Imported Inputs, Quality Complementarity, and Skill Demand*

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Abstract

This paper analyzes how access to imported inputs affects firms in developing countries, where domestically produced high-quality inputs are relatively costly. We build an O-Ring type model with quality complementarity across input tasks, ranking tasks by their quality-sensitivity. Because high-quality inputs are relatively cheap in international markets, firms use these instead of domestic inputs for quality-sensitive production steps. This substitution effect lowers the demand for domestic input quality (such as skilled labor), while it raises output quality. At the same time, the complementarity effect increases the return to quality in the remaining domestic tasks. This raises output quality further; it also increases the demand for domestic input quality (skills), counterbalancing the first effect. To provide evidence for this mechanism, we match high-resolution data from Chilean customs to a large firm-level panel for the period 1992-2005. In line with the model's predictions, importers use ceteris paribus a lower share of skilled workers, while their skill demand increases significantly with the quality of imports.

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1 Introduction

Trade has important effects on the allocation of productive resources across firms. A large literature following Melitz (2003) has shown that more productive firms profit relatively more from export opportunities. More recently, several contributions have examined the role of imports: Access to inputs from international markets can have substantial effects on firm performance in developing countries. By lowering the cost of imported inputs, trade liberalization raises firm productivity (Amiti and Konings, 2007), fosters the introduction of new products (Goldberg, Khandelwal, Pavcnik, and Topalova, 2010), and increases profits (De Loecker, Goldberg, Khandelwal, and Pavcnik, 2012). The integration of higher-quality imported inputs in the production process in poorer countries is an important channel for these effects. This firm-level evidence is in line with several empirical contributions showing that rich, skill-abundant countries tend to supply product varieties of higher quality (Schott, 2004; Hummels and Klenow, 2005; Hallak, 2006) – an observation that motivates models with endogenous quality differentiation.

So far, theory and evidence on heterogenous product quality at the firm level has mainly focused on *output* quality differentiation. For example, Bastos and Silva (2010) and Manova and Zhang (2012) show that firms tend to ship higher-quality versions of the same product to richer markets.[1] On the other hand, existing models with heterogenous *inputs* (e.g., Grossman and Rossi-Hansberg, 2008; Costinot and Vogel, 2010) typically do not analyze the input quality dimension. In sum, while there is strong evidence for an important role of trade in inputs of heterogenous quality, this "quality fragmentation of production" has not yet been formally analyzed.

This paper explores the role of heterogenous input quality in the production process of developing countries. We assume that rich countries have a cost advantage at producing high-quality products, so that trade liberalization lowers the effective cost of high-quality inputs in the developing world. Firms combine a continuum of production tasks (or inputs) to produce their final product – a differentiated variety with endogenous quality. Tasks differ with respect to their quality intensity, and the quality of each task is also chosen endogenously. This choice is affected by a quality-complementarity across inputs in the spirit of Kremer's (1993) O-Ring theory. The combination of a continuum of inputs with quality complementarity leads to a number of novel predictions that we subsequently test using a detailed Chilean firm panel.

Tasks can either be performed by workers or purchased in the form of inputs. The higher the

[1] Kugler and Verhoogen (2012) provide a model where both input and output quality vary across firms, but input quality is homogenous within each firm. Their model features a complementarity between the quality of inputs and output, which can explain the empirical observation that more productive firms choose both higher input and output quality.

skill level of workers, the higher their quality of task performance. If import tariffs are prohibitively high, all tasks are performed by domestic labor. When tariffs fall, firms in a developing country substitute highly skilled workers with high-quality imported inputs. At the same time, the return to quality in the remaining tasks increases, due to quality complementarity with the imported input. Thus, our model predicts two opposing effects of access to imported inputs on firms in developing countries: A substitution effect that reduces the demand for high-quality inputs because they are replaced by imports, and a complementarity effects that raises the return to quality in firms that purchase high-quality inputs abroad. The net impact of falling import tariffs on skill demand depends on the relative strength of the two effects.

We use a comprehensive database of Chilean firms over the period 1995-2005 to provide evidence for the model's predictions. This includes information on firm productivity, prices, and the type of workers employed. We pair the firm panel with information on imports from Chilean customs, covering the firm-specific imports at the detailed HS-8 level. To measure import quality at the firm level, we construct two proxies. First, an index based on the price of each firm's imports, relative to the average price paid by all other firms for the same import. This reflects the assumption that prices indicate product quality, following Schott (2004) and Hummels and Klenow (2005). Second, "import skill intensity" – the proportion of white-collar workers that is employed in producing the corresponding product in U.S. manufacturing. This assumes that high-quality goods are produced by skilled workers (c.f. Verhoogen, 2008) and that U.S. manufacturing is representative of the world technology used to produce Chilean imports.[2] Both input quality measures yield similar results.

We begin by analyzing the cross-sectional dimension of the panel, motivated by the fact selection across firms is typically identified as the most important driver in the empirical trade literature (c.f. Clerides, Lach, and Tybout, 1998; Bernard and Jensen, 1999; Pavcnik, 2002). We compare firms within narrowly defined output sectors in each year. First, we show that the data replicate previously established stylized facts (Bernard, Jensen, Redding, and Schott, 2007): Importing firms are larger, more productive, and more capital intensive. In addition, importing firms use higher-quality domestic inputs and produce higher-quality output. We then move on to the main prediction of the model. In line with the skill substitution effect, importing Chilean firms are less skill intensive than their non-importing peers. We also find strong support for the complementarity effect: Firms with higher import quality employ a significantly larger share of skilled workers.

[2]This measure is also firm-specific. For example, one firm producing optical equipment may import only lenses while another also imports electronic components. Since lenses and electronic components are produced using different skill shares in the U.S., the difference in imported inputs for the two firms results in different "import skill intensity."

Our results suggest that the skill substitution effect lowers the share of white-collar workers by approximately 9 percentage points, while the complementarity effect raises skill demand by roughly 7 percentage points.[3] On average, firms that import inputs use about 2 percentage points fewer skilled workers, suggesting that the skill substitution effect dominates along the extensive skill margin (white- vs. blue-collar employment). However, our data suggest that the complementarity effect dominates along the intensive margin: Wages within each of the two worker categories are significantly higher for importing firms, and wages grow with both measures of import quality. Finally, we exploit variation within firms and show that both the substitution and the complementarity effect increase hand-in-hand with the years that a firm has been consecutively importing inputs. This suggests that adjustment costs may hamper the transition to a new optimal production setup after firms adopt imported inputs.

Our paper is related to a large literature that analyzes the effects of international trade on skill demand and income inequality. The strong complementarity effect in our setup can help to resolve a well-documented puzzle: While standard trade theory predicts that trade liberalization is biased towards unskilled labor in developing countries, the opposite pattern prevails in the data (Goldberg and Pavcnik, 2007). In balance, the evidence shows a substantial increase in countries' exposure to international trade and an increase in inequality during the last decades.[4]

Several recent contributions have analyzed channels via which trade can affect skill demand at the firm level. Csillag and Koren (2011) find that workers exposed to imported machines in Hungarian firms earn a higher wage than their peers who operate locally produced equipment. Bloom, Draca, and van Reenen (2012) show that increasing import competition can raise innovation within firms and reallocate labor to more productive firms, while the share of unskilled employment drops. Verhoogen (2008) presents and tests a model that links trade to wage inequality. More productive plants produce higher quality goods and demand more skilled workers, paying higher wages. This increases the bias towards skilled wages and raises income inequality. Bustos (2011) shows that, as a consequence of a regional free trade agreement, the most productive Argentinean exporters increased their skill demand, while the opposite was true for less productive ones. Amiti and Cameron (2012) analyze a particularly low-skill abundant country – Indonesia – and document that falling import tariffs reduce skill demand within firms, while there are no significant effects of lower final good tariffs. Other studies have focused on the aggregate effect of trade on the skill pre-

[3]This comparison of the two effects has to be taken with a grain of salt, because the estimates may also capture unobserved heterogeneity that reflects alternative mechanisms.

[4]During the 1980s and 1990s, the majority of developing countries experienced increases in the skill premium, and this pattern is often accompanied by trade reforms. For example, the skill premium in Mexico increased by 68% between the mid-eighties and mid-nineties (Cragg and Epelbaum, 1996), by 20% in Argentina during its trade integration experience in the nineties (Gasparini, 2003), and by 13% in India between 1987 and 1999 (Kijama, 2006).

mium. Burstein, Cravino, and Vogel (2012) develop a quantitative model in the spirit of Krusell, Ohanian, Ríus-Rull, and Violante (2000) to study the effects of importing skill-intensive capital equipment on the skill premium at the country level.[5]

Relative to the existing literature, we make several contributions. First, to the best of our knowledge, this paper is the first to provide a trade model that features heterogenous inputs and quality complementarity across these inputs. This setup allows us to analyze how access to imported inputs affects various firm-level characteristics, such as the quality of domestic inputs, output quality, and worker skills. In effect, we add a quality dimension to the "fragmentation of production" within firms (c.f. Dixit and Grossman, 1982). Second, our model provides a novel prediction: Access to imported inputs in developing countries has two opposing effects – a substitution effect that lowers the domestic demand for input quality (skills), and a complementarity effect that works the opposite way.[6] Third, taking our model to the data reveals a novel empirical pattern in line with the theory: Importing firms in Chile are on average less skill intensive (which reflects the substitution effect), but their skill demand rises with the quality of imports (complementarity effect). Finally, our finding of a strong complementarity effect provides micro-level support for the import-skill-complementarity that drives the results in aggregate studies (e.g., Burstein et al., 2012).

The paper is organized as follows. In Section 2 we outline a simple partial equilibrium model that illustrates the main mechanism. Section 3 presents our data, and Section 4 the empirical results. Section 5 concludes.

2 Model

Our model considers a single industry, in which a continuum of firms produces differentiated final goods of endogenously determined quality. We use a partial equilibrium setting, taking aggregate demand and the cost profile of input quality as given. We analyze the optimal choice of input and output quality across firms (which also involves their import decisions), while abstracting from aggregate dynamics. Production in each firm involves a continuum of inputs $i \in [0, 1]$ with different sensitivity to quality. Individual inputs are complements with respect to their quality. Firms purchase inputs in the form of hired labor, or as physical inputs, such as equipment or intermediates.

[5] Parro (2012) also presents a model along these lines. Burstein and Vogel (2012) build a multi-country model and show that the skill premium increases as a consequence of trade liberalization for the median country.

[6] The import-skill complementarity in our model is in line with Voigtlaender (2012), who uses U.S. input-output data to show that the processing of skill-intensive intermediates coincides with higher skilled labor shares in final production. The combined evidence from Verhoogen (2008) and Kugler and Verhoogen (2009) also implies an import-quality skill complementarity. The former shows that high-quality output in a Mexican car plant is associated with skilled labor; the latter uses a Columbian manufacturing firm panel to show that imported inputs are generally of higher quality than domestic ones. In section 3 we show that this holds in our sample, too.

One interpretation of this setup is that inputs reflect tasks in production. These can be performed by hiring workers or by purchasing inputs in the form of intermediates or capital equipment.[7] To simplify the exposition, we characterize individual inputs i exclusively by their quality level q_i. Whether this reflects labor or physical inputs is not crucial throughout the theoretical part of the paper. When mapping the model to the data, we will be more specific and relate the skill level of labor to the quality with which an input task is performed, so that q_i also reflects worker skills. that performs these tasks.

Each firm produces a variety ω. The sensitivity of output quality with respect to the quality of each input i is the same across firms. However, firms differ with respect to two parameters that they draw from random distributions: The cost per unit (or *quality*) of the raw material that they use, m_ω, and their *quantity*-specific productivity, A_ω. A draw of a firm is thus a set of production instructions on how to transform a basic input of a given quality into a final product. For example, the production of some varieties of watches is based on precious metal, combined with instructions for high-precision manual work, while other watches use cheap plastic inputs together with standardized low-skilled tasks. The quality of the final product is endogenous and depends only on m_ω. Quantity productivity A_ω affects profits and thus determines which firms will operate in the market.[8]

The cost function of input quality is crucial for our results. We assume that in the home country (a developing country), the cost-of-quality profile starts off low and then increases rapidly with rising input quality. Inputs that are purchased abroad, on the other hand, are relatively expensive in the low-quality range, but the cost profile is flatter (see Figure 1). Thus, high-quality inputs are less expensive when purchased from developed countries. This reflects the evidence provided by Schott (2004) and Hummels and Klenow (2005) that – within narrowly defined product categories – richer countries export higher-quality varieties.[9] Since we analyze a cross-section of firms in a partial equilibrium setting, we take the cost of input quality as given.

[Insert Figure 1 here]

Given the cost-of-quality schedules of domestic and imported inputs, we derive the optimal quality of each input, $q_{i\omega}$, used by a firm producing variety ω, as well as the quality of the final

[7] It is not essential for our argument whether imported inputs reflect intermediates or capital equipment.

[8] None of the main predictions depend on A_ω. However, with uniform A_ω, firms with high draws of m_ω (high-quality producers) would be unproductive. This would effectively introduce a cap on output quality.

[9] An alternative motivation for this assumption is that the production of high-quality inputs relies on technology designed in rich countries that is inappropriate for the lower skill levels in developing countries (Acemoglu and Zilibotti, 2001). An additional contribution to this pattern can come from transportation costs, which constitute a relatively larger proportion of low-quality products, increasing their effective cost in the destination country.

good, Q_ω. We show that firms producing higher quality output will tend to import high-quality inputs. This has a two-fold effect on the quality of *domestic* inputs in these firms: On the one hand, the average quality level drops, because the highest-quality domestic inputs are replaced by imports. This reflects the substitution effect. On the other hand, the return to quality in the remaining domestic inputs increases because of the complementarity effect. This counteracting force dampens (and possibly reverses) the impact of imported inputs on the average quality of domestically purchased inputs.

