The role of productivity and markups in determining trade liberalization's impact on firm product scope and innovation

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Abstract

This paper investigates the unequal impact of trade liberalization on firms' product scope and innovation depending on firms' heterogeneous productivity and markups. Motivated by a simple theoretical framework of international trade, firm heterogeneity and variable markups, our analysis builds on Ecuador's exogenous trade liberalization with its accession to the World Trade Organization (WTO). We show that input-tariff reductions allow firms with high-markups and productivity to import more input varieties. These firms also increase their product scope and introduce new products as input tariffs decrease. Access to more varieties drives product scope and product innovation. In consequence, the market shares of firms with highest markups and productivity rise in response to input-trade liberalization. By contrast, the increase in import competition with output tariff reductions reduces product scope and product innovations. Firms' production concentration on core products increases moderately. The market shares of firms with low markups decrease most with output-trade liberalization.

Keywords: product scope, product innovation, firm heterogeneity, variable markups, productivity, input-tariff reductions, output-tariff reductions, firm-product-level data, Ecuador.

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

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1. Introduction

Input-trade liberalization allows firms to access new varieties of inputs to introduce new products and widen their product scope (Goldberg et al. 2010). Introducing new products is, however, costly and requires investments in new production capacities. Consequently only the most productive high-markup firms may be in position to expand product scope by introducing new products. Output-trade liberalization, by contrast, likely has reverse effects as competition from abroad forces firms to concentrate on their core products rather than introduce new products (Bernard et al., 2011, Mayer et al., 2014). There is no evidence to date on the unequal impacts of input- and output-trade liberalization on firms' product scope and innovation (see Verhoogen, 2020 for a review of the evidence).

The aim of this paper is to fill this gap by investigating empirically the unequal impact of trade liberalization in Ecuador on firms' product scope and innovation, depending on firms' productivity and markups. We investigate this relationship by exploiting the tariff cuts associated with Ecuador's access to the World Trade Organisation (WTO). Unique data on Ecuadorian firms' output products and their intermediary inputs allow investigating trade liberalization's unequal impacts on product scope and innovation, depending on firms' productivity and markups.

In our paper we analyze empirically theoretical predictions motivated by a framework of international trade, firm heterogeneity and variable markups. The framework rationalizes the main mechanisms through which firms' product scope and innovation are affected by input-tariff changes. In our analysis we exploit the exogenous change in effectively applied tariffs across industries and over time with Ecuador's entry to the WTO. We implement demanding within-firm estimations that also include firm-size trends to control for all developments that affected firms of difference size. In product-level estimations, firm-product trends also control for product-specific shocks. Moreover, we apply instrumental variable estimations as in Trefler (2004) to identify the impacts of input product varieties on product scope and innovation.

Our paper contributes to the literature by extending the predictions of heterogeneous firm trade models and providing first evidence of trade liberalization's unequal impacts on firms' product scope and innovation, depending on both their productivity and markups. Our theoretical framework extends the model first introduced by Melitz and Ottaviano (2008) of heterogeneous firms and variable markups for output-trade liberalization by developing how variable markups affect firms' product scope and innovation as a result of input-trade liberalization. Our empirical analysis provides causal evidence of the heterogeneous impact of input-tariffs cuts on firms' access to new input varieties. We are first to test for the unequal effects of both input- and output-tariff cuts on firms' product scope and innovation. Differently from other studies on unequal effects, we are in position to investigate separately the impacts of differences in firms' production efficiency – as measured by quantity total factor productivity (TFPQ) - and their markups. Finally, our paper offers an in-depth assessment of trade liberalization in a developing country, Ecuador, that to date has been little explored. Our findings consequently contribute to building the external validity of heterogeneous firm trade models, complementing in this way the empirical analyses on the effects of trade liberalization on firm product scope and innovation in India (Goldberg et al. 2010), US (Bernard et al., 2011), China (Liu and Qiu, 2016).

Based on a firm-product-level dataset for Ecuador over the 1997-2007 period, we have unique information on Ecuadorian firms' product scope and any product innovations on an annual basis. We also know the sales of specific output products and the specific intermediate products that firms source. Importantly, to investigate the heterogeneous effects, we are in a unique position to investigate impacts across firms of different productivity and markups. First, differently from previous work, we have direct information to compute markups for all Ecuadorian firms.[1] Markups are measured as the ratio of output prices over marginal costs at the firm-product level, where marginal costs are computed by the difference between firms' products sales value and the value at production costs for each product. As robustness test we also measure firm-level markups by using the methodology developed by De Loecker and Warzyinsky (2012). Second, as our data provide information to compute firm-level prices, we can measure firms' efficiency relying on quantity total factor productivity (TFPQ). Differently from the widely used revenue total factor productivity (TFPR), TFPQ is not affected by

[1] The only other study we identified using direct markup information is Atkin et al. (2015) who study markup and cost dispersions of a cluster of soccer-ball manufacturers in Pakistan.

demand shifts or market power variations and allows differentiating the heterogeneous effects that are driven by firms' productivity from those driven by their markup.

The period we analyze is one of transformation for Ecuadorian firms. With trade liberalization, Ecuador's imports increased by 14% on average and doubled between 1994 and 2004. The share of single-product firms decreases 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. Importing firms use more varieties of inputs in production than firms that do not import inputs. We hypothesize that these transformations are partly driven by Ecuador's trade liberalization and consequent input-tariff cuts in particular.

Our empirical findings can be summarized as follows: First, we establish a causal link between input-tariff cuts and firms' access to new varieties of foreign inputs they did not previously use in production. For a 10-percentage-point reduction of input tariffs, importing firms increase the quantity of their foreign intermediate inputs by more than 20%. However, with input-tariff cuts only firms with higher productivity and markups import new varieties of inputs and substitute domestic for foreign inputs in their production processes. All other firms do not change their use of inputs from abroad with input-trade liberalization.

Second, heterogeneous effects also characterize expansions in product scope and product innovation. For 10-percentage point reductions in input tariffs, the most productive high-markup firms expand their product range by 6.3% and the likelihood of introducing new products increases by 10.5%. We show that our results are robust to using alternative measure of product innovation and scope, markups and productivity. Moreover, input-trade liberalization results in a positive reallocation of market shares to highly productive high-markup firms while others do not see their market shares increase.

Third, output-tariff reductions decrease product scope and innovation, particularly of high-markup firms, demonstrating the competition effects of foreign competition. Our findings also confirm the predictions of multiproduct models of Bernard et al. (2011)

and Mayer et al. (2014) concerning the effects of foreign competition that induce firms to concentrate their production on their best-selling products. In our case, however, we identify only moderate concentration effects.

Instrumental variable regression results confirm that it is access to new varieties from abroad that boosts product scope and innovation. Our results are robust and stable when we test for alternative explanations to our story, including the possible effects of new export opportunities with trade liberalization, of Ecuador's financial crisis at the end of the 1990s and other reforms and time-varying sectoral shocks.

Our findings have several important policy implications. They confirm the benefits of input-trade liberalization for firms' production upgrading in developing country contexts. Moreover, the unequal impacts on firm scope and innovation and consequent gains (losses) in market shares for more (less) productive firms point to industry-wide production upgrading. However, the importance of high markups for firm product scope and innovation requires attention. Support measures such as funding to help firms - particularly those with low markups - to upgrade production processes based on improved inputs could bring benefits from trade liberalization to all highly productive firms and not only those with large markups. Differently from the markup-reducing effects of output-trade liberalization, the increase in markups from input-trade liberalization requires policy attention so that consumers reap the benefits from trade liberalization.

Our work contributes to the empirical literature on the effects of trade liberalization on firm product scope and innovation. Closest to our paper is the study by Goldberg et al. (2010) on India who show that India's input-trade liberalization facilitates firms' access to more input varieties to expand product scope. Differently from our study, the authors do not investigate unequal firm effects, the impacts on product innovation and effects of output-tariff reductions. Our paper also relates to Bernard et al. (2011) who study the impacts of output-trade liberalization on firms' product scope in the United States. We also complement the works on the effects of trade liberalization on R&D investments (Bustos, 2011), patents (Liu and Qiu, 2016) and foreign technology upgrading (Bas and Berthou, 2017). Those papers, however, do not focus on the heterogeneous effects of trade liberalization on firms' innovation depending on firms' productivity and markups.

Our paper also relates to the voluminous literature on trade liberalization's impacts on firm productivity (e.g. Pavcnik, 2002; Fernandes, 2007; Amiti and Konings, 2007; Foster et al., 2008; De Loecker, 2011; Topalova and Khandelwal, 2011; Lileeva and Trefler, 2010; Brandt et al, 2019).

Finally, our results also complement the literature on trade liberalization's effects on firms' markups, including early works by Levinsohn (1993) and Harrison (1994). Important recent contributions include De Loecker et al. (2016) and Fan et al. (2018) who study input-trade liberalization's impacts on firms' markups in India and China. Brant et al. (2017) investigate the impacts of output trade liberalization in China on the evolution of firm level markups.

