rho)^{\sigma-1} \varphi^{\sigma-1} \gamma^{\sigma-1} - f\eta \tag{4}$$

Technology Choice

Firms choose the technology that attains higher profits: $\pi(\varphi) = \max\{\pi_l(\varphi), \pi_h(\varphi)\}$.

Then they use technology h if:

$$\pi_h(\varphi) > \pi_l(\varphi) \Leftrightarrow \frac{1}{\sigma} E(P\rho)^{\sigma-1} \varphi^{\sigma-1} (\gamma^{\sigma-1} - 1) > f(\eta - 1) \tag{5}$$

The benefit of using technology h (the LHS of eq. 5) is that the firm makes higher revenues, as demand is elastic ($\sigma > 1$). The cost of using technology h (the RHS of eq. 5) is its higher fixed cost. Note that this cost is the same for all firms while the benefit is increasing in the firm's productivity. Then, technology choice is characterized by a cutoff productivity level φ_h above which all firms use technology h. This cutoff is defined by $\pi_h^x(\varphi_h) = \pi_l^x(\varphi_h)$.

Technology choice is represented in Figure 1, where π_h are profits for using technology h as a function of productivity $(\varphi^{\sigma-1})$ and π_l are profits for using technology l. The equilibrium depicted is one where only the most productive firms use technology h, which is the case when adoption costs are relatively high. The parameter restriction required to obtain this equilibrium is $\eta > \gamma^{\sigma-1}$ (see Appendix A).

Figure 1: Technology Choice
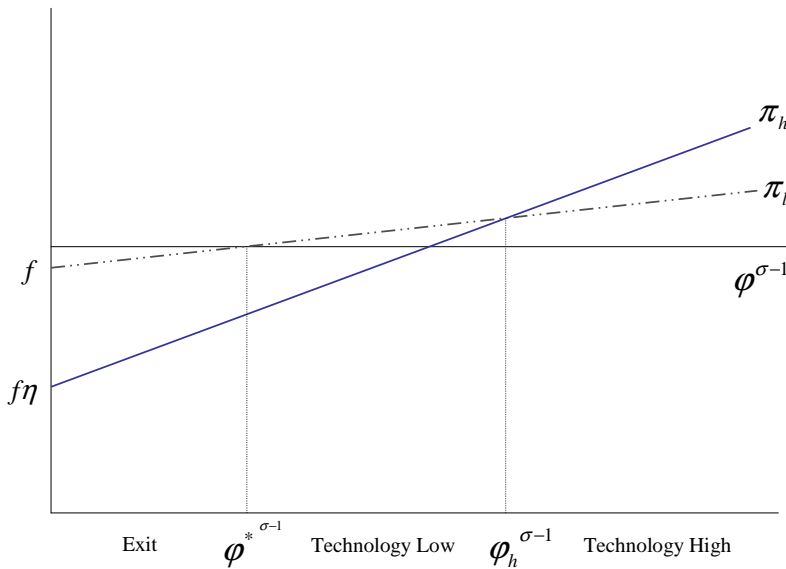
Exit

As in Melitz (2003), I only consider steady state equilibria in which the aggregate variables stay constant over time. As the productivity of each firm is constant, the optimal per-period profit of firms also stays constant over time. Thus, the expected present value of profits is:

$$v(\varphi) = \max\left\{0, \sum_{t=s}^{\infty}(1-\delta)^{t-s}\pi(\varphi)\right\} = \max\left\{0, \frac{1}{\delta}\pi(\varphi)\right\}$$

As profits are increasing in productivity, firms below a certain threshold φ^* make negative profits and exit. Note that, as only the most productive firms adopt technology h, this threshold is defined by the zero profit condition under technology l:

$$\pi_l(\varphi^*) = \frac{1}{\sigma}E(P\rho)^{\sigma-1}(\varphi^*)^{\sigma-1} - f = 0 \tag{6}$$

2.1.3 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:

$$f_e = [1 - G(\varphi^*)]\frac{1}{\delta}\bar{\pi} \tag{7}$$

where $1 - G(\varphi^*)$ is the probability of survival, $\bar{\pi}$ are per-period expected profits of surviving firms:[10]

$$\bar{\pi} = \frac{1}{\sigma}E(P\rho)^{\sigma-1}\tilde{\varphi}^{\sigma-1} - f - f(\eta-1)\frac{1-G(\varphi^h)}{1-G(\varphi^*)} \tag{8}$$

and $\tilde{\varphi}$ is defined as the ex-post-weighted-average productivity level of active firms:[11]

$$\tilde{\varphi} = \left(\int_{\varphi^*<\varphi<\varphi_h}(\varphi)^{\sigma-1}\frac{g(\varphi)}{1-G(\varphi^*)}d\varphi + \int_{\varphi_h<\varphi}\gamma^{\sigma-1}(\varphi)^{\sigma-1}\frac{g(\varphi)}{1-G(\varphi^*)}d\varphi\right)^{\frac{1}{\sigma-1}} \tag{9}$$

To solve for the free entry condition (eq. 7) I follow steps analogous to Melitz (2003): I first use the zero profit condition for the marginal firm (eq. 6) to write φ_h, $\tilde{\varphi}$ and $\bar{\pi}$ as a

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[10] See Appendix A for derivations.

[11] By ex-post I mean that for firms adopting technology h effective productivity is $\gamma\varphi$.

function of φ^*, then I use the free entry condition (eq. 7) to solve for φ^*. These derivations are detailed in Appendix A where I obtain the following solution for expected profits:

$$\bar{\pi} = \left(\frac{\sigma-1}{k-(\sigma-1)}\right)f\Delta \tag{10}$$

where $\Delta = 1 + \left((\gamma^{\sigma-1}-1)^{\frac{k}{\sigma-1}}(\eta-1)^{1-\frac{k}{\sigma-1}}\right) > 1$.[12] Note that expected profits take the simple form of a multiple $\left(\frac{\sigma-1}{k-(\sigma-1)}\right)$ of the expected fixed production cost ($f\Delta$). To see this note that $f\Delta$ can be written as $f\Delta = f\left\{1 + (\eta-1)\left(\frac{\eta-1}{\gamma^{\sigma-1}-1}\right)^{-\frac{k}{\sigma-1}}\right\} = \left\{f + (f_h - f)\left(\frac{\varphi^h(\varphi^*)}{\varphi^*}\right)^{-k}\right\}$

where $f_h - f = (\eta-1)f$ is the fixed cost of technology h and $\left(\frac{\varphi^h(\varphi^*)}{\varphi^*}\right)^{-k}$ is the fraction of firms that use technology h.