2.1 Consumption

Consumers derive utility from quality-adjusted varieties within an industry, as given by the CES function:

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

where Q_ω represents the quality of variety ω, and x_ω is the corresponding quantity consumed. Ω is the set of varieties that are produced within a given industry, and σ corresponds to the elasticity of substitution between (quality-adjusted) varieties. We assume that varieties are substitutes such that $\sigma > 1$. Following Kugler and Verhoogen (2012), we interpret the quality of a variety as any product attribute valued by the consumers, and adopt the notation X to represent the quality-adjusted consumption aggregate (reflecting the market size of the industry in question). Consumers minimize the cost of consumption, $\int_{\omega \in \Omega} p_\omega x_\omega d\omega$, subject to $U(\cdot) \geq X$. This yields the demand for varieties ω:

$$x_\omega = Q_\omega^{\sigma-1} \left(\frac{P}{p_\omega} \right)^{\sigma} X \, , \tag{2}$$

where $P \equiv \left(\int_{\omega \in \Omega} \left(\frac{Q_\omega}{p_\omega} \right)^{\sigma-1} d\omega \right)^{\frac{1}{1-\sigma}}$ is the aggregate price index corresponding to X. Since we focus on partial equilibrium, we take both P and X as given.[10] Crucially, following (2), demand increases in the quality of a variety.

2.2 Production

Firms optimize with respect to both quality and quantity of output. We begin with the former, and use $q_{i\omega}$ to denote the quality of individual inputs $i \in [0, 1]$, used by the firm that produces variety ω. Each input i reflects one specific task that needs to be performed in production. The quality of

[10] We do not make an explicit assumption about trade in final products. If trade liberalization affects P and X, this will change the number of firms in general equilibrium, but will not affect any of our cross-sectional results.

variety ω is given by:

$$Q_\omega = \left(\int_0^1 \alpha_i q_{i\omega}^{\frac{\rho-1}{\rho}} di \right)^{\frac{\rho}{\rho-1}} \quad (3)$$

where ρ is the elasticity of substitution between the quality of the different inputs. The smaller ρ, the stronger is the degree of quality complementarity. In the extreme, with $\rho = 0$, having a single input with low quality will decrease the overall quality Q_ω proportionately, even if all other inputs are of high quality. With $\rho > 0$, higher quality of some inputs i can partially compensate lower quality of others. We assume $0 < \rho < 1$ to represent complementarity between the quality of inputs in the spirit of Kremer (1993). The parameter α_i reflects the sensitivity of output quality Q_ω with respect to the quality of input i. We rank inputs by their quality sensitivity, beginning with the lowest α_i. In the following, we use the simplest formulation that delivers such a ranking, $\alpha_i = i$.

Similar to Sutton (2007), each firm ω is characterized by a quality parameter m_ω and a (quantity-specific) productivity parameter A_ω. The former reflects the unit cost of the raw material used to produce variety ω, while the latter represents the number of units of *each* input $i \in [0, 1]$, and of the raw material, needed to produce one unit of output.[11] We will show that m_ω alone determines the quality of output and inputs in production, while A_ω affects other variables related to firm performance, such as sales and profits. The quality-dependent unit cost function is given by:

$$C(\{q_{i\omega}\}) = \frac{1}{A_\omega} \left(\int_0^1 c(q_{i\omega}) di + m_\omega \right) \quad (4)$$

The cost of input quality has a quadratic form. This is an analytically convenient way to represent a convex quality-cost profile. The cost of one unit of input i in the production of variety ω is given by:

$$c(q_{i\omega}) = a_c + b_c \cdot q_{i\omega}^2 \ , \quad (5)$$

where a_c corresponds to the cost of a zero-quality input, and b_c indicates how steeply costs rise in quality. The subscript c represents the country where the input is purchased – home (H) vs. foreign countries (F). We assume that the home country is a developing country with relatively cheap low-quality inputs (e.g., unskilled labor), so that a_H is low. However, the home country faces a relatively steep slope parameter b_H. The opposite is true for imported inputs, whose costs are higher for low-quality inputs but reflect a flatter profile. Therefore, $a_H < a_F$ and $b_H > b_F$. As shown in Figure 1, the two input-quality cost functions for H and F intersect at point $\hat{q}$. For $q_{i\omega} \leq \hat{q}$, it is optimal to purchase input i domestically, e.g., by hiring local workers to perform task

[11]With regard to *quantity* production, firms thus face a Leontief-type technology, while the *quality* of each unit of output is described by (3).

i. Otherwise, for $q_{i\omega} > \hat{q}$, the producer of variety ω will import variety i. Falling import tariffs shift the import cost function downward, so that $\hat{q}$ decreases. We will see that this favors producers of high-quality output who import their most quality-sensitive inputs.

In addition to the cost components in (4), firms have to pay a fixed cost of production f each period, which is independent of the quality produced. Total costs are thus given by $x_\omega C(Q_\omega) + f$. Consequently, profits of a firm producing variety ω are given by $[p_\omega - C(Q_\omega)]\, x_\omega - f$. Substituting for x_ω from (2) yields:

$$\Pi_\omega = [p_\omega - C(Q_\omega)]\, Q_\omega^{\sigma-1} \left(\frac{P}{p_\omega}\right)^{\sigma} X - f \; . \tag{6}$$

2.3 Optimization

When firms import some of their inputs, the integral in (4) can be split into two parts. All inputs below the cutoff $\hat{\imath}_\omega$ (i.e., those with low quality-sensitivity $\alpha_i = i$) are purchased domestically, while those with $i > \hat{\imath}_\omega$ are purchased abroad. This implies:

$$C(\{q_{i\omega}\}, \hat{\imath}_\omega) = \frac{1}{A_\omega}\left(\int_0^{\hat{\imath}_\omega} c_H(q_{i\omega})di + \int_{\hat{\imath}_\omega}^1 c_F(q_{i\omega})di + m_\omega\right)$$

Both the set of input-specific quality $\{q_{i\omega}\}_{i\in[0,1]}$ and the cutoff $\hat{\imath}_\omega$ are chosen optimally by each firm. We derive the optimal choice of these variables, as well as quality and quantity of output, in four steps. First, we analyze the cost-minimizing choice of input quality $q_{i\omega}$ for a given quality $\bar{Q}_\omega$. This yields the cost of quality production, $C(\cdot)$ as a function of *output* quality $\bar{Q}_\omega$. In the second step, we derive the profit-maximizing price from (6) as a markup over the cost per unit of a given quality, $C(\bar{Q}_\omega)$. Third, we obtain the optimal choice of quality, Q^*_ω. The profit-maximizing quality ensures that the average quality-specific cost $AC(Q_\omega)$ is at its minimum, so that Q^*_ω is obtained from the simple relationship $MC(Q^*_\omega) = C(Q^*_\omega)$. Simultaneously, we obtain the optimal cutoff $\hat{\imath}^*_\omega$. Finally, we derive the quantity of production of each variety as well as firm profits.

Step 1: Optimal choice of input quality

We begin by deriving the optimal choice of the quality with which each input i is performed, $q_{i\omega}$, in order to produce variety ω at a given quality $\bar{Q}_\omega$. For now, we take the cutoff $\hat{\imath}_\omega$ as given and solve the expenditure minimization problem

$$\min_{q_{i\omega}} \left\{ \frac{1}{A_\omega}\left(\int_0^1 c(q_{i\omega})di + m_\omega\right) \quad s.t. \quad \left(\int_0^1 \alpha_i q_{i\omega}^{\frac{\rho-1}{\rho}} di\right)^{\frac{\rho}{\rho-1}} \geq \bar{Q}_\omega \right\}.$$

In Appendix A.1, we show that the optimal choice of $q_{i\omega}$ implies that the cost of quality – as a function of output quality Q_ω – is given by:

$$C(Q_\omega, \hat{\iota}_\omega) = \frac{1}{A_\omega}\left[I(\hat{\iota}_\omega)^{\frac{1+\rho}{1-\rho}} \cdot Q_\omega^2 + C_{f,\omega}(\hat{\iota}_\omega)\right] , \tag{7}$$

where $C_{f,\omega}(\hat{\iota}_\omega) = \hat{\iota}_\omega a_H + (1-\hat{\iota}_\omega)a_F + m_\omega$ is the cost component that is not directly affected by Q_ω. Because $a_H < a_F$, we have $C'_{f,\omega}(\hat{\iota}_\omega) < 0$. Thus, more imported inputs (i.e., a lower cutoff $\hat{\iota}_\omega$) raises $C_{f,\omega}$. The integral $I(\hat{\iota}_\omega)$ is defined as

$$I(\hat{\iota}_\omega) = \int_0^{\hat{\iota}_\omega} \alpha_i^{\frac{2\rho}{1+\rho}} b_H^{\frac{1-\rho}{1+\rho}} di + \int_{\hat{\iota}_\omega}^1 \alpha_i^{\frac{2\rho}{1+\rho}} b_F^{\frac{1-\rho}{1+\rho}} di . \tag{8}$$

Using Leibniz' rule and $b_H > b_F$, it is straightforward to show that $I'(\hat{\iota}_\omega) > 0$. Thus, the integral decreases when more inputs are imported; a larger proportion of imports puts a higher weight on inputs with the flatter foreign cost function.

Step 2: Pricing and profits

Next, we derive the profit-maximizing price of variety ω. We begin by deriving (6) with respect to p_ω, still taking Q_ω as given. Note that this corresponds to profit maximization with respect to *quantity* of output, which yields the standard result that the price is a constant markup over (quantity-specific) marginal cost:[12]

$$p_\omega = \frac{\sigma}{\sigma-1} C(Q_\omega, \hat{\iota}_\omega) . \tag{9}$$

For given price and quality-dependent cost, a variety producer's profits from (6) are then given by:

$$\Pi_\omega = \left(\frac{1}{\sigma-1}\right)^{1-\sigma}\left(\frac{1}{\sigma}\right)^{\sigma}\left(\frac{C(Q_\omega, \hat{\iota}_\omega)}{Q_\omega}\right)^{1-\sigma} P^\sigma X - f . \tag{10}$$

Step 3: Optimal output quality

We can now derive the optimal quality of variety ω. Individual producers maximize (10) with respect to Q_ω and $\hat{\iota}_\omega$. Note that $C(Q_\omega, \hat{\iota}_\omega)/Q_\omega \equiv AC(Q_\omega, \hat{\iota}_\omega)$ is the average *quality-specific* cost of variety ω. In other words, $AC(\cdot)$ represents the average cost of each unit of quality of variety ω. Our assumption that varieties ω are substitutes implies that $1-\sigma < 0$. Thus, maximizing (10) amounts to minimizing $AC(\cdot)$. For a given $\hat{\iota}_\omega$, average cost is therefore minimized at the quality

[12] While the unit cost $C(Q_\omega, \hat{\iota}_\omega)$ varies with quality, it is constant with respect to quantity produced – see (4). Thus, with respect to quantity, $C(\cdot)$ represents both unit cost and marginal cost.

Q^*_ω where $AC(Q_\omega, \hat{\iota}_\omega) = \partial C(Q_\omega, \hat{\iota}_\omega)/\partial Q_\omega$, i.e., where average and marginal cost of output quality intersect. The optimal choice of output quality must thus satisfy $Q^*_\omega = C(Q^*_\omega, \hat{\iota}^*_\omega)/MC(Q^*_\omega, \hat{\iota}^*_\omega)$.

The left panel of Figure 2 illustrates the solution for the optimal quality Q^*_ω, by plotting the average quality-specific cost together with the marginal cost. For now, we assume that there is no trade in inputs, so that $\hat{\iota}_\omega$ does not have to be determined. In this setting, Q^*_ω is higher for the input-quality cost profile of the foreign country. This is driven by two effects: First, $a_F > a_H$ increases $C_{f,\omega}$ for the foreign country, shifting the AC curve up. Second, b_F is lower, which tilts the MC curve to the right. Both effects imply higher Q^{*F}_ω, and the model thus predicts that high-quality varieties are produced countries where high-quality inputs are relatively cheaper.

[Insert Figure 2 here]

Next, we allow for imports to be imported, so that the cutoff level $\hat{\iota}^*_\omega$ is also chosen optimally. The right panel of Figure 2 provides the intuition for the resulting AC curve: When firm ω can import inputs, it will do so in a way that minimizes its average quality-specific costs (thus maximizing profits). Therefore, the relevant AC curve is the lower envelope of the home and foreign input quality cost curves. Appendix A.2 shows this derivation in detail, together with an equation that determines $\hat{\iota}^*_\omega$. Following this optimization, the profit-maximizing quality of variety ω is given by:

$$Q^*_\omega = \sqrt{\frac{C_{f,\omega}(\hat{\iota}^*_\omega)}{I(\hat{\iota}^*_\omega)^{\frac{1+\rho}{1-\rho}}}} \tag{11}$$

A higher value of the integral $I(\hat{\iota}^*_\omega)$ (i.e., steeper marginal cost of input quality b_H or b_F) implies lower Q^*_ω. This is intuitive. Another relationship, however, needs closer examination: Higher $C_{f,\omega}$ implies *higher* quality. For example, a higher cost of the raw material, m_ω, implies that the variety will be produced at a higher quality. This is because with a higher fixed component of quality-specific cost, firms have to choose higher quality overall in order to minimize the average cost of quality. Intuitively, firms optimally use expensive raw materials in combination with high-quality inputs. Note that the optimal output quality is increasing in m_ω, but is independent of the quantity productivity A_ω.[13] This feature allows us to differentiate between productivity and quality – similar in spirit to Sutton (2007).