The remainder of the paper is structured as follows. The next section describes the theoretical motivation. Section 3 gives an overview of the trade reform in Ecuador. Section 4 provides stylized empirical facts that motivate our empirical analysis. Section 5 discusses the empirical strategy and findings while section 6 checks for alternative explanations. The last section concludes.

2. Theoretical motivation

This section introduces a simple theoretical framework in partial equilibrium that rationalizes the relationship between firms' product scope and innovation, depending on firms' markups and productivity. This allows us to derive some testable implications that guide our empirical analysis.

2.1. Conceptual framework

We propose a conceptual framework that allows studying the effects of input-trade liberalization, through access to new and high-technology inputs, on firms' product mix depending on firms' markups and productivity. The framework is built on the model developed by Melitz and Ottaviano (2008) of heterogeneous firms in terms of initial efficiency with endogenous markups and extends this framework to introduce the role of foreign inputs. We abstract from the effects of output tariff for tractability reasons and derive testable implications from expected effects of output-tariff reductions from the existent theoretical literature on multiproduct firms below.

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 $U = q_0 + \vartheta \int_{i\epsilon\psi} z_i q_i \, di - \frac{1}{2} \upsilon \int_{i\epsilon\psi} (z_i q_i)^2 \, di - \frac{1}{2} \beta \left[\int_{i\epsilon\psi} z_i q_i \, di\right]^2$, where z is any attribute of the product that the consumer values and that increases their utility.[2] q_0 is the consumption of the numeraire good, with $q_0 > 0$, and q_i is the consumption of each variety of the differentiated good.[3] 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: $q_i = \frac{R}{\vartheta z_i}\left(\hat{P} - \frac{p_i}{z_i}\right)$, 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 price and $\hat{P}$ is the ceiling price that represents the price at which demand for a variety is driven to 0.

Production

Firms can produce new products if they pay for each product fixed costs of product innovation in terms of labor. The wage is used as numeraire (w = 1). 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:

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

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 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 for all products k produced by the firm. The total number of products N

[2] 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. We choose this demand system since it allows for endogenous markups and keeps the model tractable.

[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 ($w_u = 1$).

produced by a firm is determined by profit maximisation net of the fixed cost of product innovation:

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

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 $1\text{-}\eta$ 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:

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

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 $\sigma = \frac{1}{1-\alpha}$:

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

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

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

Ω is the set of foreign input varieties imported by a firm and x_{mv} is the quantity of imported input variety v with γ_v the foreign technology, where we assume that foreign inputs are of a higher technology than domestic ones, so $\gamma_v > 1$. Plugging equation (5) into (4) and then into equation (3) one can see that the technology 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

[4] Increasing fixed costs with the amount of input varieties result from extra fixed costs for each additional foreign variety as shown empirically by Halpern et al. (2015).

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 which is used as a numeraire, $p_d = 1$. The price index of imported varieties is:

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

where $p_m(\tau_m, \gamma_v) = \frac{\tau_m}{\gamma_v}$ is the average imported input price across all varieties of foreign inputs. We disentangle both mechanisms in the imported input price index: (i) foreign-input technology 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), the foreign input parameter is the relative cost advantage due to the higher efficiency in the production process that arises from the use of inputs from abroad. The higher efficiency 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 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 technology 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-technology imported inputs increases their efficiency.

Product innovation, foreign technology upgrading and input variety

In this simple setting, product innovation (z) is modelled as the ability of firms to introduce new products. We assume that it is determined by the foreign technology embodied in imported inputs and input variety. For simplicity, we assume that the technology in domestic inputs is equal to 1, while each foreign input varieties v have a technological parameter $\gamma_v > 1$. Therefore, the capability of firms to manufacture products with new attributes (z), is an increasing function of foreign technology γ_v and the set of imported input varieties Ω with $\xi > 1$:

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

Input-trade liberalization, input variety, 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. 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), foreign input technology 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 foreign inputs, there are two opposite effects at play. On the one hand, access to high technology foreign inputs and more varieties decreases the imported input price index and thereby the input-cost index of importing firms (c_m), reducing output prices and markups due to the *cost-efficiency effect*. On the other hand, the ability of firms to introduce new products and expand product scope (z) thanks to access of new imported input varieties increases prices and markups: the *product-capability effect*. Product capability, z, determined by equation (7), is an increasing function of foreign input technology and input variety.

Under the assumption that there are increasing returns to upgrading foreign inputs and input variety on the capability to introduce products with new attributes, $\xi > 1$, the latter effect dominates and foreign technology upgrading and access to more varieties of inputs increases prices, markups, revenues and profits. Plugging equation (7) into equation (8) gives the optimal prices, markups, revenues and profits as a function of imported foreign input technology and input variety:

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

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

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:

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

Output-trade liberalization and firms' product growth

Here we add the expected impacts of output-trade liberalization compared to input-liberalization as identified in the theoretical literature. Regarding product scope, the multi-product heterogeneous firms' model presented by Bernard et al. (2011) with constant markups shows that import competition leads most productive firms to concentrate their production on their best-selling products. The multi-product model with variable markups developed by Mayer et al. (2014) predicts that all firms reduce markups on their products and concentrate on core products when they face stronger competition in export markets. This is because tougher competition reduces the distribution of markups across products and induces firms to skew their export sales toward their best performing products.

As to foreign competition's impact on product innovation, Dhingra (2013) develops a model that predicts that firms cope with import competition by cutting back on internal competition across different product lines. Consequently, trade liberalization induces firms to lower product innovation (through cannibalization). Feenstra and Ma (2008) and Eckel and Neary (2010) also develop multi-product firm models on the impact of competition on the distribution of firm product sales. Those models foresee a cannibalization effect that stems from across-firm competition in an oligopolistic setting. In these settings, foreign competition reduces products' market shares.

Finally, with regards to unequal impacts of output-trade liberalization, in Mayer et al.'s (2014) model, the reduction in product scope applies to all firms but is expected to be strongest among more productive high-markup firms because these firms produce more products to start with.

2.2. Theoretical implications

This section describes theoretical predictions for our empirical analysis on the relationship between firms' product scope and innovation, markups, productivity and trade liberalization derived from our simple model.

Hypothesis 1 (H1): Input tariff cuts give more productive high-markup firms access to more varieties of foreign inputs.

Input tariff cuts allow more productive high-markup firms to access more varieties of foreign inputs as they reduce the imported input price index due to the two mechanisms: foreign-input technology upgrading and input variety. Only more productive high-markup firms access more varieties of inputs because only these firms can afford investing in new production lines and product innovations (equation 2).

Hypothesis 2 (H2): Input tariff cuts lead more productive high-markup firms to expand their product scope by introducing new products.

Access to more varieties of foreign inputs and to inputs of better technology reduce the imported input price index reducing marginal costs and increasing firms' profits (equation 6). Consequently, firms with access to new imported varieties of high technology increase their product scope. Only more productive high-markup firms expand product scope and introduce new products because only these firms can afford fixed investment costs for new lines of production (equation 2).

Hypothesis 3 (H3): The market share of more productive high-markup firms expands in response to input-trade liberalization.

The model implies that input-trade liberalization leads to 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 final good products. This is because initially more productive firms (lower marginal costs, c) will set lower prices and have larger revenues and profits, as shown in equations (8) and (9) by the interaction between the initial productivity (*1/c*) and output capability (*z*). In this setting more productive firms with lower initial marginal cost can charge higher markups as shown in equation (8). Thereby, the effect of input-trade liberalization on firms' market shares is concentrated on firms with initial high productivity and markups.

Hypothesis 4 (H4): Output-tariff cuts lead firms introduce fewer new products, reduce their product scope and concentrate on their core products.

Output-tariff cuts increase import competition reduces firms' capacity to invest in new product lines and introduce new products and reduce their product scope. With competition from abroad firms concentrate on f concentrate on their "best" products (Bernard et al., 2011, Mayer et al., 2014). The impact is strongest for firms with high markups as their initial product scope is largest.

Hypothesis 5 (H5): Input-tariff cuts expand firms' markups while output-tariff cuts have the reverse effect.

The ability of firms to introduce new products is determined by the foreign technology embodied in imported inputs and input variety. In our setting product innovation determines firms' market power (as in equations 8 and 9). As a consequence, input-tariff cuts allows firms to access new varieties of imported inputs to produce new products and increase their markups. In this framework, the incomplete pass-through of input tariff reductions to prices is that firms can offset their reductions in marginal costs by raising markups. Output-tariff cuts are expected to reduce markups across firms' products as import competition increases market competition.

3. Ecuador's trade liberalization

3.1. Ecuador's accession to the WTO

In this section, we describe Ecuador's trade integration process, and 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 very restricted in order to shield industries from foreign competition, with high nominal tariffs and import licenses in most sectors.

