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# **Input quality and skills are complementary and increase output quality: Causal evidence from Ecuador's trade liberalization**

Maria Bas\*      Caroline Paunov\*\*

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## **Abstract**

This paper tests for the production complementarity between firms' access to high-quality intermediate inputs and their skill composition and their joint impact on output quality. Using census data at firm-product level for Ecuador for 1997-2007, we exploit exogenous tariff changes at Ecuador's entry to the World Trade Organization to show that input tariff cuts allow firms to upgrade their input quality. Next, we demonstrate by means of within-firm instrumental variable estimations that firms' choices of imported input quality drive their relative demand for skilled labor and the skill premium. Imported input quality and firms' skill-composition jointly boost firms' output quality. Moreover, we show that firms that source domestic inputs produced by industries that import high-quality inputs also upgrade their skills and output quality. Our findings are not driven by our measures of quality, foreign demand shocks (export opportunities), Ecuador's financial crisis, real exchange variations, financial liberalization and other industry-level reforms.

**Keywords:** foreign inputs quality, input-skill complementarity, skill intensity and skill premium, output product quality, input tariff reductions, firm-product-level data, Ecuador.

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

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The findings expressed in this paper are those of the authors and do not necessarily represent the views of the OECD or its member countries.

## 1. Introduction

With input-trade liberalization, access to high-quality imported intermediate goods increased substantially in the last decades (Bas and Strauss-Kahn, 2015; Fan et al., 2015, 2018). This plays a central role in developing countries where firms depend on foreign technology to upgrade production processes.<sup>1</sup> Research has shown that access to high-quality inputs allows firms to upgrade the quality of their products (Kugler and Verhoogen, 2012; Hallak and Sivadasan, 2013; Atkin et al. 2017). Inputs of higher quality alone, however, may not allow upgrading production processes but also require skilled labor to produce higher quality outputs (Verhoogen, 2008; Fieler et al., 2018).

Exploiting firm-product level data from Ecuador, this paper presents a unified empirical framework to test for the complementarity between firms' skill composition and imported input quality and their joint impact on firms' output quality. Our work makes several novel contributions to the literature. We show causal evidence that firms' choices of imported input quality drive their relative demand for skilled labor and the skill premium. To the best of our knowledge, we are the first to show in the same empirical framework that this complementarity between skills and imported input quality resulted in firms' output product quality upgrading. Moreover, we demonstrate that the impacts of importing higher quality inputs as a result of input-trade liberalization extend beyond importers as a result of input-output linkages. Finally, we present an in-depth study of the effects of input-trade liberalization of a developing country, Ecuador that has not been studied to date. By providing evidence for Ecuador, we contribute to validating the wider applicability of trade models with endogenous input- and output-quality choices.

During Ecuador's period of trade liberalization, average input tariffs decline by 7 percentage points, while the average firms' output quality improves by 55% over the same period. The skill intensity of the average firm increases by 8% and the average skill premium by 2.5%. We hypothesize that these changes partly result from Ecuador's input-trade liberalization due to better access to higher-quality inputs. In line with this hypothesis, our data shows that importing firms pay more for imported inputs of higher quality than for domestic products. Descriptive statistics suggest that the differences in skill intensity and skill premia across firms within an industry are related to access to high quality imported inputs relative to domestic ones. Interestingly, the origin of the input (domestic vs. foreign) per se is not correlated with difference in the skills composition across firms within an industry.

Our empirical identification strategy captures the causal impact of access to high-quality foreign inputs on firms' skill intensity to produce high-quality output. We apply within-firm instrumental

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<sup>1</sup> See Verhoogen (2020) for a review of the determinants of production upgrading in developing countries.

variable estimators to study the causal relationship between the firm-level skill composition and imported input quality upgrading. We identify causal effects by exploiting exogenous input tariff reductions across industries when Ecuador joined the WTO in the mid-1990. These estimations test for the complementarity between imported input quality and skills. They control for the possible impact of access to more variety of inputs and include firm-size trends to control for shocks affecting firms of different sizes. We also apply firm and year fixed effects to account for unobserved time-invariant firm heterogeneity and any macroeconomic shocks during the period. We then regress firm- 11-digit final good quality on firms' skill intensity, imported input quality and its interaction term including firm-final good trends to account for differences in output quality across final goods. We rely on within firm-final good instrumental variable estimations that control for firm-final good trends, firm-size trends as well as year fixed effects.

We first show that Ecuadorian firms upgraded the quality of imported inputs, the skill intensity and the skill premium due to input tariff cuts, while the access to more varieties of inputs was limited. The 7-percentage-point reduction of input tariff in Ecuador from 1997 to 2007 is associated with an increase in input quality of 30%. The probability of importing a new input variety increases by less than 1%. These findings confirm previous evidence in the literature of input-trade liberalization and firm performance (Bas and Strauss-Kahn, 2015; Fan et al., 2015, 2018; Chen et al., 2017; Fieler et al., 2018).

Next, our results from instrumental variable estimations show a positive effect of imported input quality upgrading, as a result of input tariff cuts, on firms' skill intensity and skill premium. A one standard deviation increase in the relative quality of imported input increases the skill intensity by 5.5% and the skill premium by 18%. We find no effect of imported input variety on skills. Then, we test if this complementarity between skilled labor and high-quality imported inputs resulted in within firm-product output quality upgrading. Our results show that output quality upgrading is driven by more skill intensive firms that upgrade imported input quality. We find that the quality of inputs rather than their variety results in improved output quality.

In extensions, we also show that access to high quality imported inputs, as a result of input tariff cuts, also benefits firms that use domestic inputs due to input-output linkages. Firms which source domestic inputs from industries that rely more on higher-quality imported intermediate goods experience an increase in their skill composition and an increase in output quality. We also show heterogeneous impacts on firms' skill intensity and output quality depending on initial productivity. This part of our analysis validates leading trade models' predictions of endogenous input and output quality (Verhoogen, 2008, Kugler and Verhoogen, 2012; Hallak and Sivadasan, 2013; Fieler et al., 2018).

Those models predict that only the most productive firms source higher-quality inputs and increase their use of skills to produce outputs of higher quality.

Several sensitivity checks confirm our findings. Our results hold for a sub-sample of single final good firms that produce only one product during the whole sample period for which all the intermediate inputs and skilled labor are allocated to produce that single final good. The impact of input tariff cuts on output quality and skills we identify is not a consequence of machinery imports but of higher-quality foreign intermediate inputs, suggesting that intermediate inputs help upgrade production if they are of the right quality. Moreover, we show that our results are driven by foreign demand shocks, Ecuador's financial crisis, real exchange rate variations, the reform of the financial sector and other industry-level reforms of the 1997-2006 period.

Our paper contributes to the empirical literature on input-trade liberalization's impacts on firms' use of skilled labor and their output quality upgrading. The literature has shown that access to high-quality inputs allows firms to upgrade their export products thanks to input-trade liberalization in China (Bas and Strauss-Kahn, 2015; Fan et al. 2015, 2018). Kugler and Verhoogen, (2012), Hallak and Sivadasan (2013), Bastos et al. (2018) have also shown that Colombian, Indian and Portuguese firms relying on high-quality (price) inputs also sell final goods at higher prices, an indicator of higher output product quality. Other research explores the effects of input-trade liberalization on the skill intensity of production and the skill premium in Indonesia, China and Colombia (Amiti and Cameron, 2012; Chen et al., 2017; Fieger et al., 2018). Relative to this literature, our unique contribution is to provide causal evidence on the complementarity of high-quality imported inputs and skills and their impact on the production high-quality goods within the same empirical framework.

Our findings have important policy implications regarding the impacts of input-trade liberalization. We show that input tariff cuts support improvements in firms' production techniques that result in higher quality outputs. This points to the importance of trade reforms for knowledge transfer and improvements of firms' production processes. We also show that complementary investments in skills are needed for firms to be in position to upgrade their production processes. This means for developing countries that investments in boosting the skills of the workforce are important as otherwise the benefits of input-trade liberalization are likely limited to only those firms who can afford scarce skilled workers. What is more, in the absence of those investments, our results point to the risk of increased wage inequalities as a result of input-trade liberalization.

The remainder of the paper is organized as follows: Section 2 provides the theoretical motivation for our analysis. Section 3 presents Ecuador's trade liberalization and the country's economic context in the 1990s and 2000s. Section 4 discusses the data and provides new stylized facts on the skill

premium. Section 5 shows findings of our empirical analysis, while Section 6 discusses results of sensitivity checks. The last section concludes.

## **2. Theoretical motivation**

### ***2.1. Insights from the theoretical literature***

This section describes the theoretical channels of the relationship between input-trade liberalization, access to high-quality intermediate goods, and its impact on the firm level skill composition and output quality. We base our discussion on Fieler et al (2018) who develop a unified quantitative model that synthesizes the effects of trade liberalization on intermediate goods and skills and consequent impacts on firms' output quality.

Fieler et al (2018) propose a quantitative model of input-trade liberalization with monopolistic competition and heterogeneous firms, where firms endogenously choose output quality as a function of their productivity, their use of skilled labor and inputs of different quality. Output quality requires both intermediate inputs of high-quality as in Kugler and Verhoogen's (2012) or Hallak and Sivadasan's (2013) models and skilled labor as in Verhoogen's (2008) theoretical framework. High quality intermediates and skilled labor are complementary inputs in the production of output quality. If foreign inputs are of higher quality than domestic inputs, then input-trade liberalization allows firms to access higher quality inputs. Input-trade liberalization can also result in scale effects as firms have access to higher quality foreign inputs and can now afford paying the fixed cost involved in using foreign technology as in Bas and Berthou (2017).

As to firms' demand for skilled labor, in Fieler et al. (2018) output quality is a latent variable that relates to firms' sales volume, their skill intensity and their input quality. The model by Verhoogen (2008) predicts that firms require skilled labor to produce higher quality outputs for the export market. An alternative explanation for skills upgrading with input-trade liberalization that we will test for empirically is that firms source more capital goods from abroad. The complementarity of imported capital goods and skills due to skill-biased technical change embodied in those capital goods then boosts firms' production skill intensity (Burstein et al, 2013; Koren and Csillag, 2011; Parro, 2013). This explanation differs from the input-quality explanation that hypothesizes that all intermediate inputs of high quality and not only capital goods affect the demand for skills in production. To provide just one example from our database, an Ecuadorian firm improved the quality of the jerseys, pullovers and related articles (HS-6 code 611090) it produced, importing as part of the quality upgrading process higher quality fibres (HS-6 code 550700).

