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What gains and distributional implications result from trade liberalization?

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Abstract

This paper investigates the distributional impacts of trade liberalization across firms, consumers and workers. Using firm-product-level census data for Ecuador, we exploit exogenous tariff changes at entry to the World Trade Organization. We show that with input tariff cuts firms access higher quality and new input varieties. Consequently, firms increase their product scope and quality, while their production's skill-intensity increases and costs decrease. "Real" productivity (TFPQ) increases only in the medium run, following adjustments to produce more and higher quality products. Positive immediate revenue productivity (TFPR) gains result because firms' markups increase. Consumers still gain as quality-adjusted prices decrease and varieties increase. Workers benefit differentially: skilled workers' wages rise compared to less skilled workers' wages. Input-tariff liberalization also has distributional impacts across firms. Only more productive firms with high markups increase product scope and quality and gain market shares. With output-trade liberalization the least productive firms decrease their product scope.

Keywords: gains from trade, input and output tariff reductions, product scope, product quality, market share, quantity and revenue total factor productivity (TFPQ, TFPR), skill premium, markups, price, foreign inputs quality and variety, firm-product-level data, Ecuador.

JEL Codes: F16, O30, D22, O12, O54, L6.

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Introduction

While the productivity gains from trade liberalization for the average firm have been widely documented, more evidence is needed to determine economies' gains from trade liberalization. The promise of trade liberalization in developing countries is not only that productivity improves, but also that firms upgrade production processes, offering better and more diverse products. Consumers could consequently access more variety and higher quality products at lower price. However, better and more diverse product may allow firms to increase their profit margins instead, providing less benefits to consumers. Moreover, the gains from trade liberalization may be unequally distributed across workers, depending on the skills firms require, and leave those workers with the right skills better off while others without the skills will be worse off. In addition, the distributional effects of trade liberalization across firms matters to understand aggregate gains from trade. Benefits for the economy arise if more productive firms expand as a result of trade liberalization while other less productive firms loose and contract.

This paper provides a comprehensive assessment of the distributional impacts of trade liberalization in Ecuador across firms, consumers and workers. Following an analysis of the effects of input-trade liberalization on firms' input and output product scope and quality, the paper investigates changes in production processes across firms of different "real" productivity - i.e. firms' production efficiency as computed using quantity-based total factor productivity (TFPQ) - and profitability. We also analyze the relative returns to different workers, consumers and firms. Our empirical analysis relies on Ecuador's unilateral trade reform when the country joined the WTO (World Trade Organization) in 1996. In particular, we exploit the exogenous change in effectively applied tariffs across products and over time in highly demanding within-firm estimations that also include firm-size trends to remove time-varying trends across firms of different size.

Our paper's unique contribution to the literature consists in providing a comprehensive causal assessment of the distributional impacts of trade liberalization. Based on a unique firm-product-level dataset for Ecuador over the 1997-2007 period, we measure directly changes of firms' production processes with regard to production costs and markups. Information on input and output product quantities and sales values allow estimating input and output quality and obtaining a measure of “real” productivity: quantity total factor productivity (TFPQ). Differently from the widely used revenue total factor productivity (TFPR), TFPQ is not affected by demand shifts or market power variations and allow us to differentiate impacts of input-trade liberalization on production efficiency and markups. We are consequently in position to evaluate the distributional implications on firms by investigating to what extent trade affects efficiency or market power. We can also determine how firms, consumers and workers benefit by investigating trade liberalization’s impacts on quality-adjusted price changes, markups and skill premia. Relative to the existing literature, our analysis goes one step further and investigates the heterogeneous effects of trade liberalization on firms’ production choices on both firms’ efficiency (TFPQ) and their market power. Finally, this paper sheds new light on previous findings that did not have such information and validate estimation techniques used in other studies that lack this information; our findings are in line with those of De Loecker et al. (2016) and validate the methods they employ to estimate firm-product markups and proxy for employment in productivity computations.

The period we analyze is one of transformation for Ecuadorian firms. The share of single-product firms decreases substantially over the period of trade liberalization in Ecuador from 48% in 1997 to only 23% in 2007. Over the 1997-2007 period, 30% of final goods produced in 2007 are new products compared to those produced by the same firms in 1997. The average product quality improves by 55% over the same period for firms present in both periods. The skilled intensity of a firm (the share of skilled workers) increases by 8% on average, increasing the average skill premium by 2.5%. Firms’ average markups also increase by 13% from 1997 to 2007, while at the same time quality-adjusted prices decrease by 7%.

We hypothesize that these transformations are partly driven by Ecuador’s trade liberalization and consequent input tariff cuts in particular. Importing firms pay more for imported inputs than for domestic products and use more varieties in production than firms that do not import inputs. The quality of imported inputs has increased substantially between 1997 and 2007 due to input tariff cuts. Firms relying on imported inputs produce more final goods products and products of better quality. These firms are also more skill-intensive than non-importers of inputs.

The theoretical mechanisms motivating our empirical analysis are as follows: input-trade liberalization reduces the costs of access to imported intermediate inputs, offering firms access to more input varieties and higher quality inputs. Such access to more suitable inputs allows firms to decrease their marginal production costs due to reduced input costs for the same units of products produced of comparable quality. Higher production efficiency arises from the use of more and higher-quality inputs (as in Grossman and Helpman, 1991, Halpern et al., 2015). With fixed costs in product innovation, input-tariff reductions also allow producing additional products, expanding firms' product scope. Moreover, assuming a quasi linear-demand function and introducing product quality as a demand shifter, input-tariff cuts allow firms to upgrade their output quality.

As to the distributional implications, our model predicts that the initially most productive firms will benefit the most from input-tariff cuts to import more varieties and expand their product scope and upgrade their input- and output-quality. Building on the theoretical framework developed by Melitz and Ottaviano (2008) of heterogeneous firms with endogenous markups, our model predicts that the most productive firms gain larger markups from input-tariff cuts than less productive firms. In other words, these firms do not pass through all benefits from input-trade liberalization to consumers. With improvements in output quality firms will increase markups further. As to the implications of input-trade liberalization across different workers, skilled labor is needed to produce new products of higher-quality, increasing their demand for skilled labor and their returns.

Regarding output tariff cuts, the theoretical literature predicts similar effects to those of input tariff cuts regarding firm output product quality, productivity and investments in improved production processes (Bernard et al., 2011; Eckel et al., 2016; Mayer et al., 2016). The underlying mechanism behind those effects is increased competition in firms' markets that pushes them to invest in improving performance and differentiating products from their competitors'. As to firms' product scope, the theoretical literature suggests output tariff cuts have reverse effects than input tariff cuts as firms concentrate on their core products (Bernard et al., 2011). Markups are also expected to decrease as a result of new competition from abroad (Melitz and Ottaviano, 2008; De Loecker et al., 2016).

Our empirical findings that test those theoretical predictions can be summarized as follows: First, we establish a causal link between input-tariff cuts and within firm-product availability of higher quality intermediate goods from abroad and of more variety of foreign inputs. We estimate that a 10 percentage point reduction in input tariffs increases the quality of firms' intermediate inputs by 34%. The effect of input-tariff cuts by the same amount on the likelihood of importing a new variety of foreign inputs is of only 1%.

Second, we show that firms in industries with larger input tariff cuts expand the number of goods they produce, upgrade the quality of their final products and change their production processes in consequence. A 10 percentage point fall in input tariffs leads to a 2.4 % increase in firm product scope as a result of improved access to new imported varieties. Output tariff reductions decrease product scope by 2.8%. A 10 percentage point fall in input tariffs also leads to a 7 % to 11% increase in product quality due to higher import quality. We find no effect of output tariffs on output quality.

Third, our findings show that production processes change as a result of input-tariff cuts. Firms adopt more skill-intensive production processes and reduce production costs once the improvements in the input quality are taken into account. These findings suggest that access to imported inputs allows firms to optimize their production. However, "real" productivity as measured by TFPQ does not improve in the short run possibly as efficiency gains are offset by the costs associated with adjusting production to produce more products and products of higher quality. Consistently with previous research findings, we identify positive effects of trade liberalization through both input and output tariffs changes on TFPR (the measure used in most studies). These positive effects, however, do not relate to efficiency improvements but markups gains. However, we find positive effects of both input and output tariff reductions on "real" productivity (TFPQ) in the medium run. We also show that firms in industries that benefit more from input-trade liberalization secured higher market shares.

Fourth, regarding the distributional effects of input-trade liberalization we find that only the initially most productive firms with high-markups benefit from input-tariff cuts to expand their product range and upgrade their product quality. Output tariff cuts reduce the product scope of the least productive firms and push more productive firms with low-markups to improve their product quality. Input-trade liberalization also results in a reallocation of market shares from less productive firms but also productive firms with low-markups to initially more productive firms with high market power.

Trade liberalization also has implications for consumers and workers. Consumers benefit from access to higher quality products at lower price. However, firms do not pass through all gains to consumers: while production costs for similar quality goods decrease by 7.2%, quality-adjusted prices decrease only by 3.3% and markups increase by 11% after a 10 percentage point fall in input tariffs. Workers benefit differentially, in that new production modes require more skills. In consequence, the skill-premium increases by 5% after a 10 percentage point decrease in input tariffs.

Our findings have important policy implications as they point to substantial distributional impacts of input-trade liberalization. Our evidence confirms the positive of input tariff cuts for firms' production upgrading, supporting improvements in firms' production techniques to more innovation-intensive production. By contrast, output tariff cuts do not contribute to production process changes. This suggests that the knowledge transfer across borders from trade liberalization is at the heart of improvements to firms' production processes from trade reforms. Support measures such as training or funding to help firms - particularly those with low markups - to upgrade production processes to benefit from improved inputs could enhance benefits from trade liberalization further. Moreover, while consumers benefit from access to high quality products at lower quality-adjusted prices, firms do not pass through all gains but retain higher markups. The finding that only highly productive firms with already high markups benefit from input-trade liberalization suggests input tariff cuts poses challenges to market competition, which matters to push firms to improve production processes and ensure consumers benefit. Finally, skilled workers, gain more in demand as firms upgrade production processes, also gain relative to the less skilled ones, pushing further the inequalities between top income groups – with more skills and capital. Boosting education to equip workers with the skills to engage in new production processes can also help support gains from trade liberalization are more widespread.

Our paper adds new findings to the voluminous literature on trade liberalization's impacts on firms' performance and decisons. Early studies investigate mainly the effects of trade liberalization on within-firm productivity (e.g. Pavcnik, 2002; Fernandes, 2007; Amiti and Konings, 2007; Topalova and Khandelwal, 2011). Only few, however, focus on trade liberalization's impacts on "real" productivity or firm efficiency as measured by TFPQ but they do not look at input-trade liberalization (Foster et al., 2008, and De Loecker, 2011). A subsequent set of analyses focuses on wider changes than productivity and identified that firms require high-quality inputs (Bas and Strauss-Kahn, 2015; Fan, Li and Yeaple, 2015, Manova and Yu, 2017), skilled workers (Verhoogen, 2008) or materials (Kugler and Verhoogen, 2012) to produce high-quality goods.[1] Our results also confirm findings of Goldberg et al. (2010) for India who show that input-trade liberalization facilitates firms' access to more varieties of inputs of higher quality to expand product scope. We complement those findings by showing positive effects on product quality and identifying associated production cost reductions, skills upgrading and "real" productivity (TFPQ) effects in addition to identifying distributional implications of those changes across firms, workers and consumers.

Our paper also contributes to a more recent literature on distributional effects of trade liberalization across firms. The theoretical models of Melitz (2003) and Melitz and Ottaviano (2008) predict that output-trade liberalization induces the exit of the least productive firms and a reallocation of resources towards most productive firms. An empirical literature has tested for those heterogeneous effects, including Topalova and Khandelwal (2010), Bas and Berthou (2017) and Bas (2012). Differently from our study, this literature focuses on the impacts of output-trade liberalization and uses revenue-based productivity (TFPR) or other proxies (such as firm size) as dimensions of firm heterogeneities. Our contribution is to test the theoretical mechanisms of an extension of Melitz and Ottaviano (2008) that predicts heterogeneous effects of input-trade liberalization, differentiating distributional effects at initial differences across firms in terms of "real" productivity (measured by TFPQ) and market power.

[1] The descriptive analysis in Kugler and Verhoogen (2009) also connects to our work here; their evidence uncovers price differences between imported and domestic inputs and hypothesizes quality differences.

Finally, with regards to the distributional question of who benefits from trade liberalization, our work adds to Levinsohn (1993), Harrison (1994) and De Loecker et al. (2016) who investigate the impacts of trade liberalization on markups, prices and costs. We also add to their study by showing how input-trade liberalization has those distributional impacts as a result of improving access to input variety and quality and consequent changes to firm production processes in view of changes in product scope and quality. We also expand on their analysis on distributional gains by documenting implications on workers of different skills. This aspect of our study also links to the literature on the effects of input-trade liberalization and the skill premium (Amiti and Cameron, 2012; Chen et al., 2017).