Finally, we derive the optimal quality used of each individual input (see Appendix A.1 for

[13] We show in Appendix A.2 that the optimal cutoff point $\hat{\iota}^*_\omega$ depends only on the input-quality cost functions $c_H(q)$ and $c_H(q)$, and on the firm's draw of raw material quality, m_ω. In particular, $\hat{\iota}^*_\omega$ does not depend on A_ω. Thus, $q^*_{i\omega}(Q^*_\omega)$ in (12) is independent of A_ω.

details):

$$q^*_{i\omega}(Q^*_\omega) = \left(\frac{\alpha_i}{b_{i\omega}}\right)^{\frac{\rho}{1+\rho}} \sqrt{\frac{C_{f,\omega}(\hat{\iota}^*_\omega)}{I(\hat{\iota}^*_\omega)}} \tag{12}$$

where $b_{i\omega} = b_H$ if $i \leq \hat{\iota}^*_\omega$, and $b_{i\omega} = b_F$ otherwise. This equation identifies the determinants of input quality. First, the larger α_i, the higher is the optimal quality of the corresponding input i.[14] Second, a lower marginal cost of quality for an *individual* input i, $b_{i\omega}$, is associated with higher quality of the corresponding input i. Third, a drop in the marginal cost of input quality *in general* (reflected by smaller $I(\hat{\iota}^*_\omega)$, e.g., due to lower b_H or b_F) leads to higher $q^*_{i\omega}$ for all inputs i. Finally, higher $C_{f,\omega}$ (e.g., raw material cost m_ω) leads to higher input quality – analogous to the effect on output quality. As was the case for output quality in (11), input quality is not affected by the quantity productivity term A_ω.

At the cutoff point $i = \hat{\iota}^*_\omega$, input purchases switch from the domestic to the foreign market. The corresponding drop from $b_{i\omega} = b_H$ to $b_{i\omega} = b_F$ implies that input quality jumps upward at this point. This is illustrated in the left panel of Figure 3, which shows the optimal choice of inputs for a given firm with and without access to imports. The difference between the solid line (with imports) and the dashed line (no access to imports) shows that importing raises the quality of both newly imported inputs ($i > \hat{\iota}^*_\omega$), but also for those that are still purchased domestically ($i \leq \hat{\iota}^*_\omega$). The latter is a result of the complementarity effect which we discuss in more detail below.

[Insert Figure 3 here]

Step 4: Price, Revenue, and Profit

Finally, we derive profits and the quantity of firms' output. Substituting (11) in (7), we obtain the unit cost of output at the optimal quality level. Using this result in (9), we also derive the price of variety ω:

$$C(Q^*_\omega) = \frac{2C_{f,\omega}(\hat{\iota}^*_\omega)}{A_\omega} \quad \text{and} \quad p_\omega = \frac{\sigma}{\sigma - 1}\frac{2C_{f,\omega}(\hat{\iota}^*_\omega)}{A_\omega} \tag{13}$$

The profit-maximizing unit cost and price are increasing in $C_{f,\omega}$ (and thus in the cost of raw material, m_ω), and decreasing in quantity productivity A_ω. Next, we use the result for $C(Q^*_\omega)$ together with (11) to derive an equation for the average cost of quality:

$$AC(Q^*_\omega, \hat{\iota}^*_\omega) = \frac{C(Q^*_\omega, \hat{\iota}^*_\omega)}{Q^*_\omega} = \frac{2}{A_\omega}\sqrt{C_{f,\omega}(\hat{\iota}^*_\omega) \cdot I(\hat{\iota}^*_\omega)^{\frac{1+\rho}{1-\rho}}} \tag{14}$$

[14] Note, however, that an increase in the quality sensitivity of all inputs (i.e., increasing all α_i by the same factor) will not affect $q^*_{i\omega}$. To see this, multiply all α_i in (8) and (12) by a constant.

This expression is useful when analyzing firm revenues and profits, because both depend on $AC(\cdot)$ as the only factor that varies across firms in our setup. Firm revenues follow from (2) and are given by:

$$p_\omega(Q^*_\omega)x_\omega(Q^*_\omega) = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} AC(Q^*_\omega, \hat{\iota}^*_\omega)^{1-\sigma} P^\sigma X \ , \tag{15}$$

Because output varieties are substitutes ($\sigma > 1$), revenues are a decreasing function of $AC(\cdot)$. The same is true for profits, which follow from (10). Using $AC(\cdot) = C(\cdot)/Q^*_\omega$ in this expression shows that profits are also proportional to $AC(\cdot)^{1-\sigma}$. Note that high-quality firms (with more expensive raw material m_ω) face a larger $C_{f,\omega}(\cdot)$ and thus smaller profits. However, a higher A_ω counterbalances this effect. In other words, high-quality producers are only profitable if they also have a relatively high quantity productivity, compensating their higher input costs. This completes the characteristics of a cross-section of firms in a given industry.

2.4 Discussion of Results

In this section, we present testable empirical predictions of our model that relate import status to input and output quality, profits, and skill demand. While input and output quality follow in a straightforward way from the previous equations, the predictions for skill demand rely on how we interpret quality sensitivity α_i and input quality q_i. We discuss this in detail below, using the assumption that high-skill workers have a comparative advantage in performing high-q_i inputs, which follows the setup in Costinot and Vogel (2010). We will differentiate between the extensive margin of skill demand (white-collar vs. blue-collar workers) and the intensive margin (the 'quality' of workers within each category).

Quality of individual inputs and output quality

Our first proposition relates import status to optimal output and input quality in a cross-section of firms:

Proposition 1. *Firms that import relatively more inputs produce higher-quality output and use higher-quality inputs for any given input skill sensitivity α_i. Thus, importing firms c.p. produce higher quality output and purchase higher-quality inputs.*

PROOF. Because $C'_{f,\omega}(\hat{\iota}_\omega) < 0$ and $I'(\hat{\iota}_\omega) > 0$, the first result follows directly from (11), and the second from (12). The second part of the proposition follows trivially because for non-importers, $\hat{\iota}_\omega = 1$, while $\hat{\iota}_\omega < 1$ for importers. □

This result is driven by the fact that high-quality producers sort into importing. Intuitively, high-quality production needs high-quality inputs – and these are relatively cheaper in the foreign market. The right panel of Figure 3 illustrates this pattern, showing that input quality $q_{i\omega}$ is larger for all i in an importing firm. Note that even without access to imports, a high-quality firm would use higher quality for all input tasks i. Importing amplifies this difference: Inputs in the region $i > \hat{\iota}_\omega$, are of even higher quality because they are purchased at a lower marginal quality-cost (as reflected by a low $b_{i\omega} = b_F$ in (12)). Due to the complementarity effect this also raises the quality of domestic inputs in the region $i \leq \hat{\iota}_\omega$.

Firm revenue and profits

Next, we turn to sales and profits. Access to imported inputs expands the possibilities of firms to optimally choose their input quality from domestic and foreign inputs. Thus, their quality-specific cost must decrease. This is illustrated in the right panel of Figure 2. When using the optimal cutoff point $\hat{\iota}^*_\omega$ to split between domestic and foreign inputs, the average quality cost curve is always below or identical to AC_H and AC_F.[15] Consequently, profits are either unchanged or augmented under access to foreign inputs, and high-quality producers will profit relatively more from importing. This discussion leads to the following corollary:

Corollary 1. *As a result of access to imported inputs, revenues and profits of high-quality producers increase, while they remain unchanged for low-quality producers that do not import.*

PROOF. Access to imported inputs can be represented in the model by a downward-shift of the foreign quality cost profile (e.g., due to a decline in import tariffs). Thus, $c_F(q_i)$ in (5) declines so that, in effect, both a_F and b_F fall. Using (7) and (8), we can write the average cost of quality as:

$$AC(Q_\omega, \hat{\iota}_\omega) = \frac{1}{A_\omega Q_\omega}\left[\left(\int_0^{\hat{\iota}_\omega} \alpha_i^{\frac{2\rho}{1+\rho}} b_H^{\frac{1-\rho}{1+\rho}} di + \int_{\hat{\iota}_\omega}^1 \alpha_i^{\frac{2\rho}{1+\rho}} b_F^{\frac{1-\rho}{1+\rho}} di\right)^{\frac{1+\rho}{1-\rho}} \cdot Q_\omega^2 + \hat{\iota}_\omega a_H + (1-\hat{\iota}_\omega) a_F + m_\omega\right]$$

This shows that a decline in a_F and b_F will favor an importing firm (with $\hat{\iota}_\omega < 1$), but not a firm that only purchases domestic inputs (with $\hat{\iota}_\omega = 1$), for which only a_H and b_H are relevant. Also, following Proposition 1, high-quality firms sort into importing, while low-quality producers do not. Therefore, only high-quality producers experience a decline in their $AC(\cdot)$ and thus rising revenues and profits, according to (10) and (15). □

Extensive margin of skill demand: the white-collar labor share

In the following we analyze the firm-level relationship between imported inputs and the extensive margin of skill demand – the *share* of skilled workers. We have already derived the prediction

[15] For low output quality, firms use only domestic inputs, so that their average cost under optimized choice of input quality is identical to AC_H. The opposite is true for producers of extremely high-quality output, so that their optimal input quality choice implies an average cost curve identical to AC_F.

that importing firms use higher quality of individual inputs (see Proposition 1). When taking the model to the data, we face two issues: First, inputs are not only purchased outside the firm, but are also performed by workers within firms. Thus, firms will typically purchase a mix of labor inputs and physical inputs produced by other firms in the domestic market. Imported inputs, on the other hand, only have the physical dimension. In the empirical section we thus differentiate between labor and physical domestic inputs. Second, we do not observe individual tasks performed by workers in production (which would correspond to i_ω in our model). What we do observe is the division into white-collar workers and blue-collar workers.

To map our continuum of input tasks to the two worker categories, we assume that high-quality tasks are more skill intensive. For example, Verhoogen (2008) describes that within the same Mexican Volkswagen plant, the production line for the original and the new version of the Beetle differed dramatically with respect to equipment and workers used – with the new version involving skilled specialists.[16] In addition, we follow Costinot and Vogel (2010) in assuming that white-collar (skilled) workers have a comparative advantage in tasks with high skill intensities. In combination, this leads to high-quality input tasks being performed by white-collar workers, while low-quality tasks are performed by blue-collar workers. We define the quality cutoff level q^{BW} such that all input quality levels $q_i > q^{BW}$ require white-collar workers.[17] This is represented by the horizontal line in Figure 4. This setup implies a firm-specific, endogenously determined cutoff task i_ω^{BW}, such that all tasks $i \in [0, i_\omega^{BW})$ use blue-collar labor, and the remainder $i \in (i_\omega^{BW}, \hat{\iota}_\omega^*]$ is performed by skilled white-collar workers. In Figure 4, the cutoff i_ω^{BW} is determined by the intersection of the horizontal quality threshold q^{BW} with the (endogenous) input quality profile of each firm. For high-quality producers, the cutoff i_ω^{BW} is thus shifted to the left, so that relatively more tasks are performed by white-collar workers. This means that even input tasks with a relatively low quality sensitivity (low $\alpha_i = i$) can require white-collar workers if the firm wants to perform them at a high quality standard.

[Insert Figure 4 here]

Following this discussion, the next proposition relates the share of white-collar workers in a firm to its imports.

[16]One concrete example is that the new Beetle has an automatic window-raising mechanism, while windows in the original Beetle are operated by hand. If task i is 'install window-raising mechanism', then this task will only require mechanic skills for the old version, but also electrical knowledge for the new version.

[17]This is similar to the cutoff levels for immigrant, offshore, and native workers in Ottaviano, Peri, and Wright (2013), who also assume that the different worker types have a comparative advantage over different ranges of the skill-intensity spectrum.

Proposition 2. *The proportion of skilled (white-collar) workers employed by variety producer ω decreases in the proportion of imported inputs (substitution effect), and it increases in the quality of these imports (complementarity effect).*

PROOF. First recall that all input tasks $i \in (i_\omega^{BW}, \hat{\imath}_\omega^*]$ are performed by domestic white-collar workers. Thus, the share of white-collar workers is given by $(\hat{\imath}_\omega^* - i_\omega^{BW})/i_\omega^{BW}$ (assuming the non-trivial case that the firm hires at least some white-collar workers ($\hat{\imath}_\omega^* > i_\omega^{BW}$), and abstracting for the moment from the quality dimension that is captured by the cutoff q^{BW}). The substitution effect then follows directly from the fact that more imports imply a lower threshold $\hat{\imath}_\omega^*$. Using additionally the result from Proposition 1 leads to the complementarity effect: Because smaller $\hat{\imath}_\omega^*$ is associated with higher input quality, the threshold q^{BW} is reached at a lower input index i, which increases the demand for white-collar workers. □

Figure 4 illustrates Proposition 2. A high-quality producers (firm 1) imports part of its inputs, which leads to a decline in white-collar worker demand (W_1). On the other hand, because firm 1 uses a higher quality of all inputs, its $q_{i\omega}$ function crosses the threshold q^{BW} further to the left. Consequently, some lower-ranked input tasks are also performed by white-collar workers, which raises W_1 and decreases blue-collar demand B_1. This reflects the complementarity effect. The net effect on skill demand is ambiguous, as the comparison with firm 2 shows – a low-quality producer that does not import inputs.

Intensive margin of skill demand: worker quality and wages

Our previous assumption related the individual input tasks in our model to the two types of workers that we observe. The missing dimension in mapping the model to the data is the intensive margin of skill demand – the quality of workers within the two skill groups. We will show that the substitution and the complementarity effect operate along this dimension, as well.