In conclusion, these models predict that input-trade liberalization creates incentives for firms to access high-quality foreign inputs and to upgrade output quality. Since output quality upgrading requires high-quality imported inputs as well as increasing firms' production skill intensity, these models also predict that firms' skilled intensity and skill premium increase when firms upgrade input quality to produce high-quality output.

## ***2.2. Testable implications***

In this section, we discuss three testable hypotheses from the theoretical predictions of different models we outline above and our contribution relative to the existing literature on this topic.

*Hypothesis 1: Input tariff cuts increase firms' access to intermediate inputs of higher quality.*

Bas and Strauss-Kahn (2015) and Fan et al. (2015) show that input tariff cuts in China allow firms to access higher quality inputs. Relative to these works we also take into account in our framework the import variety channel driven by input-trade liberalization. As shown by Goldberg et al. (2010), input tariff cuts also increase the access to new varieties of imported inputs.

*Hypothesis 2: Access to high quality imported inputs increases skilled labor demand and therefore the skill premium because high-quality imported inputs and skilled labor are complementary.*

Previous works in the literature have provided evidence on input-trade liberalization's impact on firms' skill intensity (Amiti and Cameron, 2012, for Indonesia; Chen et al., 2017, for China and Fielser et al., 2018, for Colombia). They show that input-tariff cuts impact the relative demand of skilled labor and the skill premium. However, they do not show that it is the access to high quality imported inputs that drives skill upgrading. Input tariff changes could also be capturing other channels different to the quality mechanism such as changes in import status or access to new varieties of inputs. Also, Koren and Csillag (2011) provide evidence from a pseudo-panel of a link between imported machinery and skill premia by demonstrating that Hungarian workers that were likely to be exposed to imported machines receive higher wages. Relative to this literature, the contribution of our work is to provide novel causal evidence that the firm choice of imported input quality drives firm choices of the relative demand of skilled labor and the skill premium once we take into account the imported input variety channel.

*Hypothesis 3: Higher imported input quality and skilled labor jointly result in output quality upgrading.*

The previous works do not provide evidence on firms' output product quality upgrading as a result of firms' input quality upgrading and changed skill intensity. Verhoogen (2008) shows that Mexican producers of high-quality products demand more skilled labor and pay higher wages to skilled workers. However, the study offers no causal evidence on the relation between skills and output quality and does not discuss the role that higher quality inputs from abroad may play. Bas and Strauss-Kahn (2015) and Fan et al. (2015) show that input tariff cuts in China increase the output quality of exporting firms. However, they do not study what role skilled labor plays as complementary input to higher quality foreign intermediate goods to produce high-quality exports. Fieler et al's (2018) empirical results for Colombia show that input tariff cuts increase skilled labor, input quality and output quality. Their parameter estimates on Colombian firm data during trade liberalization (1982-1988) also imply that firms producing high-quality goods are intensive in skilled labor (and in high-quality inputs). They do not, however, establish empirically that the increase in skilled labor is driven by access to high quality foreign inputs. They also do not establish the joint effect of skill and input quality upgrading on output quality improvements. Our contribution complements theirs by establishing the causal effects of input quality on firms' skill demand and of the importance of skilled labor to complement high-quality inputs for firms to be able to produce higher-quality output.

### **3. Ecuador's trade liberalization, other reforms and the economic crisis**

#### ***3.1. Ecuador's accession to the WTO***

In this section, we describe Ecuador's trade integration process of the 1990s and early 2000s, including the major change that resulted from the country's accession to the WTO.

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

A unilateral trade-reform plan was launched with Ecuador's accession to the World Trade Organization (WTO) in 1996. The main consequence of joining the WTO was a unilateral trade liberalization process in Ecuador with substantial tariff reductions. During the period 1997-2000, multilateral negotiations on specific accession commitments of Ecuador within WTO took place. These negotiations led to further tariff reductions.<sup>2</sup>

After Ecuador entered WTO, the government signed the "Foreign Trade Law" (1997) to create the Ministry of Foreign Trade. The Ministry's goal was to promote export diversification and foreign

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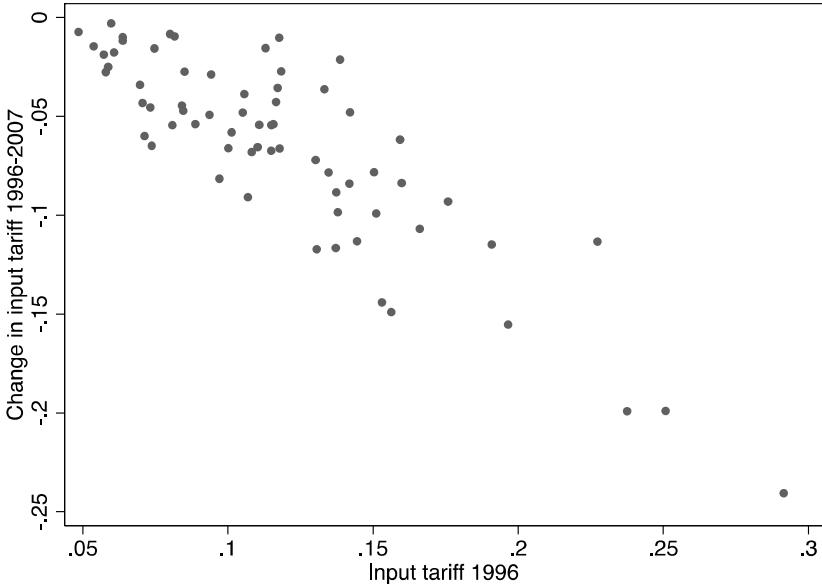
<sup>2</sup> More details about these negotiations can be found at [https://www.wto.org/english/thewto\\_e/acc\\_e/a1\\_ecuador\\_e.htm](https://www.wto.org/english/thewto_e/acc_e/a1_ecuador_e.htm)



technology transfer through imports of intermediate inputs and capital goods. Ecuador consequently reduced import restrictions and modernized trade institutions by improving customs procedures and simplifying trade procedures as set out in the “Customs Law”. Other measures were also adopted to facilitate firms’ access to foreign markets, such as the improved trade preferences Ecuador received from the United States within the Andean Trade Promotion Act (ATPA). Moreover, Ecuador adopted the “Law of Export Facilitation and Maritime Transport” to promote exports.

Regarding tariff reductions, the highest initial input tariffs experienced the largest 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 product-level input tariffs 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-based product code of Ecuadorian firms’ input products and the HS 6-digit level.

### *3.2. Ecuador's financial crisis and other reforms of the 1990s and 2000s*

Aside from trade reforms, in the beginning of the 1990s Ecuador's government announced other structural reforms to liberalize its economy, including policies to encourage foreign direct investment (FDI), privatizations and reforms of its fiscal and financial system. As to FDI, the elimination of entry barriers for foreign firms to produce in Ecuador in 1990 resulted in a tripling of FDI inflows from 1992 to 1994 (UNCTAD, 2001). However, 80% of the investments went into Ecuador's oil industry that, because of its specific nature and remote geographic location, has few linkages with the rest of the economy.

Privatization reforms in the 1990s were only and at minor scale implemented in the oil sector while fiscal and tax reforms were not introduced. The Modernization Law of 1993 established the Consejo Nacional de Modernización (CONAM) that was tasked to execute the privatization of states enterprises. Public investment increased with operational losses that forced public enterprises to rely more on fiscal resources to finance their investments and resulted in growing public debt. This was reinforced by the lack of debt-reducing fiscal and tax reforms (UNCTAD, 2001).

With regards to the financial sector, the 1994 Law of the Financial System Institutions (LFSI) created the legal basis for financial sector reforms. The liberalization of the sector promoted free entry and exit of institutions to the financial market and levelled the playing field between domestic and foreign banks. The reforms increased the number of financial institutions from 31 in 1993 to 44 in 1996 (Jácome, 2004). Firms' access to finance may have improved as a result. The IMF's index of financial liberalization, however, suggests that the changes were relatively minor with a moderate increase for Ecuador over the 1997-2004 period (Abiad et al., 2008).

In 2000, the Economic Transformation Law introduced several structural reforms for macroeconomic stability and growth in response to Ecuador's major political, economic and social crisis of 1998/1999. In 1996, the Populist Party won the elections with a campaign that promised economic and social reforms, but Congress unseated the president in 1997. The large fiscal deficit and expansionary money policy led to a massive devaluation of the national currency in 1999. The financial crisis was characterized by the default on Brady bonds and Eurobonds and devaluation of Ecuador's currency. GDP per capita contracted by 7%. As a consequence, in 2000 the government introduced the dollar as national currency. Fiscal and financial reforms and privatizations followed but were implemented starting in the mid-2000s only.

In conclusion, the major reform Ecuador experienced in the 1990s was a unilateral trade liberalization with the country's entry to the WTO. FDI liberalization and privatization efforts in the early 1990s only affected the oil and petroleum sector. The liberalization of Ecuador's financial sector was

moderate with possible minor improvements in firms' access to finance. As to the reforms in the 2000s, only the dollarization was effective in 2000 while all other reforms were implemented after the period we analyze.

### ***3.3. Implications for the empirical analysis***

First, we validate that Ecuador's accession to WTO provides for a natural experiment to test for the impacts of trade liberalization and exogenous instrument by exploiting tariff 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. It should not be the case that firms of distinct characteristics that produce 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 over the period on a number of industry characteristics and firm performance in the initial year. Tables 1 shows that input and output tariff changes between 1996 and 2007 were uncorrelated with industry-level characteristics (panel A and B) and with initial firm performance measures (panel C). If the government had targeted specific firms and industries during trade liberalization, then tariff changes would have been correlated with initial firm and industry performance.

Unfortunately, firm level data is only available from 1997 onwards. Therefore, it is not possible to provide an analysis of firm-product or firm's pre-trends prior to trade reform. We will include 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.

Second, since Ecuador introduced other reforms aside from trade liberalization in the 1990s and 2000s and experienced a major crisis in 1999/2000, we have to check that our results are robust to possible effects of these contemporaneous changes. This includes the possible impact of foreign demand shocks, Ecuador's financial crisis, the real exchange rate variations, financial liberalization measures as well as industry-specific reforms and shocks. We deal with those alternative explanations in section 6.