The solution for the exit cutoff can be obtained substituting the solution for expected profits (eq. 10) in the free entry condition (eq. 7):

$$\varphi^* = \left[\frac{f}{\delta f_e}\left(\frac{\sigma-1}{k-(\sigma-1)}\right)\right]^{\frac{1}{k}}\Delta^{\frac{1}{k}} \tag{11}$$

The solution for the productivity cutoff to adopt technology h is then:

$$\varphi^h = \left(\frac{\eta-1}{\gamma^{\sigma-1}-1}\right)^{\frac{1}{\sigma-1}}\varphi^* = \left(\frac{\eta-1}{\gamma^{\sigma-1}-1}\right)^{\frac{1}{\sigma-1}}\left\{\frac{f}{\delta f_e}\left(\frac{\sigma-1}{k-\sigma-1}\right)\right\}^{\frac{1}{k}}\Delta^{\frac{1}{k}} \tag{12}$$

Welfare can be measured by the real wage, which is the inverse of the price index (P). The price index is determined by the number of firms and the weighted average productivity of firms: $P = \left(\rho\tilde{\varphi}M^{\frac{1}{\sigma-1}}\right)^{-1}$. Solutions for the price index, the measure of firms M, and average productivity are derived in Appendix A. The equilibrium price index is:

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[12] Note that expected profits are independent of φ^*, which is due to the use of a Pareto distribution for $G(\varphi)$. In general, changes in φ^* have two effects on expected profits: a direct positive effect as each firm has a higher productivity which makes each firm's profit increase; and an indirect negative effect as a higher φ^* implies productivity of competitors is higher, thus the price index is lower and each firm's profits fall. In the case of a Pareto distribution both effects cancel out, and as a result average profits are independent of the cutoff.

$$P = \frac{1}{\rho}\left(\frac{\sigma}{L}\right)^{\frac{1}{\sigma-1}}(\delta f_e)^{\frac{1}{k}} f^{\frac{1}{\sigma-1}-\frac{1}{k}}\left(\frac{(\sigma-1)}{k-(\sigma-1)}\right)^{-\frac{1}{k}}\Delta^{-\frac{1}{k}} \tag{13}$$

Discussion

To analyze the mechanics of the model with technology choice it is useful to compare it with the model with only one technology. The solution to that model is identical to the one presented in eqs. (11), (12) and (13) except that $\Delta = 1$. Not surprisingly, the option to upgrade technology increases welfare in the closed economy. This is the case because some firms upgrade technology which increases average productivity in the industry. Thus, the price index falls forcing the least productive firms to exit the industry. Exit has two feedback effects on the price index: first, it reduces *P* by increasing average productivity; second it increases it by reducing the measure of varieties offered. As can be seen in eq. 13 the first effect dominates and the price index falls.

2.2 Open Economy

In the absence of trade frictions the open economy model would be identical to the closed economy one, except that the relevant size of the economy (*L*) would increase to represent the size of all trading partners. In this context, trade opening would not induce technology adoption, as φ_h is independent of market size (*L*) (see eq. 12). As the exit cutoff φ^* does not depend on market size either (see eq. 11), average productivity would remain the same. The only effect of opening up to trade would be an increase in the measure of firms, or varieties offered worldwide, exactly as in Krugman (1980) (see solution for the number of firms in Appendix A). Similarly, if there were only variable trade costs all firms would export and, as will be shown below, a reduction in variable trade costs would have no effect on technology adoption. Thus, I follow Melitz (2003) and introduce two types of trade frictions:

1. Per-unit iceberg costs, so that τ units need to be shipped for 1 unit to make it to the foreign country.

2. An initial fixed cost of f_{ex} units of labor to start exporting, incurred after firms have learnt φ.

I consider the simple case of two symmetric countries that engage in a bilateral trade liberalization, thus all parameters, including τ, are identical for both countries.

2.2.1 Firm Behavior

Profit Maximization

Profits from sales in the domestic market are identical as in the closed economy (eqs. 3 and 4) with the exception that the price index P now takes into account the prices of varieties imported from foreign. Profits from export sales (under technology l, as an example) would be:

$$\pi_l^e(\varphi) = \tau^{1-\sigma} \frac{1}{\sigma} E(P\rho)^{\sigma-1} \varphi^{\sigma-1} - f_x$$

where the symmetry assumption implies that the price index (P) and the expenditure level (E) in foreign are the same as at home. Revenues in the export market are reduced in a fraction $\tau^{1-\sigma}$ as firms charge a higher price in the export market $(p_l^x(\varphi) = \frac{1}{\rho} \frac{1}{\varphi} \frac{1}{\tau})$ and demand is elastic $(\sigma > 1)$. Finally, exporting profits reflect the per-period fixed exporting cost.

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 resulting choices, which are described below.

Profits if only servicing 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 servicing 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:

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

Profits if also exporting and using technology h:

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

Exporting and technology choices are represented in Figure 2, where the four possible profits are depicted as a function of firm's productivity.[13] The equilibrium depicted is obtained

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

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 B I show that in this equilibrium firms sort into four different groups: the least productive firms $(\varphi < \varphi^*)$ exit, the low productivity firms $(\varphi^* < \varphi < \varphi_x)$ only serve the domestic market and use technology l, the medium productivity firms $(\varphi_x < \varphi < \varphi_h)$ still use technology l but also export, and the most productive firms $(\varphi_h < \varphi)$ both export and use technology h.

Note that in Figure 2 using technology h and only servicing 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 $(\varphi^x < \varphi^h)$ in what follows and provide the necessary parameter restrictions for this ordering of cutoffs to apply. The opposite case $(\varphi^x > \varphi^h)$ 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 2

Exporting and Technology Choices
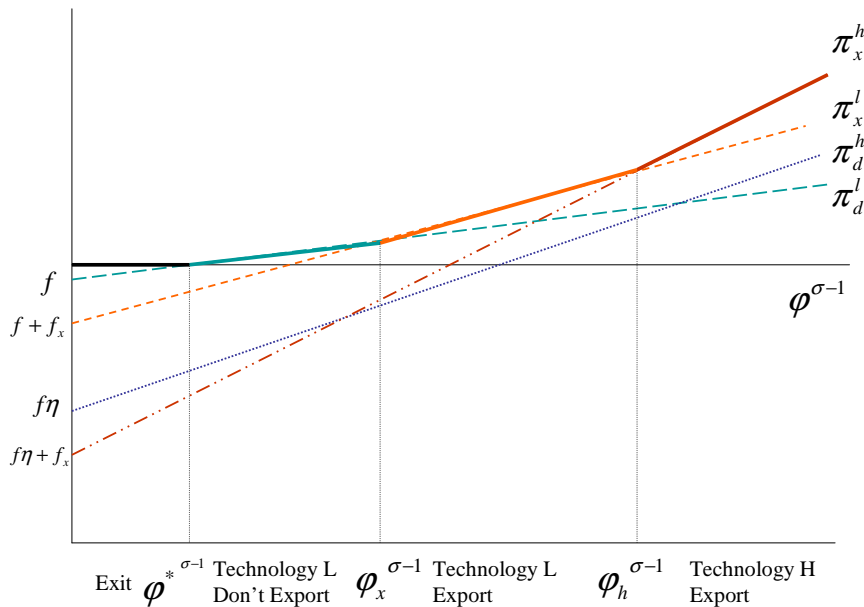
As in the closed economy, to solve for the equilibrium price (P_t), measure of firms (M_t) and the distribution of active firm's productivity in the economy it is convenient to write all the equilibrium conditions as a function of the exit productivity cutoff φ^*. This is achieved using the zero profit condition for the marginal active firm to partial out the effects of the aggregate variables (E and P) on firm's profits, and leave the export and technology adoption cutoffs as functions only of the parameters that affect those groups of firms differentially. I next state the conditions for exit, entry in the export market and technology adoption as a function of the exit cutoff.