A large literature following Mincer (1974) uses wages as an indicator for worker 'quality'.[18] This is also in line with Kremer (1993), who assumes that the quality of an input-task is equivalent to the skill level of the worker performing it. Thus, we use the input-quality dimension q_i to represent wages, whenever the respective input task is performed by workers (rather than physical inputs). Since we do not observe individual worker-task-wage pairs, we need to derive a measure for the *average* quality specific to blue- and white-collar workers. We begin by deriving a measure

[18] In a more recent contribution, Fox and Smeets (2011) show that the wage bill of workers reflects a large part of underlying worker characteristics, such as prominent human capital measures.

for the average quality of all inputs performed by domestic labor in the production of variety ω:

$$\bar{q}_\omega = \frac{1}{\hat{\imath}^*_\omega} \int_0^{\hat{\imath}^*_\omega} q^*_{i\omega} di = \xi \cdot \left(\frac{\hat{\imath}^*_\omega}{b_H} \right)^{\frac{\rho}{1+\rho}} \cdot \sqrt{\frac{C_{f,\omega}(\hat{\imath}^*_\omega)}{I(\hat{\imath}^*_\omega)}} \,, \tag{16}$$

where we used (12) and our assumption $\alpha_i = i$ to derive the second equality, and define $\xi = (\rho+1)/(2\rho+1)$. The expression in parentheses in (16) illustrates the substitution effect: As more inputs are imported, the threshold $\hat{\imath}^*_\omega$ declines. Thus, the average skill level (or quality) of employed workers falls. However, the square root in the equation will increase, because $C'_{f,\omega}(\hat{\imath}_\omega) < 0$ and $I'(\hat{\imath}_\omega) > 0$. This is responsible for the complementarity effect.

We now perform the final step to map the model to the data – define the average quality of tasks performed by blue-collar and white-collar workers, by extending equation (16) to the two sub-groups. Provided that importing firms use a positive mass of white-collar workers ($\hat{\imath}^*_\omega > i^{BW}_\omega$), this yields:[19]

$$\begin{aligned} \bar{q}^B_\omega &= \frac{1}{i^{BW}_\omega} \int_0^{i^{BW}_\omega} q^*_{i\omega} di = \xi \cdot \left(\frac{i^{BW}_\omega}{b_H} \right)^{\frac{\rho}{1+\rho}} \cdot \sqrt{\frac{C_{f,\omega}(\hat{\imath}^*_\omega)}{I(\hat{\imath}^*_\omega)}} \\ \bar{q}^W_\omega &= \frac{1}{\hat{\imath}^*_\omega - i^{BW}_\omega} \int_{i^{BW}_\omega}^{\hat{\imath}^*_\omega} q^*_{i\omega} di = \xi \cdot \left(\frac{\hat{\imath}^*_\omega - i^{BW}_\omega}{b_H} \right)^{\frac{\rho}{1+\rho}} \cdot \sqrt{\frac{C_{f,\omega}(\hat{\imath}^*_\omega)}{I(\hat{\imath}^*_\omega)}} \end{aligned} \tag{17}$$

Under our assumption that wages reflect worker quality, we can now state the following proposition:

Proposition 3. *If the complementarity effect is strong, firms that import more inputs pay higher wages to both blue-collar and white-collar workers.*

PROOF. We begin with the direct effect of an increase in the import share (a lower threshold $\hat{\imath}^*_\omega$) on wages (i.e., taking i^{BW}_ω as given for the moment. For blue-collar workers, a lower $\hat{\imath}^*_\omega$ only affects the square root in (17). Because $C'_{f,\omega}(\hat{\imath}_\omega) < 0$ and $I'(\hat{\imath}_\omega) > 0$, a smaller $\hat{\imath}^*_\omega$ implies higher $\bar{q}^B_\omega$, and thus higher wages. For white-collar workers, we begin with the substitution effect: a lower $\hat{\imath}^*_\omega$ translates into lower $\bar{q}^W_\omega$, as represented by the term in parentheses in the second equation in (17). The complementarity effect arises because the square root term is larger for smaller $\hat{\imath}^*_\omega$. Quality complementarity in the model is the stronger the lower the parameter ρ. As (17) shows, when $\rho \to 0$, changes in $\hat{\imath}^*_\omega$ will no longer affect the term in parentheses, so that the square root term dominates the overall effect on $\bar{q}^W_\omega$. Thus, with a strong complementarity, lower $\hat{\imath}^*_\omega$ is associated

[19] Otherwise, if $\hat{\imath}^*_\omega \leq i^{BW}_\omega$, $\bar{q}^W_\omega$ is not defined, while the definition of $\bar{q}^B_\omega$ is unchanged – and so is the definition in (16).

with a higher quality of white-collar workers, and thus with higher wages. Finally, as shown in Figure 4, there is a second-order effect because the complementarity effect moves up the $q_{i\omega}$ curve of importing firms, so that i_{ω}^{BW} falls. For white-collar workers, this will increase wages. For blue-collar workers, it the opposite is true. However, if the complementarity effect is strong (small ρ), then the decline in i_{ω}^{BW} will be have a minor effect relative to the direct effect of increasing i_{ω}^{BW} (the square root term in (17)). Thus, blue collar wages increase, as well, if the complementarity effect is strong. □

3 Data Sources and Descriptive Statistics

We use data on Chilean firms and Customs for our empirical analysis. The Chilean firm panel was previously used, among others, by Pavcnik (2002) and Kasahara and Rodrigue (2008).[20] Chile has liberalized its trade gradually over time, and import tariffs decreased again substantially between 1995 and 2005 – the period that we analyze.

Description of the Data Set

We use firm-level data of imports and tariffs from Chilean Customs, combined with plant-level data on industrial sectors from ENIA (Encuesta Nacional de Industria Anual). This dataset is a census of Chilean plants with more than 10 employees, which is collected by INE (the Chilean national statistical agency). The majority of firms in Chile run only one plant. About 4% percent of firms run several plants. In such cases of multiple-plant firms, we aggregate all plants to the firm-level before matching the data with the Customs information.

ENIA also provides the corresponding four-digit ISIC category for each plant. We use the following variables from ENIA: White-collar workers, blue-collar workers, total employment, amount of exports in a given year, the level of sales, value added, raw materials, intermediate goods used in production, the region where the plant is located and the capital stock. The white-collar category includes specialized workers involved in the production process, as well as administrative and executive employees. Blue-collar workers comprise less-qualified employees working directly or indirectly in the production process and those working in the service area.[21]

[20] Pavcnik finds that trade liberalization in the 1970s and 80s increased plant productivity and that much of this effect was driven by reallocating resources to more productive producers, as in the framework by Melitz (2003). Kasahara and Rodrigue (2008) show that productivity increases can also be attributed to Chilean plants becoming importers of intermediate inputs.

[21] The exact definition of these categories in ENIA has changed several times over the years. We pay particular attention to 1995, where there is a significant change in the way questions are asked. We group employment categories using similar criteria before and after that year, but a jump in the proportion of white-collar workers remains. However, the size of this jump is unrelated to our explanatory variables, and our results are unchanged when restricting the

Data reliability is a common concern for plant-level survey data from developing countries. We drop plant-level observations when there are signs of unreliable reporting. In particular, we exclude plants that have missing or zero values for total employment, demand for electricity, investment, demand of raw materials, sales, operational income and value added. We also drop observations where a huge variation is observed in total employment, value added and sales. This procedure leaves 68,383 firm-year observations for the period between 1992 and 2005. The year with the highest number of observations is 2004 with 5.153 and the lowest number is 4.506 in 2001.

Data on imports and tariffs come from Chilean Customs and are disaggregated at eight digits of the Harmonized System (HS). These data allow us to identify the CIF value of an import of good j, purchased by firm i in year t, as well as the tariff associated with that import. In order to keep the sample tractable, we aggregate the HS-8 customs data to the commonly used HS-6 detail. We obtain more than 1.1 million firm-level observations with non-zero imports for approximately 3,800 firms at annual frequency between 1992 and 2005. Over this period, the Chilean economy experienced a marked trade integration with the rest of the world. Import tariffs were significantly reduced, falling from more than 10 percent in 1992 to less than 3 percent in 2005.

3.1 Main variables

From the various categories of workers, we include "specialized workers in the productive process" as well as supervisors and executives in our baseline measure of skilled workers. Dividing these by the total number of employees, we obtain the share of skilled workers, h_{it}. Note that this variable does not include administrative staff. We also define a broader measure to check the robustness of our results. The variable h^w_{it} reflect the share of white-collar workers. It additionally includes administrative staff as well as "employees hired for a commission". The remaining (blue-collar) category comprises "non-qualified workers directly involved in production", "non-qualified workers indirectly involved in production," and "personal services and security workers". We use the same division to calculate white-collar and blue-collar wages $wage^W$ and $wage^B$, respectively.[22]

3.2 Proxies for import quality

We use two proxies for the quality of imported inputs. The first index is based on import prices, while the second uses the skill intensity with which each import category is produced in the US.

sample to the post-1995 period.

[22]Wage data and not available consistently for the finer categories corresponding to h_{it}.

The import price index

To construct our first index for input quality, we follow Kugler and Verhoogen (2012), using prices within given product categories as an indicator for product quality. We build on this approach and extend it to the case where a firm imports several the same good in different units of measurement. Let V_{ikj} denote the value that firm i imports of product k (at the HS-8 detail), where j gives the units in which k is measured. For example, k='chemicals' may be measured in kilograms or cans. Q_{ikj} denotes the corresponding quantity, measured in the specified unit j. We define $P_{ikj} = V_{ikj}/Q_{ikj}$ as the price per unit.[23]

In a first step, we calculate the weighted average price of imports in HS-8 category k that are measured in unit j:

$$\bar{P}_{kj} = \frac{\sum_{i=1}^{I} V_{ikj}}{\sum_{i=1}^{I} Q_{ikj}} = \sum_{i=1}^{I} P_{ikj} \frac{Q_{ikj}}{\hat{Q}_{kj}} \tag{18}$$

where $\hat{Q}_{kj} = \sum_{i=1}^{I} Q_{ikj}$ is the total quantity imported of HS-8 product k, measured in unit j, by all firms in our sample. $\bar{P}_{kj}$ is an indicator for the average quality of HS-8 product k (measured in unit j). Next, we derive a quality measure for the case when a firm imports the same HS-8 product measured in several different units j. For example, a firm may import \$400 worth of chemicals measured in kilograms and \$800 in cans. Even if this is the exact same chemical, the two observations cannot be joined as long as we do not know how many kilograms there are in a can – and this is the case in our dataset. Nevertheless, we know how much other firms in the sample pay on average for the same category of chemicals, measured in kg and cans. Based on this information, we calculate the following index:

$$\theta_{ik} = \sum_{j=1}^{J} \omega_{ikj} \ln\left(\frac{P_{ikj}}{\bar{P}_{kj}}\right), \quad \text{where} \quad \omega_{ikj} \equiv \frac{V_{ikj}}{\hat{V}_{ik}} \tag{19}$$

where $\hat{V}_{ik} = \sum_{j=1}^{J} V_{ikj}$ is the total value of firm i's imports of product category k (comprising all units j). θ_{ik} is thus an index for the quality (as proxied by prices) of import(s) k used by firm i, relative to the quality of k used by all other firms in the sample.[24] Using (19), we can derive a

[23] More precisely, we use unit values. To simplify notation, we refer to these as prices.

[24] To illustrate θ_{ik}, suppose that a firm imports 10kg of chemicals worth \$400 and 80 cans worth \$800 of the same HS-8 chemical. Then $\hat{V}_{ik} = 1,200$, $P_{ik1} = 40$, and $P_{ik2} = 10$. In addition, suppose that the average prices in the sample are $\bar{P}_{k1} = 8$ and $\bar{P}_{k2} = 30$ (where the former is measured in \$ per kg, and the latter in \$ per can). Consequently, $\theta_{ik} = \frac{10}{8}\frac{400}{1,200} + \frac{40}{30}\frac{800}{1,200} = 1.31$. That is, the price of chemicals in HS-8 category k purchased by firm i is, on average, 31% higher than the price that other companies pay for chemicals in the same HS-8 category. We would interpret this number as indicating relatively high quality of chemical category k purchased by i. Note that because of the logarithm used in (19), $\exp(\theta_{ik})$ represents the weighted geometric mean of $P_{ikj}/\bar{P}_{kj}$.

similar index for all imported inputs of firm i:

$$\theta_i = \sum_{k=1}^{K} \frac{\hat{V}_{ik}}{\hat{V}_i}\, \theta_{ik} \ , \tag{20}$$

where $\hat{V}_i = \sum_{k=1}^{K} \hat{V}_{ik}$ is the total value of firm i's imports. We refer to θ_i as the input quality index of firm i. If prices within narrow product categories reflect product quality, we will obtain $\theta_i < 1$ if i's imported inputs are on average below the quality of the same inputs purchased by other firms. If i's inputs are above average quality, $\theta_i > 1$.

Relative quality of imported vs. domestic inputs

Our argument relies on the assumption that imported inputs are of higher quality than domestic ones. In the following, we use data from ENIA to provide supporting evidence. For the period 1996-2000, ENIA reports, for each firm i and year t, the value V_{ikt} and quantity Q_{ikt} of domestic and imported inputs by detailed product categories k. The latter follow an ENIA-specific classification that is broadly comparable to the HS-8 product code. Units are product-specific (e.g., kg, thousands, or liters). We use these data to derive two price-based quality indexes of imported vs. domestically purchased inputs for each input type k in year t. The first index uses within-firm and within-product variation of input prices:

$$\theta_{ikt}^{rel} \equiv \ln\left(\frac{P_{ikt}^{imp}}{P_{ikt}^{dom}}\right) = \ln\left(\frac{V_{ikt}^{imp}/Q_{ikt}^{imp}}{V_{ikt}^{dom}/Q_{ikt}^{dom}}\right) \tag{21}$$

The weighted average of this measure (using total input value $V_{ikt}^{imp} + V_{ikt}^{dom}$ as weights) is 0.19, implying that within firms, imported products are about 20% more expensive than the domestic inputs of the same product category. The measure θ_{ikt}^{rel} uses only observations for which a firm purchases the same input both domestically and internationally. This drops more than 80% of the approximately 147,000 firm-product-year observations, discarding input quality-variation across firms. For example, suppose that a vehicle manufacturer imports high-quality steel from abroad, while a building materials supplier purchases lower-grade steel domestically. Neither of these will influence θ_{ikt}^{rel}. To exploit this additional between-firm variation of input quality, we construct the alternative measure θ_{kt}^{rel}.

$$\theta_{kt}^{rel} \equiv \ln\left(\frac{\bar{P}_{kt}^{imp}}{\bar{P}_{kt}^{dom}}\right) = \ln\left(\frac{\sum_i V_{ikt}^{imp}/\sum_i Q_{ikt}^{imp}}{\sum_i V_{ikt}^{dom}/\sum_i Q_{ikt}^{dom}}\right) \tag{22}$$

where $\bar{P}_{kt}^{dom}$ is the average price of product k purchased domestically by all firms, and $\bar{P}_{kt}^{imp}$ is the equivalent measure for imported units of good k. Figure 5 shows the distribution of θ_{kt}^{rel}; the measure has a mean of 1.54, indicating that imported inputs are about $\exp(1.54) = 4.6$ times as expensive as domestic ones, when taking into account variation across importers and non-importers. This number is slightly smaller when using the median (1.24) instead, which implies a premium of 3.4.