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

**Panel A: Change In input tariffs from 1996 to 2007**

Dependent variable:	Change in input tariffs, 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: Change in output tariffs from 1996 to 2007**

Dependent variable:	Change in output tariffs, 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

**Panel C: Initial firm characteristics in 1997 and tariff changes between 1996 and 2007**

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

*Notes:* In Panel A and B, 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. In Panel C, 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. Standards errors clustered at the 3-digit industry level are reported in parentheses.

**4. The data and stylized facts**

#### ***4.1. Data and variables description***

We use a Census panel dataset that is 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 estimating sample contains 12,343 manufacturing plant-year observations and has information on plants overall sales and value-added, skilled (non-production workers) and unskilled (production workers) employment and wages. The online annex table OA.1. presents the number of plant-year observations by 2-digit ISIC-Rev. 3 industry level.

The distinctive feature of our data is that it is complemented by two other datasets, which have information on plants' intermediate inputs and on plants' output final good products, respectively. The first dataset gives annual plant-level information on primary materials, auxiliary materials, replacements and accessories, and packing materials used in production. For each intermediate input, plants provide information on quantities and values separately for national and foreign inputs. The second dataset has information on each plant's final good products on quantities and values sold in the market. Both input and output products are provided by INEC at detailed 11-digit product code level that is built on the ISIC-Rev. 3 industry classification.

We implement several data cleaning procedures and check the quality of our dataset following Bernard et al. (2010), Kugler and Verhoogen (2012) and Goldberg et al. (2010). This includes testing for firms with irregular output product drops (i.e. products that disappear from production and then reappear again) and firms with product jumps (i.e. products that are produced only once in the intermediate years of firm presence in the sample). These tests are satisfactory in that product drops and jumps are relatively infrequent. Moreover, the consistency of importer characteristics to those Kugler and Verhoogen (2012) obtain for Colombia gives additional confidence in the quality of the new data (see Bas and Paunov, 2019, for these statistics). The online annex describes the dataset and cleaning procedures in more detail (see also Paunov, 2011).

The firm level skill composition is measured by skill intensity, the share of the non-production workforce relative to the total workforce, and the skill premium, the ratio of the wage of non-production workers relative to the total firm' wages.

Our firm-final good output (input) product level datasets allow us to compute measures of input and output prices (unit values) and quality at the firm-product level. We rely on the methodology developed by Khandelwal et al. (2013) where quality is a residual of demand function estimation. The measures of firm-product level input and output quality are described in detailed in the annex. Next, we aggregate input quality (prices) at the firm level as the weighted average of the quality (prices) of all

imported (domestic) inputs used by a firm in a year relying on constant initial weights. This approach was applied widely to capture product quality (Bas and Strauss-Kahn, 2015; Fan et al., 2015, 2018, Manova and Yu, 2017, among others) and is also closely related to other methods that estimate quality at the product level such as Hummels and Klenow (2005), Khandelwal (2010), Hallak and Schott (2011), and Feenstra and Romalis (2014). For our analysis, we obtain the firms' relative imported input quality computed as the ratio of the imported inputs quality over the domestic input quality at the firm level.

As in the work of Kugler and Verhoogen (2012) on Colombian firms, we find in our data of Ecuadorian firms a positive correlation between firm-final good prices (unit values) and firm-level input prices presented in Table 2. Firm-final good prices are positively correlated with firm level input prices across firms within an industry (including 2-digit industry fixed effects in column 1), within-firm over time across products (including firm fixed effects in column 2), within-firm-product over time (including firm-product fixed effects in column 3) and also for single final goods producers (columns 4 and 5).

**Table 2: Output and input prices correlation**

Dependent variable	Firm-final good prices				
	Multiple final good producing firms			Single final good producing firms	
	(1)	(2)	(3)	(4)	(5)
Input prices (i,t)	0.514*** (0.008)	0.028*** (0.009)	0.019** (0.008)	0.620*** (0.052)	0.071** (0.030)
Industry-year fixed effects	yes	no	no	yes	no
Firm fixed effects	no	yes	no	no	yes
Firm-final good fixed effects	no	no	yes	no	no
Year fixed effects	yes	yes	yes	yes	yes
Observations	55,668	57,767	57,324	3,092	3,180
R-squared	0.80	0.92	0.93	0.85	0.96

*Notes:* The dependent variable is the logarithm of firm-product level output prices (unit values) computed as the output value over the quantity at the firm-product level. Input prices (i,t) at the firm level are the weighted average of the intermediate inputs unit values (values over physical quantity) of all inputs used by a firm in a year relying on constant initial weights. Industry fixed effects included are at 2-digit ISIC-Rev.3 level. \*\*\*, \*\*, and \* indicate significance at the 1, 5 and 10 percent levels respectively.

As an alternative measure of input quality, we rely on the complexity of the bundle of intermediate inputs used by a firm. We use the methodology developed by Hausmann and Hidalgo (2009, 2011) to define the complexity of an intermediate input as the weighted average of the GDP per capita of the countries that export the HS 6-digit product to Ecuador, where the weight is given by the country's revealed comparative advantage index, following Hausmann and Hidalgo (2009, 2011). We compute complexity at the firm level as the weighted average of the product complexity of all imported (domestic) intermediate inputs used by a firm in a year relying on constant initial weights. For our

analysis, we obtain the relative imported input complexity as the ratio of the imported input complexity over the domestic one at the firm level.

We also make use of our firm-input data to obtain a measure of imported input varieties. We compute this measure as the share of imported input varieties relative to the total imported and domestic input varieties of a firm in a year.

Finally, 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. We link the tariff data to our data on Ecuadorian firms by establishing a product correspondence between the 11-digit ISIC-Rev. 3-based product codes of Ecuadorian firms' output and input products and the HS 6-digit product level categories. In the firm-product estimations, input tariffs are at the HS 6-digit product level, while in the firm level estimations both output and input tariff measures are aggregated at the 3-digit ISIC-Rev.3 industry level using constant weights. Output and input tariffs at the industry level are computed as a weighted average at the 3-digit industry level of the output or input tariffs at the HS 6-digit product level faced by each firm using constant weights averaged over the period.

#### ***4.2. Stylized facts on skill premia and imported inputs***

In this section, we present descriptive evidence on the relationship between firm-level skill composition and input choices. We follow the extensive literature on skill premia as reviewed in Bernard et al. (2012) and obtain by building on the following cross-sectional estimation framework:

$$S_{ijpt} = \alpha + \gamma_m \text{Importer}_{i,t} + \gamma_{fc} X_{i,t} + \varphi_j + \pi_{pt} + \varepsilon_{ijpt} \quad (\text{I})$$

where  $S_{ijpt}$  is in Panel A the skill intensity of firm  $i$  producing in industry  $j$  in province  $p$  in year  $t$  measured as the share of the non-production workforce relative to the total workforce and in Panel B the skill premium measured as the ratio of the wage of non-production workers relative to the total firm' wages. *Importer* indicates firm  $i$ 's importer status in year  $t$ . Firm level controls  $X$  at  $t$  are capital intensity, share of inputs over sales and share of imports over sales.  $\varphi_j$  and  $\pi_{pt}$  are respectively 2-digit ISIC Rev.3 industry and province-year fixed effects.

Column (1) of Table 3 shows that firms that source intermediate goods from abroad within 2-digit sectors are more skill intensive (panel A) and have a higher skill premia (panel B) than non-importers once we control for firms' capital intensity, share of inputs over sales and share of imports over sales and unobserved time varying shocks across provinces.

We add to this literature by distinguishing the quality of the input and by controlling for the possible impacts of input variety. We first include in the estimation framework (I) a proxy of the relative imported input quality computed as the ratio of the imported inputs quality over the domestic input quality at the firm level. Our two firm-product-level quality measures are aggregated at the firm level as the weighted average of the quality (complexity) of all imported (domestic) inputs used by a firm in a year, with initial weights constant over time. The imported input variety channel is measured by the share of distinct imported input varieties at the firm level.

Our findings show that once we include the relative imported input quality (columns 2 to 5 of Table 3) the effects of the importer status on skill intensity is no longer significant (panel A). Firms' importer status is also uncorrelated with the skill premium if the complexity quality measure is used (columns 4 and 5 of Panel B).

We then add input variety computed as the ratio of the number of imported input varieties over the domestic ones at the firm level. As shown in columns (3) and (5), the imported input variety channel is not correlated with firms' skill composition. These findings suggest that skill composition and skill premia within an industry are not affected by inputs' importer status or their variety but by the quality of imported inputs relative to domestic ones.

**Table 3: Descriptive statistics on imported inputs and skill premia**

**Panel A: Skill intensity**

Dependent variable:	Skill intensity				
	(1)	(2)	(3)	(4)	(5)
Importer status(i,t)	0.005* (0.003)	0.005 (0.006)	0.005 (0.006)	-0.011 (0.009)	-0.013 (0.009)
Relative imported input quality(i,t)		0.238** (0.103)	0.238** (0.103)		
Relative imported input complexity(i,t)				0.182** (0.081)	0.191** (0.082)
Share of imported input varieties(i,t)			-0.000 (0.002)		0.001 (0.002)
Firm level controls	yes	yes	yes	yes	yes
Industry-year fixed effects	yes	yes	yes	yes	yes
Province-year fixed effects	yes	yes	yes	yes	yes
Observations	12,343	12,343	12,343	12,343	12,343
R-squared	0.29	0.29	0.29	0.29	0.29

**Panel B: Skill premium**



Dependent variable:	Skill premium				
	(1)	(2)	(3)	(4)	(5)
Importer status(i,t)	0.062*** (0.019)	0.061*** (0.010)	0.060*** (0.010)	0.004 (0.030)	-0.004 (0.031)
Relative imported input quality(i,t)		0.460** (0.235)	0.459* (0.235)		
Relative imported input complexity(i,t)				0.645** (0.299)	0.689** (0.299)
Share of imported input varieties(i,t)			0.001 (0.004)		0.006 (0.007)
Firm level controls	yes	yes	yes	yes	yes
Industry-year fixed effects	yes	yes	yes	yes	yes
Province-year fixed effects	yes	yes	yes	yes	yes
Observations	12,343	12,343	12,343	12,343	12,343
R-squared	0.29	0.29	0.29	0.29	0.29

*Notes:* Firm level controls are capital intensity, share of inputs over sales and share of imports over sales. Industry fixed effects included are at 2-digit ISIC-Rev.3 level. Standard errors are clustered at the firm level. \*\*\*, \*\*, and \* indicate significance at the 1, 5 and 10 percent levels respectively.