The remainder of the paper is structured as follows. The next section describes the theoretical motivation. Section 2 gives an overview of the trade reform in Ecuador. Section 3 provides stylized empirical facts that motivate our empirical analysis. Section 4 discusses results of the effect of tariff cuts on firms' imported input quality and variety, while Section 5 describes effects on product variety and quality and wider production processes. Section 6 investigates distributional effects of trade liberalization across firms, workers and consumers. The last section concludes.

1. Theoretical motivation

This section introduces a simple theoretical framework in partial equilibrium that rationalizes the relationship between input-trade liberalization, access to new and better quality inputs, firm product variety and quality as well as firm production costs and productivity. The framework also identifies distributional implications of input-trade liberalization on firms' skill premia and markups. The final section discusses expected effects of output-tariff reductions.

Demand

The representative consumer has preferences over a continuum of varieties indexed by i and a homogeneous good used as numeraire. Preferences are described by a quasi-linear utility function[2] $U = q_0 + \vartheta \int_{i\epsilon\psi} z_i q_i \, di - \frac{1}{2} \upsilon \int_{i\epsilon\psi} (z_i q_i)^2 \, di - \frac{1}{2} \beta \left[\int_{i\epsilon\psi} z_i q_i \, di \right]^2$, where z is the output quality that acts as a demand shifter. Output quality from the demand side is any attribute of the product that the consumer values and that increases their utility. q_0 is the consumption of the numeraire good, with $q_0 > 0$, and q_i is the consumption level of each variety of the differentiated good.[3] The substitution between the differentiated varieties and the numeraire is captured by $\vartheta > 0$ and $\beta > 0$ parameters, while $\upsilon > 0$ represents the degree of product differentiation between the varieties. The maximization of the quasi-linear quadratic utility function subject to the consumer's budget constraint gives the optimal linear demand for the typical variety. This linear market demand system can be expressed as : $q_i = \frac{R}{\vartheta z_i}\left(\hat{P} - \frac{p_i}{z_i}\right)$, where $\hat{P} = \frac{\vartheta \upsilon + \beta M P}{\beta M + \upsilon}$ and $P = \frac{1}{M} \int_{i\epsilon\psi} \frac{p_i}{z_i} di$. M are the varieties consumed, P is the average quality-adjusted price and $\hat{P}$ is the ceiling price adjusted for output quality that represents the price at which demand for a variety is driven to 0.

Production

Firms can produce new products paying for each product fixed costs of product innovation in terms of skilled non-production labor (*S*), $w_s f_k$, where w_s is the wage of skilled workers. The rationale is that new product design requires the use of skilled workers. This assumption implies a complementarity between skilled labor and product innovation, in line with the literature on this topic (e.g. Griliches, 1969, Doms et al. 1997, Bresnahan et al. 2002). The total fixed cost of product innovation for a firm is an increasing function of the set of final good products produced by the firm:

$$F_k(|N|) = w_s f_k |N|^\rho \tag{1}$$

with *N* the set of final products k produced by a firm and $f_k > 0$ and $\rho > 0$. The subscript for firms is omitted. The final goods products k, produce by a firm are aggregated as $K = \left(\int_{\kappa \epsilon \mathrm{N}} (k)^\theta \, d\kappa \right)^{\frac{1}{\theta}}$, where k is the quantity of each final good. The

[2] We choose this demand system since it allows for endogenous markups and keep the tractability of the model. This linear demand system with horizontal product differentiation developed by Ottaviano, Tabuchi and Thisse (2002) and used by Melitz and Ottaviano (2008).
[3] The numeraire good is produced using only production labor hired in a perfectly competitive labor market. This gives the unit wage for production workers ($w_u = 1$).

price index of final products is $P_k = \left(\int_\kappa (p_k)^{\frac{\theta}{\theta-1}} d\kappa\right)^{\frac{\theta-1}{\theta}}$. The total profits of the firm over all its products is $\pi = P_k K - C - F_k$, where C is the variable cost of production at the firm level over all the products k produced by the firm. The total number of products *N* produced by a firm is determined by profit maximisation net of the fixed cost of product innovation:

$$N = \arg\max_N \{\pi - F_K(|\mathrm{N}|)\} \tag{2}$$

Firms combine intermediate inputs (*X)* and production labor (*L*) to produce each final product (*k*). The production function for product k of a firm is given by a Cobb-Douglas technology with factor shares η and *1-*η and $\frac{1}{c}$ is the specific firm-productivity modelled as a heterogeneous component of the marginal costs. As in Melitz and Ottaviano (2008) the marginal costs, c, is heterogeneous across firms:

$$q(\mathrm{k}) = \frac{1}{c} X^\eta L^{1-\eta} \tag{3}$$

As in Halpern et al. (2015), firms produce each final product k using both domestic X_d and imported X_m input varieties combined those inputs in a CES function with an elasticity of substitution between the two types of inputs equal to $\sigma = \frac{1}{1-\alpha}$:

$$X(k) = ({X_d}^\alpha + (X_m)^\alpha)^{\frac{1}{\alpha}} \tag{4}$$

where the input bundle of imported inputs is a CES aggregate :

$$X_m = \int_{v\epsilon\Omega} (\gamma_v x_{mv})^\theta \, dv)^{\frac{1}{\theta}} = \Omega \widetilde{x_{mv}} \widetilde{\gamma_v} \tag{5}$$

Ω is the set of foreign input varieties imported by a firm and x_{mv} is the quantity of imported input variety v with quality $\gamma_v > 1$. Plugging equation (5) into (4) and then into equation (3) one can see that the quality of imported inputs (γ_v) as well as the number of imported input varieties raise the quantity of product k produced.

There are variable costs of importing inputs represented by the input tariffs, τ_m, and fixed costs of importing inputs, F_m. Only the more profitable firms will be able to source inputs from abroad. The fixed cost of importing is an increasing function of the set of imported input varieties (Ω) as in Gopinath and Neiman (2014).[4] The fixed cost of importing is then given by: $F_m(|\Omega|) = f|\Omega|^{\lambda}$ with $f > 0$ and $\lambda > 0$.

The corresponding price index of intermediate inputs is: $P_x = \left(p_d^{\frac{\alpha}{\alpha-1}} + (P_m)^{\frac{\alpha}{\alpha-1}}\right)^{\frac{1-\alpha}{\alpha}}$. The price of domestic intermediate inputs is equal to the wage of unskilled labor which is used as a numeraire, p_d = 1. The price index of imported varieties is:

$$P_m = \left(\int_{v\in\Omega} \left(\frac{\tau_m}{\gamma_v}\right)^{\frac{\theta}{\theta-1}} dv\right)^{\frac{\theta-1}{\theta}} = \Omega^{\frac{\theta}{\theta-1}} p_m(\tau_m, \widetilde{\gamma_{\iota v}}) \tag{6}$$

where $p_m(\tau_m, \widetilde{\gamma_{\iota v}}) = \frac{\tau_m}{\widetilde{\gamma_v}}$ is the average imported input price across all varieties of foreign inputs of different qualities. We disentangle both mechanisms in the imported input price index: (i) foreign-input quality upgrading and (ii) input variety. Both mechanisms drive imported input price reductions and consequent lower unit production costs. As in Grossman and Helpman (1991) and Halpern et al. (2015), input quality is the relative cost advantage due to the higher efficiency in the production process that arises from the use of high-quality inputs. The higher the quality of imported inputs the lower the input price index. As in Gopinath and Neiman (2014), the imported input price index is a decreasing function of the amount of imported input varieties because the elasticity of substitution between imported input varieties ranges from $0 < \theta < 1$.

The unit cost indexes for firms relying only on domestic inputs (index by *d*) and importing firms (index by *m*) are as follows. For firms relying only of domestic inputs, the unit cost is equal to $c_d = 1$ since the price of domestic inputs is equal to the wage of non-production workers (*L*) which is used as a numeraire, $c_d = 1$. For importing firms, the unit cost index is a function of imported input price index determined by input tariffs, foreign input quality and varieties: $c_m = \left(1 + (P_m)^{\frac{\alpha}{\alpha-1}}\right)^{\frac{(\alpha-1)\eta}{\alpha}}$. Importing firms pay a fixed cost, while importing reduces their marginal cost as access to high-quality imported inputs increases their efficiency.

[4] The presence of fixed costs of importing that increased with the amount of input varieties is consistent with the idea that each additional foreign variety requires paying an extra fixed importing costs and it is in line with the empirical evidence found by Halpern et al. (2015).

Output quality

The quality of each product k is determined by the quality of inputs and input variety. For simplicity we assume that domestic inputs are of quality equal to 1, while each foreign input variety v with quality $\gamma_v > 1$. Therefore, output quality, z depends on the average input quality of all varieties $\widetilde{\gamma_v}$ and the set of imported input varieties Ω:

$$z = (\Omega\widetilde{\gamma_v})^{\xi} \tag{7}$$

with $\xi > 1$ .The output quality increases with input quality upgrading and with access to new imported inputs varieties[5].

Input-trade liberalization, input variety, input and output quality, prices, markups

Firms maximize profits for each product k separately and choose their optimal price and output level subject to the linear demand they face for each product k derived from the quasi-linear utility function: $\pi_k = p_k q(\mathrm{k}) - w_u L - p_d X_d - P_m X_m - w_s f_k$. Importing firms' optimal price p_k, markup μ_k, revenues and profits for product k are given by:

$$p_k(c) = \frac{c_m}{2}\left[\hat{P}z + c\right] \qquad \mu_k(c) = \frac{c_m}{2}\left[\hat{P}z - c\right] \tag{8}$$

$$r_k(c) = \frac{c_m L}{4v}\left[\widehat{P^2} - \left(\frac{c}{z}\right)^2\right] \qquad \pi_k(c) = \frac{c_m L}{4v}\left[\hat{P} - \frac{c}{z}\right]^2$$

The optimal output price and markup depend on the initial productivity (1/c), input quality and input variety. As in the baseline model of Melitz and Ottaviano (2008), initially more productive firms (with lower initial marginal cost) charge higher markups. In our setting with input quality and variety, there are two opposite effects at play. On the one hand, access to high quality foreign inputs and more varieties decreases the imported input price index and thereby the input-cost index of importing firms (c_m) putting down output prices and markups (cost-efficiency effect). On the other hand, product quality (z) increases prices and markups. Product quality, z, determined by equation (7), is an increasing function of input quality and input variety. Under the assumption that there are increasing returns to upgrading input quality and input variety on output quality, $\xi > 1$, the latter effect dominates and input quality

[5] There are increasing returns to scale to upgrading input quality and input variety since the parameter $\xi > 1$.

upgrading and access to more varieties of inputs increases prices, markups, revenues and profits. Plugging equation (7), output quality, into equation (8) gives the optimal prices, markups, revenues and profits as a function of imported input quality and input variety.

$$p_k(c) = \frac{c_m}{2}\left[\hat{P}(\Omega\widetilde{\gamma_v})^{\xi} + c\right] \qquad \mu_k(c) = \frac{c_m}{2}\left[\hat{P}(\Omega\widetilde{\gamma_v})^{\xi} - c\right] \tag{9}$$

$$r_k(c) = \frac{c_m L}{4\upsilon}\left[\widehat{P^2} - \left(\frac{c}{(\Omega\widetilde{\gamma_v})^{\xi}}\right)^2\right] \qquad \pi_k(c) = \frac{c_m L}{4\upsilon}\left[\hat{P} - \frac{c}{(\Omega\widetilde{\gamma_v})^{\xi}}\right]^2$$

After profit maximization, firms also choose optimally their demand for production workers (L), domestic (X_d) and foreign inputs (x_{mv}). The set of foreign input varieties is also determined endogenously by profit maximisation net of the fixed cost of importing varieties, where π_i is total profits of the firm:

$$\Omega = \arg\max_{\Omega} \{\pi \quad - F_m(|\Omega|)\} \tag{10}$$

Theoretical implications

Our simple framework generates the following three testable hypotheses:

(i) Input-tariff cuts lead to firms' increasing their product scope and quality.

Since there are fixed costs of producing new final goods products, the increase in firms' variable profits after input-tariff cuts allows firms to introduce new varieties of final goods, expanding their product scope *N* as shown in equation (2). As output quality is an increasing function of imported input quality and inputs varieties (equation 7), input-trade liberalization - which improves access to input quality and variety - allows firms to upgrade the product quality.

(ii) Input-tariff cuts reduce firms' production costs, increase their productivity and raise the skill-intensity of production.