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:

$$\pi_l^d(\varphi^*) = 0 \Leftrightarrow \frac{1}{\sigma} E(P\rho)^{\sigma-1}(\varphi^*)^{\sigma-1} - f = 0 \tag{14}$$

Exporting

The marginal exporting firm uses technology l, thus the exporting cutoff (φ_x) is defined by:

$$\pi_l^d(\varphi_x) = \pi_l^x(\varphi_x) \Leftrightarrow \tau^{1-\sigma} \frac{1}{\sigma} E(P\rho)^{\sigma-1}(\varphi^x)^{\sigma-1} - f_x = 0 \tag{15}$$

φ_x can be expressed as a function of φ^* by substituting the zero profit condition for the marginal firm (eq. 14) in eq. (15):

$$\varphi^x = \varphi^* \tau \left(\frac{f_x}{f} \right)^{\frac{1}{\sigma-1}} \tag{16}$$

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:

$$\pi_h^x(\varphi_h) - \pi_l^x(\varphi_h) = 0 \Leftrightarrow (\gamma^{\sigma-1} - 1)(1 + \tau^{1-\sigma}) \frac{1}{\sigma} E(P\rho)^{\sigma-1}(\varphi^h)^{\sigma-1} = f(\eta - 1) \tag{17}$$

As in the closed economy, the benefit of technology adoption (the LHS of eq. 17) is proportional to a firm's variable profits. These are higher in the open economy by a factor

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$\left(1+\tau^{1-\sigma}\right)$, as firms do not only sell at home but also in the export market. Thus, the exporting option increases the profitability of technology adoption. Next, φ_h can be expressed as a function of φ^* by using the zero profit condition for the marginal firm (eq. 14):

$$\varphi^h = \varphi^* \frac{1}{\left(1+\tau^{1-\sigma}\right)^{\frac{1}{\sigma-1}}} \left(\frac{\eta-1}{\gamma^{\sigma-1}-1}\right)^{\frac{1}{\sigma-1}} \tag{18}$$

The share of active firms adopting technology h (that is $\left(\frac{\varphi^h}{\varphi^*}\right)^{-k}$) is higher in the open (eq. 18) than in the closed economy (eq. 12) as the cutoff for adoption falls relative to the exit cutoff $\left(\frac{\varphi^h}{\varphi^*}\right)$ because $\left(1+\tau^{1-\sigma}\right)^{\frac{1}{1-\sigma}} < 1$. This is so because in the open economy exporting increases revenues, making technology adoption more profitable.

By comparing equations (16) and (18) we can see that the parameter restriction for $\varphi^h > \varphi^x$ is that technology adoption costs are high enough relative to fixed exporting costs:

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

2.2.2 Industry Equilibrium

The exit cutoff is determined by the free entry condition:

$$f_e = \left[1-G\left(\varphi^*\right)\right] \frac{1}{\delta} \bar{\pi}_t \tag{19}$$

that is identical to the closed economy one except that expected profits $\bar{\pi}_t$ now account for the possibility of exporting:

$$\bar{\pi}_t = \bar{\pi}_d(\tilde{\varphi}_d) + p_x \bar{\pi}_x(\tilde{\varphi}_x) \tag{20}$$

where $\tilde{\varphi}_d$ is the expected productivity level of home surviving firms that has the same expression as $\tilde{\varphi}$ in the closed economy (eq. 9); $\bar{\pi}_d(\tilde{\varphi}_d)$ are expected profits from domestic sales, that have the same expression as in the closed economy (Appendix A); $p_x = \frac{1-G(\varphi_x)}{1-G(\varphi^*)}$ is the probability of exporting and $\bar{\pi}_x(\tilde{\varphi}_x)$ are expected exporting profits:

$$\bar{\pi}_x(\tilde{\varphi}_x) = \frac{1}{\sigma} E(P\rho)^{\sigma-1} \tau^{1-\sigma} \left[\tilde{\varphi}_x(\varphi^*)\right]^{\sigma-1} - f_x \tag{21}$$

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

$$\tilde{\varphi}_x = \left[\int_{\varphi_x < \varphi < \varphi_h} (\varphi)^{\sigma-1} g(\varphi) d\varphi + \int_{\varphi_h < \varphi} \gamma^{\sigma-1} (\varphi)^{\sigma-1} g(\varphi) d\varphi\right]^{\frac{1}{\sigma-1}} \tag{22}$$

Then, to solve for the free entry condition (eq. 19) we need to solve for expected profits $\bar{\pi}_t$ in eq. (20). The derivations are detailed in Appendix B:

$$\bar{\pi}_t = \left(\frac{\sigma-1}{k-(\sigma-1)}\right) f\Delta_t \tag{23}$$

$$\Delta_t = \left\{1 + \left(\tau\left(\frac{f_x}{f}\right)^{\frac{1}{\sigma-1}}\right)^{-k} \frac{f_x}{f} + \left[\left(\frac{\eta-1}{(1+\tau^{1-\sigma})(\gamma^{\sigma-1}-1)}\right)^{-\frac{k}{\sigma-1}} (\eta-1)\right]\right\} \tag{24}$$

By substituting the solution for average profits (eq. 23) in the free entry condition (eq. 19) we can solve for the exit cutoff:

$$\varphi_t^* = \left[\frac{f}{\delta f_e}\left(\frac{\sigma-1}{k-(\sigma-1)}\right)\Delta_t\right]^{\frac{1}{k}} \tag{25}$$

By substituting the solution for the cutoff in eqs. 17 and 18 a solution for the exporting and technology adoption cutoffs can be obtained:

$$\varphi^x = \left[\frac{f}{\delta f_e}\left(\frac{\sigma-1}{k-(\sigma-1)}\right)\right]^{\frac{1}{k}} \Delta_t^{\frac{1}{k}} \tau\left(\frac{f_x}{f}\right)^{\frac{1}{\sigma-1}} \tag{26}$$

$$\varphi^h = \left[\frac{f}{\delta f_e}\left(\frac{\sigma-1}{k-(\sigma-1)}\right)\right]^{\frac{1}{k}} \Delta_t^{\frac{1}{k}} \frac{1}{(1+\tau^{1-\sigma})^{\frac{1}{\sigma-1}}} \left(\frac{\eta-1}{\gamma^{\sigma-1}-1}\right)^{\frac{1}{\sigma-1}} \tag{27}$$