## 5. Findings

This section explores the hypotheses identified in section 2 on the impacts of input tariff reductions on imports of high-quality inputs and its effects on firms' skill intensity and premium to produce high-quality outputs.

### 5.1. Input-trade liberalization effects on firm-product imported input quality and variety

*Hypothesis 1: Input tariff cuts increase firms' access to intermediate inputs of higher quality*

First, we look at the effects of input tariff reductions on firms' foreign input quality. We use our input quality measure,  $IQ_{kijt}$ , of firm  $i$  that imports input goods  $k$  at 11-digit product code level belonging to industry  $j$  in year  $t$  as dependent variable in the following specification:

$$IQ_{kijt} = \alpha + \gamma_{I\tau} \text{Input } \tau_{k,t-1} + \gamma_{O\tau} \text{Output } \tau_{j,t-1} + \gamma_S \text{Size}_{i,t0} * \eta_t + \gamma_k q_{i,k,t0} * \eta_t + \mu_{ik} + \theta_t + \varepsilon_{kijt} \quad (\text{II})$$

where  $\text{Input } \tau_{k,t-1}$  are the input tariffs that Ecuador effectively applies to intermediate input good  $k$  at 6-digit HS level. We also include the output tariffs at the industry level,  $\text{Output } \tau_{j,t-1}$ .  $\text{Size}_{i,t0} * \eta_t$  are firm size trends with size at  $t = 0$  to control for unobservable shocks to firms of similar sizes over time. Estimations also include input-good-firm trends,  $q_{i,k,t0} * \eta_t$ , where  $q$  is the input quantity imported in the initial period and firm-input goods fixed effects,  $\mu_{ik}$ . These variables control respectively for differences in input quality across inputs within a firm and unobservable and time-invariant firm-input goods characteristics. Finally, year fixed effects,  $\theta_t$ , that control for macroeconomic shocks. In view of our variable of interest, input tariffs, in this specification standard errors are clustered at the HS 6-digit product level.

Column (1) of Table 4 presents the results: our coefficient of interest on import tariffs on inputs at the 6-digit HS level is negative significant, indicating that for the 7-percentage-point reduction of input tariffs, importing firms increase the quality of their intermediate inputs by around 30%. Then, we verify that the effects we identify are not simply the result of technological progress that may have improved input quality and be correlated with import tariffs. If this was the case, we should identify the same effects on both domestic and foreign inputs. We run a falsification test and estimate the effect of import tariffs on the quality of domestic intermediate inputs. We reject this alternative hypothesis as import tariffs have no significant effect on the quality of domestic inputs (column 2). Next, we rely on input price as measured by unit values as an alternative measure of quality. Column (3) shows that firms pay high-price foreign inputs after input trade liberalization, while there is no significant effect on domestic input prices (column 4).

We also investigate the effect of input-trade liberalization on access to new varieties of imported inputs. The dependent variable that captures imports of a new variety at the firm- input good level is a dummy variable equal to one if the firm imports a new input good that has not been sourced in the domestic or foreign market in the previous years. Results, presented in column (5) of Table 4, suggest that for a 10-percentage point reduction of input tariffs, the probability of importing a new variety of inputs increased by 1%. Conducting the same falsification test as before on input quality, we investigate the effect of input tariff on the probability of sourcing a new variety of domestic intermediate goods. Results presented in column (6) suggest the likelihood that firms buy new varieties of domestic inputs is lower, possibly because they substituted domestic varieties for imported varieties.

We next conduct the analysis at the firm level by regressing tariffs on different measures of firm' input quality (imported input quality, relative imported input quality and relative imported input complexity) and share of imported input varieties. We aggregate those quality measures at the firm level as the weighted average of the quality (complexity) of all imported (domestic) inputs used by a firm using initial period weights. Columns (7) to (9) show that on average firms upgrade their imported input quality relative to the domestic input quality after input tariff cuts. Column (10) shows that input-trade liberalization allowed firms also to increase the share of distinct imported input varieties relative to domestic ones.

In the next subsections, we investigate the complementarity between input quality and firms' skilled labor composition and its effects on output quality by relying on instrumental variable estimations that use tariff changes as exogenous shocks that boost firms' input quality.

**Table 4: Input-trade liberalization, input quality and variety**

Dependent variables:	Input quality		Input prices		New variety		Imported input quality	Relative import input quality	Relative import input complexity	Share of imported input varieties
	Imported	Domestic	Imported	Domestic	Imported	Domestic				
	Firm-input good level estimations									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Input tariffs(k,t-1)	-4.182*** (1.115)	0.759 (0.741)	-0.777* (0.400)	-2.605 (1.902)	-0.097** (0.040)	0.269*** (0.059)	-3.634*** (1.073)	-0.997* (0.540)	-0.028* (0.016)	-0.120* (0.071)
Output tariffs(j,t-1)	6.080 (4.777)	1.205** (0.555)	-0.948* (0.526)	0.291 (0.568)	0.218*** (0.052)	0.000 (0.077)	0.317 (0.618)	0.004 (0.310)	0.029*** (0.009)	-0.004 (0.044)
Firm-input good trends	yes	yes	yes	yes	yes	yes	no	no	no	no
Initial year firm size trends	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm-input good fixed effects	yes	yes	yes	yes	yes	yes	no	no	no	no
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	no	no	no	no	no	no	yes	yes	yes	yes
Observations	15,416	41,720	15,395	41,689	61,827	61,827	12,343	12,343	12,343	12,343
R-squared	0.18	0.31	0.77	0.76	0.30	0.39	0.15	0.41	0.78	0.87

*Notes:* The dependent variables used are as follows: columns (1), (2) and (7) input quality computed following Khandelwal et al. (2013) as described in section 4.1 and in the Annex, columns (3) and (4) input prices (unit values) as the input value over the quantity at the firm-product level, columns (5) and (6) the new variety of inputs is a dummy variable equal to one if the firm imports a new product that has not been sourced in the domestic or foreign market in the previous years, columns (8) the relative imported inputs quality is the ratio of the imported inputs quality over the domestic input quality at the firm level, column (9) the relative imported input complexity is the ratio of the imported input complexity over the domestic one at the firm level each, column (10) the share of imported input varieties is the ratio between the number of imported input varieties over the domestic ones at the firm level. In columns (1) to (6), estimations are at the firm-input product-year level, input tariffs are at the HS 6-digit product level. Standard errors are clustered at the 3-digit industry level. \*\*\*, \*\*, and \* indicate significance at the 1, 5 and 10 percent levels respectively.

## 5.2. Testing for the complementarity of imported input quality with skilled labor

As identified in previous research (Amiti and Cameron, 2012; Chen et al., 2017 and Fieler et al., 2018), we find that input-trade liberalization increases firms' skill intensity and premium (columns 1 and 5 of Table 5). This section tests whether better access to higher quality imported inputs affected firms' skill composition and premium.

*Hypothesis 2: Access to high quality imported inputs increases skilled labor demand and therefore the skill premium because high-quality imported inputs and skilled labor are complementary.*

In order to test for the causal relationship between foreign input quality upgrading, driven by input-trade liberalization and firms' skill composition, we estimate the following equation:

$$S_{ijt} = \alpha + \gamma_Q IQ_{i,j,t} + \gamma_V IV_{i,j,t} + \gamma_S Size_{i,t0} * \eta_t + \mu_i + \eta_t + \varepsilon_{ijt} \quad (III)$$

where  $S_{ijt}$  is the skill intensity of firm  $i$  producing in industry  $j$  in year  $t$  measured as the share of the non-production workforce relative to the total workforce or the skill premium measured as the ratio of the wage of non-production workers relative to the total firms' wages. Input quality ( $IQ_{i,j,t}$ ) is one of our measures of firms' imported input quality. We control for the input variety channel including the firm level share of imported input varieties ( $IV_{i,j,t}$ ) as presented in the previous section.  $Size_{i,t0} * \eta_t$

are firm size trends with size at  $t = 0$  to control for unobservable shocks to firms of similar sizes over time. The estimation includes firm fixed effects that control for unobserved firm heterogeneity ( $\mu_i$ ) and year fixed effects to account for macroeconomic shocks. Firm level imported input quality and variety are instrumented with exogenous tariffs changes. The first stage of these instrumental variable estimations is presented in the previous section in Table 4 (columns 7-10). The estimation also includes firm initial size trend, firm fixed effects and year fixed effects. In alternative estimations available upon request, we instrument imported input quality and variety with one and two lagged years tariff measures. Results are robust and stable to this alternative instrumentation strategy and the Hansen test validates the exogeneity of instruments.

Our findings show that firms that upgrade imported input quality increase their relative demand of skilled labor (columns 2 to 4 of Table 5) and the skill premium (columns 6 to 8 of Table 5). The imported input variety channel has no effect on firms' skill upgrading. Our estimates suggest that one standard deviation increase in the relative imported input quality (1.13) increases skill intensity by 5.5% and the skill premium by 18%, while the same increase in the relative imported input complexity (0.06) leads to an upgrade of skill intensity by 1.2% and the skill premium of 4.2%. These findings appoint to the complementarity in the production process between imported input quality and skilled labor. In the following section, we explore if this complementarity between imported input quality and firms' skill composition resulted in output quality upgrading.