Input tariffs reductions lower the relative unit cost of importing firms.[6] As shown in equation (6), the greater the imported input quality (γ_v) the higher the efficiency of foreign varieties in the production process and the lower the imported input price

[6] Plugging the imported input price index (equation (6)) into c_m and partially differentiating c c_m with respect to the input tariffs, we obtain $\frac{\partial c_m}{\partial \tau_m} > 0$.

index and consequently the unit production cost.[7] This increase in profits for importers of higher quality inputs in turn allows firms to import more varieties as shown in equation (10). The growth in the set of foreign input varieties induces a further reduction of the imported input price index - as shown in equation (6) - decreasing even more the unit cost of importers.

Productivity gains from foreign input quality upgrading arise as importing firms can produce more output with the same amount of inputs of better quality. This can be seen by plugging equation (5) into (4) and then into equation (3).

Producing new products also requires additional non-production workers to cover the fixed cost of product innovation that is skill intensive as shown in equation (1) as skilled labor accounts for the fixed costs of innovation.

(iii) Input-tariff cuts benefit more productive firms with higher markups and affect quality-adjusted consumer prices, firms' markups and skill premia positively.

The model implies a positive reallocation of market shares across firms within an industry as more productive firms are more prone to change production processes and introduce more and higher quality products. This is because initially more productive firms (lower marginal costs, c) will set lower prices and have larger revenues and profits. Input-trade liberalization will allow firms to improve the quality and varieties of foreign inputs raising output quality that increases firms' revenues and profits. This effect will be stronger for more productive firms (lower c) as shown in equations (8) and (9) by the interaction between the initial productivity ($1/c$) and output quality (z). In this setting more productive firms with lower initial marginal cost charge higher markups as shown in equation (8). More productive firms do not pass through the entire initial cost differential to consumers in their prices. Consumers may still benefit depending on the extent to which firms increase their markups and/or pass through gains in the form of lower quality-adjusted prices. Equation (9) also show that output quality upgrading as a result of access to more input varieties and higher quality allow most productive firms (lower c) to increase output quality and markups.

[7] This outcome is already present in Grossman and Helpman (1991) and Halpern et al. (2015), where the quality of foreign inputs is interpreted as a relative cost advantage due to the higher efficiency in the production process that arises from the use of high-quality inputs.

As to workers, with the skill-intensity of production required for new products to be produced from high-quality inputs, input-trade liberalization, enhances skilled labor demand of firms producing new final goods and so it will raise the relative wage of skilled labor.

Theoretical implications of output trade liberalization

In the theoretical framework presented above, we abstract from the effects of output tariff reductions for tractability reasons. In this section we discuss the similarities and differences in expected impacts of output-trade liberalization compared to input-liberalization as identified in the relevant theoretical literature.

Regarding product scope, the multi-product firms' model developed by Bernard et al. (2011) predicts that firms will reduce their product scope and concentrate their production in the core products to face tougher foreign competition resulting from output-tariff cuts. They also provide empirical evidence. This suggests a reverse effect of output-trade liberalization compared to input-trade liberalization on product scope.

By contrast, models on output-trade liberalization's effects project positive impacts on firm product quality as expected for input-trade liberalization. Antoniades (2015) extends the heterogeneous firms model developed by Melitz and Ottaviano (2008) to include output quality and shows that competition raises the scope for quality differentiation. Most productive firms upgrade output quality to face competition. Investments to improve product quality also relates to the literature on firms' innovating to escape competition (Aghion and Howitt, 2005; Aghion et al., 2005, 2009). Amiti and Khandelwal (2013) and Fernandes and Paunov (2013) show firms upgrade the quality of their products after output tariffs cuts.

As to firm production processes, output-trade liberalization is expected to push firms to improve their productivity, adding to expected gains from input-tariff cuts (Bernard et al., 2011; Mayer et al., 2016). Several empirical works using micro-data have found positive effects of foreign competition on within-firms' TFPR (e.g. Pavcnik, 2002, Fernandes, 2007; Amiti and Konings, 2007; Topalova and Khandelwal, 2011; among others). In addition, Eckel et al. (2015) provide a model and show empirically that foreign competition leads firms to change their production, including their investments to improve product quality.

As to the distributional implications, finally, several models predicts the pro-competitive effects of trade on markups as in the model of Melitz and Ottavianno (2008). In a framework with variable markups and heterogeneous firms, they show that trade liberalization through the competition channel will reduce markups. Levinsohn (1993), Harrison (1994) and De Loecker et al. (2016) show that output tariff cuts have pro-competitive effect of reducing firms' markups.

2. Ecuador's trade liberalization

Ecuador's accession to the WTO

In this section, we describe Ecuador's trade integration process, and in particular the major change brought by the country's accession to the WTO in the mid-1990s, and the trade-policy instruments that were applied.

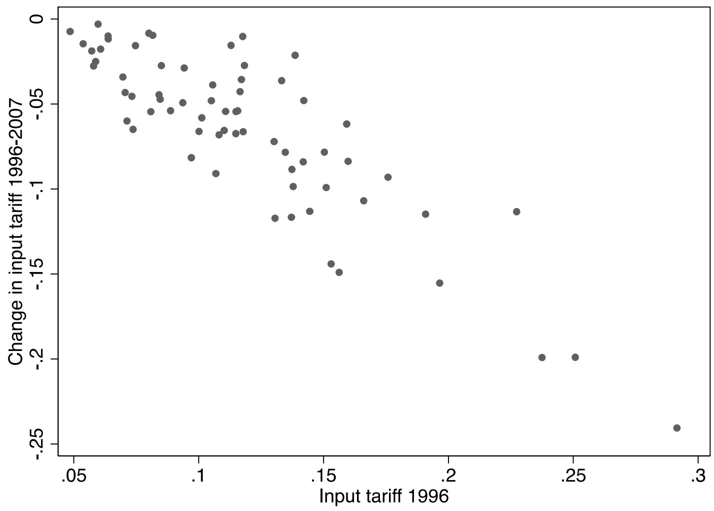
Ecuador's trade policy during the 1970s and 1980s was characterized by trade protection policies focusing on import substitution as in other Latin American and Caribbean countries during this period. Trade was consequently very restricted in order to shield industries from foreign competition, with high nominal tariffs and import licenses in most sectors.

A unilateral trade-reform plan was launched in the mid-1990s due to the accession to the World Trade Organization (WTO) in 1996. The main implication of acceding to WTO was a unilateral trade liberalization process in Ecuador that consisted in substantial tariff reductions that was accompanied by other measures that facilitated firms' access to foreign markets and to intermediate inputs from abroad: reductions to import restrictions, the modernization of trade institutions (customs procedures and simplification of steps for trade procedures), and a reinforcement of trade preferences that Ecuador received from the U.S. within the ATPA (Andean Trade Promotion Act). Several laws promoting free trade were also signed, including the "Law of Export Facilitation and Maritime Transport" and the "Customs Law". The latter reduced customs procedures from 18 steps to only 3 and simplified them.

After Ecuador entered WTO, the government signed the "Foreign Trade Law" (1997). This law resulted in the creation of the Ministry of Foreign Trade. The aim of this new Ministry was to promote export diversification and foreign technology transfer through imports of inputs and capital goods. During the period 1997-2000, multilateral negotiations within WTO took place focusing on specific accession commitments of Ecuador. These negotiations led to further tariff reductions and the elimination of import licenses in specific sectors.[8]

With tariff reductions, the highest initial input tariffs experienced the biggest reduction over the period. Figure 1 shows the variation in industry level input tariffs between 1996 and 2007. Input tariffs at the industry level are computed as the input tariffs at the product level faced by each firm using constant weights averaged over the period. Average output tariffs declined by 6 percentage points and average input tariffs declined by 7 percentage points during the period. The maximum level of reduction of input tariffs is 28 percentage points for the 3-digit industry 315 (manufacture of electric lamps and lighting equipment) from an input tariff of 33% in 1996 to 5% in 2007. The minimum input tariffs of almost zero in 2007 correspond to the 3-digit industry 369 (manufacture n.e.c of musical instruments, toys jewelry). Our empirical framework makes use of the sectoral differences in input tariff reductions.

Figure 1: Changes in input tariffs from 1996-2007



Source: Authors' calculation based on input tariff at the product level faced by firms constructed by matching the Ecuador's effectively applied import tariffs with respect to the rest of the world at HS 6-digit product level from WITS (World Bank) with our data by establishing a product correspondence to the 11-digit ISIC-Rev. 3 categories of Ecuadorian firms' input products and the HS 6-digit level.

[8] See for more details the description of these negotiations can be found at https://www.wto.org/english/thewto_e/acc_e/a1_ecuador_e.htm

Exogeneity of tariff changes

Our analysis exploits the changes in input-tariffs across industries over the 1996-2007 period. For this approach to be valid, potential reverse causality between tariff changes and firm performance needs to be excluded. In particular, it should not be the case that firms producing in industries with greater input-tariff cuts lobbied for these lower tariffs.

We test whether tariff changes are exogenous to initial industry and firm characteristics. As done in previous studies such as Topalova and Khandelwal (2010) and Goldberg et al. (2010), we regress first changes in input and output tariffs on a number of industry characteristics and firm performance in the initial year. Annex Tables A.1 and A.2 show that input and output tariff changes between 1996 and 2007 were uncorrelated with industry-level characteristics and with initial firm performance measures. If the government had targeted specific firms and industries during trade liberalization, then tariff changes would have been correlated with initial firm performance.

3. A first glance at the data

Firm-product level data

We use a Census panel dataset collected by the Ecuadorian Institute of Statistics (INEC) of formal manufacturing plants (corresponding to ISIC Rev. 3 category D) with 10 or more employees for the period 1997-2007.[9] The manufacturing dataset contains 16,678 manufacturing plant-year observations and has information on plants overall sales and value-added, employment, capital investments as well as expenditures on production as provided in most firm census data.

The distinctive feature of our data is that we can link this information to two other datasets, which contain information on plants' intermediate inputs and on plants' output products, respectively. The first dataset gives annual plant-level information on primary materials, auxiliary materials, replacements and accessories, and packing materials used for production. For each intermediate input, plants provide information on the purchasing price and quantity separately for national and foreign supplies. The

[9] The dataset collects information at the plant level. For convenience we refer to the terms plant and firm interchangeably.

second dataset provides information for each plant's final products. We have information at the firm-11 digit product level on quantities and values are sold in the market as well as quantities produced and the cost of production for each product.

We implement several data cleaning procedures and check the quality of our dataset following Bernard et al. (2010), Kugler and Verhoogen (2011) and Goldberg et al. (2010). We test the quality of our products data by identifying firms with irregular output product drops (i.e. products that disappear from production and then reappear again) and firms with product jumps (i.e. products that are produced only once in the intermediate years of firm presence in the sample). These tests, which follow Bernard et al. (2010), are satisfactory in that product drops and jumps are relatively infrequent. Moreover, the consistency of our findings to those Kugler and Verhoogen (2012) obtain for Colombia on importer characteristics provide additional confidence in using this novel dataset for empirical analysis. The data appendix describes the dataset and cleaning procedures in detail (see Tables A.6 to A.9).

We find similarities between statistics based on our product level data and those obtained based on comparable data for other countries. Ecuadorian firms' core products represent 77%, 50% and 43% for plants that produce 2, 6 and 8 products respectively.[10] This compares to the evidence by Bernard et al. (2010) for the United States and Goldberg et al. (2010) for India. The average firm produces 2.5 goods (s.d. 2), while the maximum products sold by a firm is 14. Single-product firms represent, on average across 1997-2007, about 32% of overall output sales, a lower share compared to the numbers for India and the United States. The share of single-product firms decreased substantially over the period: In 1997, 48% of Ecuadorian firms are single-product firms in 1997, while in 2007 only 23% of firms are single-product firms. Among those firms that are present over the entire period, 30% of their 2007 products were new relative to 1997. The number of inputs used in production is less skewed than for outputs reflecting the multiple set of inputs needed for output production.[11]

[10] These and other unreported findings are available from the authors upon request.

[11] We also compare the standard deviations of purged unit values for 2-digit ISIC Rev. 3 industries with the same standard deviations obtained for a Colombian products dataset by Kugler and Verhoogen (2009, 2012). Purged unit values are the residuals from regressions of log unit values on product fixed effects or from regressions of log unit values on product-year fixed effects. Our standard deviations are somewhat larger than theirs but are sufficiently within bounds to be explained by the fact that we consider more aggregate industry categories and a country with a distinct profile of manufacturing production.

Our data allow obtaining measures of quality-adjusted prices, firm markups – using information on product sales value and production costs - and quantity total factor productivity (TFPQ) and the more conventional revenue-based total factor productivity (TFPR). We obtain productivity indexes as used in Aw et al. (2001) and Arnold and Javorcik (2009) based on Caves et al. (1982) which allow for flexible and heterogeneous production technologies and consistent comparisons of TFP in plant-level panel data (Van Biesebroeck, 2007). We use firm-level output prices to obtain TFPQ and industry-level output prices to obtain TFPR. The advantage of TFPQ relative to TFPR is that we can disentangle efficiency gains from pure price (markup) effects (Foster et al., 2008; De Loecker, 2011). The data appendix describes how these productivity indexes are obtained.