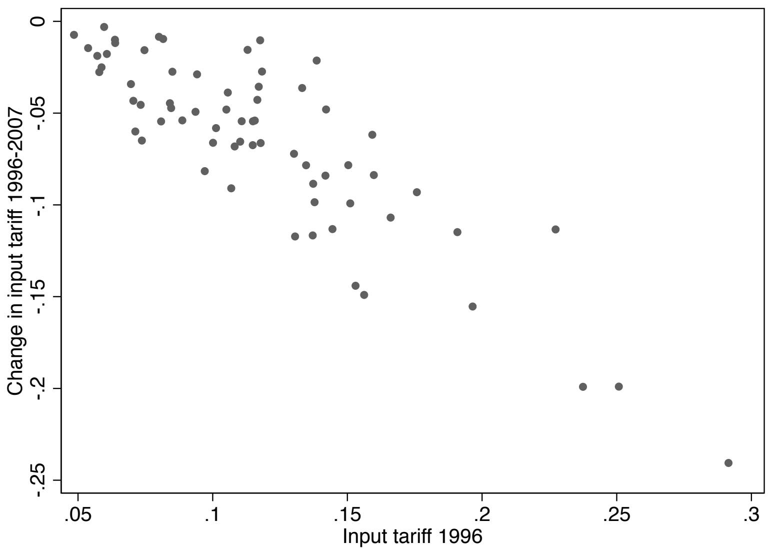
A unilateral trade-reform plan was launched in the mid-1990s due to the accession to the World Trade Organization (WTO) in 1996. The main implication of acceding to WTO was a unilateral trade liberalization process in Ecuador that consisted in substantial tariff reductions that was accompanied by other 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.[5]

[5] 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

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.

3.2. 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.2 and A.3 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.

Unfortunately, firm level data is only available from 1997. Thereby, it is not possible to provide an analysis of firm-product or firm's pre-trends prior to trade reform. Nevertheless, firm-product estimations include product-firm level trends to control for differences in input and output quality across products within a firm. Moreover, all firm level estimations include initial size trend that takes into account different trends across firms.

3.3. Other reforms introduced in Ecuador during the 1990s and 2000s

Ecuador also launched a package of structural reforms during the 1990s and 2000s that aimed at attracting more foreign direct investment (FDI) liberalization, reforming the tax and fiscal systems and privatizing the large public sector.

As to FDI, the reduction of barriers to FDI did not lead to widespread inflows but mainly benefited the oil industry. This sector received 80% of all FDI inflows Ecuador received in the 1990s. The specific nature of the industry and its remote geographic location facilitated little benefits to the remainder of the economy. Moreover, FDI inflows grew at a slower pace than those into other Latin American countries, including the neighboring Andean countries (UNCTAD, 2001).

Privatization did not materialize in the 1990s in spite of corresponding efforts with the Modernization Law of 1993 that established the Consejo Nacional de Modernización (CONAM) that was tasked with executing the privatization of states enterprises. The only sector in which private firms were allowed to operate was the oil sector. In consequence, Ecuador became the only country in Latin America with growing public investment with operational losses that forced public enterprises to rely more on fiscal resources to finance their investments, resulting in a growing public debt. This lack of effective fiscal and tax reforms further exacerbated the challenge (UNCTAD, 2001).

Another wave of reforms were introduced following Ecuador's political, economic and social crisis but until the mid-2000s only resulted in the introduction of the dollar in 2000. The crisis of 1998 led to a 100% inflation rate and a contraction of GDP of 7%. The financial crisis was characterized by the default on Brady bonds and on Eurobonds and devaluation of the currency culminating with a hyperinflation. The Economic Transformation Law introduced structural reforms to attaint macroeconomic stability and growth. The main immediate outcome was the dollarization of the economy as a means to stop hyperinflation. The other reforms were only implemented starting in the mid-2000.

To sum up, even though there were other reforms announced during the period under analysis 1997-2006, only tariff cuts had widespread effects across all industries while other reforms of the 1990s mainly affected the oil industry. There were also efforts aimed at facilitating exports from Ecuador. As to the reforms that were introduced following the major political, economic and social crisis, the adoption of the dollar as currency was the only measure undertaken in 2000. Other reforms materialized in the mid-200s. In Section 6.2, we conduct tests that deal directly with alternative developments in Ecuador to validate our explanation for increased product scope and innovation.

4. A first glance at the data

4.1. 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. 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. 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. Online Annex 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.

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 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. 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 product level based on the ISIC Rev. 3 classification.

Bas and Paunov (2019) implement several data cleaning procedures and check the quality of the dataset following Bernard et al. (2010), Kugler and Verhoogen (2009, 2012) and Goldberg et al. (2010). These tests, which follow Bernard et al. (2010), are satisfactory in that product drops and jumps are relatively infrequent. They also find similarities between statistics based on our product level data and those obtained based on comparable data for other countries. 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. Detailed information can be found in Bas and Paunov (2019).

We are in position to identify firms' product scope and product innovation and their access to input varieties, including those from abroad. The product scope is the total number of products the firm produces in any year, as well as product innovation, the number of distinct products the firm introduces in year *t* at 11-digit product level the firm never produced before. We measure firms' access to input varieties as the number of distinct inputs firms obtain at 11-digit product level. The definitions of these and all the main variables we use is provided in Annex Table A.1.

Moreover, our data allow measuring of firm markups – using information on product sales value and production costs - and quantity total factor productivity (TFPQ). Firm-product level markups are measured as the ratio of output prices over marginal costs at the firm-product level. As an alternative measure, we compute markups at firm level using the methodology developed by De Loecker and Warzyinsky (2012). As to productivity, with information on firm-level output prices we obtain TFPQ, which relative to the widely used TFPR allows disentangling efficiency gains from pure price (markup) effects (Foster et al., 2008; De Loecker, 2011). Following Aw et al. (2011) and Arnold and Javorcik (2009) we obtain productivity indexes as developed by Caves et al. (1982). These are flexible and accommodate heterogeneous production technologies to allow for comparisons of TFPQ in plant-level panel data (Van Biesebroeck, 2007). As an alternative, we also obtain TFPQ based on production function estimations as introduced by Olley and Pakes (1996) using firms' sales deflated by firm' output prices as dependent variable.[6]

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 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 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.

[6] We also applied the methodology used by De Loecker (2011) and De Loecker et al. (2016) to estimate firm productivity in a multiproduct setting. Their approach consists in estimating the production function for a sub-sample of single product firms and then apply the elasticities to all firms. In our case less than half of the relatively small sample are single product firms. As a result, coefficients on input elasticities were for several industries insignificant due to the reduced sample.

4.2. Stylized facts

This section presents a set of descriptive evidence that supports testing for the hypotheses as set out in our conceptual framework.

Product scope and innovation among Ecuadorian firms

Regarding product scope and innovation, the average Ecuadorian firm produces 2.4 goods (s.d. 2), while the maximum products sold by any 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.

Importers differ from other firms. They produce on average 3 products compared to 2 products (for non-importers) for 1997-2007 and source 6.5 more inputs domestically and from abroad than non-importers firms which only source 4 inputs on average. Table 1 presents similar descriptive evidence as the one provided by Kugler and Verhoogen (2009) on Colombia and shows, as is the case for Colombian firms, that the correlation of importing and more input varieties is also robust to controlling for region, industry and year fixed effects (column 1 of Table 1) and firm and year fixed effects (column 4 of Table 1). Columns 2,3, 5 and 6 of Table 1 also show that importers produce more final goods (product scope) and introduce more new varieties of final products in the market (product innovation) than non-importers. Interestingly, importers of inputs rely to important extents on imports with, on average 60% of their inputs coming from abroad. Importers are also more productive and have higher markups than their counterparts.

Important changes to product scope and innovation took place over the trade-liberalization period. The share of single-product firms decreased substantially over the trade-liberalization period with new product innovations: 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.

Table 1: Variety of inputs, product scope and product innovation of importing firms

Dependent variable:	Input varieties (1)	Product scope (2)	Product innovation (3)	Input varieties (4)	Product scope (5)	Product innovation (6)
Importer	1.004***	0.262**	0.046***	0.807***	0.169**	0.060***
	(0.160)	(0.108)	(0.012)	(0.115)	(0.074)	(0.020)
Region fixed effects	Yes	Yes	Yes	No	No	No
Industry fixed effects	Yes	Yes	Yes	No	No	No
Firm fixed effects	No	No	No	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N (firm-year observations)	12,588	12,588	11,366	12,570	12,570	11,348
R-squared	0.283	0.162	0.105	0.855	0.835	0.313

Notes: Robust standard errors clustered at the plant level in parenthesis. ***, ** and percentage level.

Product scope and innovation in relation to firm productivity and markups

Consistently with our theoretical model, we find product scope and innovation to be positively correlated with firm productivity and markups. This result is obtained in regressions of firms' product scope (or product innovation) on a dummy equal to one if the firm has higher-than-median markups. These regressions also control for firms' initial size trend (where the initial size of firm *i* is defined by the logarithm of total production of the firm) and industry-year fixed effects. Results reported in Table 2 show that within an industry and conditional on firms' size, firms with higher markups produce more final goods (column 1) and introduce new products in the market (column 4). The same is the case for more productive firms (columns 2 and 5) and for firms that both have high productivity and high markups (columns 3 and 6).