**Table 5: Imported input quality and skilled labor complementarity**

Dependent variables:	Skill intensity				Skill premium			
	Within est. with tariffs	Fixed effects instrumental variable estimations			Within est. with tariffs	Fixed effects instrumental variable estimations		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Input tariffs(j,t-1)	-0.077* (0.045)				-0.502*** (0.166)			
Output tariffs(j,t-1)	-0.019 (0.025)				0.067 (0.089)			
Imported inputs quality(i,t)		0.082** (0.042)				0.380** (0.166)		
Relative imported inputs quality(i,t)			0.049** (0.025)				0.160** (0.080)	
Relative imported input complexity(i,t)				0.188* (0.108)				0.709* (0.422)
Share of imported input varieties(i,t)		-0.161 (0.187)	-0.446 (0.251)	-0.312 (0.222)		-0.502 (0.830)	-0.917 (0.809)	-1.354 (0.864)
Initial year firm size trends	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Observations	12,343	12,253	12,253	12,343	12,332	12,253	12,253	12,343
R-squared	0.77				0.71			
Root MSE		0.09	0.11	0.09		0.35	0.34	0.34

Notes: Columns (1) and (5) present within-firm estimates of the effects of industry level tariffs on skill intensity and skill premium. Columns (2) to (4) and (6) to (8) present instrumental variable estimations using input and output tariffs as instruments for the three measures of imported input quality and the share of imported input varieties. The first stage of these

instrumental variable estimations is presented in columns (7) to (10) of Table 4. In columns (1) and (5) standard errors are clustered at the 3-digit industry level. In columns (2) to (4) and (6) to (8) standard errors are clustered at the firm level. \*\*\*, \*\*, and \* indicate significance at the 1, 5 and 10 percent levels respectively.

### 5.3. Output quality upgrading as a result of input quality and skilled labor complementarity

This section tests the complementarity between imported input quality and skilled labor in the production process to upgrade output quality.

*Hypothesis 3: Higher imported input quality and skilled labor jointly result in output quality upgrading.*

We estimate the following production function of output quality,  $Q_{gijlt}$ , of firm  $i$  that produces final good  $g$  belonging to industry  $j$  in year  $t$ , applying an instrumental variable estimation:

$$Q_{gijt} = \alpha + \gamma_Q IQ_{i,j,t} + \gamma_S S_{ijt} + \gamma_{QS} IQ_{i,j,t} \times S_{ijt} + \gamma_V IV_{i,j,t} + \gamma_{S'} Size_{i,t0} * \eta_t + \gamma_{k'} q_{i,g,t0} * \eta_t + \mu_{gi} + \eta_t + \varepsilon_{gijt} \quad (IV)$$

where  $Q_{gijt}$  is firm-final good level output quality estimated following the methodology of Khandelwal et al. (2013) (as described in Section 4.1 and in the annex). We rely on the previous measures at the firm level of imported input quality ( $IQ_{i,j,t}$ ), skill intensity ( $S_{ijt}$ ) and input variety ( $IV_{i,j,t}$ ). Our coefficient of interest that tests for the complementarity between intermediate inputs quality and skill composition in production is  $\gamma_{QS}$ . In these estimations we use input tariffs as instruments for imported input quality, relative imported input quality and relative imported input complexity. The interaction term between input quality and skill intensity is also instrumented using the interaction term between input tariffs and skill intensity in the initial sample year. We also include final good -firm level trends,  $q_{i,g,t0} * \eta_t$ , to control for differences in output quality across final goods within a firm and firm-final good fixed effects,  $\mu_{gi}$ , to capture within firm-final good quality changes. As in the previous specification, we control for firm-size trends and for year fixed effects to capture any time shocks.

We first confirm previous research findings on the positive impacts of input tariff cuts on firms' final good quality (column 1 of Table 6). For the 7-percentage-point reduction of input tariffs, the average firm increases output quality by 5%. This evidence is in line with the findings of Bas and Strauss-Khan (2015) that show that Chinese input-trade liberalization increases firms' export quality upgrading.

Next, we go one step further from the literature and test for the joint effect of high-quality foreign inputs and firms' skill intensity. Results of our estimation of equation (IV) are presented in columns (2)

and (3) of Table 6. The estimates in column (2) show that imported input quality and skilled labor both increase within firm-output quality. In column (3) we include the interaction term between both variables to test for complementary effects between high-quality imported inputs and skilled labor. Estimates in columns (4) to (9) present an alternative test for this complementarity by splitting the sample between firms that have a higher skill intensity (above the median of the industry in the initial year) and a lower one (below the median sample). Results confirm the finding presented in column (3) on the complementarity between imported input quality and firm level skill composition to produce high quality products. The positive effect of imported input quality on within firm-product output quality upgrading is only significant for high-skill-intensity firms – where high skill intensity is the skill intensity in the initial period - in columns (4), (6) and (8). In alternative estimations available upon request, we use as instruments one and two lagged years tariff measures. Results are robust to this alternative instrumentation strategy and the Hansen test validates the exogeneity of instruments.

**Table 6: Output quality upgrading, imported input quality and skilled labor**

Dependent variable:	Firm-final good quality								
	Within est. with tariffs	Fixed effects instrumental variable estimations							
		Full sample		High skill	Low skill	High skill	Low skill	High skill	Low skill
		(1)	(2)	intensity	intensity	intensity	intensity	intensity	intensity
Input tariffs(j,t-1)	-0.704** (0.338)								
Output tariffs(j,t-1)	-0.176 (0.196)								
Skill intensity(i,t)		5.604** (2.268)	2.524*** (0.682)						
Imported input quality(i,t) x Skill intensity(i,t)			1.390** (0.544)						
Imported input quality(i,t)		1.420*** (0.298)	-0.170 (0.198)	2.406** (1.222)	-0.265 (0.360)				
Relative imported inputs quality(i,t)						0.368*** (0.123)	0.152 (0.204)		
Relative imported input complexity(i,t)								1.233*** (0.396)	-0.946 (0.970)
Share of imported input varieties(i,t)		-0.019 (0.017)	-0.002 (0.008)	0.081* (0.044)	0.008 (0.014)	0.024** (0.009)	-0.018 (0.019)	-0.029 (0.019)	0.004 (0.014)
Firm-final good trends	yes	yes	yes	yes	yes	yes	yes	yes	yes
Initial year firm size trends	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm-final good fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	56,992	55,170	55,170	32,119	22,913	32,119	22,913	32,119	23,485
R-squared	0.39								
Root MSE		1.43	1.23	2.03	1.18	1.29	1.20	1.25	1.18

*Notes:* Column (1) presents within-firm-product estimates of the effects of industry level tariffs on firm-final good product level output quality and standards errors are clustered at the 3-digit industry level. Columns (2) to (9) present instrumental variable estimations using input and output tariffs as instruments for the three measures of imported input quality and the share of imported input varieties. In column (3) the interaction term between imported input quality and skill intensity is instrumented by lagged input tariffs interacted with initial year skill intensity of the firm. In column (1) standard errors are clustered at the 3-digit industry level. In columns (2) to (9) standard errors are clustered at the firm level. \*\*\*, \*\*, and \* indicate significance at the 1, 5 and 10 percent levels respectively.

#### 5.4. Extensions

In this section we explore to what extent the effects of input-trade liberalization extend beyond importers of foreign products and whether impacts are heterogeneous across firms.

First, the empirical literature on this topic has not analyzed whether the effect of input-trade liberalization extend also to firms that source only domestic inputs via input-output linkages. In order to investigate this question, we measure firms' input-output (IO) linkages and identify firms using domestic inputs from industries that rely more on imported inputs of high quality as described in the Annex. We then use this measure in instrumental variable regressions and investigate the impacts of those linkages on firms' skill composition and firm-product output quality. We instrument our main variable, domestic input firms IO linkages, by exogenous changes in input tariffs. The rationale for

using input-tariff changes is that these affect the quality of imported inputs. Therefore, firms producing with domestic inputs that are produced in industries that rely more on imported inputs of high quality will also benefit from input-trade liberalization by increasing the quality of their domestic inputs.

**Table 7: Effects of imported input quality on firms sourcing domestic inputs as a result of input-output linkages**

Dependent variables:	Skill intensity	Skill premium	Firm-final good quality		
			Full sample	High skill intensity	Low skill intensity
	Fixed effects instrumental variable estimations				
	(1)	(2)	(3)	(4)	(5)
Reliance on industries using high-quality imported inputs( <i>i,t</i> )	0.146** (0.063)	0.563** (0.257)	0.716** (0.311)	1.005* (0.521)	0.560 (0.379)
Initial year firm size trend	no	no	no	yes	yes
Firm fixed effects	yes	yes	no	no	no
Year fixed effects	yes	yes	yes	yes	yes
Firm-final good fixed effects	no	no	yes	yes	yes
Observations	4,915	4,914	25,961	15,274	10,625
Root MSE	0.09	0.38	1.30	1.29	1.26

*Notes:* Columns (1) and (2) present within-firm instrumental variable estimations on the effect of firms sourcing domestic inputs that rely more on imported inputs on skill intensity and skill premium. Columns (3), (4) and (5) present within firm-product instrumental variable estimations on firm-product level quality. Domestic input firms IO linkages(*i,t*) is the interaction term between the share of imported inputs over total inputs at the 4-digit main sourcing input industry of the firm and a dummy equal to one if the firm does only rely on domestic inputs in year *t*. This variable is instrumented by input tariffs. All estimations control for the imported variety channel. Standard errors are clustered at the firm level \*\*\*, \*\*, and \* indicate significance at the 1, 5 and 10 percent levels respectively.

Our findings presented in Table 7 show that these firms also upgrade their output quality (column 1). Estimates in columns (2) and (3) suggest that only non-importers, using inputs that are produced with a higher quality imported inputs, and that have higher skill intensity upgrade their output quality. The number of observations differs from previous estimations since we focus here on the sample of firms using only domestic inputs.

Second, we test for heterogeneous impacts of access to high quality imported inputs and skilled labor on output quality depending on firm initial skill-augmenting total factor productivity (TFP). We do not rely on conventional TFP measures because these estimate a Hicks-neutral productivity term which does not affect the relative demand for skilled labor. We obtain the skill-biased productivity term from a CES labor demand combining skilled and unskilled labor, which has the advantage of measuring heterogeneous effects on relative demand of labor across firms, following the work of Doraszelski and Jaumandreu (2018).<sup>3</sup> This term is estimated as a residual of a relative demand of skilled to unskilled labor from a CES production function combining both type of labor using a GMM estimator. The

<sup>3</sup> We thank an anonymous referee for suggesting us to use the skill-augmenting productivity term.



skill-augmenting productivity measure depends on the residual of that estimation and the elasticity of substitution between skilled and unskilled labor.<sup>4</sup> Annex A presents a detailed description of the methodology used to compute this productivity measure.