Finally, the price index can be obtained by substituting the exit cutoff (eq. 25) in the zero profit condition for the marginal surviving firm (eq.):

$$P = \frac{1}{\rho}\left(\frac{\sigma f}{L}\right)^{\frac{1}{\sigma-1}} \left[\frac{f}{\delta f_e}\left(\frac{\sigma-1}{k-(\sigma-1)}\right)\right]^{-\frac{1}{k}} \Delta_t^{-\frac{1}{k}} \tag{28}$$

Discussion

To interpret the solution for expected profits in (23) note that $f\Delta_t$ can be written as:

$$\Delta_t f = f + \left(\frac{\varphi^x(\varphi^*)}{\varphi^*}\right)^{-k} f_x + \left(\frac{\varphi^h(\varphi^*)}{\varphi^*}\right)^{-k} (f_h - f)$$

Then, the solution for expected profits has the same form as in the closed economy: expected profits are a multiple $\left(\frac{\sigma-1}{k-(\sigma-1)}\right)$ of expected fixed costs $(\Delta_t f)$. This is because with a Pareto distribution expected profits are a multiple of the variable profits of the marginal firm.

In the simplest case of a closed economy with only one technology $\Delta_t = 1$. Then, expected profits are a multiple of the variable profits of the marginal surviving firm, which must be equal to f. In the open economy, with probability $\left(\frac{\varphi^x(\varphi^*)}{\varphi^*}\right)^{-k}$ the firm becomes an exporter, and in that case expected profits are augmented by a multiple of f_x, the variable exporting profits of the marginal exporter. Finally, for technology adopters, which are a fraction $\left(\frac{\varphi^h(\varphi^*)}{\varphi^*}\right)^{-k}$ of surviving firms, expected profits are augmented by a multiple of the variable adoption profits of the marginal adopters which are $(f_h - f)$ exactly as in the closed economy model.

Note that the introduction of both the option to export and the option to upgrade technology has an effect on expected profits beyond the sum of the two parts: there is an interaction between the two choices: in the open economy the fraction of firms adopting technology h (that is $\left(\frac{\varphi^h(\varphi^*)}{\varphi^*}\right)^{-k}$) is higher than in the closed economy by a factor $\left(1 + \tau^{1-\sigma}\right)^{\frac{k}{\sigma-1}} > 1$. This is the case because exporting makes their revenues increase relative to those of the marginal firm, who only serves the domestic market.

2.2.3 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 exporting 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 servicing the domestic market loose revenues. As a result, the least productive firms make negative profits and exit.

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

1. *The fraction of surviving firms that export* $\left(\frac{\varphi_x(\varphi^*)}{\varphi^*}\right)^{-k}$ *and the fraction of surviving of firms that use technology h* $\left(\frac{\varphi_h(\varphi^*)}{\varphi^*}\right)^{-k}$ *increase.* This can be directly seen in eqs. (16) and (18).

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

3. *The price index at home falls, that is* $\dfrac{\partial P}{\partial \tau} < 0$

4. *The exit productivity cutoff increases, that is* $\dfrac{\partial \varphi_t^*}{\partial \tau} > 0$. Thus, exactly as in Melitz (2003) a reduction in variable export costs induces the exit of the least productive firms in the industry.

5. *The productivity cutoff for exporting increases:* $\dfrac{\partial \varphi_x}{\partial \tau} > 0$. This result replicates the findings in Melitz (2003).

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

Discussion

The new result on this 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 servicing 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 exporting profits.

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

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.

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.

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% for capital goods not produced in the country to 22% for consumption goods. Almost all import licenses were eliminated, with the exception of the automobile industry.

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. There was a transition phase between 1991 and 1994 aimed to achieve free trade within the region by the end of 1994. This new agreement 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 11%. Tariffs varied between 0 and 20% across industries. Inputs and materials had the lowest tariffs, followed by semi-finished industrial goods, 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. As a result of the agreement, in 1996 the import-weighted average intra-MERCOSUR tariff was 0.86% for Argentina and 0.02% for Brazil, while the extra-zone average tariff was 13.17% and 15.44% respectively.

The panel of firms I analyze covers the period 1992-1996, that is coincident with the regional trade liberalization, but posterior to Argentina's unilateral trade liberalization. As a result, Argentinean import tariffs had already been reduced in the period under study. In fact, between 1992 and 1996 average import tariffs increased slightly (1.28%). The modifications on import tariffs during this period are partly related to the reduction in tariffs within MERCOSUR, and the convergence to the CET, that partly reflected the structure of protection in Brazil. The source of all the tariff data I use is UNCTAD-TRAINS.

The average reduction in Argentina's tariffs for imports from Brazil was only 12 percentage points, as import tariffs in Argentina were already low before MERCOSUR was launched. Surprisingly, imports from Brazil grew exactly at the same rate as imports from the rest of the world during this period (60%).

MERCOSUR had a much bigger 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 the deep reduction in Brazilian tariffs for imports from Argentina, which fell on average 24 percentage points, with a maximum fall of 63 pp. Figure 3 reports the frequency of the variation in Brazilian import tariffs for 4-digit-SIC industries. This variation reflects import tariffs in 1992, as all tariffs were zero in 1995, except for the automobile and sugar sectors.

Figure 3

Change in Brazil's Import Tariffs with Respect to Argentina 1996-1992
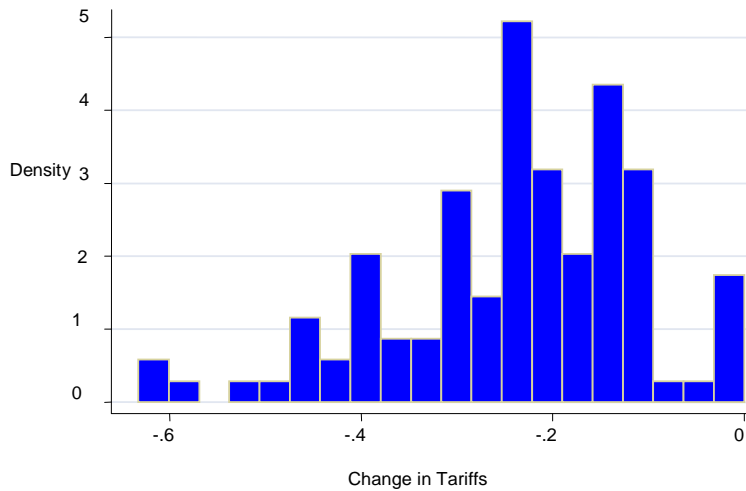
3.2 Firm-Level Data

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 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.[15]

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.