To identify the impact of tariff reductions, we use Ecuador's effectively applied import tariffs at HS 6-digit product level as provided by the WITS database of the World Bank. The effectively applied tariffs correspond to the most favorite nation (MFN) tariff or the tariff applied by the country as decided under a preferential trade agreement, if applicable. Input tariffs are computed as a weighted average of the input tariffs at the product level faced by each firm using constant weights averaged over the period. We link the tariff data to our data on Ecuadorian firms by establishing a product correspondence between the 11-digit ISIC-Rev. 3 categories of Ecuadorian firms' output and input products and the HS 6-digit product level categories. In the firm-product estimations input tariffs are at the HS 6-digit product level, while in the firm level estimations both output and input tariff measures are aggregated at the 3-digit ISIC-Rev.3 industry level using constant weights.

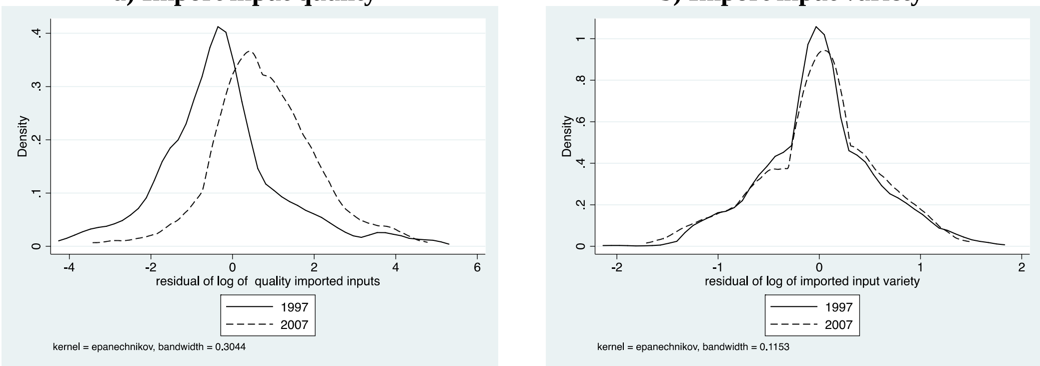
Stylized facts

With trade liberalization, Ecuador's imports increased by 14% on average and doubled between 1994 and 2004. In this section we document several empirical facts on the characteristics of imported intermediate inputs and firms' sourcing intermediate inputs from abroad relative to non-importance.

First, the quality of imported inputs of Ecuadorian firms increased but less so their access to new input varieties from 1997 to 2008 (Figure 2).

Figure 2: Distribution of imported input quality and variety between 1997 and 2007

a) Import input quality **b) Import input variety**



Notes: We compare the evolution of input-quality, measured as a residual of a demand function estimation as described in section 5.1, by regressing this variable on firm fixed effects, industry-year and province-year fixed effects and plotting the residuals. In this way we compare input-quality of the same firm since only firm-product pairs that are present in both years are included.

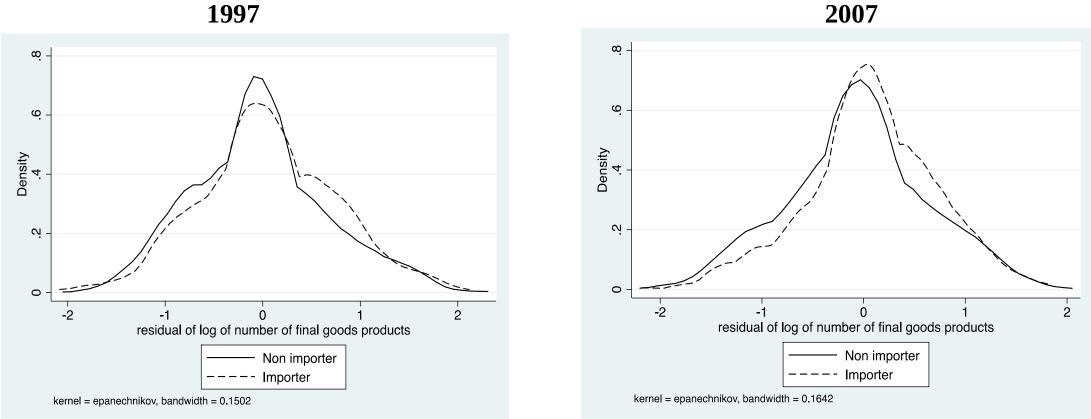
Second, Ecuador's importers rely on more varieties of inputs and pay more for inputs from abroad than non-importers. These findings (shown in Table A.3 in the Annex), which replicate an analysis conducted by Kugler and Verhoogen (2009) for Colombian firms, suggest that importing inputs allows Ecuadorian firms access higher quality inputs from abroad (inputs of higher price) and more input variety.

Third, between 1997-2007 following Ecuador's trade liberalization, importers increased the number and quality of final goods products (Figures 3a and b). The skill intensity of importers' production also increased relative to non-importers (Figure 3c).

Figure 3: Distributions of firm product scope, quality and production skill-intensities, by import status in 1997 and 2007

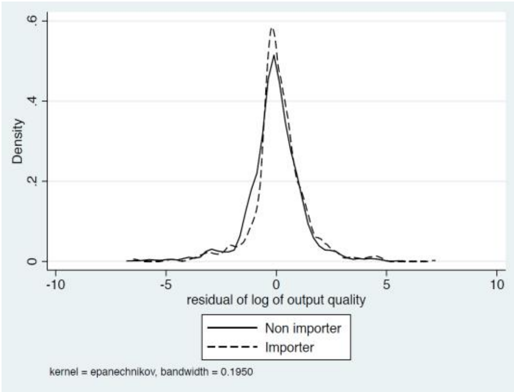
a) Product scope

1997 **2007**

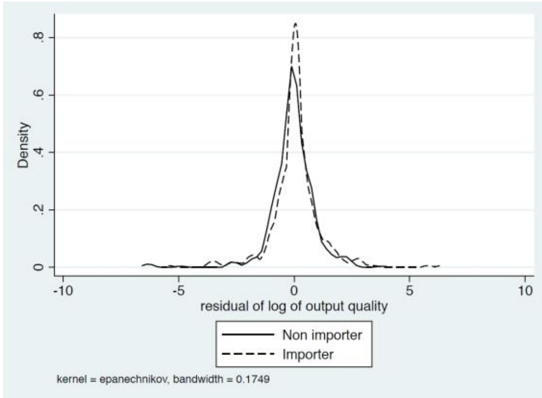


b) Product quality

1997

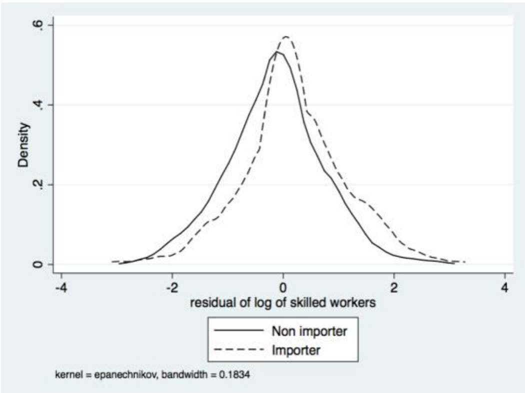


2007

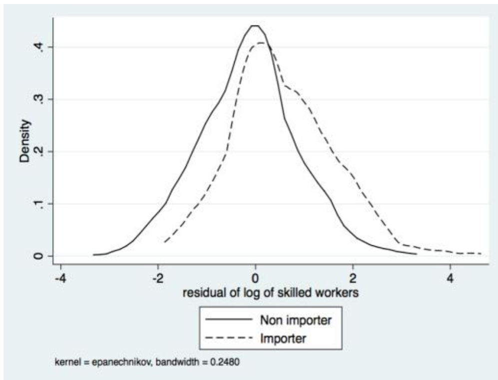


c) Skill intensity

1997



2007



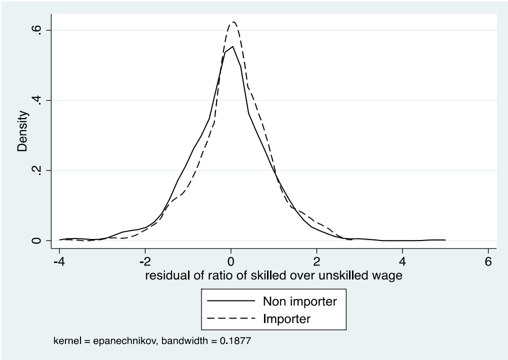
Notes: We compare the number of products, output quality and relative demand for skilled labor at the firm level in 1997 and 2007 by regressing those variables on industry-year and province-year fixed effects and plotting the residuals for importers and non-importers. Only firms that are present in both years are included.

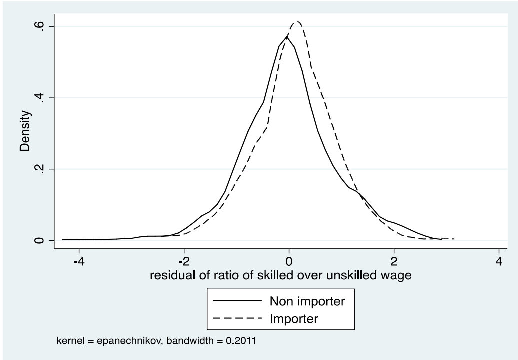
Fourth, we observe changes with regards to the returns to firms and their investors, consumers and differently skilled workers. Firms' average markups increase by 13% from 1997 to 2007. At the same time the quality-adjusted prices decrease by 7%. We also see a shift towards a higher skills wage premium in 2007 for importers relative to non-importers (Figure 4).

4. Trade liberalization's impact on input quality and variety

This section explores the causal impact of input tariff cuts on firms' access to imported input quality and on the ability of firms to source new input varieties from abroad.

Figure 4: Distributions of firms' skill premia by import status in 1997 and 2007





Notes: We compare the wage skill premium at the firm level by regressing those variables on industry-year and province-year fixed effects and plotting the residuals. Only firms that are present in both years are included.

Measuring input-quality upgrading

In order to test for the impact of imported input-quality upgrading, we first estimate imported inputs quality following the methodology proposed by Khandelwal et al. (2013) (KSW hereafter). This measure of quality developed by KSW is widely used to capture product quality (Bas and Strauss-Kahn, 2015; Fan, Li and Yeaple, 2015, 2018, Manova and Yu, 2017, among others).

KSW demonstrate that assuming a CES utility function where product quality acts as a demand shifter, the quality of each product can be estimated using information on quantities, unit values and the elasticity of substitution across products. Quality is then represented as any product attribute that shifts the demand curve as first proposed by Sutton (1991). Inferring product quality from demand functions means that conditional on prices a product with higher demand (quantity) is assigned higher quality.

KSW estimate quality as a demand shifter that corresponds to the residual of an OLS estimation of the quantity and price (unit value) on country-time fixed effects - that control for price index and income at destination - and product fixed effects that control for variation across products since prices and quantities are not necessarily comparable across products. The estimated quality is a function of the residual of such estimation and the elasticity of substitution between products. In their case, the objective is to estimate product quality of exported products at the firm level for Chinese firm-product disaggregated at the HS 6-digit level and country of destination level from customs data for the textile sector.

For our purposes we adapt KSW's estimation to estimate the quality of imported inputs by firms in Ecuador. The quality of imported inputs corresponds to the residual of an OLS estimation of the following regression:

$$x_{ikt} + \sigma p_{ikt} = \alpha_k + \alpha_t + \eta_{ikt} \tag{I}$$

where x_{ikt} and p_{ikt} denote the natural logs of the quantity and price of product *k* at 11-digit code imported by firm *i* in year *t*. The product fixed effect α_k controls for unobservable characteristics across products since prices and quantities are not necessarily comparable across products. The estimated log quality, λ_{ikt}, depends on the residual of that estimation η_{ikt} and the elasticity of substitution σ: $\lambda_{ikt} = \eta_{ikt}/(\sigma - 1)$.

We estimate quality of imported and domestic inputs separately following this method for each HS 2-digit level sector to take into account sector-specific differences. We rely on the elasticities of substitution estimated by Broda et al. (2006) for Ecuador. We also present a robustness test relying on the average elasticity of substitution equal to 5 for the United States estimated by Broda and Weinstein (2006).

The indicator of input quality derived from this estimation implies that conditional on input price, foreign varieties with higher import quantities (demand by domestic firms) are assigned a higher quality relative to other imported varieties with lower quantities within the same industry (HS 2-digit sector level).

