Trade, Competition and Quality-Upgrading: A Theory with Evidence from Colombia

Marcela Eslava, Ana Cecília Fieler and Daniel Xu

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ABSTRACT

We develop a quantitative model where international trade, by tightening competition, may have a broad impact on firm behavior, leading to upgrades in the quality of inputs and output, increases in investment and in the demand for skilled workers. The model explains the sharp increases in skill-premium and skill-intensity following a trade liberalization in developing countries. These increases contradict the predictions of the factor-proportions model, which describes cross-sectional data well if high-quality goods are more skill intensive than low-quality goods. Although skill intensity is positively correlated with firm size in the cross-section, trade liberalizations were accompanied by decreases in firm size. The standard channels of exit, export expansion and access to foreign inputs cannot quantitatively or qualitatively account for these facts. We then allow for the entry of high-quality imports during a trade liberalization to decrease the relative demand for low-quality goods. This effect may arise in preferences with habit formation, keeping-up-with-the-Joneses effects or complementarities in demand. It leads most firms, especially the most productive, to upgrade the quality of their products and increase their relative demand for skilled workers. We estimate the model structurally to data on manufacturing plants in Colombia before and after the trade liberalization.

Keywords: trade liberalization, skill-premium, quality, competition.

The Colombian automobile industry started in the 1950s and 1960s with the entry of multinationals such as Chrysler, Fiat, and Renault. While protected by trade barriers in the following decades, these firms failed to adopt the technologies and release the car models they adopted and released elsewhere. In 1991, tariffs decreased from the prohibitively high 200% to 35%, imports surged and a transformation of the industry ensued. The number of domestic car models increased from 20 to 26. New models had higher quality. The percentage of models with alloy wheels increased from 11% to 40% and with radio, from 23% to 41%. Metallic painting, hitherto nonexistent in the Colombian market, became common. To design these new cars and implement their manufacturing processes, firms bought sophisticated equipment, hired skilled workers and trained their existing employees. Despite a decade of economic growth, the clear improvements in car quality and price reductions, domestic car makers sold only 28,670 cars in Colombia in 1998 compared with 29,150 in 1986; their market shares had decreased from 100% to 48%.[1]

Foreign competition transforms laggard firms in numerous case studies, and in more comprehensive data sets, trade liberalizations are associated with increases in measured productivity, and in capital- and skill-intensity within manufacturing firms.[2] We develop a quantitative model where international trade, by tightening competition, may have a broad impact on firm behavior, leading to upgrades in the quality of inputs and output, increases in investment and in the demand for skilled workers. Our empirical application focuses on skill, partly because it is observable, partly because foreign competition helps explain puzzling changes in skill premium following the trade liberalization in numerous developing countries.

To put it in context, the factor-proportions model of trade describes well patterns of specialization if high-quality goods are more skill intensive than low-quality goods. While several countries often export goods to the same importer in the same finely-defined product category, skill-abundant countries systematically sell goods at higher unit prices.[3] In this model, if a skill-

[1]See Tovar (2011). The characteristics of cars above are an average of 1986-1989 and 1992-1995 from his table 1. The ownership of the car assemblers above changed and in 1986-1998, they were Mazda, GM and Renault. Exports of Colombian cars increased in the period but remained very small.

[2]See Das et al. (2009), Holmes and Schmitz (2010) for a survey on case studies. For productivity changes after a trade liberalization, see Eslava et al. (2011), Khandelwal and Topalova (2004), Pavcnik (2002), Trefler (2004) and references there surveyed.

[3]See Schott (2004). Similar patterns hold for capital.

scarce developing country liberalizes to trade, its production shifts toward unskill-intensive activities, thereby increasing the demand and the wages of unskilled workers relative to skilled workers. In contrast, trade liberalizations in developing countries in the 1980s and 1990s were followed by abrupt rises in the skill premium in the order of 10% to 20%.

These liberalizations are also associated with increases in the skill intensity of manufacturing firms but *not* with increases in firm size. Sectors with the largest tariff reductions experienced the largest increase in skill intensity and decrease in firm size.[4] These facts are puzzling because firm data suggest that there are economies of scale in the production of high-quality goods: Larger firms are generally more skill intensive; they sell their output and buy their inputs at higher unit prices. A decrease in firm size should then provide further incentives for firms to *downgrade* the quality of their output toward the country's comparative advantage low-quality goods, but the increase in skill-premium and skill-intensity suggests firms *upgrade*.

We introduce vertical differentiation and factor intensities into Melitz (2003). Heterogeneous firms choose the price and quality of their output from a continuum. The production of higher quality involves economies of scale, and the intensive use of skilled labor and high-quality inputs. The production side thus captures exclusively the features of production that have been robustly associated to vertically differentiated goods through the correlations of cross-sectional bilateral trade and firm-level data described above.[5] Whether a trade liberalization in this set up leads to increases in the skill-intensity depends on whether firms upgrade the quality of their products, which in turn, depends on demand. We generalize CES preferences to allow the demand for low-quality to change relative to high-quality goods.