[Insert Figure 5 here]

Import skill intensity

Our second proxy for the quality of imported inputs is import skill intensity, σ_{it}, which measures the relative importance of skilled labor used in the production of firm i's imported inputs. We combine data on imported inputs of Chilean firms with the skill intensity of producing those inputs in the United States. That is, we rely on the common assumption that the U.S. reflects the technological frontier. We define imported input skill intensity as follows:

$$\sigma_{it} = \sum_{j=1}^{N} s_{ijt} h_{jt}^{w} \ , \tag{23}$$

where $N = 4,791$ is number of imported good categories (HS-6) in our sample, and h_{jt}^{w} is the white-collar wage bill share in the production of product j in the U.S. in year t. The latter is available at annual frequency from the NBER Manufacturing Industry Database at the 4-digit SIC level. To combine it with our firm-level data, we match the 450 4-digit SIC sectors to 6-digit HS products from customs data.[25] Whenever more than one SIC sector falls into the corresponding HS-6 category, we use the average across the 4-digit SIC sectors. Finally, s_{ijt} is the share of input j in overall imports by firm i in year t: $s_{ijt} = imp_{ijt} / \sum_{j=1}^{N} imp_{ijt}$.

4 Empirical Results

In this section, we provide empirical evidence that is in line with the predictions of our model. Most empirical results are identified using the variation across firms within narrowly defined sectors. Thus, our main results are driven by firm selection along the quality dimension. This follows our model, where draw of primary material quality (m_{ω}) determines differences in quality of inputs, outputs, and importing behavior across firms. Our empirical approach is also related to a large literature that examines differences across trading and non-trading firms (for a recent overview

[25]The correspondence is available on Jon Haveman's webpage of industry concordances.

see Bernard, Jensen, Redding, and Schott, 2012). In section 4.5 we also examine the within-firm dimension. There is not enough variation within firms to obtain significant effects on a year-to-year basis. Nevertheless, we find that both the substitution and the complementarity effect become stronger with the time that a firm has been an importer of inputs. This finding would be represented in our model if we introduced adjustment costs or labor market frictions, so that firms do not converge immediately to the new optimal production pattern after beginning to import, or after switching to higher-quality imports.

4.1 Stylized Facts for Chilean Importers

Before turning to our empirical results, we check whether our data replicate previously established stylized facts. Bernard et al. (2007) document that importing firms in U.S. manufacturing are on average larger and more productive, pay higher wages, and have higher capital- and skill-intensity. Similar premia are observed for U.S. exporters. These stylized facts hold in our Chilean firm sample, as well, with the exception of skill intensity. The first two columns of Table 1 show that exporting firms within 3-digit sectors are larger both in terms of employment and sales. The same is true for firms that import inputs. Importers and exporters are also relatively more productive (column 3). Columns 4 and 5 show that Chilean importers differ from their U.S. counterparts with respect to skill intensity: Chilean importing firms use a *lower* share of white-collar workers than their non-importing peers. This is in line with the substitution effect in our model. At the same time, firms that import higher-quality inputs (as measured by our price-based proxy) employ a relatively high share of skilled workers. This provides support for the quality-skill complementarity mechanism in our model. The latter also receives support from the results in column 6, which shows that wages are larger for importing firms. Together, the results in columns 5 and 6 are in line with our model's prediction that importing firms specialize in lower-quality tasks (using smaller proportion of blue-collar workers), but perform the remaining in-house tasks at a high quality level (as indicated by higher wages). In the following, we investigate the model predictions in more detail.

[Insert Table 1 here]

4.2 Imported Inputs, Output Prices, and Domestic Input Prices

We begin by analyzing the relationship between firm's imported inputs and output quality, measured by output prices. Our model predicts that importing firms produce higher-quality output. We measure products at the highly detailed 8-digit level and estimate the regression (following Kugler and Verhoogen, 2012):

$$\ln(P^{out}_{ikjt}) = d^{imp}_{it} + \beta\theta^{imp}_{it} + \alpha_{st} + \alpha_{kjt} + \alpha_r + \gamma X_{ijt} + \varepsilon_{ijt} \tag{24}$$

Where P^{out}_{ikjt} is the price at which firm i sells product k, measured in unit j, in year t.[26] We include our price-based indicator for the quality of imported inputs, θ^{imp}_{it}, together with a dummy for importer status, d^{imp}_{it}. Standard errors are clustered at the firm level, because θ^{imp}_{it} varies at this level. We include several fixed effects: α_{st} are sector–year effects (where sectors are measured at the 3-digit level); α_{kjt} are product–unit–year effects, and α_r are region dummies. In addition, X_{ijt} represents a vector of control variables.

The results of this estimation are reported in panel A of Table 2. The first column replicates the finding in Kugler and Verhoogen (2012) that larger plants charge more for their output. Columns 2 and 3 show that the same is true for exporters and firms that import inputs. Column 4 focuses attention on importing firms only and shows that there is a strong positive relationship between our import price index and output prices. This suggests that higher quality of imports is associated with higher output quality, which is in line with the complementarity mechanism in our model. In column 5 we include export and import dummies together with the import quality index. While all remain significant, the import dummy reduces to about half the magnitude measured in column 3. This is in line with our model mechanism where the import status–quality relationship works through input quality, so that it is best captured by the coefficient on θ^{imp}_{it}. The results in column 6 further support this interpretation: the importer dummy d^{imp}_{it} becomes insignificant once we include additional controls in column 6, while the coefficient on θ^{imp}_{it} remains highly significant and positive.

[Insert Table 2 here]

Next, we turn to the relationship between the quality of inputs and firm-level imports. We use the price of domestically purchased inputs, $\ln(P^{inp}_{ikjt})$, as dependent variable and estimate the equation

$$\ln(P^{inp}_{ikjt}) = d^{imp}_{it} + \beta\theta^{imp}_{it} + \alpha_{st} + \alpha_{kjt} + \alpha_r + \gamma X_{ijt} + \varepsilon_{ijt} \tag{25}$$

The results are reported in panel B of Table 2; they mirror the findings for output prices. Columns 1-4 show strong positive correlations between input prices and firm size, export status, and importer status. Column 5 shows that the import dummy becomes smaller in magnitude and statistically insignificant once we include the variable together with exporter status and the import price index.

[26] Output is measured in several different units. For example, chemicals may be measured in liters or weight units.

The latter is highly significant and positive, and this relationship is robust to including further controls (column 6). Together, these results indicate a complementarity between the quality of imported inputs and those that are purchased domestically. This relationship dominates the direct correlation between importer status and domestic input prices, indicating that import quality is crucial.

4.3 Imported Inputs and Skilled Labor Share

We now analyze the relationship between importing inputs and the share of skilled workers employed at the firm level. We define h_{itj} as the share of skilled workers in firm i in year t and run the main regression:

$$h_{it} = d_{it}^{imp} + \beta \cdot [\text{import quality}]_{it} + \gamma X_{it} + \alpha_{jt} + \alpha_r + \varepsilon_{it} \ , \tag{26}$$

where imported quality is measured either by our price-based quality index θ_{it}^{imp} or by import skill intensity σ_{it}. X_{it} is a vector of control variables, and d_{it}^{imp} is a dummy for whether firm i is importing any inputs in year t. Finally, α_{jt} denotes sector-year fixed effects (at the 3-digit level), and α_r are regional dummies. We report the results for the import quality index θ_{it}^{imp} in Table 3. The first three columns restrict the sample to firms that import at least some of their inputs. Across importing firms, there is a strong positive correlation between import prices and the share of skilled workers. This is in line with the complementarity effect in our model, which implies that c.p. (i.e., conditional on importing the same fraction of inputs), firms with higher-quality inputs will also demand a higher proportion of skilled labor. In additional, we find strong support for the substitution effect: the higher the import share of firms, the lower the proportion of skilled workers that they employ. This suggests that imported inputs tend to fill in for tasks that would otherwise be performed by relatively skilled workers. These results are robust to controlling for capital worker and productivity (proxied by log value added per worker). Both of these controls are strongly positively associated with the share of skilled workers. We also control for the share of intermediate inputs overall in production because part of higher import shares might merely be due to firms using more intermediates. This control variable is insignificant and switches signs when including fixed effects in columns 2 and 3.

[Insert Table 3 here]

Columns 4-6 of Table 3 use our full sample of firms, including also those that do not import any inputs. This more than doubles the number of observations. The coefficient of the dummy variable d_{it}^{imp} shows that these firms use on average a significantly lower proportion of skilled workers. In addition, conditional on being an importer, the skill share falls further with the import share. Both observations are in line with the substitution effect in our model. We also continue to find strong support for the complementarity effect – the coefficient on import prices θ_{it}^{imp} is highly significant and positive. Finally, the coefficients and significance of control variables are largely unchanged.

Table 4 repeats the previous regressions, using import skill intensity σ_{it} as a proxy for the quality of imported inputs. This alternative measure does not need to rely on the assumption that prices reflect quality. Instead, it assumes that products which require a larger proportion of white-collar workers (using U.S. production techniques as reference point) are more complex or of higher quality. We obtain qualitatively very similar results as with θ_{it}^{imp}: Firms that import more skill intensive imports use a higher share of skilled workers in production. This supports the complementarity effect.

[Insert Table 4 here]

In Table 5 we include interaction terms of our import quality proxies θ_{it}^{Imp} and σ_{it} with the ratio of imports to sales. For both variables we find positive and significant interaction terms. In columns 1 and 4, we only include the respective import quality measure, the import share, and the interaction term. Columns 2 and 4 add control variables, and columns 3 and 6 extend the analysis to the full sample of firms, controlling for importer status with the dummy variable d_{it}^{Imp}. These results suggest that the complementarity effect is the stronger the larger the share of imported inputs. Specifically, the implied combined coefficient on the input quality measures roughly triples when going from the 10th to the 90th percentile of the import share.[27]

[Insert Table 5 here]

Table 6 checks whether our results are driven by the quality of exports or domestic inputs. For example, producing high-quality output for foreign markets could require both high-quality imported inputs and skilled workers. In this case, the correlation between import quality and white-collar labor share would be driven by the demand for quality in exported goods, rather than by a complementarity effect in connection with access to high-quality imports. Column 1 adds an exporter dummy together with the export quality index θ_{it}^{Exp} to our standard specification.[28] Neither of the two is significant, and the correlation between θ_{it}^{Imp} and h_{it} is unchanged. In column 2,

[27] The 10th and the 90th percentile of the import share are, respectively, .0056 and .420. The combined coefficient is obtained by multiplying these with the interaction term and adding the coefficient on θ_{it}^{imp} (for columns 1-3) or σ_{it} (columns 4-6).

[28] θ_{it}^{Exp} is constructed analogous to θ_{it}^{Imp} in (20), comparing the price of firm i's exports to the price of other exporters within the same HS-8 product categories. Data are from Chilean customs.

we also add a price-based quality index for domestic inputs, θ_{it}^{Dom}.[29] The coefficient is small and statistically insignificant, and all previous results are unchanged. Column 3 adds non-importing firms to the sample, together with the importer dummy d_{it}^{Imp}. Our main result is confirmed: Importing firms are c.p. less skill intensive, but higher import quality has an effect in the opposite direction. Finally, columns 4-6 repeat the analysis using import skill intensity as an alternative measure for import quality. All previous results are confirmed in these specifications.

[Insert Table 6 here]

The results in column 6 in Table 6 allow us to gauge the magnitude of effects.[30] Import status in isolation implies a 9% lower share of white-collar workers, but this is always compensated by the effect of import skill intensity, σ_{it}^{Imp}. Among all importers, the lowest (highest) 10-percentile of this variable is .33 (.46). Thus, firms that import low-σ_{it}^{Imp} inputs are about 3 percentage points less skill intensive than non-importers, while for importers of high-quality inputs, this difference is close to zero. Thus, for high-quality importers, the substitution and complementarity effect roughly offset each other. Finally, for imports of average quality inputs ($\sigma_{it}^{Imp} = .40$), the complementarity effect raises skill demand by about 7 percentage points, so that these firms have a 2 percentage points smaller white-collar labor share.

4.4 Wages, Import Shares, and Import Quality

We now turn to the relationship between import quality and wages, which our model predicts to be positive, both for average wages and within the blue- and white-collar categories. The results in Table 7 provide strong support for this prediction – in the importer-only sample (columns 1-3), as well as in the full sample (columns 4-6). Our model also features an ambiguous relationship between wages and the share of imported inputs. On the one hand, more imports replace more highly skilled workers, but they also imply a higher return to quality (skills) of the remaining workers. If the second (complementarity) effect is strong, the correlation between import share and wages is predicted to be positive. This is borne out by the data, as shown by the positive and significant coefficients in the second row of Table 7. The positive and significant importer dummy in columns 4-6 also supports this finding. Nevertheless, these findings have to be interpreted with caution. That importers pay higher wages is not a novel observation (c.f. Bernard et al., 2007); import share and wages can be positively associated for other reasons than a strong complementarity effect. To

[29] θ_{it}^{Dom} is constructed using output prices (unit values) reported in ENIA, following the same methodology as the construction of θ_{it}^{Imp} in (20). Because a few importing firms do not purchase any domestic inputs, we also add a dummy for domestic input buyers. None of our results changes if we drop it.