Table 2: Firms' product scope, markups and productivity

	Product scope			Product innovation		
	(1)	(2)	(3)	(4)	(5)	(6)
High Markups (i,97)	0.072***			0.040***		
	(0.010)			(0.009)		
High TFPQ (i,97)		0.076***			0.015*	
		(0.010)			(0.009)	
High TFPQ (i,97) x High Markups (i,97)			0.053***			0.019**
			(0.010)			(0.009)
Initial size trend	yes	yes	yes	yes	yes	yes
Industry x year fixed effects	yes	yes	yes	yes	yes	yes
Observations	12,209	12,209	12,209	10,998	10,998	10,998
R-squared	0.28	0.28	0.28	0.21	0.21	0.21

Notes: In columns (1) to (3) the dependent variable is firms' product scope measured as the logarithm of the number of 11-digit products manufactured by firm *i* in year *t*. In columns (4) to (6) the dependent variable is a dummy equal to one if the firm produces a new 11-code product that has not been produced in the previous year. Heteroskedasticity-robust standards errors are reported in parentheses. Standard errors are clustered at the firm level. ∗∗∗, ∗∗, and ∗indicate significance at the 1, 5 and 10 percent levels respectively.

5. Empirical evidence

This section explores whether the five hypotheses we specify in our conceptual discussion hold in the data.

Hypothesis 1: Input-tariff cuts give more productive high-markup firms access to more varieties of foreign inputs.

First, we explore the causal impact of input tariff cuts on firms' access to imported inputs and, in particular, on new input varieties from abroad. We first look at the effects of input-trade liberalization on the quantity of imported inputs k of firm i in year t, q_{ikt}, and implement the following regression:

$$q_{ijkt} = \alpha + \gamma_{I\tau} \text{ Input}\,\tau_{\,k,t-1} + \gamma_{O\tau} \text{ Output}\,\tau_{\,j,t-1} + \gamma_S \text{ Size}_{\,i,t0} * \eta_t + \gamma_q \text{ Q}_{\,i,k,t0} * \eta_t + \mu_{ik} + \eta_t + \varepsilon_{ikjt} \quad \text{(I)}$$

where Input $\tau_{k,t-1}$ represents the input tariffs that Ecuador effectively applies to product k in year *t-1*. While output tariffs (Output $\tau_{j,t-1}$) have no direct impact on imported inputs, they are correlated with input tariffs and consequently included as control variable in all specifications. We also introduce firm-size and firm-product trends, $Size_{i,t0} * \eta_t$ and $Q_{i,k,t0} * \eta_t$, respectively, to take into account time-variant shocks affecting firms of different size and firms' products. $Size_{i,t0} * \eta_t$ corresponds to initial firm size trends, where the initial size of firm i is defined by the logarithm of total firm sales. $Q_{i,k,t0} * \eta_t$ are constructed as initial size of the product sold by a firm measured by the logarithm of firm-product quantity in the initial year interacted with year dummies. In addition our specifications include firm-product fixed effects (μ_{ik})and year fixed effects (η_t) that take into account time-invariant differences across firm-products and years.

Table 3 present the results. Column (1) 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 more than 20%. We also conduct a sensitivity test and look at whether we find input tariff to impact on the domestic quantity of intermediate goods. Results presented in column (2) of Table 3 show that firms have substituted domestic inputs for foreign ones during trade liberalization.

Table 3: Impacts of input-tariff cuts on intermediate inputs

	Quantity of inputs		New input variety		New imported variety		
	Imported	Domestic	Imported	Domestic			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Input tariffs (k,t−1)	-2.088***	0.875**	-0.086**	0.386***			
	(0.636)	(0.376)	(0.043)	(0.068)			
Output tariffs(j,t-1)	1.436**	0.952***	0.220***	-0.079			
	(0.652)	(0.363)	(0.054)	(0.073)			
Input tariff(j,t-1) x High Markups(i,97)					-0.159**		
					(0.065)		
Input tariff(j,t-1) x Low Markups(i,97)					0.011		
					(0.076)		
Output tariff(j,t-1) x High Markups(i,97)					0.171***		
					(0.046)		
Output tariff(j,t-1) x Low Markups(i,97)					0.302***		
					(0.062)		
Input tariff(j,t-1) x High TFPQ(i,97)						-0.096*	
						(0.054)	
Input tariff(j,t-1) x Low TFPQ(i,97)						.-0.107	-0.049
						(0.058)	(0.061)
Output tariff(j,t-1) x High TFPQ(i,97)						-0.061	
						(0.037)	
Output tariff(j,t-1) x Low TFPQ(i,97)						0.054	0.080*
						(0.042)	(0.043)
Input tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)							-0.172**
							(0.078)
Input tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)							-0.110
							(0.105)
Output tariff(j,t-1) x Low TFPQ(i,97) x High Markups(i,97)							0.190***
							(0.061)
Output tariff(j,t-1) x Low TFPQ(i,97) x Low Markups(i,97)							0.353***
							(0.082)
Firm-product trend	yes	yes	yes	yes	yes	yes	yes
Initial firm size trend	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects							
Firm-product fixed effects	yes	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes
Observations	15,631	41,912	56,635	26,701	56,419	55,802	55,802
R-squared	0.78	0.77	0.30	0.23	0.29	0.29	0.29

Notes: The quantities of imported and domestic inputs are given in log terms. Robust standard errors reported in parentheses are clustered at the industry level in columns (1) and (2) and at the input product level in columns (3) to (9). ∗∗∗, ∗∗, and ∗indicate significance at the 1, 5 and 10 percent levels respectively.

Next we turn to investigate the impact of input-trade liberalization on new imported varieties. We do so by regressing an indicator of whether the firms' input product is new to the firm at firm-product level on import tariffs applied by Ecuador at the HS 6-digit level that also includes as in our model (I) firm-product and year fixed effects as well as firm initial size trend and product-firm level trends. The approach differs from Goldberg et al. (2010) who rely on input product data at industry level to identify how tariff cuts affected imported inputs varieties. We are in position to conduct this analysis as our data uniquely allow for identifying for each firm new varieties (at the 11-digit level) that firms have sourced from either national or foreign producers. Results, presented in column (3) of Table 3, show a positive impact of input tariff reductions on new varieties of inputs. Conducting the same falsification test as before on new variety of domestic intermediate goods, results presented in column (4) 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 2).

Moreover, we test our model's predictions that input tariff cuts only lead firms with high markups and productivity source more imported varieties. We test for this prediction by interacting our input tariff measures with an indicator of whether firms' markups are higher or lower than the median. We do the same for productivity and for both measures combined. Results in columns (5), (6) and (7) of Table 3 show that only firms with high markups and productivity benefitted from input tariff cuts to access more varieties of inputs. The most productive firms charging higher markups increase the probability of importing a new variety of inputs by 1.7% for a 10 percentage point reduction of input tariffs, while firms with low productivity and firms with high productivity but low markups do not benefit from input tariff cuts.

Hypothesis 2: Input-tariff cuts lead more productive high-markup firms to expand their product scope by introducing new products.

We now test for the heterogeneous impacts of input-tariff cuts on firms' product scope and product innovation. We estimate the following model, using as before a within-firm estimator, to test this relationship:

$$\ln Y_{ijt} = \alpha + \gamma_{I\tau'} \text{ Input } \tau_{j,t-1} + \gamma_O \text{ Output } \tau_{j,t-1} + \gamma_{s'} \text{ Size}_{i,t0} * \eta_t + \mu_i + \eta_t + \varepsilon_{ijt} \quad \text{(II)}$$

where $\ln Y_{ijt}$ measures product scope i.e. the logarithm of the number of products firm *i* in a 3-digit industry *j*, and year *t* produces and, alternatively, product innovation, i.e. an indicator variable that is equal to 1 if the firm introduces new products in the market in year *t* it did not produce before.

Then, 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, $Size_{i,t0} * \eta_t$. The estimation includes firm fixed effects, μ_i, to take into account unobservable shocks varying across time affecting all firms in the same way and year fixed effects, η_t. Since tariffs vary at the 3-digit industry level over time, the standard errors are clustered at the 3-digit industry level.

Results of columns (1) and (2) of Table 4 show a positive and significant effects of reductions in tariffs. When introducing differences in markups and productivity, results show that only high-markup and more productive firms increase their product scope and introduce new products (columns 3 and 4). The evidence reported in column (4) shows that only high-markup firms with high productivity increase their product scope by 6.4% by increasing their product innovation by 10.5% for a 10-percentage-point reduction in input tariffs. These results imply that those firms introduce two additional new products thanks to input-trade liberalization.