Input-trade liberalization and imported inputs quality upgrading

In this section, we look at the relationship between import tariff cuts and changes in the quality of imported inputs. We use the estimated quality, λ_{ijkt}, of firm *i* importing product *k* in industry *j* in year *t* as the dependent variable and regress it on input tariffs applied by Ecuador at the HS 6-digit product level, including firm-product, industry-year fixed effects as well as firm initial size trend (where the initial size of firm *i* is defined by the logarithm of total production of the firm):

$$\lambda_{ijkt} = \alpha + \gamma_{I\tau} \text{ Input } \tau_{\ k,t-1} + \gamma_S \text{ Size}_{\ i,t0} * \eta_t + \mu_{ik} + \theta_{jt} + \varepsilon_{ikjt} \tag{II}$$

where Input $\tau_{k,t-1}$ represents the input tariffs that Ecuador effectively applies to product *k*. In this specification, where we estimate within firm-product effects of trade liberalization on the quality of imports at the firm-product level, the import tariffs that

Ecuador applies to a specific input product k are the tariffs on intermediate inputs. Output tariffs at the industry level that capture foreign competition effects on the domestic market have no direct impact on imported inputs and consequently are not included in this specification. $Size_{i,t0} * \eta_t$ corresponds to initial firm size trends, where the initial size of firm i is defined by the logarithm of total firm sales. These variables control not only for pre-existing firm trends but also for unobservable shocks to firms of similar sizes over time. All specifications include firm-product fixed effects μ_{ik}, that take into account unobservable and time-invariant firm-product characteristics and industry-year fixed effects, θ_{jt}, that control for macroeconomic shocks varying across sectors and time affecting all firms in the same sector in the same way.

Columns (1) and (2) of Table 1 present the results. The coefficient of interest on import tariffs at the product level is negative and significant, indicating that input-trade liberalization allows firms to upgrade the quality of their imported inputs. The estimated coefficient suggests that for a 10 percentage point reduction of input tariffs, importing firms increase the quality of their intermediate inputs by 34%. Column 2 shows that these results are robust to using the median sigma for the US (5) to estimate imported inputs quality. As expected the magnitude of the effect is much smaller in this latter case as we assume the elasticity of substitution is the same across all sectors and equal to 5.

Next we subject these results to a series of validation tests. First, we verify that the effects we identify are not simply the result of technological progress that may have improved input quality and be correlated with import tariffs. If this was the case, we should have the same effect on both domestic and foreign inputs. We run a falsification test and estimate the effect of import tariffs on the quality of domestic intermediate inputs. We find that import tariffs have no significant effect on the quality of domestic inputs (columns 3 and 4 of Table 1).

Second, it may be that our input quality measure is capturing higher prices but not quality. If this was the case, we would expect firms not to increase the quantity of intermediate inputs purchased from abroad. We test for this possibility and look at the effects of input-trade liberalization on the quantity of imported inputs. Column (5) shows that firms increase the quantity of imported inputs with input tariff cuts. The estimated coefficient suggests that for a 10 percentage point reduction of input tariffs, importing firms increase the quantity of their foreign intermediate inputs by 20%.

Table 1: Input tariff cuts, inputs quality and quantity

	Input quality				Quantity of inputs	
	Imported		Domestic		Imported	Domestic
	sectoral sigma	sigma 5	sectoral sigma	sigma 5		
	(1)	(2)	(3)	(4)	(5)	(6)
Input tariffs(k,t−1)	-3.409**	-0.882**	1.074	0.682	-2.065*	1.725*
	(1.608)	(0.419)	(0.800)	(0.435)	(1.234)	(0.888)
Initial firm size trend	yes	yes	yes	yes	yes	yes
Firm-product fixed effects	yes	yes	yes	yes	yes	yes
Industry-year fixed effects	yes	yes	yes	yes	yes	yes
Observations	15,273	15,273	41,580	46,167	16,142	46,171
R-squared	0.33	0.43	0.42	0.48	0.79	0.80

Notes: In columns (1) to (4) the dependent variable is the estimated quality of imported (domestic) inputs of firm i and product k in year t. In columns (5) and (6) the dependent variable is the logarithm of the quantity of imported (domestic) products. Heteroskedasticity-robust standards errors are reported in parentheses. Standard errors are clustered at the product level. ∗∗∗, ∗∗, and ∗indicate significance at the 1, 5 and 10 percent levels respectively.

Third, we look at the effect of input tariff on the domestic quantity of intermediate goods. Results presented in column (6) suggest that firms have substituted domestic inputs by foreign ones during trade liberalization. The estimated coefficient indicates that actually Ecuadorian firms have reduced the demand for domestic inputs by the same amount that they have increased the demand for foreign intermediate inputs.

Input-trade liberalization and new varieties of imported inputs

Next we turn to investigate the possible impact of input-trade liberalization on new varieties. We identify from our data new varieties of foreign inputs (at the 11-digit level) that have not been sourced in the previous year from national producers or abroad. The approach allows testing for the within-firm effect of input tariffs cuts on access to new varieties of foreign inputs. The approach differs from Goldberg et al. (2010) who rely on aggregate input product data to identify the effect of tariff cuts on imported inputs varieties.

In order to test the input variety mechanism, we carry out two types of tests at different level of aggregation: at the firm-product-year and at the firm-year levels. First, we look at the probability domestic firms have of sourcing a new variety from abroad by regressing a new variety of foreign inputs indicator variable at the firm-product level on import tariffs applied by Ecuador at the HS 6-digit level, including firm-product fixed effects and, as in our previous model (II), industry-year fixed effects and a firm initial size trend. The dependent variable that captures imports of a new variety at the firm-product level is a dummy variable equal to one if the firm imports a new 11-code product that has not been sourced in the domestic or foreign market in the previous year. Results, presented in column (1) of Table 2, suggest that for a 10 percentage point reduction of input tariffs, the probability of importing a new variety of inputs increased by 1%.

Conducting the same falsification test as before on input quality, we investigate the effect of input tariff on the probability of sourcing a new variety of domestic intermediate goods. Results presented in column (2) suggest the likelihood that firms buy new varieties of domestic inputs is lower, possibly because they substituted domestic varieties for imported varieties. This evidence is consistent with the previous finding that tariff cuts reduce firms' demand for domestic inputs (column 6, Table 1).

Second, we investigate the effects of input tariff cuts on the number of new varieties of foreign inputs that a firm purchases in a year and the share of new imported varieties over all varieties that the firm purchases. In this case, we test whether firms in industries facing greater input tariff cuts have increased the amount of imported input varieties they did not source before, relative to firms facing lower input tariff cuts.[12] The coefficient in column (3) and (4) of Table 2 suggest that after a 10 percentage point reduction of input tariffs, firms increase the number of new imported varieties by 5 % and the share of new imported input varieties relative to total inputs by 1.2 %.

Table 2: Input tariff cuts and new varieties of imported inputs

	Firm-product-year level estimations		Firm-year level estimations	
	New imported variety dummy	New domestic variety dummy	Number of new imported varieties	Share of new imported varieties
	(1)	(2)	(3)	(4)
Input tariffs (k,t−1)	-0.106**	0.242***	-0.542***	-0.125*
	(0.054)	(0.079)	(0.198)	(0.068)
Initial firm size trend	yes	yes	yes	yes
Firm-product fixed effects	yes	yes		
Industry-year fixed effects	yes	yes		
Firm fixed effects			yes	yes
Year fixed effects			yes	yes
Observations	61,709	61,709	12,352	12,352
R-squared	0.32	0.41	0.42	0.87

Notes: Standard errors are clustered at the product level. ∗∗∗, ∗∗, and ∗ indicate significance at the 1, 5 and 10 percent levels respectively.

[12] Input tariff at the industry level were constructed as explained in Section 3.2.

5. Impacts on trade liberalization on firms' production

This section explores the impacts of trade liberalization on firms' product scope and quality and implications on firms production processes with regard to production costs, skill intensity and productivity.

Product scope and quality

We investigate the relationship between the availability of imported intermediate goods due to input-tariff reductions and firms' product scope and output quality. We estimate the following model, using as before a within-firm estimator, to test this relationship:

$$\ln Y_{ijt} = \alpha + \gamma_{I\tau}, \text{Input}\,\tau_{j,t-1} + \gamma_O \text{ Output}\,\tau_{j,t-1} + \gamma_s, \text{Size}_{i,t0} * \eta_t + \mu_i + \eta_t + \varepsilon_{ijt} \quad \text{(III)}$$

where $\ln Y_{ijt}$ is one of the outcome variables measuring firms' production choices: the logarithm of the number of products firm i produces (the products are available in the dataset at 13-digit levels) and output quality across all the products a firm i produces, in a 3-digit industry j and year t.

Output quality is measured at the firm-11-digit product-year level following the methodology developed by KSW we also use to compute input quality in the previous section. The quality of an 11-digit product produced by a firm in a year is the residual of a demand function estimation as in equation (I) including product and year fixed effects. In the firm level estimations, we aggregate output quality across all the products a firm produces at firm-year level. In the case of output quality we look at the effects of industry level input tariff cuts on both the firm-level measure of output quality as well as the disaggregated measure of product quality at the firm 11-digit product level applying in the latter case firm-product fixed effects.

The input $\tau_{j,t-1}$ is the corresponding input tariffs of the 3-digit industry computed as a weighted average of the input tariffs at the product level faced by each firm producing in that industry using constant weights averaged over the period. Output $\tau_{j,t-1}$ is the corresponding output tariffs of the 3-digit industry. As in the previous specification we control for pre-trends at the firm level, $Size_{i,t0} * \eta_t$ that corresponds to initial firm size trends. The estimation includes firm fixed effects in addition to time fixed effects, η_t, in order to take into account unobservable shocks varying across time affecting all firms in the same way. Since tariffs vary at the 3-digit industry level over time, the standard errors are clustered at the 3-digit industry level.

Table 3 presents the estimation results for equation (III). Our findings show that lower input tariffs affect firms' product growth. In column (1) the coefficient of input tariffs is negative and significant at the 5% confidence level, indicating that a 10 percentage point drop in input tariffs increased firms' product scope by 2.4%. Results also show that output-trade liberalization, which enhances foreign competition for Ecuadorian firms, has a negative effect on their product scope. For the average output tariff reduction over the period (6 percentage points), firms reduced their product scope by 2.8%. This result on output tariff reductions is in line with the work of Bernard et al. (2011), they find that the US-Canada trade agreement by reducing output tariff induce firms to drop products.

Next, we explore the effects of input quality upgrading and new imported varieties on changes in firms' product scope. Since firms' import quality upgrading and access to new varieties of inputs are endogenous to firms' improvement of their production process, we rely on instrumental variable estimator in a 5-year difference equation to disentangle the effects of input quality and variety. Input quality upgrading at the firm level is computed as a dummy equal to one if the firm increases the quality of its products between *t* and *t-5*. Following the same procedure, we obtain a measure of a dummy for firm access to new imported varieties. We instrument input quality upgrading and firm changes in access to new varieties following the approach used by Trefler (2004). Results are presented in column (2) of Table 3. Estimates show that access to new imported varieties is the main mechanism that affects firm product scope, confirming the findings of Goldberg et al. (2010) for India.

Moreover, we analyze the effect of input-trade liberalization on firms' output quality upgrading. Column (3) of Table 3 presents the firm-level and column (4) the firm-product level estimations. Our findings show that for a 10 percentage point reduction of input tariffs, the average firm has improved the quality of their final good products by 7 (column 4) to 11% (column 3), depending on the specification. Only in the firm-product level estimation output tariff reductions, through foreign competition, has a positive and significant effect on output quality upgrading (column 4). For a 10 percentage point reduction of output tariffs, firms improve their product quality by

5.7%. This finding complements results for Goldberg et al. (2010) who focus only on the input variety channel.

Table 3: Impacts of input and output tariffs on product scope and output quality

	Product scope		Product quality		
		Growth rates of firm *i* between t and t-5		firm-product level	Growth rates of firm *i* between t and t-5
	(1)	(2)	(3)	(4)	(5)
Input tariff(j,t-1)	-0.246**		-1.152**	-0.671**	
	(0.125)		(0.553)	(0.310)	
Output tariff(j,t-1)	0.477***		0.443	-0.571**	
	(0.077)		(0.287)	(0.271)	
Import quality upgrading		-0.194			1.244*
		(0.120)			(0.662)
New imported varieties		0.544*			-2.131
		(0.321)			(1.430)
Initial firm size trend	yes		yes	yes	
Firm fixed effects	yes		yes		
Year fixed effects	yes	yes	yes	yes	yes
Firm-product fixed effects				yes	
Observations	12,343	5,593	12,343	56,031	5,588
R-squared	0.84		0.55	0.39	
P-value of Hansen Test		0.51			0.45

Notes: For the instrumental variable estimates reported in columns 2 and 5, instruments used are 5 year changes in input tariffs and initial input tariffs in 1996 interacted with initial levels of firms' imported input variety and input quality indicator. Heteroskedasticity-robust standards errors are reported in parentheses. For results reported in columns 1, 3 and 4 standard errors are clustered at the 3-digit industry level. For results in columns (2) and (5) in the instrument variables the coefficients are clustered at the firm level since import quality upgrading and new imported varieties are dummies at the firm level. ∗∗∗, ∗∗, and ∗ indicate significance at the 1, 5 and 10 percent levels respectively.