[30] We use our import skill intensity measure, rather than the import price index in column 3, because the former allows for a clearer interpretation of the coefficient.

alleviate this concern, we include controls for prominent other channels that affect wages – such as capital intensity, foreign ownership, or exporter status and export quality.

[Insert Table 7 here]

4.5 Variation within Firms

So far, we have exploited variation across firms within narrowly defined industries. In the following, we investigate how skill demand evolves over time along with a firm's importer status. We calculate the variable 'years as importer', Y^{Imp}, as the number of years that a firm as been consecutively importing inputs. In Table 8, we interact Y^{Imp} with the import quality index and find positive and significant effects. This suggests that the complementarity effect becomes more important over time. A possible reason for this is that hiring frictions may delay changes in the skill composition within firms.[31] Importer duration Y^{Imp} itself has a negative and significant coefficient. This suggests that the substitution effect also gains strength over time. In sum, the longer a firm has been importing imports, the lower is its share of white collar workers. However, the complementarity effect also gains strength over time, affecting skill demand in the opposite direction for firms that import high-quality imports.

[Insert Table 8 here]

5 Conclusion

We examine the effect of access to imported inputs on firms in developing countries. Our model features inputs of heterogeneous quality levels, combined with an O-Ring-type quality complementarity. Assuming that high-quality inputs are relatively cheaper in rich countries, the model predicts that firms in developing countries replace quality-sensitive domestic inputs by imported ones. This substitution effect *lowers* the demand for input quality (e.g., skills) in importing firms. However, the quality-complementarity effect operates in the opposite direction: Importing high-quality inputs *raises* a firm's demand for quality in the inputs that are still purchased domestically, thus increasing the demand for skills.

We find strong evidence in line with these predictions, using a large panel of manufacturing firms in Chile, paired with detailed import data from Chilean customs. Within narrowly defined

[31] Note that the direct effect of the import quality index is now negative. This implies that when firms begin to import, their share of white-collar workers drops more for higher import quality. Over time, however, the net effect of import quality (interaction coefficient $\times Y^{Imp}$ + direct effect) becomes positive – it reaches zero after about two years, and becomes approximately .01 after 5.1 years of importing (the average for Y^{Imp} in our sample). This is in line with the estimates in Table 6.

industries, importing firms are ceteris paribus less skill intensive. This indicates that the prominent "fragmentation of production" across countries has an input-quality dimension: Importing firms in developing countries specialize in low-skill tasks, while their imported inputs replace high-skill tasks. However, we find that higher quality of imports also raises skill demand, which supports the complementarity effect. In addition, the data show that importing firms pay higher wages to both blue-collar and white-collar workers – this also follows from the model if the complementarity effect is relatively strong.

In a broader context, our results imply that O-Ring type quality complementarities operate across firms and borders – embedded in imported inputs. This can help to explain why empirical studies typically document rising skill premia associated with trade liberalization in developing countries – contradicting the prediction of standard trade theory that skill premia should fall. On the one hand, the substitution effect in our model is in line with factor endowment theory: It predicts that importing firms in developing countries perform low-quality tasks domestically, while purchasing high-quality inputs abroad. This leads to lower skill demand. On the other hand, quality complementarity implies that trade has a silver lining for skilled workers in developing countries: The same high-quality inputs that replace skills also augment the need for able hands and minds.

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FIGURES

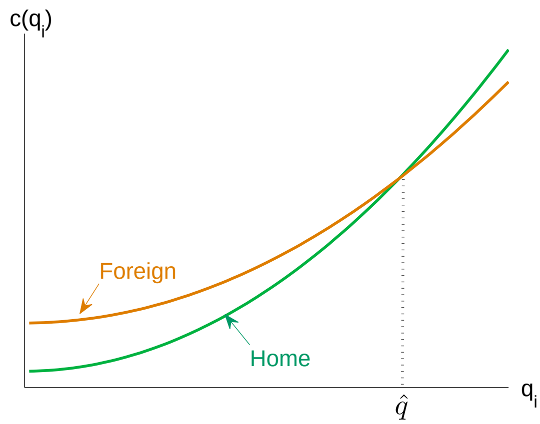

Figure 1: Cost of input quality in domestic and foreign market

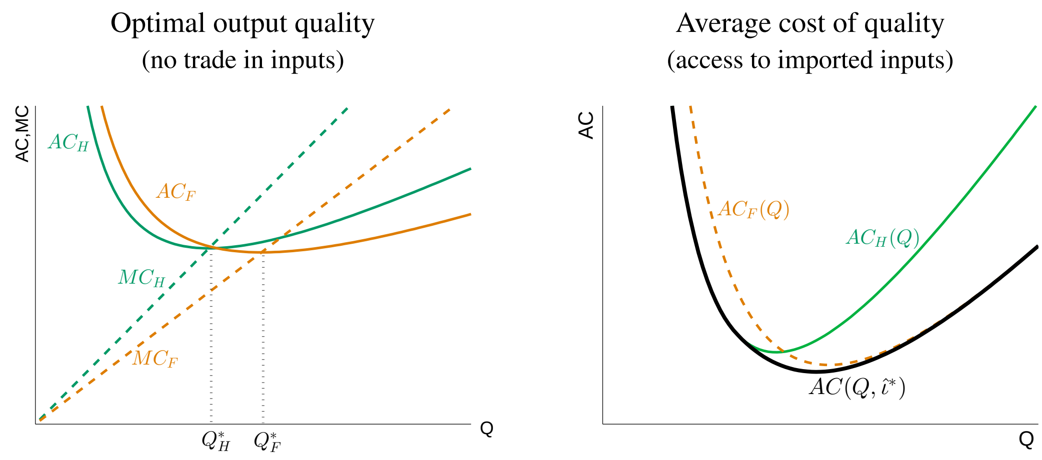

Figure 2: Optimal choice of output quality, and average cost of quality

Notes: The left panel shows the optimal choice of output quality for the steeper domestic input cost-quality profile (subscript H), and for the flatter foreign profile (subscript F), assuming that each country only has access to its own inputs. The right panel shows the average quality-specific cost for a domestic firm that also has access to imported inputs, conditional on choosing the optimal import cutoff $\hat{\imath}^*$.

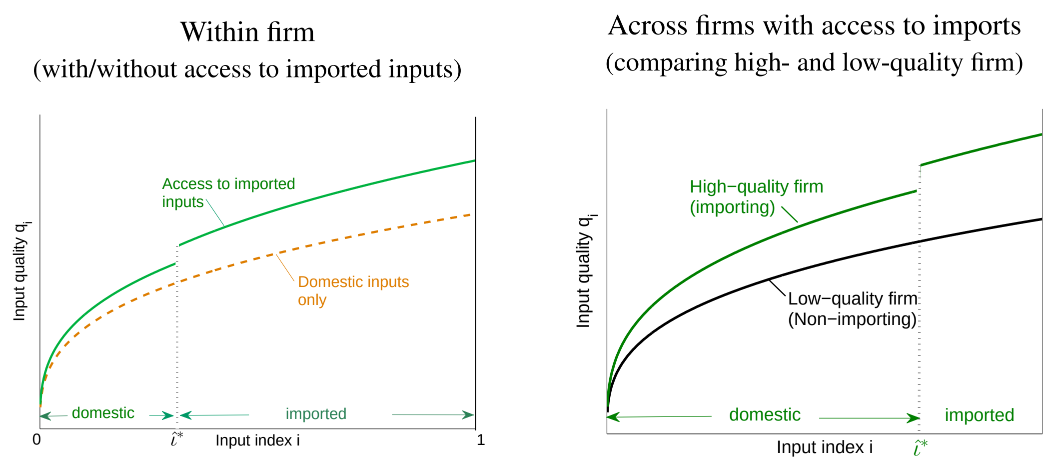

Figure 3: Optimal choice of input quality

Notes: The left panel shows the quality of inputs $i \in [0, 1]$ for the same firm, with and without access to imported inputs. The right panel compares two firms that both have access to imported inputs. While the high-quality producer imports all inputs with $i > \hat{\imath}^*$, the low-quality firm's optimal choice implies zero imports.

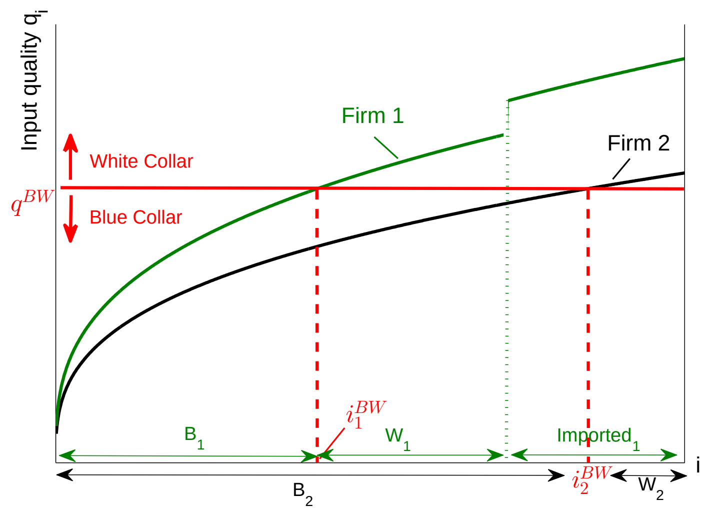

Figure 4: Mapping the model to the data: white collar (W) and blue-collar (B) workers

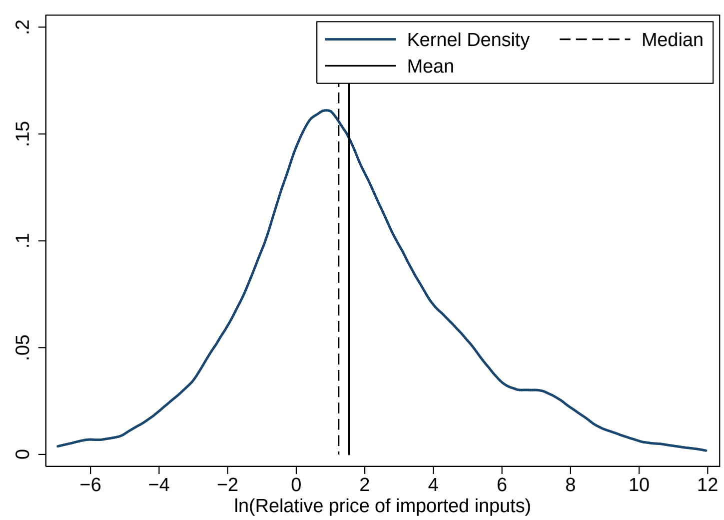

Figure 5: Quality of imported inputs as compared to domestic inputs

Notes: The figure uses the price-based quality index θ_{kt}^{rel}, as given by (22) for product k in year t. This measure equals zero if imported and domestically purchased inputs of category k have the same price, on average; it is greater than zero of imports of the same good are more expensive. The Kernel density is based on 2,489 observations of θ_{kt} between 1996 and 2000. The median and mean are 1.24 and 1.54, respectively.

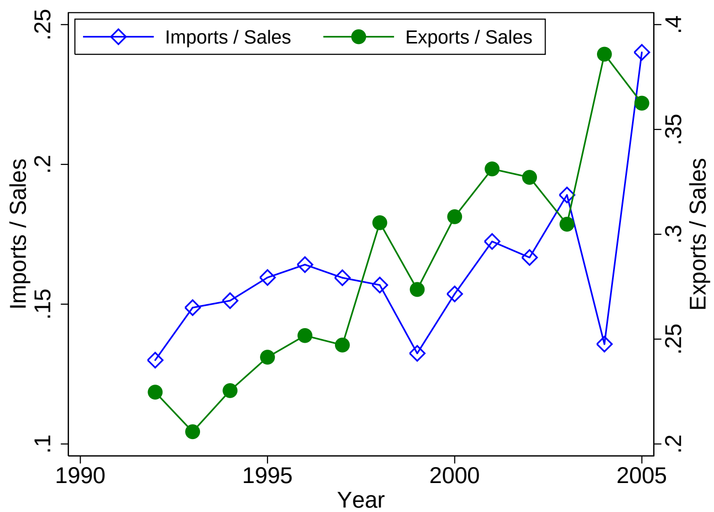

Figure 6: Imports and exports as shares of total sales

Notes: Imports and exports for each firm from Chilean customs data (see section 3). Total sales from matched ENIA data.

TABLES

Table 1: Previous and novel stylized facts.

	(1)	(2)	(3)	(4)	(5)	(6)
	Firm Size		Productivity	———- Skills ———-		
Dependent Variable	ln(workers)	ln(Sales)	ln(VA/workers)	White-collar share		ln(wage)
Import dummy	.808***	1.352***	.599***	-.0160***	-.0164***	.308***
	(.019)	(.027)	(.014)	(.004)	(.004)	(.009)
Export dummy	.877***	1.290***	.424***	-.00286	-.00285	.270***
	(.026)	(.035)	(.017)	(.004)	(.004)	(.011)
Import price index					.00922***	.0219***
					(.002)	(.004)
Sector-Year FE	✓	✓	✓	✓	✓	✓
Region dummies	✓	✓	✓	✓	✓	✓
R^2	.46	.54	.40	.13	.13	.56
Observations	63,987	62,063	63,177	63,987	63,987	63,907

Notes: Clustered standard errors (at firm level) in parentheses. Key: *** significant at 1%; ** 5%; * 10%.

Table 2: Output prices, domestic input prices, and importer characteristics.