Table 4: Impacts of input-tariff cuts on product scope and innovation

	Product scope				Product innovation			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Input tariff(j,t-1)	-0.246**				-0.566**			
	(0.125)				(0.265)			
Output tariff(j,t-1)	0.477***				0.589***			
	(0.077)				(0.163)			
Input tariff(j,t-1) x High Markups(i,97)		-0.415**				-0.842**		
		(0.164)				(0.331)		
Input tariff(j,t-1) x Low Markups(i,97)		-0.031				-0.189		
		(0.169)				(0.377)		
Output tariff(j,t-1) x High Markups(i,97)		0.526***				0.590***		
		(0.103)				(0.210)		
Output tariff(j,t-1) x Low Markups(i,97)		0.402***				0.588**		
		(0.108)				(0.244)		
Input tariff(j,t-1) x High TFPQ(i,97)			-0.402**				-0.642*	
			(0.163)				(0.334)	
Input tariff(j,t-1) x Low TFPQ(i,97)			-0.064	-0.060			-0.465	-0.465
			(0.171)	(0.171)			(0.367)	(0.367)
Output tariff(j,t-1) x High TFPQ(i,97)			0.629***				0.609***	
			(0.101)				(0.212)	
Output tariff(j,t-1) x Low TFPQ(i,97)			0.288**	0.290**			0.559**	0.564**
			(0.116)	(0.116)			(0.242)	(0.242)
Input tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)				-0.638***				-1.053**
				(0.217)				(0.426)
Input tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)				-0.100				-0.047
				(0.225)				(0.489)
Output tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)				0.555***				0.624**
				(0.137)				(0.275)
Output tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)				0.776***				0.593*
				(0.143)				(0.325)
Initial firm size trend	yes	yes	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Observations	12,343	12,343	12,343	12,343	11,123	11,123	11,123	11,123
R-squared	0.84	0.84	0.84	0.84	0.32	0.32	0.32	0.32

Notes: Standard errors clustered at the 3-digit industry level are reported in parentheses. ∗∗∗, ∗∗, and ∗indicate significance at the 1, 5 and 10 percent levels respectively.

Sensitivity tests: Alternative measures and estimations

We next conduct sensitivity tests on the outcome variables, the measures used to assess heterogeneity and the estimation model. First, the measures of product scope and innovation rely on product information at the 11-digit ISIC level. A possible problem with this measure is that this disaggregate measure may inadequately measure product scope and innovation. Firms producing a set of very similar products may be identified as having a larger product scope but not differ in their product scope as much. Product innovations identified at this disaggregate level may also indicate little actual innovation. We address this criticism by measuring product scope as the number of distinct firm production lines at 5-digit ISIC level and product innovation as new products only for any that differ at the 5-digit ISIC level. Our results, shown in columns 1 and 4 of Table 5, confirm our baseline findings.

Second, our product innovation measure may simply point to easy-to-implement shifts in production lines rather than substantial changes associated with firm product innovation. We test whether we are identifying the latter rather than the former by obtaining an alternative measure of new-to-the-firm innovation. Our measure is equal to 1 if the distance of the firms' new product compared to all existing firm products is high and 0 otherwise. Distance is measured by an index of proximity of the new product introduce by a firm to the firm's past production capabilities based on Hidalgo et al. (2007) and Boschma et al. (2012) that accounts for the relative closeness between the firms' established industries and those of the new products. Results, reported in column 5 of Table 5, are positive significant, suggesting that we measure product innovation and not simple adjustments in firms' production that result in new products.

Third, we test for alternative measures of markups and productivity. As alternative measure of markups, we compute the firm-level markup developed by De Loecker and Warzynski (2012). Results shown in columns (2) and (6) of Table 5 confirm our baseline findings. The magnitude is smaller as we rely on firm-product markups in the main specification. As alternative measure of productivity, we compute TFPQ using the production function approach by Olley and Pakes (1996). We report the evidence that confirms our results in columns (3) and (7) of Table 5.

Fourth, we show that relying on the linear probability model for our product innovation regressions is adequate. Results using conditional logit regressions confirm our evidence (column 8 of Table 5).

Table 5: Sensitivity tests

	Product scope			Product innovation				
	aggregated	alt. markup	alt. TFP	aggregated	novelty	alt. markup	alt. TFP	Condit. logit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Input tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)	-0.518**	-0.557***	-0.519**	-0.641*	-0.381*	-0.693*	-0.995**	-5.734**
	(0.245)	(0.191)	(0.220)	(0.332)	(0.198)	(0.401)	(0.439)	(2.803)
Input tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)	0.167	-0.180	-0.072	0.789**	0.164	-0.572	-0.564	0.892
	(0.251)	(0.225)	(0.198)	(0.366)	(0.239)	(0.492)	(0.440)	(3.549)
Output tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)	0.350**	0.690***	0.553***	0.692***	0.245**	0.710***	0.779***	3.843**
	(0.148)	(0.118)	(0.134)	(0.212)	(0.118)	(0.256)	(0.274)	(1.734)
Output tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)	0.567***	0.543***	0.410***	-0.017	-0.184	0.466	0.881***	3.060
	(0.157)	(0.138)	(0.131)	(0.228)	(0.145)	(0.306)	(0.285)	(2.276)
Input tariff(j,t-1) x Low TFPQ(i,97)	0.065	-0.067	-0.169	-0.100	-0.075	-0.463	-0.165	-3.279
	(0.215)	(0.162)	(0.182)	(0.284)	(0.205)	(0.364)	(0.382)	(2.626)
Output tariff(j,t-1) x Low TFPQ(i,97)	0.182	0.287***	0.455***	0.610***	-0.050	0.562**	0.152	3.635**
	(0.130)	(0.100)	(0.124)	(0.200)	(0.150)	(0.233)	(0.261)	(1.673)
Initial firm size trend	yes	yes	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Observations	12,343	12,343	12,343	11,123	11,123	11,123	11,123	8,044
R-squared	0.79	0.84	0.84	0.25	0.25	0.32	0.32	

Notes: Standard errors clustered at the 3-digit industry level are reported in parentheses. ***, **, and *indicate significance at the 1, 5 and 10 percent levels respectively.

We also run all our estimations on subsamples excluding sectors that may present specific patterns such as the oil sector that was affected by other reforms such as privatization and FDI and manufacturers of agricultural goods. More precisely, we exclude firms from the manufacture of coke, refined petroleum products and nuclear fuel (ISIC 2 digit revision 3 code 23), tobacco (ISIC 2 digit revision 3 code 16), food and beverage (ISIC 2 digit revision 3 code 15) from the analysis. Also, we test if our results are driven by firms entering and exiting the sample. We run our baseline regression on the subset of firms that are present over the entire period. Unreported results that are available from the authors upon request show that our findings are maintained and not affected by sample selection issues.

Finally, we test for the impact of input-trade liberalization on product churning, the alternative mechanism to product innovation that affects product scope. In this case, our dependent variable is a dummy equal to one if the firm drops an 11-digit product in year *t* it produced in year *t-1*. Results are presented in Table 6. We find that input-trade liberalization leads firms with high levels of productivity to drop existing products (column 3 of Table 6) and among these firms, only those with highest markups (column

4 of Table 6). This evidence points to fundamental changes in the production processes of these firms with input trade liberalization. They discontinue existing products and, as shown by results of Table 4, replace them with high amount of new products that increase their product scope.

Table 6: Impacts of input-tariff cuts on product churning

	Product churning			
	(1)	(2)	(3)	(4)
Input tariff(j,t-1)	-0.284			
	(0.228)			
Output tariff(j,t-1)	-0.035			
	(0.125)			
Input tariff(j,t-1) x High Markups(i,97)		-0.283		
		(0.282)		
Input tariff(j,t-1) x Low Markups(i,97)		-0.291		
		(0.319)		
Output tariff(j,t-1) x High Markups(i,97)		-0.079		
		(0.153)		
Output tariff(j,t-1) x Low Markups(i,97)		0.040		
		(0.206)		
Input tariff(j,t-1) x High TFPQ(i,97)			-0.579**	
			(0.271)	
Input tariff(j,t-1) x Low TFPQ(i,97)			0.063	0.062
			(0.318)	(0.319)
Output tariff(j,t-1) x High TFPQ(i,97)			0.129	
			(0.161)	
Output tariff(j,t-1) x Low TFPQ(i,97)			-0.236	-0.236
			(0.188)	(0.188)
Input tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)				-0.774**
				(0.344)
Input tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)				-0.322
				(0.393)
Output tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)				0.187
				(0.200)
Output tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)				0.047
				(0.263)
Initial firm size trend	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes
Observations	12,343	12,343	12,343	12,343
R-squared	0.84	0.84	0.84	0.84

Notes: Standard errors clustered at the 3-digit industry level are reported in parentheses. ∗∗∗, ∗∗, and ∗indicate significance at the 1, 5 and 10 percent levels respectively.

Hypothesis 3: The market share of more productive high-markup firms expands in response to input-trade liberalization.