With this skill-biased productivity measure at hand we test the heterogeneous effects of imported input quality and skill composition to produce output quality. We split the sample into two groups of firms: (i) initially high-skill-augmenting productivity (above the median industry skill-biased productivity in the initial year) and (ii) initially low-skill-augmenting productivity (below the median industry skill-biased productivity in the initial year). We first present the instrumental variables estimations reported in Table 5 on the effect of imported input quality on skill intensity and the skill premium for the two sub-samples of firms with high- and low-skill-augmenting productivity.

Our findings in columns (1) to (4) of Table 8 confirm that the positive effect of imported input quality on skill composition is concentrated on firms with initial high-skill-augmenting productivity. Next, we look at the joint effect of input quality and skill composition on firm-product output quality relying on the instrumental variable estimations reported in Table 6 for the two sub-samples of firms with high- and low-skill-augmenting productivity. Results in columns (5) to (8) of Table 8 show that firms with initially high skill-augmenting productivity are the ones for which the complementarity between skilled labor and imported input quality, due to input tariff cuts, increase within firm-final good product output quality.<sup>5</sup>

## 6. Sensitivity checks

In this section, we examine whether our results are robust to using output price as measure of quality. We also look at the effects on single final good producers for which all inputs are allocated to produce the single final good. We also test the sensitivity of our results to the following alternative explanations: imports of capital goods, foreign demand shocks (export opportunities) and Ecuador's financial crisis and other reforms of the 1990s and 2000s.

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<sup>4</sup> Harrigan et al. (2021) also estimate the elasticity of substitution between skilled and unskilled labor based on an estimation of the relative demand of skilled labor from a CES function using firm level data from France.

<sup>5</sup> In unreported estimations, we show that the heterogeneous effects of input quality on skill composition and their joint effect on firm-final goods product output quality are similar if we rely on a standard measure of firm TFP-Q (using physical quantities and deflated input expenditures with firm-input prices) for multiproduct firms following De Loecker et al. (2016) methodology.

**Table 8: Heterogeneous effects depending on firm skill-augmenting productivity**

Dependent variable:	Skill intensity		Skill premium		Firm-final good quality			
	Fixed effects instrumental variable estimations							
	High TFP (1)	Low TFP (2)	High TFP (3)	Low TFP (4)	High TFP (5)	TFP (6)	TFP (7)	Low TFP (8)
Imported input quality(i,t)	0.130*	0.280	0.387*	-1.177	0.397*	-0.486	0.289**	-0.437
	(0.073)	(0.439)	(0.232)	(1.617)	(0.226)	(0.527)	(0.128)	(0.662)
Skill intensity(i,t)					5.474**	3.671**	3.283**	1.395
					(2.352)	(1.472)	(1.331)	(0.875)
Imported input quality(i,t) x Skill intensity(i,t)						2.808*		1.851
						(1.702)		(1.697)
Firm controls (size trend, input variety)	yes	yes	yes	yes	yes	yes	yes	yes
Firm-final good trend	no	no	no	no	yes	yes	yes	yes
Firm-final good fixed effects	no	no	no	no	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	no	no	no	no
Observations	5,363	6,176	5,363	6,165	23,675	23,549	24,002	23,952
Root MSE	0.05	0.11	0.17	0.47	1.20	1.20	1.22	1.26

*Notes:* Columns (1) to (4) present instrumental variable estimations on firm level skill intensity and skill premium splitting the sample between firms with initial high-skill-augmenting productivity and low-skill-augmenting TFP. Columns (5) to (8) present instrumental variable estimations on firm-final goods product level output quality. Standard errors are clustered at the firm level. \*\*\*, \*\*, and \* indicate significance at the 1, 5 and 10 percent levels respectively.

### 6.1. Using output price as alternative output quality measure

We use the output prices (unit values) at the firm-final good product level as an alternative measure of quality as done in an extensive empirical trade literature, including Bastos and Silva (2010), Bastos et al. (2018), Kugler and Verhoogen (2012), Martin (2012), Manova and Zhang (2012), Fernandes and Paunov (2013), Harrigan et al. (2015), Hallak, (2006), Hallak and Sivadasan (2013). The rationale for using price as measure of quality is that if quality is costlier to produce, then those goods require selling at higher price than equivalent products of lower quality. Consumers are willing to pay higher price for higher-quality products. Table 9 shows that our findings with regard to output quality are robust and of similar magnitude when we use output prices.

### 6.2. Single final good producing firms

This section presents evidence on single final good product firms that remained like that over the whole sample period. For these firms, skilled labor and intermediate inputs used in the production can be assigned to the single final good produced by the firm. Table A.1. in the Annex presents the results. Columns (1) and (2) show that input tariff cuts increase the skill intensity and the skill premium for single product firms. Moreover, our instrumental variable estimation in column (3) also shows that the increase in the relative imported input quality, driven by input tariff, has a positive effect on the relative demand of skilled labor of single final good firms. Finally, results of column (6) confirm that

the complementarity between imported input quality and skilled labor increases output quality of single product firms.

**Table 9: Sensitivity results using output prices (unit values)**

Dependent variable:	Firm-final good unit value								
	Full sample		High skill intensity		Low skill intensity		High skill intensity		Low skill intensity
	Within est. with tariffs								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Input tariffs(j,t-1)	-0.717** (0.304)								
Output tariffs(j,t-1)	-0.280 (0.177)								
Skill intensity(i,t)		4.788** (2.145)	2.632*** (0.654)						
Imported input quality(i,t) x Skill intensity(i,t)			1.709*** (0.522)						
Imported input quality(i,t)		1.282*** (0.282)	-0.349* (0.190)	1.751* (1.059)	-0.443 (0.345)				
Relative imported inputs quality(i,t)						0.264** (0.114)	0.042 (0.214)		
Relative imported input complexity(i,t)								1.146*** (0.372)	-1.331 (0.952)
Firm controls (size trend, input variety)	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm-final good trends	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm-final good fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	56,992	55,170	47,766	32,119	22,913	32,119	22,913	32,119	23,485
R-squared	0.39								
Root MSE		1.36	1.18	1.76	1.13	1.21	1.13	1.17	1.16

Notes: In column (1) standard errors are clustered at the 3-digit industry level. In columns (2) to (9) standard errors are clustered at the firm level. \*\*\*, \*\*, and \* indicate significance at the 1, 5 and 10 percent levels respectively.

### 6.3. Testing for the impact of quality and machinery imports

An alternative explanation to our story of intermediate input of higher quality is that imports of machinery lead importing firms to upgrade output quality more than other firms. We test for this alternative explanation by including the imported capital goods status of the firm in our model interacted with tariffs. The importer of capital goods status is defined as a dummy equal to one if the firm imports machinery goods (identified by code 84 of the HS-2 classification) in at least one year during the period of analysis.

We first test directly whether the possible complementarity of capital with skills drives the relative demand for skills following input-trade liberalization (Burstein et al, 2013; Koren and Csillag, 2011; Parro, 2013). Koren and Csillag (2011) show that workers with occupation related to imported machine have larger earnings. Results presented in Table A2 in the Annex confirm the impact of imported input quality on firms' skill intensity and the complementary effect of input quality and skills on output quality.

#### ***6.4. Foreign demand shocks (export opportunities)***

The expansion of export opportunities may also raise firms' incentives to upgrade their output quality (Verhoogen, 2008). More export revenues may allow overcoming the fixed costs of upgrading quality enabled by higher-quality inputs and empirical evidence has shown that importing intermediate inputs increased firms' exports (Feng et al., 2016; Bas, 2012).

To test whether export opportunities drive output quality upgrading and the skill intensity of production, we introduce in the previous specifications the tariff faced by Ecuadorian firms at the 4-digit ISIC Rev. 3 industry level set by Ecuador's main trading partners (Latin American countries, the United States, the European Union and China) to Ecuador (export tariff) during the 1996-2007 period. In addition to those tariff data from the WITS dataset (World Bank), we include an interaction term between exporter status and export tariffs. Results of Table A3 show our findings are robust to the inclusion of export tariffs. The effect of the export tariff reductions on quality upgrading is positive but not significant across all specifications we test. The effect of export status and the interaction term are in general not significant.

#### ***6.5. Ecuador's financial crisis and other reforms of the 1990s and 2000s***

Then, we test whether our results are affected by Ecuador's financial crisis and RER variations. To do so, we first interact our tariff measures with an indicator variable for the crisis years 1999-2000. The evidence presented in Table A4 confirms results are not driven by Ecuador's economic crisis. Moreover, we explicitly explore whether the depreciation of the Ecuadorian currency and its dollarization had impacts by controlling for differences in real exchange rates variations (RER) faced by Ecuadorian firms.<sup>6</sup> Results presented in Table A5 confirm that our previous findings are robust to these controls.

Next, we analyze whether Ecuador's financial sector reforms affected our results. We do so by including an indicator of Ecuador's financial liberalization, the IMF's financial liberalization index (Abiad et al., 2008), interacted with the firm industry's dependence on external finance as initially developed by Rajan and Zingales (1998) and subsequently updated by Braun (2002). This estimation approach is based on the assumption that if changes in access to finance play a role, then they should be more (less) important in sectors that rely more (less) on external finance. Results of our analysis, reported in Table A6 in the Annex, show that financial sector reforms are positively linked to output quality improvements, possibly because of a positive impact of better access to finance on output

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<sup>6</sup> Since the firm-product level data from Ecuador does not report the origin country where firms are sourcing their inputs (it is only indicated if the input is domestic or foreign), we rely on COMTRADE data for Ecuador imports at the hs6 product level and sourcing country to construct a measure of product level Real Exchange Rate faced by Ecuadorian firms over the period.

quality upgrading. These reforms, however, do not affect our results on the impacts of input quality and the complementary role of inputs and skills on output quality.

Moreover, we estimate all results on subsamples that exclude the oil sector that was the main sector affected by other reforms such as privatization and FDI. More precisely, we exclude firms from the manufacture of coke, refined petroleum products and nuclear fuel (ISIC 2-digit revision 3 code 23), from the analysis. We also exclude agricultural goods (ISIC 2-digit revision 3 code 15) and tobacco (ISIC 2-digit revision 3 code 16) as the price for these commodities is subject to quite different shocks. Unreported results indicate that these industries do not drive our results.