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[15] 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.

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 these different dimensions: 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.[16]

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 16 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 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 skill intensity and labor productivity 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.

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

3.3 Sector-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). Finally, I use the elasticity of substitution in the industry as estimated by Broda and Weinstein (2006).

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 prediction 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 old technology, the medium productivity firms still use the old technology but also export, and the most productive firms both export and use the new 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 4 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. Whiting 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 4

Effect of Falling Variable Export Costs
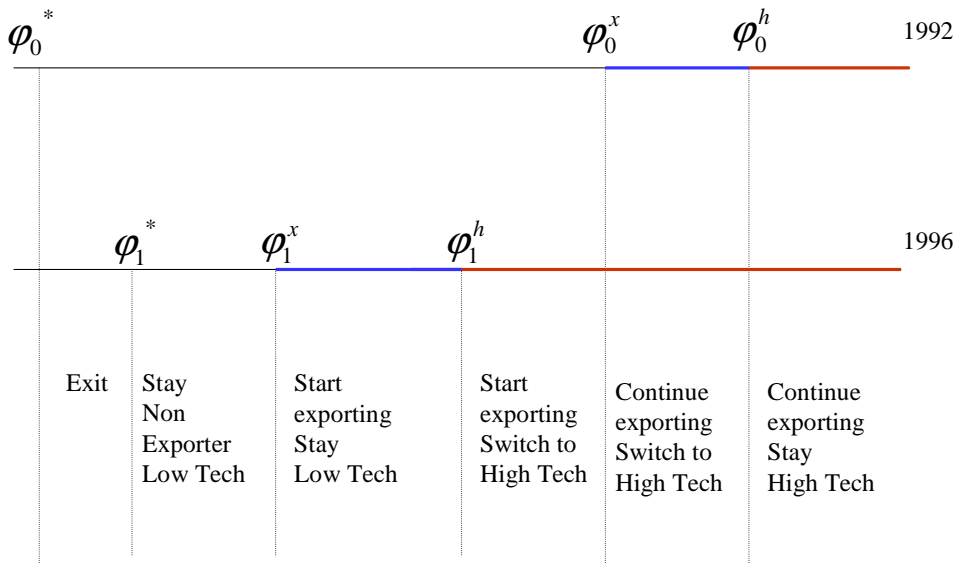
To check whether the sorting pattern in figure 4 and the parameter restrictions required to obtain it are consistent with the data I divide firms into three groups: continuing exporters,[17] new exporters,[18] and never exporters[19] and compute differences in characteristics for firms operating within the same 4-digit-SIC industry.

Table 1 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

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[17] Firms that were already exporting in 1992.
[18] Firms that export in 1996 but were not exporting in 1992.
[19] Firms that do not export in 1992 nor 1996.

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 1). 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 or viceversa, or whether both are caused by a third factor. Some alternative explanations for the results in Table 1 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 between exporting and technology adoption, by linking these outcomes directly to the reduction in Brazil's tariffs for imports from Argentina.

4.2 The Impact of the Reduction in Brazil's Tariffs
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 exporting 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[20] in 1995, thus *changes* in tariffs are predetermined by the 1991 tariff *levels* in Brazil. Second, the 1991 import tariffs of Brazil are practically the same for Argentina and the rest of the world thus are unlikely to be targeted to industry characteristics particular to Argentina, whose share of Brazil's trade was only 7.7%.[21] As changes in tariffs are predetermined, they can't 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: it is determined by 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 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 trade theory predicts 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

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[20] 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.

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

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.[22]

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

Entry in the Export Market

I estimate a linearized version of the entry in the export market choice described by equation (26). This linearization does not respect functional form thus estimation only attempts to recover the signs of the partial derivative of interest ($\frac{\partial \varphi_x}{\partial \tau}$) and to assess the economic significance of the estimated coefficients. I empirically analyze the entry in the export market decision using an index model:

$$EXP_{ijt} = \begin{cases} 1 & if \ \beta_{\mathrm{T}} \tau_{jt} + I_{st} + k_{ij} + \varepsilon_{ijt} > 0 \\ 0 & otherwise \end{cases} \tag{29}$$

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_{ijt} 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 at the 4-digit-SIC industry and across time; k_{ij} are plant fixed effects that capture unobserved constant plant heterogeneity (φ) and 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)[23]; I_{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:

$$EXP_{ijt} = \beta_{\tau} \tau_{jt} + I_{st} + k_{ij} + \varepsilon_{ijt} \tag{30}$$

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[22] An important point to note is that Argentina's tariffs with the rest of the world were very similar to tariffs with respect to Brazil in 1992 (the correlation is 0.92), thus 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. In effect, as discussed earlier, Argentina had already gone through a process of unilateral trade liberalization before 1992, thus its tariffs were already low in 1992 and there was no change in the share of Argentinean imports from MERCOSUR in the period 1992-1996 (stayed at 24%).

[23] 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.

In this case, first differencing eliminates the constant plant and sector heterogeneity:

$$\Delta EXP_{ij} = \beta_\tau \, \Delta \tau_j + \Delta I_s + \Delta \varepsilon_{ij} \tag{31}$$

Estimation of equation (31) by OLS is reported in the first column of Table 2, 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) is negative (-0.421) and significant (t = -5.01), meaning that the average drop in Brazil's tariffs (24 percentage points) increases the probability of entry in the export market by 10 percentage points.

There are several potential problems with the estimation of equation (31). First, it is a linearized version of a nonlinear probability function, then if the true function is nonlinear first differencing does not eliminate constant unobserved plant and sector characteristics, and these might be correlated with tariffs. One way to check if the linear specification in equation (31) is correct is to include in the regression initial firm and industry characteristics that are expected to be proxies for constant firm and industry heterogeneity:

$$\Delta EXP_{ij} = \beta_\tau \, \Delta \tau_j + \beta_z z_{ij1992} + \beta_c c_j + \Delta I_s + \Delta \varepsilon_{ij} \tag{32}$$

where z_{ij1992} are firm characteristics in the initial year (1992) like size measured by the number of workers, productivity measured by 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 (32) is reported in columns (2) to (6) of Table 2, 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. I also control for the change in import tariffs in case these had some indirect effect on exporting, but these are not significant. The coefficients in the regressions including all controls (columns 4 and 6) are -0.536 (t=-5.58) and -0.522 (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 13 percentage points.

It is interesting to note that the results reported in Table 2 imply that more productive firms are more likely to enter the export market, as predicted by the model. Measures for the change in Argentina's tariffs with the world are not significant (Columns 3 and 4), and the change in Argentina's tariffs with respect to Brazil is also not significant (Columns 5 and 6).