We next test for the input tariff cuts on firm-product level market shares, which are computed as the percentage share of sales of 11-digit product of a firm over total sales in that product industry in year *t*. Our findings show a positive effect of input tariff cuts on firm-product market shares (column 1 of Table 7). We also find evidence of heterogeneous effects depending on markups in column 2 and TFPQ in column 3 of Table 7. High-TFP and high-markup firms see an increase in their market shares (column 4) by 1% for a 10-percentage-point decrease in input tariffs. This is as expected based on our conceptual framework that predicts market share increases only for those firms that benefit from new input varieties from abroad to widen product scope and innovate. 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.

Table 7: Input tariff cuts and firms' market shares and markups

	Market shares				Markups	
	(1)	(2)	(3)	(4)	(5)	(6)
Input tariff(j,t-1)	-0.080***				-1.267**	
	(0.0204)				(0.492)	
Output tariff(j,t-1)	0.026				-0.432	1.134*
	(0.0177)				(0.420)	(0.678)
Input tariff(j,t-1) x High Markups(i,97)		-0.050***				
		(0.016)				
Input tariff(j,t-1) x Low Markups(i,97)		.-0.044				
		(0.026)				
Output tariff(j,t-1) x High Markups(i,97)		-0.008				
		(0.017)				
Output tariff(j,t-1) x Low Markups(i,97)		0.083***				
		(0.019)				
Input tariff(j,t-1) x High TFPQ(i,97)			-0.109***			
			(0.028)			
Input tariff(j,t-1) x Low TFPQ(i,97)			-0.005	0.010		
			(0.030)	(0.031)		
Output tariff(j,t-1) x High TFPQ(i,97)			-0.005			
			(0.017)			
Output tariff(j,t-1) x Low TFPQ(i,97)			-0.025	-0.024		
			(0.019)	(0.019)		
Input tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)				-0.153***		
				(0.027)		
Input tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)				-0.003		
				(0.037)		
Output tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)				0.012		
				(0.025)		
Output tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)				0.029		
				(0.032)		
Input tariff(j,t-1) x High product scope(i,97)						-2.619***
						(0.613)
Input tariff(j,t-1) x Low product scope(i,97)						-1.059
						(0.593)
Initial firm size trend	yes	yes	yes	yes	yes	yes
Initial firm-product trend	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
Observations	57,933	56,969	58,380	57,336	49,442	46,188
R-squared	0.54	0.63	0.58	0.58	0.79	0.86

Notes: Robust standard errors clustered at the 3-digit industry level are reported in parentheses. ∗∗∗, ∗∗, and ∗indicate significance at the 1, 5 and 10 percent levels respectively.

Hypothesis 4: Output-tariff cuts lead firms introduce fewer new products, reduce their product scope and concentrate on their core products.

Output-tariff cuts have reverse effects to input-tariff cuts. Increase in foreign competition after output tariff liberalization induces firms to reduce product scope and innovation. Results reported in columns (1) and (5) of Table 4 show that for the average 6-percentage-point output tariff reduction over the period, firms reduced their product scope by 2.8% and the probability of adding products by 3.5%. We find that all firms independently of markup and productivity reduce their product scope and innovation with output-tariff cuts. This result is in line with the findings of Bernard et al. (2011) on the impacts of tariff reductions on US firms.

We next estimate the impact of output-tariff cuts on measures of firm core product concentration and find moderate effects. In Table 8, we show positive moderate impacts of output tariffs on firms' core product ratios as used in Mayer et al. (2014) (column 1), firms' product Herfindahl indexes (column 2) and the shares of sales of the top 30th percentile of firms' products (column 3). These effects are concentrated on firms with high markups (columns 4, 5 and 6) and, among those, firms with high productivity (columns 7, 8 and 9). Input tariffs do not have an impact on firms' core product concentration. The finding that the negative effect on product scope stems from less product innovation (columns 5-8 of Table 4) rather than product churning (column 1-4 of Table 6) corroborates that output-trade liberalization has modest effects on Ecuadorian firms' existing production processes.

With regards to market shares, our findings of Table 7 show there is no average effect of output tariffs (column 1). Results of column (2) show that low markup firms' market shares only are negatively affected. We do not find evidence of unequal effects of output-trade liberalization depending on firm productivity (columns 3 and 4).

In conclusion, we find that output-tariffs reduce firms' product innovation and consequently reduce their product scope. However, we find only modest effects of output-trade liberalization on firms' production processes with moderate concentration on core products, no effect on ongoing product lines and no reduction in market shares except for low-markup firms.

Table 8: The effects of input and output tariffs on firms' core product concentration

	Core product ratio	Product Herfindhal	Share top 30 perc	Core product ratio	Product Herfindhal	Share top 30%	Core product ratio	Product Herfindahl	Share top 30 perc
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Input tariff(j,t-1)	0.030	0.103	-0.030						
	(0.084)	(0.087)	(0.060)						
Output tariff(j,t-1)	-0.077*	-0.130**	-0.072**						
	(0.047)	(0.054)	(0.037)						
Input tariff(j,t-1) x High Markups(i,97)				0.006	0.091	-0.082			
				(0.055)	(0.114)	(0.081)			
Input tariff(j,t-1) x Low Markups(i,97)				0.023	0.100	-0.017			
				(0.069)	(0.120)	(0.080)			
Output tariff(j,t-1) x High Markups(i,97)				.-0.066*	-0.194***	-0.098**			
				(0.037)	(0.068)	(0.046)			
Output tariff(j,t-1) x Low Markups(i,97)				-0.002	0.003	0.059			
				(0.059)	(0.079)	(0.054)			
Input tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)							0.007	0.151	-0.117
							(0.098)	(0.144)	(0.099)
Input tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)							0.116	0.189	0.047
							(0.106)	(0.164)	(0.102)
Input tariff(j,t-1) x Low TFPQ(i,97)							-0.018	-0.028	-0.042
							(0.086)	(0.120)	(0.088)
Output tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)							-0.007	-0.141*	-0.099*
							(0.056)	(0.084)	(0.059)
Output tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)							-0.111	-0.046	-0.027
							(0.078)	(0.118)	(0.079)
Output tariff(j,t-1) x Low TFPQ(i,97)							-0.058	-0.065	-0.013
							(0.051)	(0.078)	(0.052)
Initial firm size trend	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	12,374	12,427	12,374	12,374	12,427	12,374	12,374	12,427	12,374
R-squared	0.73	0.83	0.72	0.75	0.83	0.72	0.75	0.83	0.72

Notes: Standard errors clustered at the 3-digit industry level are reported in parentheses. ∗∗∗, ∗∗, and ∗indicate significance at the 1, 5 and 10 percent levels respectively.

Hypothesis 5: Input-tariff cuts expand firm-product markups while output-tariff cuts have the reverse effect.

How are both input and output tariff reductions benefiting firms and consumers? To answer this question, we look at the effect of input tariff cuts on firms' product-level markups. We obtain firm-product level markups as the ratio of output prices over marginal costs at the firm-product level. We find that for a 10-percentage-point reduction of input tariffs the average firm-product level markup increased by 20 % (column 5 of Table 7). Finally, our theory suggests that firms that expand their product range and add new products due to input-trade liberalization (through access to new imported varieties) increase their markups. Column (6) of Table 7 shows that only firms with initially high product scope raise their market power as a result of input tariff cuts. For a 10-percentage-point reduction of input tariffs firms with high initial product scope in (above the median product scope in 1997) increase their firm-product level markup by 26 %. These results suggest that 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 to consumers.

Finally, we do not find strong evidence of hypothesized impacts from output tariff cuts. Results of column (5) of Table 7 do not find any effect of output tariff cuts on markups while those of column (6) point to a decrease that is statistically significant at the 10 percent level.

6. Testing the role of imported varieties and alternative explanations

In this section, we test whether improved access to imported varieties drive product innovation and the increase in product scope as a result of trade liberalization. We also examine whether several alternative explanations – new export opportunities, Ecuador's financial crisis and other reforms – drive our findings.

6.1. The role of imported varieties

In this section we test whether, as in our conceptual framework, access to new imported varieties is the main driver of increased innovation and an increased product scope. We confront this hypothesis with an alternative channel through which input-trade liberalization might affect firm' product scope and innovation: imported input quality upgrading. In previous work, we show that Ecuadorian firms improve the quality of their foreign inputs with input tariff cuts (Bas and Paunov, 2019).

We first regress our variables of interest on a dummy variable that indicates whether the firm imports a new 11-code product that has not been sourced in the domestic or foreign market in the previous year. We also include as in the previous specifications initial firm size trends as well as firm and year fixed effects. We control for the foreign input quality upgrading channel by constructing a variable at the firm level that is equal to one if the firm increases the quality of its products between t and t-5. We estimate firms' imported inputs quality following the methodology proposed by Khandelwal et al. (2013) and applied widely to capture product quality (Bas and Strauss-Kahn, 2015;

Fan et al., 2015, 2018, Manova and Yu, 2017, among others) as is described in Bas and Paunov (2019).