In addition, using the same instrumental variable approach described above, we find suggestive evidence that access to high-quality inputs explains firms' output quality upgrading (column 5). These results are in line with a story that firms require complementary high-quality inputs (foreign intermediates and skilled labor) to produce high-quality output products.

Finally, in sensitivity tests reported in Annex Tables A.4 and A.5, we show that these results and those reported in the following section are not due to the expansion of export opportunities and higher export profits nor a result of Ecuador's financial crisis of 1999-2000.

Impacts on the cost-effectiveness, skill intensity and productivity

We next analyze whether trade liberalization affects firms' production as would be expected in view of the impacts on product variety and quality. First, we investigate whether the nature of production changes towards more skill-intensive processes as predicted by our theoretical framework. We test this prediction by using, as widely done in the literature (Pierce and Schott, 2016), information on firms' total production and non-production workers as a proxy of low-skilled and skilled labor.[13] Results, presented in column (1) of Table 4, show that input-tariff cuts have a positive but modest effect on firms' skilled intensity. Our estimates suggest that for a 10 percentage point reduction of input tariffs firms have increased their skill intensity by 0.7%, while output tariff cuts have no significant effect on skill intensity.

Second, we test whether access to intermediate inputs from abroad helped firms save production costs. Estimates at firm-product level shown in column (2) suggest that the cost of production adjusted once input quality accounted for is reduced: for a 10 percentage point reduction of input tariff decreases firm-product costs by 11%. This confirms evidence provided in De Loecker et al. (2016) who also find for India's trade liberalization a 11% reduction of marginal cost after a 10 percentage point reduction in input tariff.

There are two explanations for cost reductions in production. Firms' production costs may fall because the input costs for goods of comparable quality decrease for the same units produced as a result of relying on better inputs. More adequate inputs may also allow producing items consuming less energy and fewer material inputs than before as less is wasted. Alternatively, firms may become more efficient in producing outputs with the new combination of inputs, even as quality and price differences of inputs are taken into account.

We investigate which mechanism explains production cost reductions by testing directly for impacts of input-trade liberalization on production efficiency. Several studies have argued for such gains. These, however, are mostly based on revenue total factor productivity (TFPR) (e.g., Fernandes, 2007; Amiti and Konings, 2007; Topalova and Khandelwal, 2011). TFPR does not allow disentangling the effects of trade liberalization on firm' production efficiency, in terms of producing greater units of output with the same amount of inputs, and firms' price decisions to adjust markups.

[13] Berman et al. (1994) show that, for the United States manufacturing sector, the production/non-production classifications reflect differences in average educational attainment. Machin and Van Reenen (1998) also find that, for the United Kingdom and the United States, the evolution of employment for production/non-production and educational groups is very similar.

This is a serious shortcoming as our model predicts changes in firms' markups with input-trade liberalization. Fortunately, our data provide a measure of "real" productivity, TFPQ. Using this measure, we do not find evidence of improvements in productivity (TFPQ) in the short run. A possible reason for the absence of gains in the short-run may be firms' adjustment processes to entirely new production processes.

Table 4: The impacts of tariffs on skill intensity, production costs, TFPQ and TFPR

Dependent variables:	Skill intensity	Cost adjusted for quality	TFPQ			TFPR					
		firm-product level					industry prices			official deflators	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	.(11)
Input tariff(j,t-1)	-0.077*	1.140***	-0.310			-0.421**			-1.160***		
	(0.045)	(0.438)	(0.276)			(0.212)			(0.269)		
Output tariff(j,t-1)	-0.019	0.373	-0.254			-0.348*			0.05		
	(0.025)	(0.374)	(0.249)			(0.186)			(0.228)		
Input tariff(j,t-2)				-0.469*			-0.596***			-1.221***	
				(0.277)			(0.213)			(0.275)	
Output tariff(j,t-2)				-0.592**			-0.497**			-0.01	
				(0.291)			(0.218)			(0.267)	
Input tariff(j,t-3)					-0.483*			-0.557***			-1.140***
					(0.270)			(0.207)			(0.268)
Output tariff(j,t-3)					-0.007			-0.001			0.141
					(0.283)			(0.209)			(0.237)
Initial firm size trend	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes		yes	yes	yes	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm-product fixed effects		yes									
Observations	12,343	46,464	10,047	10,047	10,047	10,047	10,047	10,047	7,657	7,657	7,657
R-squared	0.77	0.58	0.63	0.63	0.63	0.63	0.63	0.63	0.75	0.75	0.75

Notes: Definitions of all outcome variables are provided in the data annex. Heteroskedasticity-robust clustered at the 3-digit industry level are reported in parentheses. ∗∗∗, ∗∗, and ∗ indicate significance at the 1, 5 and 10 percent levels respectively.

By contrast, consistently with the above-mentioned literature we find positive significant effects of input-trade liberalization using TFPR measures using both aggregated from the firm level prices (columns 6 to 8) and the official industrial deflators from Ecuador Statistical Office (columns 9 to 11). These findings suggest that TFPR impacts are driven by increases in firms' markups. Section 7 explores this potential explanation and confirms this to be the case.

When we introduce longer lags of input and output tariffs in columns 6, TFPQ improves after both input and output tariff cuts: for a 10 percentage point reduction of 2-year to 3-year lagged input tariffs (output tariffs) average firm efficiency improved by almost 5 % (6%) in columns (4) and (5).

The findings presented in this section show that, consistently with our theoretical model, firms producing in industries with larger input tariff reductions increased the number of final goods produced and improved their quality and that firms' production processes become more skill intensive, cost-effective and, in the longer run, more productive.

6. The distributional implications of input-trade liberalization

We next test for the distributional impacts of input-trade liberalization across firms of different "real" productivity (measured by TFPQ) and markups on product scope and product quality and implications on their market share. Then we look implications for consumers, firms' investors and owners and workers by testing for effects on quality-adjusted prices, markups and wage skill premium.

Impacts on higher productivity and markup firms

Our theoretical framework that gains from input-tariff cuts will be concentrated on the initially most productive firms. This would benefit the national economy as the more efficient firms improve production processes and consequently would be expected to gain larger market shares (reducing those of less productive firms). In order to investigate the heterogeneous effects of input-trade liberalization we first classify firms into two groups depending on their initial productivity level. Then we extend our baseline estimation to include interaction terms between input (output) tariffs and high (low) initial TFP Q (above and below the median initial TFPQ). We classified firms according the their TFPQ in the initial year of the sample to avoid changes in productivity arising from trade liberalization to affect our findings.

Columns (1) and (3) in Table 5 show the results for product scope from firm level estimations and output quality for firm-product level estimations. Our findings indicate that the effects of input-trade liberalization are concentrated on initially more productive firms: for a 10 percentage point reduction of input tariffs the most productive firms increase their product range by 4% and improve their product quality by 10% while the least productive firms do not benefit from input tariffs cuts (columns 1 and 3). Output tariffs cuts induce product rationalization for both high and low productive firms (column 1).

Column (5) confirms that the initially most productive firms but not the least productive gain market shares. Thus, we find positive distributional effects of input-trade liberalization across firms.

Table 5: Distributional implications of trade liberalization

	Product scope firm-level		Product quality		Market share		Quality-adjusted price	Markup	Skill premium firm level
					firm-product level				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Input tariff(j,t-1) x High TFP(i,97)	-0.402**		-1.012***		-0.128***				
	(0.163)		(0.392)		(0.026)				
Input tariff(j,t-1) x High TFP(i,97) x High Markups(97)		-0.638***		-1.228***		-0.157***			
		(0.217)		(0.412)		(0.027)			
Input tariff(j,t-1) x High TFP(i,97) x Low Markups(97)		-0.100		-0.121		-0.009			
		(0.225)		(0.563)		(0.037)			
Input tariff(j,t-1) x Low TFP(i,97)	-0.064	-0.060	-0.256	-0.204	-0.019	-0.204			
	(0.171)	(0.171)	(0.424)	(0.467)	(0.028)	(0.467)			
Output tariff(j,t-1) x High TFP(i,97)	0.629***		-0.475		0.036				
	(0.101)		(0.364)		(0.024)				
Output tariff(j,t-1) x High TFP(i,97) x High Markups(97)		-0.021		-0.146		0.019			
		(0.137)		(0.377)		(0.025)			
Output tariff(j,t-1) x High TFP(i,97) x Low Markups(97)		0.732		-1.141**		0.041			
		(0.143)		(0.488)		(0.032)			
Output tariff(j,t-1) x Low TFP(i,97)	0.288**	0.290**	-0.669*	-0.346	0.015	-0.346			
	(0.116)	(0.116)	(0.348)	(0.284)	(0.023)	(0.284)			
Input tariff(j,t-1)							0.339*	-1.113**	-0.502***
							(0.183)	(0.496)	(0.166)
Output tariff(j,t-1)							-0.041	0.088	0.067
							(0.160)	(0.426)	(0.089)
Initial firm size trend	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm-product fixed effects			yes	yes	yes	yes	yes	yes	
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes							yes
Observations	12,343	12,343	56,031	56.031	57,933	57,933	49,442	49,442	12,332
R-squared	0.84	0.84	0.39	0.58	0.58	0.39	0.79	0.79	0.71

Notes: Definitions of all outcome variables are provided in the data annex. High (Low) TFP(i,97) is a dummy equal to one if the firm has an initial level of firm TFP Q that is higher (lower) than the median TFP Q of all firms in the initial year 1997. High (Low) Markups(97) in column (2) are measured as a dummy equal to one if the firm has an average markups at the firm level across all products produced by the firm in year 1997 that is greater (lower) than the median. In columns (4) and (6) markups are measured at the firm-product level in 1997. Heteroskedasticity-robust clustered at the 3-digit industry level are reported in parentheses. ∗∗∗, ∗∗, and ∗ indicate significance at the 1, 5 and 10 percent levels respectively.

Second, we take advantage of our data to test whether differences in markups affect how firms are affected by trade liberalization. To test for those effects, we divide firms into those with high/low initial markup at firm (column 2) and product levels (column 4). We split firms and firm-product into high (low) markups in the initial year of the sample (above and below the median).

Our findings show initially more productive firms charging higher markups expand their product scope by 6% (column 2) and upgrade their product quality by 12% (column 4) after a 10 percentage point reduction of input tariffs, while the least productive firms and firms with high productivity and lower markups do not benefit. Output tariff reductions have no effects on highly productive firms, but positively affect product quality of firms with lower markups.

We also find that this result in a reallocation of market shares from least productive firms towards most productive firms charging higher markups (columns 6). This finding points to missed opportunities for optimal reallocations of market shares as firms with high productivity but initially low markups do not gain, possibly due to a lack of resources to invest in production process changes.

Impacts on consumers, workers and firms

Did consumers benefit from input-trade liberalization by improving their access to products at cheaper prices? We answer this question by investigating the effects of input tariff reductions on quality-adjusted prices, which we compute as the change in output prices (unit values) relative to quality. Results, shown in Column (7) of Table 5, indicate that input-tariff reductions benefited consumers as for a 10 percentage point reduction of input tariffs quality-adjusted product prices fall by 3.3%. We do not find a similar effect from output tariffs, pointing to price adjustments from improved production processes rather than tougher competition.

Did firms' pass-through all gains from input-trade liberalization to consumers? Comparing the magnitude of the coefficients on price reductions with firm-product cost reductions (column 2 of Table 4), the cost reductions are more substantial (of 7-11% for a 10 percentage point reduction). We examine whether improved market power for firms from upgraded production processes - notably from offering more differentiated products - explains the incomplete pass-through of input-trade liberalization gains. We obtain firm-product level markups as the ratio of output prices over marginal costs at the firm-product level, where marginal costs are computed as the difference between firms' product sales value and production costs. We find that for a 10 percentage point reduction of input tariffs the average firm-product level markup increased by 11 % (column 8 of Table 5).

Finally, we look at the impacts across workers by investigating impacts on the skills premium from trade liberalization with the transformation of production structures that rely more on skilled workers (as shown in Column 9 of Table 5). We find that for a 10 percentage point reduction of input tariffs, the average firm has increased the relative wage of skilled workers by 5% during the period.

These results are robust when we control for other potential explanations like foreign demand shocks or the financial crisis in Ecuador (see Table A.5 in the Annex).

Conclusion

This paper provides a comprehensive assessment of the distributional impacts of trade liberalization in Ecuador across firms, consumers and workers. We find strong positive impacts of input-trade liberalization on firms' ability to improve product variety and quality and upgrade production processes to be more skill-intensive and cost effective and, in the longer run, more productive. Consumers also gain from access to lower-priced products after trade liberalization. Yet, Ecuador's trade liberalization also raises challenges: Input-tariff cuts boost the market shares of firms with higher markups prior to the reforms, leading to incomplete pass through of benefits to consumers. High market concentration may also stifle firms' incentive to upgrade their production processes. In addition, the already better off – the more skilled and firms' owners and investors – benefit more than the less well off. This is a challenge in a country of already high levels of income inequality. Policies to support productive firms with fewer resources (and market power) to benefit from trade liberalization as well as adequate training and competition policies would help trade liberalization contribute to ensuring the gains from trade liberalization reach all.