Finally, we conduct a more general test to control for impacts of reforms of the 1990s and 2000s and any unobservable time-varying shocks across industries. Those shocks are already absorbed in product-firm regressions we discuss above as these include product-year trends but not in firm-level analyses. We do so here by including aggregate industry trends in all firm-level specifications. Unreported results show that our coefficients of interest in those regressions are not affected, excluding the possibility that they pick up the effect of other industry-specific reforms or any other shocks.

## **7. Conclusion**

We present new evidence on the causal effects of input-trade liberalization on foreign high-quality inputs and its impacts on firms' skill intensity to upgrade output quality. Our main contribution is to demonstrate that the complementarity between skilled labor and the quality of foreign inputs drives output quality improvements, suggesting that investments in training and education can boost production upgrading following input-trade liberalization. The absence of skilled labor may restrain the number of firms that are in position to upgrade their production processes. Our findings also confirm several predictions of models of trade liberalization with heterogenous skills and endogenous input- and output-choices that have not been tested to date for an unexplored developing country, Ecuador, by exploiting the country's unilateral liberalization as it entered the WTO.

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## Annex

### A. Details on variable computations

#### *Input and output quality*

We estimate imported inputs quality and output quality following the methodology proposed by Khandelwal et al. (2013) (KSW hereafter). They demonstrate that assuming a CES utility function where product quality acts as a demand shifter, the quality of each product can be estimated using information on quantities, unit values and the elasticity of substitution across products. Quality is then represented as any product attribute that shifts the demand curve as first proposed by Sutton (1991). Inferring product quality from demand functions means that conditional on prices a product with higher demand (quantity) is assigned higher quality.

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

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

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

where  $x_{ikt}$  and  $p_{ikt}$  denote the natural logs of the quantity and price of input product  $k$  or output product  $g$  at 11-digit ISIC-Rev. 3-based product code imported and, for the quality of final goods, produced by firm  $i$  in year  $t$ . The product fixed effect  $\alpha_k$  controls for unobservable characteristics across products since prices and quantities are not necessarily comparable across products. The estimated log quality,  $\lambda_{ikt}$ , depends on the residual of that estimation  $\eta_{ikt}$  and the elasticity of substitution  $\sigma$ :  $\lambda_{ikt} = \eta_{ikt}/(\sigma - 1)$ .

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

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

#### *Skill-augmenting productivity*

We rely on an extension of the work of Doraszelski and Jaumandreu (2018), who estimate labor augmenting productivity. The skill-augmenting productivity term ( $\Omega_{Sit}$ ) can be estimated as a residual of a relative demand of skilled ( $S_{it}$ ) to unskilled ( $U_{it}$ ) labor from the following CES production function combining both type of labors as  $L_{it} = ((\Omega_{Sit} S_{it})^\rho + U_{it}^\rho)^{1/\rho}$ , where  $\rho = \frac{\varphi-1}{\varphi}$ . The relative demand of skilled to unskilled labor from this CES function is given by:  $\frac{S_{it}}{U_{it}} = \left(\frac{W S_{it}}{W U_{it}}\right)^{-\varphi} \Omega_{Sit}^{\varphi-1}$ .

Taking logs of the relative demand of skilled labor, the estimating equation of the skill ratio is:

$$s_{it} - u_{it} = -\varphi (ws_{it} - wu_{it}) + v_{it}$$

where  $v_{it} = (\varphi - 1)\ln\Omega_{S,it}$ ,  $s_{it}$  is the logarithm of skilled labor demand,  $u_{it}$  is the logarithm of unskilled labor demand,  $ws_{it}$  is the logarithm of the wage of skilled labor and  $wu_{it}$  is the logarithm of the wage of unskilled labor of firm  $i$  in year  $t$ . The estimated logarithm of the skill-augmenting productivity,  $\Omega_{S,it}$ , depends on the residual of that estimation,  $v_{it}$ , and the elasticity of substitution between skilled and unskilled labor,  $\varphi$ . We estimate this equation using a GMM estimator. We rely on the time assumption made by Doraszelski and Jaumandreu (2018) and use as instruments the lag values of the relative wage of skilled to unskilled labor and a time trend. Next, we recover the residual ( $v_{it}$ ) and the elasticity of substitution between skilled and unskilled labor ( $\varphi$ ) from this estimation and we are able to compute a skill-biased productivity measure as  $\ln\Omega_{S,it} = v_{it}/(\varphi - 1)$ .

### *Firms' input-output linkages*

We measure firms' downstream linkages with industries that import high-quality inputs as follows: First, we match the output product firm data with the weighted average firm level imported input quality across all imported inputs used by the firm. Next, we construct the weighted average imported input quality at the 6-digit output product level for goods sell in the domestic market. We then classified domestic output products into two categories those relying on high-quality imported inputs (above the median of the sample) and low-quality imported inputs (below the median). Then, we identify for each Ecuadorian firm producing with domestic inputs the main 6-digit input product and we match it with the previous variable indicating if the 6-digit input product is classified as being in an industry that rely on high (low) imported input quality.

### **B. Additional robustness tests**

**Table A.1: Sub-sample of single product final goods firms**

Dependent variables:	Skill intensity Skill premium		Skill intensity Skill premium		Firm-final good quality		
	Within est. with tariffs		Fixed effects instrumental		Within est. Fixed effects instrumental		
	(1)	(2)	variable estimations		with tariffs	variable estimations	
					High skill	Low skill	
	(1)	(2)	(3)	(4)	(5)	intensity	intensity
Input tariffs(j,t-1)	-0.150** (0.068)	-0.760*** (0.256)			-2.247* (1.234)		
Output tariffs(j,t-1)	0.019 -0.043	0.334** (0.160)			0.897 (0.710)		
Relative imported inputs quality(i,t)			0.055* (0.032)	0.321 (0.242)		0.608** (0.359)	-0.137 (0.620)
Initial year firm size trend	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes	yes	yes
Observations	5,171	5,163	4,817	4,817	4,086	1,350	1,559
R-squared	0.81	0.75			0.65		
Root MSE			0.11	0.09		0.35	0.34

*Notes:* The estimations in this table are for the sub-sample on single final good firms that produce only one product during the whole sample period. The dependent variables in columns (1) to (4) are the skill intensity and the skill premium at firm level and in columns (5) to (7) is the firm-final good product output quality of single product firms. In columns (1), (2) and (5) standard errors are clustered at the 3-digit industry level. In columns (3), (4), (6) and (7), standard errors are clustered at the firm level. \*\*\*, \*\*, and \* indicate significance at the 1, 5 and 10 percent levels respectively.

**Table A.2: Testing for the impact of imports of capital goods on firms' skill intensity, skill premium and output quality**

Dependent variables:	Firm skill intensity		Firm skill premium		Firm-final good quality				Full sample
	(1)	(2)	(3)	(4)	High skill	Low skill	High skill	Low skill	
					intensity	intensity	intensity	intensity	
Fixed effects instrumental variable estimations									
Relative imported inputs quality(i,t)	0.053** (0.024)		0.165* (0.085)		0.477*** (0.158)	0.142 (0.211)			
Relative imported input complexity(i,t)		0.274* (0.143)		1.028* (0.560)			1.634*** (0.403)	-1.398 (1.044)	
Input tariffs(j,t-1) x Importer capital goods	0.372 (0.204)	0.094 (0.194)	0.635 (0.707)	-0.348 (0.762)	-3.195** (1.452)	-3.775 (2.939)	1.949 (1.591)	-3.580* (2.053)	-1.916* (1.150)
Output tariffs(j,t-1) x importer capital goods	0.208 (0.229)	0.331 (0.309)	0.592 (0.795)	1.553 (1.210)	7.811*** (1.857)	3.618 (3.700)	1.074 (1.424)	0.664 (3.109)	3.385*** (1.130)
Skill intensity(i,t)									2.122*** (0.706)
Imported input quality(i,t) x Skill intensity(i,t)									1.963*** (0.549)
Imported input quality(i,t)									-0.249 (0.201)
Firm controls (size trend & input variety)	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	no	no	no	no	no
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm-final good trends	no	no	no	no	yes	yes	yes	yes	yes
Firm-final good fixed effects	no	no	no	no	yes	yes	yes	yes	yes
Observations	12,253	12,466	12,253	12,455	32,119	22,913	32,119	23,485	55,170
Root MSE	0.10	0.10	0.34	0.40	1.30	1.20	1.26	1.20	1.24

Notes: This table replicates estimations presented in Table 5 and 6 including the interaction between importer of capital goods and tariffs. Input and output tariffs are used as instruments for the imported input quality, complexity and imported input variety measures. Standard errors are clustered at the firm level. \*\*\*, \*\*, and \* indicate significance at the 1, 5 and 10 percent levels respectively.

**Table A.3: Testing for the impact of foreign demand shocks on firms' skill intensity, skill premium and output quality**

Dependent variables:	Firm skill intensity		Firm skill premium		Firm-final good quality				Full sample
	(1)	(2)	(3)	(4)	High skill	Low skill	High skill	Low skill	
					intensity	intensity	intensity	intensity	
Fixed effects instrumental variable estimations									
Relative imported inputs quality(i,t)	0.052** (0.025)		0.177** (0.084)		0.351*** (0.122)	0.093 (0.214)			
Relative imported input complexity(i,t)		0.184* (0.100)		0.634* (0.382)			1.508*** (0.427)	-2.018 (1.298)	
Export tariffs(j,t-1)	0.027 (0.056)	-0.004 (0.042)	-0.026 (0.182)	-0.106 (0.159)	-0.618 (0.609)	-2.621* (1.525)	1.005 (0.721)	-2.996* (1.529)	-0.136 (0.339)
Exporter status	-0.014 (0.008)	-0.007 (0.006)	-0.058* (0.026)	-0.034 (0.024)	-0.024 (0.059)	-0.199 (0.142)	-0.045 (0.058)	-0.154 (0.105)	-0.111* (0.049)
Export tariffs(j,t-1)* Exporter	0.124 (0.081)	0.025 (0.075)	0.685** (0.265)	0.255 (0.286)	1.084* (0.557)	1.59 (1.190)	0.779 (0.485)	2.089 (1.647)	0.684 (0.462)
Skill intensity(i,t)									2.204*** (0.689)
Imported input quality(i,t) x Skill intensity(i,t)									1.410*** (0.538)
Imported input quality(i,t)									-0.232 (0.198)
Firm controls (size trend & input variety)	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	no	no	no	no	no
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm-final good trends	no	no	no	no	yes	yes	yes	yes	yes
Firm-final good fixed effects	no	no	no	no	yes	yes	yes	yes	yes
Observations	12,253	12,466	12,253	12,455	32,119	22,913	32,119	23,485	55,170
Root MSE	0.11	0.09	0.35	0.33	1.28	1.21	1.25	1.26	1.23

Notes: This table replicates estimations presented in Table 5 and 6 including export tariffs, export status and its interaction as controls. Export tariff is the average effectively applied tariff faced by Ecuadorian firms at the 4-digit ISIC Rev. 3 industry level set by Ecuador's main trading partners (in Latin America, USA, European Union and China) to Ecuador. Input and output tariffs are used as instruments for the imported input quality, complexity and imported input variety measures.