	(1)	(2)	(3)	(4)[‡]	(5)	(6)
			PANEL A: Dependent Variable: ln(output price)			
ln(workers)	.0535***					.0201*
	(.009)					(.011)
Export dummy		.116***			.0933***	.0358
		(.026)			(.027)	(.031)
Import dummy			.0834***		.0487**	- .0157
			(.022)		(.023)	(.027)
Import price index				.0694***	.0741***	.0599***
				(.015)	(.014)	(.015)
Further controls						✓
Product-Year FE	✓	✓	✓	✓	✓	✓
Sector-Year FE	✓	✓	✓	✓	✓	✓
Region dummies	✓	✓	✓	✓	✓	✓
R^2	.141	.14	.14	.146	.141	.147
Observations	101,572	101,572	101,572	49,578	101,572	87,058
			PANEL B: Dependent Variable: ln(domestic input price)			
ln(workers)	.0477***					.0451***
	(.008)					(.010)
Export dummy		.0732***			.0592***	.00357
		(.021)			(.023)	(.025)
Import dummy			.0530***		.0284	- .0153
			(.018)		(.018)	(.022)
Import price index				.0506***	.0484***	.0394***
				(.012)	(.012)	(.013)
Further controls						✓
Product-Unit-Year FE	✓	✓	✓	✓	✓	✓
Sector-Year FE	✓	✓	✓	✓	✓	✓
Region dummies	✓	✓	✓	✓	✓	✓
R^2	.067	.066	.066	.061	.067	.069
Observations	276,358	276,358	276,358	137,985	276,358	234,130

[‡] Column 4 includes only firms that import some of their inputs.

Notes: Clustered standard errors (at firm level) in parentheses. Additional controls comprise the import share in total sales, capital per worker, ln(value added per worker), and the intermediate input share. Key: *** significant at 1%; ** 5%; * 10%.

Table 3: Price-based import quality and skilled labor share.

Dependent variable: Firm-level skilled labor share, h_{it}.

Sample	Importers only			All firms		
	(1)	(2)	(3)	(4)	(5)	(6)
Import price index	.00988***	.00711***	.00713***	.00966***	.00717***	.00772***
θ_{it}^{Imp}	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)
Import share	-.0348**	-.0504***	-.0469***	-.0321**	-.0538***	-.0460***
Imports_{it} / Sales_{it}	(.014)	(.015)	(.016)	(.014)	(.015)	(.015)
Capital per worker	.0173***	.0202***	.0212***	.0235***	.0249***	.0281***
$\ln(k_{it})$	(.003)	(.004)	(.004)	(.003)	(.004)	(.004)
Productivity	.0301***	.0292***	.0288***	.0195***	.0212***	.0206***
ln(VA per worker_{it})	(.003)	(.004)	(.004)	(.003)	(.003)	(.003)
Interm. Input share	-.0128	.00884	.0120	-.0392***	-.00111	-.00182
Inputs_{it}^{int} / Sales_{it}	(.012)	(.012)	(.012)	(.010)	(.009)	(.010)
Foreign owner	.0187**	.0228***	.0218***	.0199***	.0284***	.0283***
	(.008)	(.008)	(.008)	(.008)	(.007)	(.007)
Importer Dummy				-.0377***	-.0302***	-.0309***
d_{it}^{Imp}				(.004)	(.004)	(.004)
Region-Year FE		✓	✓		✓	✓
Sector FE		✓	✓		✓	✓
Sector-Year FE			✓			✓
R^2	.077	.116	.164	.084	.116	.146
Observations	24,949	24,949	24,949	53,351	53,351	53,351

Notes: Clustered standard errors (at the firm level) in parentheses. Key: *** significant at 1%; ** 5%; * 10%. The share of skilled workers is defined as +++. The Import price index θ_{it}^{Imp} is derived as in equation (20). Sectors reflect 89 4-digit ISIC manufacturing sectors; sector-year FE include separate fixed effects for each sector in each year.

Table 4: Import skill intensity and skilled labor share.

Dependent variable: Firm-level skilled labor share, h_{it}.

Sample	Importers only			All firms		
	(1)	(2)	(3)	(4)	(5)	(6)
Import skill intensity	.223***	.186***	.176***	.175***	.133***	.143***
σ_{it}^{Imp}	(.045)	(.050)	(.052)	(.045)	(.048)	(.049)
Import share	-.0363**	-.0504***	-.0472***	-.0359**	-.0557***	-.0480***
Imports$_{it}$ / Sales$_{it}$	(.015)	(.015)	(.016)	(.014)	(.015)	(.015)
Capital per worker	.0174***	.0201***	.0210***	.0236***	.0249***	.0281***
$\ln(k_{it})$	(.003)	(.004)	(.004)	(.003)	(.004)	(.004)
Productivity	.0294***	.0297***	.0293***	.0193***	.0213***	.0208***
ln(VA per worker$_{it}$)	(.003)	(.004)	(.004)	(.003)	(.003)	(.003)
Interm. Input share	-.0138	.00883	.0118	-.0399***	-.00151	-.00231
Inputs$_{it}^{int}$ / Sales$_{it}$	(.012)	(.012)	(.012)	(.010)	(.009)	(.010)
Foreign owner	.0164**	.0219***	.0209***	.0183**	.0277***	.0275***
	(.008)	(.008)	(.008)	(.008)	(.007)	(.007)
Importer Dummy				-.107***	-.0832***	-.0878***
d_{it}^{Imp}				(.018)	(.020)	(.020)
Region-Year FE		✓	✓		✓	✓
Sector FE		✓	✓		✓	✓
Sector-Year FE			✓			✓
R^2	.077	.116	.164	.084	.115	.146
Observations	24,949	24,949	24,949	53,351	53,351	53,351

Notes: Clustered standard errors (at the firm level) in parentheses. Key: *** significant at 1%; ** 5%; * 10%. The share of skilled workers is defined as +++. Import skill intensity σ_{it}^{Imp} is derived as in equation (23). Sectors reflect 89 4-digit ISIC manufacturing sectors; sector-year FE include separate fixed effects for each sector in each year.

Table 5: Interaction regressions

Dependent variable is the firm-level skilled labor share, h_{it}.

Import quality measure	Import price index (θ_{it}^{Imp})			Import skill intensity (σ_{it}^{Imp})		
Sample	Importers only		All firms	Importers only		All firms
	(1)	(2)	(3)	(4)	(5)	(6)
Import Quality	.00604***	.00513**	.00577***	.145***	.119**	.082
θ_{it}^{Imp} / σ_{it}^{Imp}	(.002)	(.002)	(.002)	(.055)	(.058)	(.054)
Imports/Sales	.0103	-.0374**	-.0345**	-.179**	-.240**	-.261***
	(.013)	(.015)	(.015)	(.083)	(.098)	(.097)
Imp. Qual. $\times$ (Imp/Sales)	.0227*	.0277*	.0270*	.459**	.492**	.549**
	(.013)	(.015)	(.014)	(.208)	(.243)	(.243)
Capital per worker		.0219***	.0285***		.0217***	.0285***
$\ln(k_{it})$		-(.004)	-(.004)		-(.004)	-(.004)
Productivity		.0305***	.0221***		.0308***	.0222***
ln(VA per worker$_{it}$)		(.004)	(.003)		(.004)	(.003)
Interm. Input share		.0169	.000934		.0159	.000186
Inputs$_{it}^{int}$ / Sales$_{it}$		(.013)	(.010)		(.012)	(.010)
Importer Dummy			-.0303***			-.0621***
d_{it}^{Imp}			(.004)			(.022)
Region FE	✓	✓	✓	✓	✓	✓
Sector-Year FE	✓	✓	✓	✓	✓	✓
R^2	.13	.16	.14	.14	.16	.14
Observations	27,692	24,949	53,351	27,692	24,949	53,351

Notes: Clustered standard errors (at firm level) in parentheses. Key: *** significant at 1%; ** 5%; * 10%.

Table 6: Controlling for quality of exports and domestic inputs

Dependent variable is the firm-level skilled labor share, h_{it}.

Import quality measure	Import price index (θ_{it}^{Imp})			Import skill intensity (σ_{it}^{Imp})		
Sample	Importers only		All firms	Importers only		All firms
	(1)	(2)	(3)	(4)	(5)	(6)
Import quality	.00782***	.00776***	.00913***	.198***	.197***	.184***
θ_{it}^{Imp}	(.002)	(.002)	(.002)	(.049)	(.049)	(.046)
Export quality index	.00205	.00202	.00157	.00243	.00239	.00194
θ_{it}^{Exp}	(.003)	(.003)	(.003)	(.003)	(.003)	(.003)
Domestic input price index		.00305	.00269		.00311	.00277
θ_{it}^{Dom}		(.002)	(.002)		(.002)	(.002)
Exporter Dummy	.0000845	.000164	-.00264	.000717	.000788	-.00234
d_{it}^{Exp}	(.004)	(.004)	(.004)	(.004)	(.004)	(.004)
Domestic Input Dummy		-.00195	-.00723		-.00163	-.0071
d_{it}^{Dom}		(.006)	(.005)		(.006)	(.005)
Importer Dummy			-.0163***			-.0898***
d_{it}^{Imp}			(.004)			(.019)
Region FE	✓	✓	✓	✓	✓	✓
Sector-Year FE	✓	✓	✓	✓	✓	✓
R^2	.133	.133	.126	.133	.133	.126
Observations	29,193	29,193	63,987	29,193	29,193	63,987

Notes: Clustered standard errors (at firm level) in parentheses. Key: *** significant at 1%; ** 5%; * 10%.

Table 7: Import quality and wages.

Dependent variable: Firm-level wages.

	Importers only			All firms		
	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.	ln(wage)	ln(wage$^{\mathrm{W}}$)	ln(wage$^{\mathrm{B}}$)	ln(wage)	ln(wage$^{\mathrm{W}}$)	ln(wage$^{\mathrm{B}}$)
Import price index	.0289***	.0202***	.0250***	.0294***	.0227***	.0263***
θ_{it}^{Imp}	(.005)	(.006)	(.004)	(.005)	(.006)	(.004)
Import share	.295***	.307***	.189***	.316***	.301***	.202***
Imports$_{it}$ / Sales$_{it}$	(.037)	(.043)	(.032)	(.035)	(.042)	(.031)
Capital per worker	.130***	.0805***	.0995***	.0880***	.0458***	.0700***
$\ln(k_{it})$	(.011)	(.011)	(.010)	(.007)	(.009)	(.007)
Interm. Input share	-.190***	-.227***	-.166***	-.260***	-.314***	-.226***
Inputs$_{it}^{int}$ / Sales$_{it}$	(.031)	(.038)	(.029)	(.021)	(.027)	(.020)
Foreign owner	.224***	.220***	.133***	.240***	.234***	.147***
Inputs$_{it}^{int}$ / Sales$_{it}$	(.023)	(.024)	(.020)	(.022)	(.023)	(.019)
Export quality index	.00849	-.00642	.00320	.00917	-.00512	.00585
θ_{it}^{Exp}	(.006)	(.008)	(.006)	(.006)	(.007)	(.006)
Exporter Dummy	.225***	.297***	.146***	.216***	.304***	.138***
d_{it}^{Exp}	(.012)	(.015)	(.011)	(.011)	(.013)	(.010)
Importer Dummy				.251***	.356***	.183***
d_{it}^{Imp}				(.009)	(.012)	(.009)
Year-Region FE	✓	✓	✓	✓	✓	✓
Sector-Year FE	✓	✓	✓	✓	✓	✓
R^2	.555	.378	.508	.599	.466	.538
Observations	24952	24559	23411	53379	50326	48116

Notes: Clustered standard errors (at the firm level) in parentheses. Key: *** significant at 1%; ** 5%; * 10%. Wages are measured as annual salary (in pesos); wage$^{\mathrm{W}}$ (wage$^{\mathrm{B}}$) denotes the wage of white (blue) collar workers. The Import price index θ_{it}^{Imp} is derived as in equation (20). Sectors reflect 89 4-digit ISIC manufacturing sectors; sector-year FE include separate fixed effects for each sector in each year.

Table 8: Interactions with duration as importer

Dependent variable: Firm-level skilled labor share, h_{it}.

Sample	Importers only			All firms		
	(1)	(2)	(3)	(4)	(5)	(6)
Import price index	-.00583**	-.00731**	-.00583**	-.00621**	-.00542**	- .00381
θ_{it}^{Imp}	(.003)	(.003)	(.003)	(.003)	(.002)	(.002)
Years as importer	-.00378***	-.00299**	-.00362***	-.00578***	-.00780***	-.00565***
Y^{Imp}	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
Interaction	.00302***	.00152***	.00124**	.00324***	.00142***	.00116**
$\theta_{it}^{Imp} \times Y^{Imp}$	(.001)	(.001)	(.001)	(.001)	(.001)	(.001)
Importer Dummy				.0136***	.0191***	.0132***
d_{it}^{Imp}				(.004)	(.004)	(.005)
Region FE	✓	✓	✓	✓	✓	✓
Sector-Year FE	✓		✓	✓		✓
Firm FE		✓	✓		✓	✓
R^2	.14	.57	.54	.13	.56	.51
Observations	29,193	29,193	29,193	63,987	63,987	63,987

Notes: Clustered standard errors (at the firm level) in parentheses. Key: *** significant at 1%; ** 5%; * 10%. Sectors reflect 89 4-digit ISIC manufacturing sectors; sector-year FE include separate fixed effects for each sector in each year. The average years of import status (conditional on being an importing firm) is 5.1 years.

Online Appendix

Imported Inputs, Quality Complementarity, and Skill Demand

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A Technical Appendix

A.1 Optimal input quality and cost of quality

In this section, we solve the model for the optimal quality of output, Q_{ω}^{*}, as well as for the corresponding input quality $q_{i\omega}^{*}$. The choice of input quality depends on the cost function (5). When import tariffs are prohibitively high, the parameters a and b are the same for all inputs. However, when import tariffs fall, high-quality inputs can be purchased cheaper abroad. To allow for this possibility, we keep track of the input-variety specific costs $a_{i\omega}$ and $b_{i\omega}$ when solving the model.