Columns (1) and (2) of Table 9 show the estimates of regressing product scope and product innovation on the imported input variety and input quality upgrading indicator variables. These estimates show that only access to new imported input varieties has a positive effect on firms' product scope and product innovation.

To test the causal relationship between input quality and variety and product innovation, we follow Trefler (2004) and use an instrumental variable estimator in a 5-year difference equation and regress long changes in product scope on 5-year changes in access to new imported varieties and to imported input quality. Instruments used are 5-year changes in input tariffs and initial input tariffs in 1996 interacted with initial levels of firms' imported input variety, quality and industry size measured by total number of workers in the initial year. Results of columns (3) and (6) of Table 9 suggests that only access to new imported input varieties explains increases in firms' product scope and their product innovations, while imported input quality upgrading has no significant effect. We run the same instrumental variable estimation for firms with high initial TFP and markups and for all other firms in the sample. Findings in columns (4), (5), (7) and (8) show that only the most productive firms with high markups expand their product range and introduce new products thanks only to access to new imported varieties of inputs.

To sum up, these findings confirm that access to new imported varieties after input-trade liberalization are the main channel for most productive firms with high markups to expand their product scope and innovate.

Table 9: Controlling for possible impact of quality on product scope and innovation

Dependent variables:	Product scope	Product innovation	△ Product scope			△ Product innovation		
			Growth rates between *t* and *t-5*					
			Full sample	High TFP & markups = 1	High TFP & markups = 0	Full sample	High TFP & markups = 1	High TFP & markups = 0
	OLS		Instrumental variable estimations					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
New imported variety dummy (i,t)	0.033***	0.109***						
	(0.009)	(0.014)						
High imported input quality dummy(i, t)	0.011	-0.011						
	(0.008)	(0.012)						
△ New imported variety dummy (i,t, t-5)			0.916**	1.113*	0.028	0.084**	0.137***	0.313
			(0.397)	(0.623)	(0.045)	(0.039)	(0.050)	(0.252)
△ High imported input quality dummy (i,t, t-5)			0,646	0.325	0.016	-0.260	-0.258	-0.107
			(0.354)	(0.375)	(0.183)	(0.242)	(0.366)	(0.289)
Initial firm size trend	yes	yes						
Firm fixed effects	yes	yes						
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Observations	12,357	11,135	5,593	1,901	3,972	4,525	1,588	3 182
R-squared	0,84	0,32						
P-value of Hansen test			0,73	0,81	0,51	0,16	0,13	0,11

Notes: For results in columns (3) to (8) instruments used are 5-year changes in input tariffs, initial input tariffs in 1996 interacted with initial levels of firms' imported input variety and quality as well as industry size in the initial year. Standard errors clustered at the firm level are reported in parentheses. ∗∗∗, ∗∗, and ∗indicate significance at the 1, 5 and 10 percent levels respectively.

6.2. Testing for alternative explanations

Product scope and innovation may also be affected by changes in foreign demand because of changes in trade variable costs faced by exporters as described in the model by Mayer et al. (2020). The underlying reason is that more export opportunities can raise firms' export profits and allow firms to overcome the fixed costs of product innovation (Bustos, 2011). If export opportunities are correlated with changes in tariffs, then it may be the case that our results reflect export opportunities rather than effects of input tariffs.

We test for the role of the export channel by including in the previous specification the average effectively applied tariff set by Ecuador's main trading partners - neighboring Latin American countries, the USA, the European Union and China - at 4-digit ISIC Rev. 3 industry level. We also include an indicator of firms' exporter status and an interaction term between export status and export tariffs. Our results, as reported in Online Annex Table OA.2, show that the measured impacts of input and output tariff cuts on product scope and innovation is not affected. The effect of firms' export status of the firm on product scope and innovation is positive and significant, consistently with previous works on multiproduct exporters (Mayer et al., 2014 and 2020).[7]

Next, we test whether our results are affected by Ecuador's financial crisis of 1999-2000 or by impact of other reforms in Ecuador. We account for the crisis by interacting our tariff measures with an indicator variable for the crisis years. The evidence presented in Online Annex Table OA.3 confirms results on product scope and innovation are not driven by Ecuador's economic crisis. As a way to account for other reforms, we control for those reforms and all unobservable time-varying shocks across industries by including industry trends. Results show that our coefficients of interest are robust to those additions (Online Annex Table OA.4)

Conclusion

This paper provides new evidence on the unequal impact of trade liberalization on firms' product scope and innovation in Ecuador across firms. We show that input-tariff reductions with Ecuador's entry to the WTO allow national firms with high-markups and productivity to import more input varieties and introduce new products. In consequence, the market shares of firms with highest markups and productivity rise in response to input-trade liberalization. By contrast, the increase in import competition with output tariff reductions reduces the likelihood that firms introduce product innovations but has only moderate effects on firms existing production processes and no impact on market shares.

This evidence confirms the benefits of input-trade liberalization for firms' production upgrading in developing country contexts. Moreover, the unequal impacts on firm scope and innovation and consequent gains (losses) in market shares for more (less) productive firms indicate industry-wide production upgrading. However, the importance of high markups for firms to source more varieties and introduce new products to expand their product scope implies that not all highly productive firms benefit. Moreover, consumers also see fewer gains than possible as input-trade liberalization increases firms' markups.

[7] Unreported results that are available from the authors upon request confirm results on market shares and markups also hold for these and all other results reported in this section.

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Annex: Variable definitions and exogeneity tests

Table A.1: Variable descriptions

Variable	***Description***
Product scope	The logarithm of the number of 11-digit products based on the ISIC Rev. 3 classification produced by firm *i* in year *t*.
Product innovation	The variable is equal to 1 if firm *i* introduces an 11-digit product based on the ISIC Rev. 3 classification in year *t* it did not produce before.
Product churning	The variable is equal to 1 if firm *i* drops an 11-digit product based on the ISIC Rev. 3 classification in year *t* it produced in year *t-1*.
Output / Input tariffs	Output / Input tariffs are computed as a weighted average of the output / input tariffs at the product level faced by each firm using constant weights averaged over the period. We link tariff data to our data on Ecuadorian firms by establishing a product correspondence between the 11-digit product categories of Ecuadorian firms' output and input products and the HS 6-digit product 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.
Markup	1./ Baseline: Firm-product level markups are measured 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 11-digit product. 2. / Robustness: Markup measure (columns 2 and 6 of Table 6) relies on De Loecker and Warzyinsky (2012) methodology. Firm-level markups are the deviation between the elasticity of output with respect to a variable input and that input's share of total revenue. We rely on the elasticity of output with respect to materials that comes from estimates of a production functions at the industry level using the Olley and Pakes (1996) methodology to estimate the production function and firms' sales deflated by firm' output prices.
TFPQ	Methods: 1./ Baseline: The total factor productivity index of plant *i* in year *t* is expressed as deviation from a single reference point and defined as follows for plant *i* in year *t* the index $$ln\,TFPQ_{it} = \left(ln\,Y_{it} - \overline{\ln Y_t}\right) + \sum_{\tau=2}^{t}\left(\overline{lnY} - \overline{lnY_{\tau-1}}\right) - \left[\sum_{j=1}^{m}\frac{1}{2}\left(s_{jit} + \overline{s_{jt}}\right)\left(lnX_{jit} - \overline{lnX_{jt}}\right) + \sum_{\tau=2}^{t}\sum_{j=1}^{m}\frac{1}{2}\left(\overline{s_{j\tau}} + \overline{s_{j\tau-1}}\right)\left(\overline{lnX_{j\tau}} - \overline{lnX_{j\tau-1}}\right)\right]$$ 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.

Table A.1: Variable descriptions (continued)

Variable	*Description*
(continued) TFPQ	(continued) 2/ Robustness: Measure (columns 3 and 7 of table 6) relies on the method proposed by Olley and Pakes (1996) that relies on production function estimates to address endogeneity and uses firms' sales deflated by firm' output prices. Price indexes and deflators and capital stock measures: We obtain firm-level prices by computing a Tornquist index as in Eslava et al. (2004). We use deflators on the gross capital formation from the World Development Indicators to obtain real capital. Deflators to obtain real value of energy and services deflators were 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).
Input varieties	The logarithm of the number of 11-digit distinct intermediary inputs of firm *i* in year *t*.
Input quantity	The logarithm of units of physical quantity of intermediary inputs at 11 digit of firm *i* in year *t*.
New (imported) input variety	The variable is a dummy variable equal to 1 if the firm purchases (imports) a new product at 11-digit ISIC-Rev.3 level in year *t* that has not been sourced in the domestic or foreign market in the previous year.
Product ratio	Ratio of the sales of firm *i*'s top product in terms of sales relative to its second product in year *t*.
Product Herfindahl index	The variable is sum of the squares of the product shares in total shares of firm *i* in year *t* and ranges from 0 to 1.
Share top 30 percentiles	Variable is the share of the sales of the top 30 percentiles of products of firm *i* in year *t*.
Market share	Variable at the firm-product-year is the percentage share of firm *i*'s that product over total sales in that product industry in year *t*.