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Annex 1: Exogeneity of input and output tariffs

Table A.1: Tariff reductions between 1996 and 2007 and pre-reform industrial characteristics

Panel A: Dependent variable: change in input tariffs between 1996-2007				
	(1)	(2)	(3)	(4)
Sales(j)	0.003			
	(0.002)			
N products(j)		-0.001		
		(0.003)		
Employment(j)			0.001	
			(0.003)	
N importing inputs firms(j)				0.001
				(0.004)
Observations	143	149	149	119
R-squared	0.51	0.49	0.49	0.50

Panel B: Dependent variable: change in output tariffs between 1996-2007				
	(1)	(2)	(3)	(4)
Sales(j)	-0.001			
	(0.002)			
N products(j)		0.001		
		(0.004)		
Employment(j)			-0.004	
			(0.002)	
N importing inputs firms(j)				-0.004
				(0.005)
Observations	144	151	151	120
R-squared	0.54	0.57	0.58	0.53

Notes: The dependent variable is the changes in input or output tariffs between 1996 and 2007. The table shows regressions at the 3-digit industry level of changes in input tariffs on different industry-level characteristics. All industry-level variables are expressed in logarithms. Heteroskedasticity-robust standards errors are reported in parentheses.

Table A.2: Initial firm characteristics in 1997 and tariff changes between 1996-2007

	Importer inputs	N products	Employment	Production
	(1)	(2)	(3)	(4)
Change input tariffs(j,07,96)	2.279	0.437	2.473	4.410
	(2.978)	(0.567)	(2.435)	(3.995)
Change output tariffs(j,07,96)	-0.913	1.499	-0.727	-0.359
	(1.628)	(0.999)	(1.594)	(3.400)
Observations	503	504	504	494
R-squared	0.38	0.21	0.22	0.30

Notes: The dependent variables in each column are the initial firm-level outcomes in the initial year of the sample. The table shows the coefficients on changes in input tariffs between 1996 and 2007 from firm-level regressions of initial firm characteristics on output and input tariff changes and 2-digit industry fixed effects. Firm-level variables are expressed in logarithms except for the importer of inputs dummy. Heteroskedasticity-robust standards errors are reported in parentheses. Errors are corrected for clustering at the 3-digit industry level.

Annex 2: Additional results tables

Table A.3: Regression results for Ecuador of Kugler and Verhoogen (2009)

	(1)	(2)	(3)	(4)
Panel A: Dependent variable: log real gross output				
Importer	1.461***	1.106***	0.101**	0.098**
	(0.078)	(0.069)	(0.041)	(0.041)
Exporter		1.566***		0.175***
		(0.072)		(0.034)
R^2	0.45	0.55	0.93	0.93
Panel B: Dependent variable: number of inputs				
Importer	1.257***	1.180***	0.879***	0.875***
	-0.161	-0.159	-0.132	-0.132
Exporter		0.338**		0.215**
		-0.154		-0.084
R^2	0.401	0.402	0.861	0.861
Region fixed effects	Yes	Yes	No	No
Industry fixed effects	Yes	Yes	No	No
Plant fixed effects	No	No	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
N (plant-year observations)	13,037	13,037	13,037	13,037
N (distinct plants)	1501	1501	1501	1501
Panel C: Dependent variable: log real input price				
Importer (of relevant input)	0.138***	0.284***	0.172***	0.302***
	(0.032)	(0.030)	(0.020)	(0.030)
Observations (plant-product-year)	81309	81309	81309	81309
R^2	0.83	0.86	0.95	0.89
Panel D: Dependent variable: log real (domestic or imported) input price				
Imported product	0.206***	0.327***	0.261***	0.339***
	(0.030)	(0.022)	(0.031)	(0.028)
Observations (plant-product-year-origin)	86417	86417	86417	86417
R^2	0.82	0.85	0.94	0.88
Panel E: Dependent variable: log real domestic *input price*				
Importer (of relevant input)	-0.079	0.049	0.049	0.043
	(0.051)	(0.041)	(0.042)	(0.052)
Observations (plant-product-year)	64062	64062	64062	64062
R^2	0.84	0.87	0.95	0.90
Region, industry fixed effects	Yes	No	No	No
Product-year fixed effects	Yes	Yes	Yes	Yes
Plant fixed effects	No	Yes	No	No
Plant-product fixed effects	No	No	Yes	No
Plant-year fixed effects	No	No	No	Yes
Plant-product-year fixed effects	No	No	No	No

Notes: Robust standard errors clustered at the plant level in parenthesis. ***, ** and percentage level. Only plant-year observations with information on the number of input Panel A and B. In Panels C to E, Column 2-4 were calculated using Stata a2reg procedure (from Amine Ouazad) with bootstrapped standard errors, using 50 replications with draws on distinct cross-sectional units (plants). Plant-year observations in Panels A and B are 13037. Plant-product-year observations in Panels C and D are 81309 and in Panel E 64062.

Table A.4.1: Controlling for foreign demand shocks (export-channel)

	Product scope	Output quality	Skill intensity	Cost adjusted for quality	TFPQ	TFPR industry prices	Quality-adjusted price	Markup	Skill premium
		firm level		firm-product level	firm level		firm level		firm level
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Input tariff(j,t-1)	-0.231*	-1.251**	-0.078*	1.242*	-0.287	-0.394*	0.345**	-1.268*	-0.503***
	(0.125)	(0.562)	(0.045)	(0.658)	(0.275)	(0.211)	(0.172)	(0.675)	(0.168)
Output tariff(j,t-1)	0.473***	0.379	-0.020	0.514	-0.287	-0.427**	-0.028	-0.142	0.063
	(0.078)	(0.288)	(0.025)	(0.656)	(0.252)	(0.189)	(0.161)	(0.663)	(0.089)
Export tariff(j,t-1)	-0.046	0.946**	0.050	-0.629	-0.025	0.159	-0.058	0.992	0.159
	(0.097)	(0.411)	(0.034)	(0.637)	(0.227)	(0.175)	(0.154)	(0.648)	(0.126)
Initial firm size trend	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm-product fixed effects				yes			yes	yes	
Firm fixed effects	yes	yes	yes		yes	yes			yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	12,253	12,253	12,253	45,277	9,996	9,996	55,940	49,362	12,242
R-squared	0.84	0.55	0.77	0.90	0.63	0.63	0.97	0.79	0.71

Notes: Heteroskedasticity-robust standards errors are reported in parentheses. Errors are corrected for clustering at the 3-digit industry level. ∗∗∗, ∗∗, and ∗ indicate significance at the 1, 5 and 10 percent levels respectively. Export tariffs are the average applied tariffs by all trading partners of Ecuador at 4-digit ISIC industry level provided by the WITS database. Section 4 of the data appendix provides definitions for all other variables.

Table A.4.2: Controlling for foreign demand shocks (export-channel)

	Product scope		Product quality		Market share	
	firm level		firm-product level			
	(1)	(2)	(3)	(4)	(5)	(6)
Input tariff(j,t-1) x High TFP(i,97)	-0.390**		-1.167***		-0.127***	
	(0.163)		(0.395)		(0.026)	
Input tariff(j,t-1) x High TFP(i,97) x High Markups(i,97)		-0.628***		-1.338***		-0.156***
		(0.218)		(0.414)		(0.027)
Input tariff(j,t-1) x High TFP(i,97) x Low Markups(i,97)		-0.082		-0.291		-0.007
		(0.225)		(0.567)		(0.037)
Input tariff(j,t-1) x Low TFP(i,97)	-0.048	-0.043	-0.380	-0.310	-0.019	0.013
	(0.172)	(0.172)	(0.426)	(0.469)	(0.028)	(0.031)
Output tariff(j,t-1) x High TFP(i,97)	0.622***		-0.664*		0.035	
	(0.102)		(0.370)		(0.024)	
Output tariff(j,t-1) x High TFP(i,97) x High Markups(i,97)		0.554***		-0.302		0.017
		(0.137)		(0.382)		(0.025)
Output tariff(j,t-1) x High TFP(i,97) x Low Markups(i,97)		0.760***		-1.249**		0.039
		(0.144)		(0.491)		(0.032)
Output tariff(j,t-1) x Low TFP(i,97)	0.287**	0.290**	-0.844**	-0.412	0.014	-0.026
	(0.117)	(0.117)	(0.354)	(0.285)	(0.023)	(0.019)
Export tariff(j,t-1)	-0.043	-0.055	0.811	0.713	0.001	0.004
	(0.097)	(0.097)	(0.473)	(0.470)	(0.018)	(0.018)
Initial firm size trend	yes	yes	yes	yes	yes	yes
Firm-product fixed effects			yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes				
Observations	12,343	12,343	56,031	56.031	57,933	57,933
R-squared	0.84	0.84	0.39	0.58	0.58	0.39

Notes: Heteroskedasticity-robust standards errors are reported in parentheses. Errors are corrected for clustering at the 3-digit industry level. ∗∗∗, ∗∗, and ∗ indicate significance at the 1, 5 and 10 percent levels respectively. Export tariffs are the average applied tariffs by all trading partners of Ecuador at 4-digit ISIC industry level provided by the WITS database. Section 4 of the data appendix provides definitions for all other variables.

Table A.5.1: Controlling for effect of the economic crisis 1999-2000

	Product scope	Output quality	Skill intensity	Cost adjusted for quality	TFPQ	TFPR industry prices	Quality-adjusted price	Markup	Skill premium
		firm level		firm-product level	firm level		firm level		firm level
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Input tariff(j,t-1)	-0.242*	-1.148**	-0.062	1.264***	-0.351	-0.448**	0.345*	-1.272**	-0.463***
	(0.127)	(0.560)	(0.043)	(0.456)	(0.278)	(0.213)	(0.192)	(0.518)	(0.169)
Output tariff(j,t-1)	0.470***	0.426	-0.027	0.334	-0.232	-0.334*	-0.018	0.189	0.050
	(0.080)	(0.292)	(0.025)	(0.383)	(0.249)	(0.187)	(0.164)	(0.437)	(0.090)
Input tariff(j,t-1) x crisis	-0.048	-0.118	-0.147*	-0.626	0.566	0.365	0.008	0.877	-0.361
	(0.179)	(0.848)	(0.076)	(0.608)	(0.404)	(0.325)	(0.258)	(0.700)	(0.326)
Output tariff(j,t-1) x crisis	0.038	0.380	0.078	0.345	-0.430	-0.263	-0.114	-0.701	0.092
	(0.131)	(0.618)	(0.055)	(0.450)	(0.299)	(0.238)	(0.196)	(0.525)	(0.243)
Initial firm size trend	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm-product fixed effects				yes			yes	yes	
Firm fixed effects	yes	yes	yes		yes	yes			yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	12,253	12,253	12,253	45,342	10,047	10,047	56,031	49,442	12,242
R-squared	0.84	0.55	0.77	0.90	0.63	0.63	0.97	0.79	0.71

Notes: Heteroskedasticity-robust standards errors are reported in parentheses. Errors are corrected for clustering at the 3-digit industry level. ∗∗∗, ∗∗, and ∗ indicate significance at the 1, 5 and 10 percent levels respectively. The crisis variable is a dummy that is equal to 1 for 1998-2000 and 0 otherwise. Section 4 of the data appendix provides definitions for all other variables.