Of the sector characteristics the elasticity of demand has a significant positive effect on entry, and skill-intensity has a significant negative effect. Note that skill intensity at the firm-

level is only significant when skill-intensity at the sector level is excluded from the regression, suggestion that it is picking up the effect of this sector-level variable.

A second potential problem of the specification in equation (32) is that if there are sunk exporting costs, current exporting status might depend on lagged exporting status,[24] which in turn is likely to be correlated with the initial level of Brazil's tariffs. As the panel I am analyzing only contains data for 1992 and 1996, it is not possible to include lagged export status in the specification in differences. One way to check that this is not creating a problem in the identification on the coefficient on Brazil's tariffs is to estimate the equation restricted to firms that were not exporters in 1992. In this case, as the only possible outcome is entry, I estimate both the linear probability model (LPM) and the Probit model:

$$EXP_{ij1996} = \begin{cases} 1 & if \ \beta_\tau \, \Delta\tau_j + \beta_z z_{ij1992} + \beta_c c_j + \Delta I_s + v_{ij} > 0 \\ 0 & otherwise \end{cases} \tag{33}$$

Panel A of Table 3 reports the estimation of equation (33) by the LPM. The coefficient on the change in Brazil's tariffs is very similar to the one estimated with the full sample and significant [-0.628 (t=-4.18) and -0.602 (t=-3.15) in columns 4 and 6 where all controls are included], implying that the average reduction in tariffs increases the probability of entering the export market by 15 percentage points.

Panel B of Table 3 reports estimation of equation (33) by the Probit model. The coefficient on the change in Brazil's tariffs is similar to the one estimated with the LPM and significant (-0.740 (t=-4.08) and -0.626 (t=-3.23) in columns 4 and 6 where all controls are included), implying that the average reduction in tariffs increases the probability of entering the export market by 17 to 15 percentage points.

A potential problem in the estimation of equation (33) 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

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[24] 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.

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 in the case of the LPM (Column 2 of Panel A in Table 3) and becomes still lower in the Probit model (Column 2 of Panel B in Table 3), thus sample selection does not seem to play an important role.

Technology Adoption Decision

Spending in Technology

The technology adoption decision described in the model (equation 27) is binary, but as the best measure of technology I observe in the data is spending in technology, in this section I identify changes in technology through changes in spending in technology. In the next subsection I also analyze the binary measures of technology contained in the survey.

In the model, a firm is more likely to adopt technology h the lower is the threshold φ_h in its sector [equation (27)], and the higher is its own productivity (φ), then the level of spending in technology can be described by:

$$\log ST_{ijt} = \alpha_{\tau^x} \tau_{xjt} + \alpha_{\tau^m} \tau_{mjt} + I_{st} + k_{ij} + \varepsilon_{ijt} \tag{34}$$

where τ_m denotes Argentina's import tariffs, as adoption of new technologies depends on the size of the export market and also the size of the domestic market. In differences:

$$\Delta \log ST_{ij} = \alpha_{\tau^x} \Delta \tau_{xj} + \alpha_{\tau^m} \Delta \tau_{mj} + \Delta I_s + \Delta \varepsilon_{ij} \tag{35}$$

Estimation of equation (35) by OLS is reported in Table 4. 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 drop 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 tariffs with respect to the world, which is not surprising given that Argentina's unilateral trade liberalization took place before 1992. Instead, the inclusion of the change in Argentina's tariffs with respect to Brazil (Column 5) increases the coefficient to -1.418 (t=-2.31), possibly because these are correlated with Brazil's tariffs and they had an effect of the opposite sign in technology adoption, although not statistically significant.

Next, I estimate equation (35) for two sub-samples of firms, the ones that were not exporting in 1992 and the ones that were exporting, as the model predicts that both groups upgrade technology if the ordering of cutoffs for entry in the export market (φ_x) and for adopting the new technology (φ_h) before (t=0) and after liberalization (t=1) is $\varphi_x^1 < \varphi_H^1 < \varphi_x^0 < \varphi_H^0$. Reductions in Brazil's tariffs induce entry in the export market and adoption of the new technology for firms with productivity (φ) in the range $\varphi_x^1 < \varphi_H^1 < \varphi < \varphi_x^0 < \varphi_H^0$. Then, within the group of firms that were not exporting in 1992, bigger tariff reductions imply bigger falls in both thresholds and thus a higher likelihood that firms find themselves in the range where they enter the export market and upgrade technology. Panel A of Table 5 reports the estimation of equation (35) for the sub-sample of firms that were not exporting in 1992. The coefficient $\alpha_{\tau x}$ is significant in all specifications and similar to the one estimated for the full sample.

For firms that were exporting in 1992, the reduction in tariffs would induce technology upgrading if they are on the range $\varphi_x^1 < \varphi_H^1 < \varphi_x^0 < \varphi < \varphi_H^0$ which is more likely the bigger the drop in φ_h, thus the larger the reduction in Brazil's tariffs. Panel B of Table 6 reports the estimation 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 all specifications except in column (4) where the inclusion of all sector-level controls and the change in Argentinean tariffs with respect to the world results in bigger standard errors, but the coefficient is still of a similar size as in column (3).

The result that firms that were already exporting in 1992 upgrade technology is consistent with technology upgrading being driven by the increase in revenues, which results from the assumption that adoption of the new technology requires payment of a fixed cost. 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, and there would be no effect on the sample restricted to firms that exported in 1992.

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 the technology they are using, instead of just expanding production by increasing the use of all factors proportionally. In Appendix E I report estimates of equation (35), replacing the growth in spending in technology

by the growth in spending in technology per worker as the dependent variable. The estimates of α_{tx} are very similar to the ones reported in Tables 4 and 5.[25]

An important caveat in the interpretation of the results presented in this section is that equation (35) can only be estimated on a sub-sample of firms that have positive ST in 1992 and 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 and more productive, thus results might not be representative for the smallest firms. In the following section I analyze some binary measures of technology that are available for a bigger sub-sample of firms (1319 to 1310 firms).

Binary Measures of Technology

In this section I analyze alternative measures of technology to asses the robustness of the results presented above. I use a set of questions on improvements in products, production process and organization of production to construct indexes for the fraction of questions in each category and overall that were answered positively by the firm. The reason for aggregating these questions is that the model does not distinguish between different types of innovation but treats product improvements and cost reducing innovations as substitutes.

Table 6 reports OLS estimates of equation (35), replacing the growth in spending in technology by indexes of innovation as a dependent variable. The coefficient in the change in Brazil's tariffs is negative, significant and of similar size for all and each type of innovations, consistent with the results presented in the previous section. The size of the coefficient reported in column 1 implies that the average reduction in Brazil's tariffs induces firms to perform 0,07 more product innovations overall, which is 15% of the average innovations per firm (0,44).