We begin by deriving an expression for the quality-dependent unit cost function, $C(Q_{\omega})$. Deriving (7) with respect to $q_{i\omega}$ yields

$$q_{i\omega} = \left(\frac{\alpha_i}{c'\left(q_{i\omega}\right)} \, \frac{\lambda_{\omega} A_{\omega} \, \bar{Q}_{\omega}}{\int_0^1 \alpha_i q_{i\omega}^{-\frac{1-\rho}{\rho}} di} \right)^{\rho} , \tag{A.1}$$

where $c'\left(q_{i\omega}\right)$ is the marginal cost of raising the quality of input i, i.e., the slope of the quality-cost profile. The marginal cost of *output* quality λ_{ω} corresponds to the Lagrange multiplier associated with the constraint in (A.1) and is given by

$$\lambda_{\omega} = \frac{1}{A_{\omega}} \left(\int_0^1 \alpha_i \left(\frac{c'\left(q_{i\omega}\right)}{\alpha_i} \right)^{1-\rho} di \right)^{\frac{1}{1-\rho}} \tag{A.2}$$

This expresses the marginal cost of quality as a function of individual inputs.[1] In the following, we derive the marginal cost as a function of *output* quality.

[1]Note that since we have taken the cutoff $\hat{\imath}_{\omega}$ as given so far, the integral in (A.2) is calculated across all inputs i. Below, firms also decide the optimal $\hat{\imath}_{\omega}$, so that the integral in (A.2) will be split into two parts as in (7). This also eliminates the discontinuity implicit in (A.2) at $c'\left(q_{i\omega}\right)|_{i=\hat{\imath}_{\omega}}$, i.e., at $q_{i\omega} = \hat{q}$ (the input quality at which it becomes optimal to import).

Equation (A.1) implies that the ratio of the first input's quality to the quality of input i is given by

$$\frac{q_{i\omega}}{q_{1\omega}} = \left(\frac{\alpha_i}{\alpha_1}\frac{b_{1\omega}q_{1\omega}}{b_{i\omega}q_{i\omega}}\right)^{\rho} \quad \Rightarrow \quad q_{i\omega} = \left(\frac{\alpha_i b_{1\omega}}{\alpha_1 b_{i\omega}}\right)^{\frac{\rho}{1+\rho}} q_{1\omega} \tag{A.3}$$

Thus, knowing the quality choice for one input allows us to derive the quality of all other inputs. We substitute this expression in (3) to obtain:

$$Q_\omega = \left(\frac{b_{1\omega}}{\alpha_1}\right)^{\frac{\rho}{\rho+1}} \left(\int_0^1 \alpha_i^{\frac{2\rho}{1+\rho}} b_{i\omega}^{\frac{1-\rho}{1+\rho}} di\right)^{\frac{\rho}{\rho-1}} \cdot q_{1,\omega}$$

Re-arranging this expression and substituting in (A.3), we obtain the optimal input quality for a given output quality Q_ω:

$$q_{i\omega} = \left(\frac{\alpha_i}{b_{i\omega}}\right)^{\frac{\rho}{1+\rho}} \left(\int_0^1 \alpha_i^{\frac{2\rho}{1+\rho}} b_{i\omega}^{\frac{1-\rho}{1+\rho}} di\right)^{\frac{\rho}{1-\rho}} \cdot Q_\omega \tag{A.4}$$

So far, we have taken the cutoff $\hat{\imath}_\omega$ as given; it has been implicit in the integral over all inputs i. In the following, we use the fact that all inputs $i \leq \hat{\imath}_\omega$ are purchased at home, while the remainder is purchased abroad. Thus, the quality-specific unit cost is given by $C(\{q_{i\omega}\}, \hat{\imath}_\omega) = \frac{1}{A_\omega}\left(\int_0^{\hat{\imath}_\omega}(b_H \cdot q_{i\omega}^2)di + \int_{\hat{\imath}_\omega}^1 (b_F \cdot q_{i\omega}^2)di + C_{f,\omega}(\hat{\imath}_\omega)\right)$, where $C_{f,\omega}(\hat{\imath}_\omega) \equiv \hat{\imath}_\omega a_H + (1-\hat{\imath}_\omega)a_F + m_\omega$. Using this expression together with (A.4), we obtain the quality-specific cost as a function of *output* quality, as given by (7) in the paper, as well as the definition of the integral $I(\hat{\imath}_\omega)$ in (8).

Finally, we derive the *optimal* quality of inputs, i.e., given that the output quality is optimized. First, using (8) in (A.4) simplifies notation to:

$$q_{i\omega}^*(Q_\omega^*) = \left(\frac{\alpha_i}{b_{i\omega}}\right)^{\frac{\rho}{1+\rho}} I(\hat{\imath}_\omega)^{\frac{\rho}{1-\rho}} \cdot Q_\omega^*$$

Substituting Q_ω^* from (11) into this equation yields (12) in the paper.

A.2 Optimal output quality and choice of the cutoff $\hat{\imath}_\omega$

As shown in Section 2.3 in the paper, firms' profit maximization amounts to minimizing the average cost of output quality $C(Q_\omega, \hat{\imath}_\omega)/Q_\omega$, where the cost of output quality is given by

$$C(Q_\omega, \hat{\imath}_\omega) = \frac{1}{A_\omega}\Bigg[\underbrace{\left(\int_0^{\hat{\imath}_\omega} \alpha_i^{\frac{2\rho}{1+\rho}} b_H^{\frac{1-\rho}{1+\rho}} di + \int_{\hat{\imath}_\omega}^1 \alpha_i^{\frac{2\rho}{1+\rho}} b_F^{\frac{1-\rho}{1+\rho}} di\right)^{\frac{1+\rho}{1-\rho}}}_{I(\hat{\imath}_\omega)^{\frac{1+\rho}{1-\rho}}} \cdot Q_\omega^2 + \underbrace{\hat{\imath}_\omega a_H + (1-\hat{\imath}_\omega)a_F + m_\omega}_{C_{f,\omega}(\hat{\imath}_\omega)}\Bigg],$$

Minimizing $C(Q_\omega, \hat{\iota}_\omega)/Q_\omega$ with respect Q_ω and $\hat{\iota}_\omega$ yields the following first order conditions:

$$\frac{\partial}{\partial Q_\omega} : \frac{\partial C(Q_\omega, \hat{\iota}_\omega)}{\partial Q_\omega} = \frac{C(Q_\omega, \hat{\iota}_\omega)}{Q_\omega} \Rightarrow I(\hat{\iota}_\omega)^{\frac{1+\rho}{1-\rho}} Q_\omega^2 = C_{f,\omega}(\hat{\iota}_\omega)$$
$$\frac{\partial}{\partial \hat{\iota}_\omega} : \frac{\partial C(Q_\omega, \hat{\iota}_\omega)}{\partial \hat{\iota}_\omega} = 0 \Rightarrow \hat{\iota}_\omega^{\frac{2\rho}{1+\rho}} I(\hat{\iota}_\omega)^{\frac{2\rho}{1-\rho}} = \frac{1-\rho}{1+\rho} \left(\frac{a_F - a_H}{b_H^{\frac{1-\rho}{1+\rho}} - b_F^{\frac{1-\rho}{1+\rho}}} \right) \left(\frac{1}{Q_\omega} \right)^2$$

The first condition simplifies to equation (11), while the second provides an implicit solution for $\hat{\iota}_\omega$. Since $I'(\hat{\iota}_\omega) > 0$, the left-hand-side ($LHS$) is increasing in $\hat{\iota}_\omega$, and $I(0) = 0$. The right-hand side (RHS) is a positive constant for given Q_ω. Thus, the problem has a unique solution $\hat{\iota}_\omega(Q_\omega)$, for any *given* output quality Q_ω. We use the optimal $\hat{\iota}_\omega$ to obtain the unit cost function with access to imported inputs that is shown in the right panel of Figure 2.

Finally, we derive $\hat{\iota}_\omega^*$, which is associated with the *optimal* output quality Q_ω^*. We derive this by combining the two first-order conditions (FOC). First, we calculate the value of the integral:

$$I(\hat{\iota}_\omega) = \frac{1+\rho}{3\rho+1} \left[\hat{\iota}_\omega^{\frac{2\rho}{1+\rho}+1} \cdot \left(b_H^{\frac{1-\rho}{1+\rho}} - b_F^{\frac{1-\rho}{1+\rho}} \right) + b_F^{\frac{1-\rho}{1+\rho}} \right]$$

Substituting this in the second FOC above and using $Q_\omega = Q_\omega^*$ from (11) implies:

$$2\hat{\iota}_\omega(a_F - a_H) = \frac{3\rho+1}{1+\rho}(a_F + m_\omega) - \frac{1-\rho}{1+\rho} \cdot \frac{a_F - a_H}{\hat{\iota}_\omega^{\frac{2\rho}{1+\rho}} \cdot \left[\left(\frac{b_H}{b_F} \right)^{\frac{1-\rho}{1+\rho}} - 1 \right]} \tag{A.5}$$

The LHS in this equation is increasing in $\hat{\iota}_\omega$, and $LHS|_{\hat{\iota}_\omega=0} = 0$. The RHS starts off at $-\infty$ for $\hat{\iota}_\omega = 0$ and then converges to $\frac{3\rho+1}{1+\rho}(a_F + m_\omega) > 0$. The functional forms are shown in Figure A.1, and $\hat{\iota}_\omega^* < 1$ is implicitly determined by the intersection of LHS and RHS. Firm ω will import some of its inputs if $\hat{\iota}_\omega^* < 1$. This result is obtained if $LHS|_{\hat{\iota}_\omega=1} < RHS|_{\hat{\iota}_\omega=1}$, which holds if

$$2(1+\rho) + \frac{1-\rho}{\left(\frac{b_H}{b_F} \right)^{\frac{1-\rho}{1+\rho}} - 1} < (3\rho+1)\frac{a_F + m_\omega}{a_F - a_H}$$

This inequality holds if (i) b_H is large relative to b_F, i.e., if imported inputs exhibit a substantially flatter quality-cost profile, (ii) $a_F - a_H$ is large, i.e., if imported inputs of low quality are expensive relative to domestic ones, and (iii) m_ω is large, i.e., if the firm has a draw of high raw material cost.

We can now use (A.5) to prove that $\hat{\iota}_\omega^*$ is independent of A_ω: Equation (A.5), which implicitly determines $\hat{\iota}_\omega^*$, is a function of the parameters that govern the shape of $c_H(q)$ and $c_F(q)$

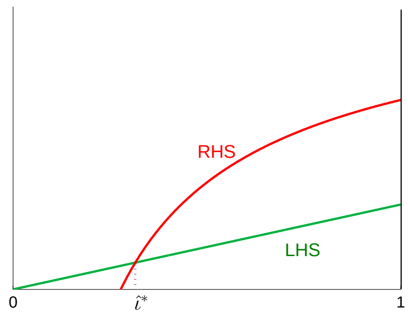

Figure A.1: Implicit solution for $\hat{\iota}^*_\omega$ in equation (A.5)

(a_H, b_H, a_F, b_F), as well as of the firm's draw of m_ω.

A.3 Constant profits across firms

In this section, we determine A_ω such that $\Pi_\omega = \bar{\Pi},\ \forall \omega$. Following (10), this implies that $AC(Q_\omega)$ must be constant. To use this fact, we first simplify $C(Q_\omega)$. Substituting (11) in (7), we obtain the unit cost of output at the optimal quality level:

$$C(Q^*_\omega) = 2C_{f,\omega} \tag{A.6}$$

Using (11), this yields average quality-specific costs:

$$\frac{C(Q^*_\omega)}{Q^*_\omega} = \frac{2}{A_\omega}\sqrt{bC_{f,\omega}}\left(\int_0^1 \alpha_i^{\frac{2\rho}{\rho+1}}\right)^{\frac{\rho+1}{2(1-\rho)}} \equiv \hat{AC}_\omega \tag{A.7}$$

where $\hat{AC}_\omega$ is constant for a given variety ω but varies across varieties. We still have to determine $\hat{AC}_\omega$ such that profits are equalized across firms. At the same time, we want the equilibrium quality to vary across firms. The latter is the case if m_ω varies by firms. Let us assume that $m_\omega \geq 0$, and use the first variety as 'numeraire' such that $m_0 = 0$ and $A_0 = 1$. Thus, (A.7) implies:

$$\hat{AC}_0 = \frac{C(Q^*_0)}{Q^*_0} = 2\sqrt{b\left(Na + \frac{N}{A_U}w_U\right)}\left(\int_0^1 \alpha_i^{\frac{2\rho}{\rho+1}}\right)^{\frac{\rho+1}{2(1-\rho)}} \tag{A.8}$$

$\hat{AC}_0$ is the average cost of variety $\omega = 0$, given that the profit-maximizing quality of this variety is produced. For all varieties $\omega > 0$, we will have $m_\omega > 0$. In order for these to make the same profit as the 'numeraire variety' producer, their average quality-related cost must satisfy: $\hat{AC}_\omega = \hat{AC}_0$.

For any given $m_\omega > 0$ this imposes a restriction on A_ω:

$$\hat{A}_\omega = \frac{2}{\hat{A}C_0}\sqrt{bC_{f,\omega}}\left(\int_0^1 \alpha_i^{\frac{2\rho}{\rho+1}}\right)^{\frac{\rho+1}{2(1-\rho)}} = \sqrt{\frac{C_{f,\omega}}{Na + \frac{N}{A_U}w_U}} = \sqrt{1 + \frac{m_\omega}{Na + \frac{N}{A_U}w_U}} \tag{A.9}$$

Finally, we can substitute (A.9) in (11) to obtain the optimal choice of quality under the regime where profits are constant across firms:

$$\hat{Q}^*_\omega = \frac{2}{\hat{A}C_0}C_{f,\omega} = \frac{2}{\hat{A}C_0}\left(Na + m_\omega + \frac{N}{A_U}w_U\right) \tag{A.10}$$

Thus, $\hat{Q}^*_\omega$ increases in m_ω.