Table A.2: 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.3: 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.

Online Annex: Additional results tables

Table OA.1: Number of firm-year observations by industry

Industry		Firms	Share in total
15	Food and beverages	2,771	22.0
16	Tobacco	488	3.9
17	Textiles	891	7.1
18	Wearing apparel	871	6.9
19	Leather products	475	3.8
20	Wood and wood products	469	3.7
21	Paper and paper products	443	3.5
22	Publishing, printing and reproduction	614	4.9
23	Coke, refined petroleum	70	0.6
24	Chemicals	904	7.2
25	Rubber and plastic products	959	7.6
26	Other non-metallic products	65	0.5
27	Basic metals	1,174	9.3
28	Fabricated metals	297	2.4
29	Machinery and equipement	676	5.4
30	Office, accounting and computing machinery	4	0.0
31	Electrical machinery	149	1.2
32	Radio, TV and communication equipment	20	0.2
33	Medical, precision and optical instruments	27	0.2
34	Motor vehicles	339	2.7
35	Other transport	679	5.4
36	Furniture	206	1.6

Notes: For each industry ISIC Rev. 3 2-digit codes are provided jointly with industry labels.

Table OA.2: Sensitivity tests on the effects of export opportunities

	Product scope				Product innovation			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Input tariff(j,t-1)	-0.233*				-0.582**			
	(0.125)				(0.266)			
Output tariff(j,t-1)	0.473***				0.563***			
	(0.078)				(0.164)			
Input tariff(j,t-1) x High Markups(i,97)		-0.417**				-0.873***		
		(0.164)				(0.331)		
Input tariff(j,t-1) x Low Markups(i,97)		0.002				-0.184		
		(0.169)				(0.378)		
Output tariff(j,t-1) x High Markups(i,97)		0.522***				0.570***		
		(0.104)				(0.211)		
Output tariff(j,t-1) x Low Markups(i,97)		0.396***				0.551**		
		(0.109)				(0.245)		
Input tariff(j,t-1) x High TFPQ(i,97)			-0.389**				-0.673**	
			(0.163)				(0.335)	
Input tariff(j,t-1) x Low TFPQ(i,97)			-0.053	-0.048			-0.460	-0.461
			(0.171)	(0.171)			(0.368)	(0.368)
Output tariff(j,t-1) x High TFPQ(i,97)			0.622***				0.586***	
			(0.102)				(0.213)	
Output tariff(j,t-1) x Low TFPQ(i,97)			0.286**	0.289**			0.529**	0.534**
			(0.117)	(0.117)			(0.243)	(0.243)
Input tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)				-0.627***				-1.097**
				(0.218)				(0.427)
Input tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)				-0.083				-0.063
				(0.225)				(0.490)
Output tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)				0.551***				0.604**
				(0.137)				(0.275)
Output tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)				0.767***				0.563*
				(0.144)				(0.327)
Export tariffs(j,t-1)	-0.029	-0.030	-0.027	-0.040	0.241	0.247	0.240	0.238
	(0.104)	(0.104)	(0.105)	(0.104)	(0.209)	(0.209)	(0.209)	(0.209)
Exporter(i,t)	0.038**	0.038**	0.038**	0.038**	0.001	0.000	0.001	0.000
	(0.017)	(0.017)	(0.017)	(0.017)	(0.032)	(0.032)	(0.032)	(0.032)
Export tariffs(j,t-1) x Exporter(i,t)	-0.086	-0.081	-0.079	-0.082	0.001	0.021	0.000	0.019
	(0.163)	(0.163)	(0.163)	(0.162)	(0.312)	(0.312)	(0.312)	(0.312)
Initial firm size trend	yes	yes	yes	yes	yes	yes	yes	yes
Firm-product fixed effects	yes				yes			
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects		yes	yes	yes		yes	yes	yes
Observations	12,343	12,253	12,253	12,253	11,123	11,045	11,045	11,045
R-squared	0.84	0.84	0.84	0.84	0.32	0.32	0.32	0.32

Notes: Standard errors clustered at the 3-digit industry level are reported in parentheses. ∗∗∗, ∗∗, and ∗indicate significance at the 1, 5 and 10 percent levels respectively.

Table OA.3: Controlling for the impact of Ecuador's crisis

	Product scope				Product innovation			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Input tariff(j,t-1)	-0.245*				-0.599**			
	(0.125)				(0.267)			
Output tariff(j,t-1)	0.472***				0.605***			
	(0.078)				(0.166)			
Input tariff(j,t-1) x High Markups(i,97)		-0.408**				-0.854**		
		(0.164)				(0.332)		
Input tariff(j,t-1) x Low Markups(i,97)		-0.036				-0.250		
		(0.170)				(0.381)		
Output tariff(j,t-1) x High Markups(i,97)		0.514***				0.586***		
		(0.104)				(0.211)		
Output tariff(j,t-1) x Low Markups(i,97)		0.408***				0.634**		
		(0.109)				(0.250)		
Input tariff(j,t-1) x High TFPQ(i,97)			-0.394**				-0.663**	
			(0.162)				(0.335)	
Input tariff(j,t-1) x Low TFPQ(i,97)			-0.072	-0.069			-0.513	-0.512
			(0.172)	(0.172)			(0.370)	(0.370)
Output tariff(j,t-1) x High TFPQ(i,97)			0.619***				0.619***	
			(0.101)				(0.214)	
Output tariff(j,t-1) x Low TFPQ(i,97)			0.290**	0.293**			0.584**	0.588**
			(0.117)	(0.117)			(0.245)	(0.245)
Input tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)				-0.626***				-1.056**
				(0.216)				(0.426)
Input tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)				-0.098				-0.093
				(0.225)				(0.490)
Output tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)				0.537***				0.612**
				(0.136)				(0.275)
Output tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)				0.779***				0.635*
				(0.144)				(0.328)
Input tariff(j,t-1) x crisis dummy	-0.033	-0.051	-0.032	-0.021	0.376	0.362	0.375	0.361
	(0.255)	(0.255)	(0.254)	(0.254)	(0.544)	(0.546)	(0.544)	(0.544)
Output tariff(j,t-1) x crisis dummy	0.022	0.035	0.026	0.020	-0.175	-0.164	-0.173	-0.162
	(0.174)	(0.174)	(0.173)	(0.173)	(0.367)	(0.368)	(0.367)	(0.367)
Initial firm size trend	yes	yes	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Observations	12,343	12,253	12,253	12,253	11,123	11,045	11,045	11,045
R-squared	0.84	0.84	0.84	0.84	0.32	0.32	0.32	0.32

Notes: Standard errors clustered at the 3-digit industry level are reported in parentheses. ∗∗∗, ∗∗, and ∗indicate significance at the 1, 5 and 10 percent levels respectively.

Table OA.4: Results including industry trends

	Product scope				Product innovation			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Input tariff(j,t-1) x High Markups(i,97)	-0.283**	-0.449***			-0.666**	-0.949***		
	(0.125)	(0.164)			(0.265)	(0.330)		
Input tariff(j,t-1) x Low Markups(i,97)	0.455***	-0.073			0.640***	-0.275		
	(0.078)	(0.170)			(0.163)	(0.379)		
Output tariff(j,t-1) x High Markups(i,97)		0.498***				0.676***		
		(0.105)				(0.211)		
Output tariff(j,t-1) x Low Markups(i,97)		0.389***				0.587**		
		(0.108)				(0.245)		
Input tariff(j,t-1) x High TFPQ(i,97)			-0.446***				-0.752**	
			(0.163)				(0.335)	
Input tariff(j,t-1) x Low TFPQ(i,97)			-0.094	-0.091			-0.553	-0.554
			(0.171)	(0.171)			(0.366)	(0.366)
Output tariff(j,t-1) x High TFPQ(i,97)			0.607***				0.665***	
			(0.102)				(0.212)	
Output tariff(j,t-1) x Low TFPQ(i,97)			0.265**	0.265**			0.604**	0.608**
			(0.116)	(0.116)			(0.241)	(0.241)
Input tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)				-0.689***				-1.168***
				(0.217)				(0.427)
Input tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)				-0.139				-0.148
				(0.226)				(0.489)
Output tariff(j,t-1) x High TFPQ(i,97) x High Markups(i,97)				0.525***				0.708**
				(0.138)				(0.275)
Output tariff(j,t-1) x High TFPQ(i,97) x Low Markups(i,97)				0.762***				0.602*
				(0.143)				(0.325)
Industry trend	yes	yes	yes	yes	yes	yes	yes	yes
Initial firm size trend	yes	yes	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Observations	12,343	12,253	12,253	12,253	11,123	11,045	11,045	11,045
R-squared	0.84	0.84	0.84	0.84	0.32	0.32	0.32	0.32

Notes: Standard errors clustered at the 3-digit industry level are reported in parentheses. ∗∗∗, ∗∗, and ∗ indicate significance at the 1, 5 and 10 percent levels respectively.