Domestic Sales

As a check that the reduction in Brazil's tariffs induces technology upgrading through increased export revenues and is not reflecting other positive shocks in the domestic market, I estimated equation (35) with the change in domestic sales as a dependent variable. The results are reported in Appendix E. Domestic sales are not significantly correlated with Brazil's tariffs, except in the specification that includes all controls plus the change in Argentina's import tariffs with respect to the world (column 4) where the coefficient is significant at 10% confidence level. Still, this

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

correlation is weak and unlikely to be behind the significance at 1% confidence level found in the equivalent regressions for entry in the export market and technology upgrading. [26]

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 variable export costs increasing revenues for exporters and making adoption of new technologies profitable for more firms. The finding that falling variable export costs 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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[26] Note that a positive correlation of domestic sales with the change in Brazil's tariffs is not inconsistent with the model as in sectors where Brazil's tariffs fall more domestic sales would be reduced for all firms as the exit productivity cutoff increases.

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Table 1: Differences between exporters and non exporters

	Levels in 1992		Changes 1992-1996		
	Continuing Exporters	New Exporters	Continuing Exporters	New Exporters	Num. of Firms
Firm Characteristic					
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 per worker	0.37	0.21	0.27	0.34	894
	[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 2: Entry in the Export Market
Full Sample, Linear Probability Model
Dependent variable: change in export status 1996-1992

	1	2	3	4	5	6
Change in Brazil's tariffs	-0.421	-0.417	-0.406	-0.536	-0.325	-0.522
	[0.084]***	[0.080]***	[0.083]***	[0.096]***	[0.091]***	[0.138]***
Change in Arg.'s tariffs w.r.t. world			0.172	0.011		
			[0.408]	[0.354]		
Change in Arg.'s tariffs w.r.t. Brazil					-0.507	-0.063
					[0.331]	[0.359]
Firm-level controls						
Log (Employment$_{1992}$)		0.014	0.014	0.014	0.013	0.014
		[0.010]	[0.010]	[0.010]	[0.010]	[0.010]
Log (Productivity$_{1992}$)		0.037	0.037	0.039	0.037	0.039
		[0.014]***	[0.014]**	[0.014]***	[0.014]**	[0.014]***
Skill Intensity		-0.155	-0.155	-0.115	-0.140	-0.114
		[0.069]**	[0.069]**	[0.070]	[0.071]*	[0.071]
Industry-level controls						
Demand elasticity				0.016		0.016
				[0.006]***		[0.006]***
US Capital intensity				-0.047		-0.047
				[0.028]*		[0.028]*
US Skill intensity				-0.136		-0.132
				[0.058]**		[0.067]*
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1380	1380	1380	1380	1374	1374
R-squared	0.03	0.04	0.04	0.04	0.04	0.04

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

Table 3: Entry in the Export Market in the Sample of non-Exporters in 1992
Panel A: Linear Probability Model. Dependent variable is export status in 1996.

	1	2	3	4	5	6
Change in Brazil's tariffs	-0.411	-0.447	-0.446	-0.628	-0.330	-0.602
	[0.108]***	[0.123]***	[0.122]***	[0.148]***	[0.150]**	[0.191]***
Change in Arg. Tariffs w.r.t.			0.007	-0.122		
			[0.573]	[0.493]		
Change in Arg. Tariffs w.r.t.					-0.693	-0.081
					[0.569]	[0.535]
Firm-level controls						
Log (Employment$_{1992}$)		0.125	0.125	0.124	0.123	0.124
		[0.016]***	[0.016]***	[0.015]***	[0.016]***	[0.015]***
Log (Productivity$_{1992}$)		0.062	0.062	0.060	0.061	0.060
		[0.018]***	[0.018]***	[0.018]***	[0.018]***	[0.018]***
Skill Intensity		-0.024	-0.024	0.038	0.002	0.039
		[0.115]	[0.116]	[0.124]	[0.120]	[0.125]
Industry-level controls						
Demand elasticity				0.010		0.010
				[0.012]		[0.012]
U.S. Capital intensity				0.030		0.030
				[0.048]		[0.048]
U.S. Skill intensity				-0.205		-0.200
				[0.082]**		[0.087]**
2-digit-SIC industry	Yes	Yes	Yes	Yes	Yes	Yes
Observations	797	797	797	797	797	797
R-squared	0.04	0.16	0.16	0.17	0.16	0.17

Panel B: Probit Model. Dependent variable is export status in 1996.

	1	2	3	4	5	6
Change in Brazil's tariffs	-0.424	-0.479	-0.487	-0.740	-0.352	-0.686
	[0.108]***	[0.138]***	[0.136]***	[0.181]***	[0.166]**	[0.212]***
Change in Arg. tariffs w.r.t. world			-0.125	-0.325		
			[0.642]	[0.575]		
Change in Arg. tariffs w.r.t. Brazil					-0.806	-0.145
					[0.709]	[0.638]
Firm-level controls						
Log (Employment$_{1992}$)		0.135	0.135	0.134	0.133	0.134
		[0.020]***	[0.020]***	[0.019]***	[0.020]***	[0.019]***
Log (Productivity$_{1992}$)		0.080	0.080	0.077	0.078	0.076
		[0.022]***	[0.022]***	[0.023]***	[0.022]***	[0.022]***
Skill Intensity		-0.027	-0.027	0.035	-0.002	0.036
		[0.119]	[0.120]	[0.130]	[0.124]	[0.130]
Industry-level controls						
Demand elasticity				0.009		0.008
				[0.013]		[0.014]
US Capital intensity				0.041		0.041
				[0.052]		[0.053]
US Skill intensity				-0.261		-0.252
				[0.109]**		[0.108]**
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	795	795	795	795	795	795
Observed P	0.289	0.289	0.289	0.289	0.289	0.289
Predicted P (at X bar)	0.282	0.257	0.257	0.253	0.256	0.253
Log-likelihood value	-467.033	-417.068	-416.856	-410.889	-414.912	-410.784
Pseudo R-squared	0.036	0.139	0.139	0.152	0.143	0.152

Notes: Marginal effects at sample means reported for probit. Standard errors clustered at the 4-digit-SIC industry level.
* indicates significant at 10%; ** significant at 5%; *** significant at 1%.