Standard errors are clustered at the firm level. \*\*\*, \*\*, and \* indicate significance at the 1, 5 and 10 percent levels respectively.

**Table A.4: Controlling for Ecuador's financial crisis on firms' skill intensity, skill premium and output quality**

Dependent variables:	Firm skill intensity		Firm skill premium		Firm-final good quality				Full sample
	(1)	(2)	(3)	(4)	High skill	Low skill	High skill	Low skill	
					intensity	intensity	intensity	intensity	
Fixed effects instrumental variable estimations									
Relative imported inputs quality(i,t)	0.051** (0.023)		0.160** (0.081)		0.364*** (0.127)	0.157 (0.205)			
Relative imported input complexity(i,t)		0.185* (0.103)		0.707* (0.399)			1.252*** (0.421)	-0.839 (1.020)	
Input tariffs(j,t-1) x crisis	0.285 (0.189)	-0.030 (0.239)	0.399 (0.671)	-0.327 (0.924)	1.258 (1.178)	-1.604 (1.603)	2.479 (1.833)	-1.229 (1.245)	-0.481 (0.771)
Output tariffs(j,t-1) x crisis	-0.065 (0.102)	-0.019 (0.104)	0.155 (0.363)	0.088 (0.404)	1.189 (0.799)	1.001 (1.382)	0.267 (1.420)	0.284 (0.961)	1.659*** (0.544)
Skill intensity(i,t)									2.564*** (0.683)
Imported input quality(i,t) x Skill intensity(i,t)									1.349** (0.543)
Imported input quality(i,t)									-0.164 (0.198)
Firm controls (size trend & input variety)	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	no	no	no	no	no
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm-final good trends	no	no	no	no	yes	yes	yes	yes	yes
Firm-final good fixed effects	no	no	no	no	yes	yes	yes	yes	yes
Observations	12,253	12,466	12,253	12,455	32,119	22,913	32,119	23,485	55,170
Root MSE	0.10	0.09	0.35	0.34	1.30	1.20	1.25	1.18	1.23

Notes: This table replicates estimations presented in Table 5 and 6 including the interaction between a crisis dummy and tariffs as controls. Crisis is defined as equal to 1 in the years 1999 and 2000, and 0 otherwise. Input and output tariffs are used as instruments for the imported input quality, complexity and imported input variety measures. Standard errors are clustered at the firm level. \*\*\*, \*\*, and \* indicate significance at the 1, 5 and 10 percent levels respectively.

**Table A.5: Controlling for real exchange rate variations on firms' skill intensity, skill premium and output quality**

Dependent variables:	Firm skill intensity		Firm skill premium		Firm-final good quality				Full sample
	(1)	(2)	(3)	(4)	High skill	Low skill	High skill	Low skill	
					intensity	intensity	intensity	intensity	
Fixed effects instrumental variable estimations									
Relative imported input quality(i,t)	0.049** (0.025)		0.159** (0.080)		0.377*** (0.121)	0.131 (0.204)			
Relative imported input complexity(i,t)		0.185* (0.111)		0.698* (0.419)			1.288*** (0.430)	-0.999 (1.039)	
RER(j,t-1)	-0.001 (0.002)	-0.002 (0.002)	-0.001 (0.008)	-0.002 (0.009)	-0.022* (0.012)	-0.040 (0.034)	-0.023* (0.013)	-0.035 (0.030)	-0.016 (0.011)
Skill intensity(i,t)									2.455*** (0.682)
Imported input quality(i,t) x Skill intensity(i,t)									1.466*** (0.544)
Imported input quality(i,t)									-0.186 (0.198)
Firm controls (size trend & input variety)	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	no	no	no	no	no
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm-final good trends	no	no	no	no	yes	yes	yes	yes	yes
Firm-final good fixed effects	no	no	no	no	yes	yes	yes	yes	yes
Observations	12,253	12,466	12,253	12,455	32,119	22,913	32,119	23,485	55,170
Root MSE	0.11	0.09	0.34	0.35	1.30	1.20	1.25	1.18	1.23

Notes: This table replicates estimations presented in Table 5 and 6 including the industry level real exchange rate as a control. Input and output tariffs are used as instruments for the imported input quality, complexity and imported input variety measures. Standard errors are clustered at the firm level. \*\*\*, \*\*, and \* indicate significance at the 1, 5 and 10 percent levels respectively.

**Table A.6: Financial liberalization on firms' skill intensity, skill premium and output quality**

Dependent variables:	Firm skill intensity		Firm skill premium		Firm-final good quality				Full sample
	(1)	(2)	(3)	(4)	High skill	Low skill	High skill	Low skill	
					intensity	intensity	intensity	intensity	
					Fixed effects instrumental variable estimations				
Relative imported inputs quality(i,t)	0.048** (0.025)		0.161** (0.080)		0.367*** (0.122)	0.154 (0.203)			
Relative imported input complexity(i,t)		0.187* (0.108)		0.714* (0.424)			1.224*** (0.400)	-0.941 (0.963)	
Financial liberalization x Financial dependence(j,t-1)	0.021 (0.025)	0.008 (0.020)	-0.019 (0.080)	-0.055 (0.080)	-0.042 (0.253)	0.098 (0.399)	0.186 (0.314)	-0.099 (0.257)	0.298* (0.152)
Skill intensity(i,t)									-0.165 (0.198)
Imported input quality(i,t) x Skill intensity(i,t)									1.398** (0.544)
Imported input quality(i,t)									2.524*** (0.680)
Firm controls (size trend & input variety)	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm fixed effects	yes	yes	yes	yes	no	no	no	no	no
Year fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Firm-final good trends	no	no	no	no	yes	yes	yes	yes	yes
Firm-final good fixed effects	no	no	no	no	yes	yes	yes	yes	yes
Observations	12,253	12,458	12,253	12,447	32,119	22,913	32,119	23,485	55,170
Root MSE	0.11	0.09	0.34	0.34	1.30	1.20	1.24	1.18	1.23

*Notes:* This table replicates estimations presented in Table 5 and 6 including as a control the IMF's financial liberalization index (Abiad et al., 2008), interacted with the firm industry's dependence on external finance as initially developed by Rajan and Zingales (1998) and subsequently updated by Braun (2002). Input and output tariffs are used as instruments for the imported input quality, complexity and imported input variety measures. Standard errors are clustered at the firm level. \*\*\*, \*\*, and \* indicate significance at the 1, 5 and 10 percent levels respectively.

## Online annex: Descriptive statistics of the data, data treatment and additional robustness tests

### OA.1. Statistics of the main plant-level dataset

We eliminate plant observations in any single year if no information on overall product sales, skilled and unskilled employment and wage payments is provided since these will be essential for our analysis. Our baseline plant-level dataset contains 12,343 plant-year observations for 1997 to 2007. Table OA.1 shows the average split across 2-digit industries for the entire sample period; more than one in four observations are of food and beverage producers.

**Table OA.1: Number of plant-year observations by 2-digit ISIC rev. 3 industry**

ISIC Rev. 3	Industry name	Plants	Share in total
15	Food and beverages	2741	22.21
16	Tobacco	483	3.91
17	Textiles	878	7.11
18	Wearing apparel	856	6.94
19	Leather products, luggage, saddlery and footwear	471	3.82
20	Wood and wood products	449	3.64
21	Paper and paper products	423	3.43
22	Publishing, printing and reproduction of recorded media	543	4.40
23	Coke and refined petroleum products and nuclear fuel	69	0.56
24	Chemicals and chemicals products	898	7.28
25	Rubber and plastics products	947	7.67
26	Other non-metallic products	65	0.53
27	Basic metals	1158	9.38
28	Fabricated metal products	297	2.41
29	Machinery and equipment n.e.c.	667	5.40
31	Electrical machinery and apparatus	149	1.21
32	Radio, television and communication equipment	20	0.16
33	Medical, precision and optical instruments, watches and clocks	27	0.22
34	Motor vehicles, trailers and semi-trailers	328	2.66
36	Furniture	677	5.48
37	Other manufacturing products n.e.c.	197	1.60

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.

### OA.2. Data treatment for input- and output-product data

We use two separate datasets at the input-plant and output-plant level for 1997-2007. The original datasets provide for each product of plants an 11-digit ISIC-Rev.3-based product code and a description of the product itself. The 11-digit ISIC-Rev.3-based product codes are based on the ISIC Rev. 3 classification. Baseline datasets include 1,861 and 1,606 distinct input and output 11-digit ISIC-Rev.3-based manufacturing product categories; these correspond to the intermediate inputs and outputs of the plant-level dataset defined above. The dataset on intermediate inputs includes also information on the purchasing price (unit value) and quantity of goods across national and international purchases. The final goods products dataset has information on the production value and quantity as well as the sales value and quantity.

We applied several basic data cleaning procedures to obtain our final dataset. First, we removed those observations without any product code for both the input and the output datasets. Second, we also exclude observations on subcontracted production since information on product values in such cases might not reflect actual market values. Third, the original dataset contains cases where firms have more than one output or import product with the same 11-digit ISIC Rev.3-based product code. We eliminate duplicate observations. As for the remaining cases when firms have more than one input

and/or output in the same year with the same 11-digit ISIC Rev.3-based product code we create a more disaggregate product category rather than aggregate these observations. Fourth, any within-product price and quantity comparisons will only be meaningful if the same units of measurement are used. While this is the case for most of the products in our datasets, in certain cases the same product is reported in a different unit of measurement by different firms. We create a supra-product category to deal with those cases whenever our analysis requires with within-product comparisons. We eliminate those products without information on the unit of measurement for analysis involving price and quantity.