Table A.5.2: Controlling for effect of the economic crisis 1999-2000

	Product scope firm-level		Product quality		Market share	
	firm level		firm-product level			
	(1)	(2)	(3)	(4)	(5)	(6)
Input tariff(j,t-1) x High TFP(i,97)	-0.427**		-0.913**		-0.135***	
	(0.168)		(0.404)		(0.026)	
Input tariff(j,t-1) x High TFP(i,97) x High Markups(i,97)		-0.671***		-1.114***		-0.164***
		(0.224)		(0.425)		(0.028)
Input tariff(j,t-1) x High TFP(i,97) x Low Markups(i,97)		-0.129		-0.024		-0.014
		(0.227)		(0.570)		(0.038)
Input tariff(j,t-1) x Low TFP(i,97)	-0.081	-0.083	-0.185	-0.115	-0.024	0.008
	(0.174)	(0.174)	(0.433)	(0.479)	(0.029)	(0.032)
Output tariff(j,t-1) x High TFP(i,97)	0.665***		-0.580		0.042*	
	(0.106)		(0.369)		(0.024)	
Output tariff(j,t-1) x High TFP(i,97) x High Markups(i,97)		0.593***		-0.229		0.023
		(0.141)		(0.381)		(0.025)
Output tariff(j,t-1) x High TFP(i,97) x Low Markups(i,97)		0.817***		-1.210**		0.044
		(0.147)		(0.491)		(0.032)
Output tariff(j,t-1) x Low TFP(i,97)	0.319***	0.324***		-0.394		-0.023
	(0.120)	(0.120)		(0.286)		(0.019)
Export tariff(j,t-1)	0.117	0.143	-0.764**		0.019	
	(0.156)	(0.156)	(0.353)		(0.023)	
Input tariff(j,t-1) x crisis	-0.180	-0.190*	-0.552	-0.548	0.035	0.032
	(0.112)	(0.112)	(0.436)	(0.439)	(0.029)	(0.029)
Output tariff(j,t-1) x crisis			0.626*	0.547*	-0.033	-0.028
			(0.331)	(0.328)	(0.022)	(0.021)
Initial firm size trend	yes	yes	yes	yes	yes	yes
Firm-product fixed effects			yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes				
Observations	12,343	12,343	56,031	56.031	57,933	57,933
R-squared	0.84	0.84	0.39	0.58	0.58	0.39

Notes: Heteroskedasticity-robust standards errors are reported in parentheses. Errors are corrected for clustering at the 3-digit industry level. ∗∗∗, ∗∗, and ∗ indicate significance at the 1, 5 and 10 percent levels respectively. The crisis variable is a dummy that is equal to 1 for 1998-2000 and 0 otherwise. Section 4 of the data appendix provides definitions for all other variables.

Data Appendix: Sample statistics, data treatment and variable definitions

Statistics of the main plant-level dataset

The original full manufacturing plant-level sample contains 17,001 plant-year observations, which is fairly balanced across 1997 – 2007 with at least 1,512 (2002) and at a maximum 1,655 (1999) firms each year. Table A.1 shows the average split across 2-digit industries for the entire sample period; more than one in four observations are of food and beverage producers.

Table A.6: Number of plant-year observations by 2-digit ISIC rev. 2 industry

Industry	Plants	Share in Total
Food and beverages [15]	4563	26.84
Tobacco [16]	18	0.11
Textiles [17]	1232	7.25
Wearing apparel [18]	1221	7.18
Leather products, luggage, saddlery and footwear [19]	597	3.51
Wood and wood products [20]	619	3.64
Paper and paper products [21]	577	3.39
Publishing, printing and reproduction of recorded media [22]	765	4.50
Coke, refined petroleum products and nuclear fuel [23]	93	0.55
Chemicals and chemical products [24]	1206	7.09
Rubber and plastics products [25]	1318	7.75
Other non-metallic mineral products [26]	1062	6.25
Basic metals [27]	544	3.2
Fabricated metal products [28]	766	4.51
Machinery and equipment n.e.c. [29]	474	2.79
Office, accounting and computing machinery [30]	4	0.02
Electrical machinery and apparatus n.e.c. [31]	239	1.41
Radio, television and communication equipment and apparatus [32]	8	0.05
Medical, precision and optical instruments, watches and clocks [33]	62	0.36
Motor vehicles, trailers and semi-trailers [34]	419	2.46
Other transport equipment [35]	40	0.24
Furniture, manufacturing n.e.c.[36]	1174	6.91

Notes: For each industry ISIC Rev. 3 2-digit codes are provided in brackets.

We eliminate plant observations in any single year if no information on overall product sales, employment and wage payments is provided since these will be essential for our analysis. In the few cases in which sales information is missing, we use product-plant data to complement the data. Our baseline plant-level dataset contains 16,678 plant-year observations for 1997 to 2007.

Data treatment for input- and output-product data

We use two separate datasets at the input-plant and output-plant level for 1997-2007. The original datasets provide for each product of plants an 11-digit product code, a description of the product itself and the unit of measurement of the quantities.[14] The 11-digit product codes are based on the ISIC Rev. 3 classification. Baseline datasets include 1,861 and 1,606 distinct input and output 11-digit manufacturing product categories; these correspond to the intermediate inputs and outputs of the plant-level dataset defined above. The dataset on intermediate inputs includes also information on

[14] The data contains the following 11 different units of measurement across inputs and outputs datasets: i) kilograms, ii) grams, iii) metres, iv) square metres, v) cubic metres, vi) units, vii) pairs, viii) litres, ix) barrils, x) gallons and xi) heads.

the purchasing price and quantity of goods across national and international purchases. The final products dataset has information on the production value and quantity as well as the sales value and quantity. Table A.2 provides a few examples of products in our dataset.

Table A.7: Examples of input and output products from the outputs and inputs datasets

Product description	ISIC Code	Unit
A. Outputs		
Sausages and similar products made of meat	15112113210	Kilograms
Woven fabrics of combed wool or of combed fine hair	17112654001	Metres
Ties, bow-ties and cravats	18102822903	Units
Footwear with uppers of leather or composition leather	19202933001	Pairs
Statuettes and other ornamental wooden articles	20293191302	Units
Gummed or adhesive paper and paperboard	21013214913	Kilograms
Exercise books	22213260001	Units
Preparations for use on the hair	24243532302	Litres
Brakes and servo-brakes and parts thereof	34304912901	Units
B. Inputs		
Tobacco extracts and essences	16002509002	Litres
Bovine leather and equine leather, without hair	19112912012	Units
Paper or paperboard lables of all kinds	21093219700	Units
Paraffin wax, crude or refined	23203350001	Kilograms
Prepared glues and other prepared adhesives	24293542005	Litres
Ceramic tableware, kitchenware and other ceramic household and toilet articles	26913722102	Units
Electrical plugs and sockets	31204621206	Units
Pressure regulators and controllers (manostats)	33134827001	Units
Spectacle lenses of glass	33204831102	Pairs

We applied several basic data cleaning procedures to obtain our final dataset. First, we removed those observations without any product code for both the input and the output datasets. Second, we also exclude observations on subcontracted production since information on product values in such cases might not reflect actual market values. Third, the original dataset contains cases where firms have more than one output or import product with the same 11-digit product code. We eliminate duplicate observations. As for the remaining cases when firms have more than one input and/or output in the same year with the same 11-digit code we create a more disaggregate product category rather than aggregate these observations. Fourth, any within-product price and quantity comparisons will only be meaningful if the same units of measurement are used. While this is the case for most of the products in our datasets, in certain cases the same product is reported in a different unit of measurement by different firms. We create a supra-product category to deal with those cases whenever our analysis requires with within-product comparisons. We eliminate those products without information on the unit of measurement for analysis involving price and quantity. (We will use the information whenever we are interested in the number of input or output products only.)

Our final datasets contain 74,823 output-plant-year and 107,359 input-plant-year observations at the 11-digit ISIC Rev. 3 product level. We will use the dataset for our analysis to compute the number of product outputs or inputs and other measures which do not require comparisons within products and/or price and quantity product information. Excluding observations with no information on units of measurement and/or subcontracted products produces a final dataset of 72,300 output-plant year observations and 100,095 input-plant year observations at the 11-digit ISIC Rev. 3 product level with a fairly equal split across years as described in Tables A.3 and A.4

below. Note that final products and inputs datasets cover most firms across all years with the only exception of 2007. For 2007 we only have information on about 64% of plants both in terms of inputs and outputs.

Table A.8: Number of plant-outputs by year

Year	Plants-Products	Share in Total	Plants	Share of All Plants
1997	6507	9.00	1535	0.94
1998	6626	9.16	1523	0.94
1999	6427	8.89	1434	0.96
2000	6550	9.06	1438	0.96
2001	6669	9.22	1446	0.96
2002	6727	9.30	1427	0.97
2003	6885	9.52	1429	0.97
2004	7097	9.82	1462	0.97
2005	6936	9.59	1440	0.97
2006	7135	9.87	1456	0.98
2007	4741	6.56	961	0.64
Total	72,300	100	15,551	0.93

Table A.9: Number of plant-inputs by year

Year	Plants-Products	Share in Total	Plants	Share of All Plants
1997	9713	9.70	1584	0.97
1998	9582	9.57	1559	0.97
1999	9033	9.02	1462	0.98
2000	9088	9.08	1461	0.98
2001	9369	9.36	1469	0.98
2002	9247	9.24	1442	0.98
2003	9425	9.42	1451	0.98
2004	9534	9.52	1485	0.98
2005	9330	9.32	1460	0.98
2006	9713	9.70	1471	0.99
2007	6061	6.06	960	0.64
Total	100,095	100	15,804	0.95

3. Converting monetary indicators for 1997-1999

Our data are provided in Ecuadorian sucre for 1997-1999 and in US dollars for 2000-2007 reflecting the country's adoption of the US dollar in 2000. In order to create a common dataset we convert 1997-1999 monetary values into US dollars using annual exchange rates from the Ecuadorian Central Bank.

4. Variable definitions

Imported input quality measured at the firm-product level is the residual of a demand function estimation based on the methodology developed by Khandelwal et al. (2013) as described in Section 4, reported in Table 1 (columns 1 and 2).

New imported input variety is a dummy variable equal to one if the firm imports a new 11-code product that has not been sourced in the domestic or foreign market in the previous year used in Table 2 (column 1).

Number of new imported input varieties is the logarithm of the number of new imported input varieties at the firm level used in Table 2 (column 3).

The share of new imported input varieties is the share of new imported varieties over total inputs at the firm level used in Table 2 (column 4).

Product scope is measured by the logarithm of the total number of 11-digit products produced by a firm in year t used in Table 3 (columns 1 and 2).

Product quality measured at the firm-product level is the residual of a demand function estimation based on the methodology developed by Khandelwal et al. (2013) as described in Section 4, reported in Table 3 (columns 3 to 5).

Firm *i*'s **skill intensity** is measured as the share of the non-production workforce relative to the entire workforce reported in Table 4 (column 1).

Production cost adjusted for input quality is obtained as the difference of the log of the cost of production and the logarithm of output quality measure reported in Table 4 (column 2).

The total factor productivity indexes - **TFPQ** and **TFPR** – express each individual plant's output and input as deviations from a single reference point. The single reference point is constructed as a hypothetical plant that has the arithmetic mean values of log output, log input and input cost shares over all plants for each 3-digit industry in each year. More specifically, for plant *i* in year *t* are indexes are defined as:

$$ln\,TFP_{it} = \left(ln\,Y_{it} - \overline{\ln Y_t}\right) + \sum_{\tau=2}^{t}\left(\overline{lnY} - \overline{lnY_{\tau-1}}\right) - \left[\sum_{j=1}^{m}\frac{1}{2}\left(s_{jit} + \overline{s_{jt}}\right)\left(lnX_{jit} - \overline{lnX_{jt}}\right) + \sum_{\tau=2}^{t}\sum_{j=1}^{m}\frac{1}{2}\left(\overline{s_{j\tau}} + \overline{s_{j\tau-1}}\right)\left(\overline{lnX_{j\tau}} - \overline{lnX_{j\tau-1}}\right.\right]$$

where *i* denotes firm, *t* year, *j* type of input, measured in real terms. Inputs (*X*) include labor (total of employees), materials, energy and services (real value) and capital stock (real value). *S* denotes input shares, that is, the ratio of the wage bill (and materials, services and energy as well as capital) to output. The first expression of the index is the deviation from the mean output in that year while the second term sums the change in the main output across all years and captures the shift of the output distribution over time by chain-linking the movement in the output reference point. The remaining terms repeat the exercise for each input *j*. The inputs are summed using a combination of the input revenue share for the plant (S_{jit}) and the average revenue share in each year as weights.

The difference between TFPQ and TFPR is the use of firm-level price deflators to obtain TFPQ. The firm-level price index is obtaining computing a Tornquist index as in Eslava et al. (2004). We computed industry deflators based on our firm-level information and also used official deflators provided by the Ecuadorian Statistical Office. Deflators to obtain real value of energy and services deflators were also obtained from the Ecuadorian Statistical Office. The capital stock was obtained using the perpetual inventory method based on investment data for buildings, machinery and equipment, transport and land with depreciation rates of 3% for buildings, 7.7% for machinery and equipment, 11.9% for transport and 0% for land as applied for Colombia (Pombo, 1999). We use deflators on the gross capital formation from the World Development Indicators to obtain real capital. The TFP measures are used in Table 4 (columns 3-5 and 6-11).

Market share at the firm-product-year level are the value of that product over total sales in the industry in a year reported in Table 5 (columns 5 and 6).

Quality-adjusted prices are measured by the difference in the logarithm of output prices (unit values) and the logarithm of output quality at the firm-product level reported in Table 5 (column 7).

Markups are measure as the ratio of output prices over marginal costs at the firm-product level, where marginal costs are computed by the difference between firms' sales value and the value at production costs for each product reported in Table 5 (column 8).

The **skill premium** is defined as the ratio of the wage-bill of non-production workers relative to the total wage-bill reported in Table 5 (column 9).

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