Table 4: Technology Adoption

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

	1	2	3	4	5	6
Change in Brazil's tariffs	-1.079	-1.076	-1.033	-0.882	-1.436	-1.418
	[0.350]***	[0.346]***	[0.319]***	[0.370]**	[0.447]***	[0.613]**
Change in Arg.'s tariffs w.r.t. world			0.635	0.662		
			[1.073]	[1.121]		
Change in Arg.'s tariffs w.r.t. Brazil					2.050	2.162
					[1.323]	[1.694]
Firm-level controls						
Log (Employment$_{1992}$)		0.102	0.103	0.102	0.106	0.106
		[0.030]***	[0.031]***	[0.030]***	[0.030]***	[0.030]***
Log (Productivity$_{1992}$)		0.554	0.557	0.528	0.572	0.534
		[0.291]*	[0.291]*	[0.280]*	[0.288]*	[0.276]*
Log (Productivity$_{1992}$)^2		-0.066	-0.067	-0.062	-0.069	-0.062
		[0.034]*	[0.034]*	[0.032]*	[0.034]**	[0.032]*
Skill Intensity		0.477	0.473	0.482	0.416	0.444
		[0.228]**	[0.228]**	[0.226]**	[0.229]*	[0.226]*
Industry-level controls						
Demand elasticity				0.023		0.031
				[0.021]		[0.022]
US Capital intensity				-0.222		-0.225
				[0.080]***		[0.083]***
US Skill intensity				0.225		0.081
				[0.165]		[0.215]
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	894	894	894	894	892	892
R-squared	0.03	0.05	0.05	0.05	0.05	0.05

Notes: in tables 2 and 3 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 by Export Status
Dependent variable: change in log (spending in technology) 1996-1992

Panel A: sample of non-exporters in 1992

	1	2	3	4	5	6
Change in Brazil's tariffs	-1.073	-1.255	-1.312	-1.180	-1.587	-1.549
	[0.520]**	[0.513]**	[0.494]***	[0.535]**	[0.682]**	[0.892]*
Change in Arg.'s tariffs w.r.t. world			-0.679	-0.511		
			[1.626]	[1.657]		
Change in Arg.'s tariffs w.r.t. Brazil					2.178	2.151
					[1.889]	[2.489]
Firm-level controls						
Log (Employment$_{1992}$)		0.167	0.167	0.162	0.173	0.168
		[0.053]***	[0.052]***	[0.053]***	[0.052]***	[0.053]***
Log (Productivity$_{1992}$)		0.284	0.281	0.273	0.304	0.297
		[0.412]	[0.416]	[0.411]	[0.411]	[0.404]
Log (Productivity$_{1992}$)^2		-0.028	-0.027	-0.025	-0.030	-0.028
		[0.051]	[0.051]	[0.051]	[0.051]	[0.050]
Skill Intensity		0.764	0.771	0.725	0.677	0.669
		[0.354]**	[0.352]**	[0.358]**	[0.369]*	[0.365]*
Industry-level controls						
Demand elasticity				0.018		0.025
				[0.043]		[0.047]
US Capital intensity				-0.095		-0.100
				[0.144]		[0.144]
US Skill intensity				0.208		0.088
				[0.210]		[0.274]
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	417	417	417	417	417	417
R-squared	0.07	0.11	0.11	0.11	0.11	0.11

Panel B: sample of exporters in 1992

	1	2	3	4	5	6
Change in Brazil's tariffs	-1.116	-1.041	-0.895	-0.793	-1.343	-1.421
	[0.382]***	[0.380]***	[0.409]**	[0.552]	[0.485]***	[0.732]*
Change in Arg.'s tariffs w.r.t. world			2.662	2.551		
			[1.596]*	[1.742]		
Change in Arg.'s tariffs w.r.t. Brazil					1.582	1.872
					[1.685]	[2.010]
Firm-level controls						
Log (Employment$_{1992}$)		0.093	0.095	0.098	0.092	0.097
		[0.045]**	[0.044]**	[0.044]**	[0.046]**	[0.046]**
Log (Productivity$_{1992}$)		0.534	0.530	0.509	0.541	0.503
		[0.494]	[0.491]	[0.472]	[0.494]	[0.464]
Log (Productivity$_{1992}$)^2		-0.074	-0.075	-0.070	-0.076	-0.068
		[0.055]	[0.055]	[0.051]	[0.055]	[0.051]
Skill Intensity		0.230	0.209	0.249	0.201	0.226
		[0.299]	[0.290]	[0.300]	[0.300]	[0.309]
Industry-level controls						
Demand elasticity				0.017		0.031
				[0.023]		[0.024]
US Capital intensity				-0.224		-0.234
				[0.110]**		[0.107]**
US Skill intensity				0.186		0.037
				[0.255]		[0.325]
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	477	477	477	477	475	475
R-squared	0.05	0.07	0.07	0.08	0.07	0.08

Standard errors clustered at the 4-digit-SIC industry level. * indicates significant at 10%; ** significant at 5%; *** significant at 1%

Table 6
Discrete Measures of Technology Adoption

Dependent variable: Index of improvements

	All Improvements		Improvements in Products		Production Process Improvements		Organization of Production Improvements	
	1	2	3	4	5	6	7	8
Change in Brazil's tariffs	-0.297 [0.095]***	-0.332 [0.121]***	-0.319 [0.102]***	-0.424 [0.127]***	-0.257 [0.094]***	-0.328 [0.127]**	-0.348 [0.111]***	-0.271 [0.134]**
Change in Argentina's tariffs w.r.t. world	-0.188 [0.225]		-0.071 [0.259]		-0.170 [0.265]		-0.400 [0.300]	
Change in Argentina's tariffs w.r.t. Brazil		0.223 [0.274]		0.493 [0.304]		0.377 [0.327]		-0.197 [0.315]
Firm-level controls								
Log (Employment$_{1992}$)	0.083 [0.006]***	0.085 [0.006]***	0.075 [0.007]***	0.077 [0.007]***	0.089 [0.007]***	0.091 [0.007]***	0.085 [0.008]***	0.086 [0.008]***
Log (Productivity$_{1992}$)	0.049 [0.010]***	0.047 [0.010]***	0.054 [0.011]***	0.051 [0.011]***	0.049 [0.012]***	0.046 [0.012]***	0.040 [0.012]***	0.037 [0.012]***
Skill Intensity	0.219 [0.054]***	0.210 [0.054]***	0.240 [0.061]***	0.228 [0.061]***	0.209 [0.056]***	0.199 [0.057]***	0.223 [0.059]***	0.220 [0.059]***
Industry-level controls								
Demand elasticity	0.004 [0.006]	0.003 [0.006]	-0.001 [0.005]	-0.001 [0.005]	0.004 [0.005]	0.004 [0.005]	0.010 [0.009]	0.008 [0.009]
U.S. Capital intensity	-0.030 [0.026]	-0.029 [0.026]	-0.058 [0.028]**	-0.057 [0.029]**	-0.011 [0.025]	-0.010 [0.026]	-0.027 [0.032]	-0.024 [0.031]
U.S. Skill intensity	-0.040 [0.045]	-0.053 [0.050]	-0.030 [0.050]	-0.062 [0.050]	-0.076 [0.048]	-0.099 [0.052]*	-0.046 [0.050]	-0.030 [0.057]
2-digit-SIC industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1264	1259	1312	1306	1319	1313	1310	1305
R-squared	0.26	0.26	0.22	0.23	0.22	0.22	0.19	0.19

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