We estimate the model using a panel of Colombian manufacturing plants in 1988 and 1994—before and after the trade liberalization in 1991. The 1988 cross-sectional joint distribution of firm size, skill-intensity, input and output prices, and status and intensity of imports

[4]See Goldberg and Pavcnik (2004, 2007) for a survey on the correlation between tariffs and skill intensity, and Tybout (2003) for a survey on tariffs and firm size.

[5]The production side combines elements of previous models in a unified quantitative framework. High-quality goods are produced with high-quality inputs and economies of scale in Kugler and Verhoogen (2011). Economies of scale and skill are linked in Bustos (2011), Helpman et al. (2010) and Helpman et al. (2012). In Burstein, Cravino and Vogel (2012) capital complements skilled labor and play a role similar to intermediate inputs here. In the model, wages exclusively reflect differences in skill. We then do not address the effect on wages studied in Helpman et al. (2010), Amiti and Davis (2012), Amiti and Cameron (2012) and Attanasio et al. (2004).

and exports provide information on the importance of economies of scale and imported inputs in the production of skill-intensive high-quality goods, and on their relative demand abroad. The post-liberalization data, in turn, provide information on import penetration, export expansion, and changes in firm size. The effects of export expansion and imported intermediates, we find, were small. In the model with CES preferences, the dominating effect is the decrease in firm size, which leads firms to downgrade their output quality and become less skill intensive, contrary to the data. With more general preferences, not surprisingly, the entry of high-quality imports decreases the relative demand for low-quality goods. Most firms then invest in quality upgrading and become more skill intensive.

Apart from the mechanics of our exercise, this disproportional decrease in the demand for low-quality goods is consistent with preferences commonly used in the literature. Take habit formation. By consuming high-quality imported goods, consumers may grow accustomed to the added features of these products and decrease the demand for goods without them. Demand may also shift as consumers observe their neighbors, the Joneses, consuming high-quality goods. If preferences are non-homothetic and real wages increase during the trade liberalization, the relative demand for low-quality goods decreases. Or if there are demand complementarities, when the overall quality of a consumer's wardrobe or house decor increases, his valuation of low-quality items may decrease.[6] We leave the interpretation of the demand system open and take the shift in relative demand as an exogenous parameter to be estimated. In the appendix, we endogenize this parameter with a utility function that exhibits demand complementarities.

In trade, Manova and Zhang (2011) provide evidence that the relative demand for high-quality goods increases with openness. They find that the same Chinese plant sells goods at higher unit price to larger and less remote markets. Since production technologies are held fixed (within-plant effect) and markups are generally lower in more competitive markets, their findings suggest that the relative demand for high-quality goods is higher in less remote mar-

[6]Preferences under habit formation and catching up with the Joneses have been extensively used in macro economics and by Atkin (forthcoming) in trade. Kuhn et al. (2011) provide empirical evidence for preferences under catching up with the Jones. As in Abel (1990), our demand system nests several cases and we leave its interpretation open. We abstract from the effect of changes in income inequalities on demand, but in most models of non-homothetic preferences, demand for high-quality goods increases with inequality.

kets. And since a trade liberalization makes a country less remote, it should accordingly shift demand toward high-quality goods.

There is a vast literature explaining the increase in skill premium following trade liberalizations in developing countries. Although the model incorporates the main mechanisms proposed, quantitatively they do not explain the Colombian experience. Bustos (2011), Helpman et al. (2012) and Verhoogen (2008) propose export expansion and increase in firm size, which as mentioned above, did not occur in the aftermath of many trade liberalization episodes—especially unilateral liberalizations, which immediately boosted imports and not exports.[7] Burstein et al. (2012) suggest a decrease in the price of capital. Like high-quality inputs in our model, capital cannot reverse comparative advantages—the relative price of skilled labor, capital and of high-quality inputs remain lower in developed countries.[8] The hypotheses of export expansion and of decrease in the price of high-quality inputs are also inconsistent with the strong opposition of industry associations to trade reforms since they generally benefit firms.[9] Caron et al. (2012) is the only other paper with a demand-side explanation for the increase in skill premium, but changes there are driven by economic growth, not trade.

Trade increases the demand for skilled workers in poor and rich countries in models of skill-bias technology change, such as Acemoglu (2003), Thoenig and Verdier (2003), Wood (1995). Although our focus is on developing countries, our model is not necessarily inconsistent with patterns in developed countries.[10] Competition increases productivity in several other models with Bertrand competition or x-inefficiencies.[11] Our question is different, however. Compe-

[7]Exports expanded early in countries that joined the WTO, such as Mexico (Feenstra, Hanson (1997)) and Vietnam (McCaig, Pavcnik (2012)). In India and many Latin American countries where trade liberalizations were unilateral, exports did not expand until about ten years after the trade liberalization. Increases in skill premium and skill intensity in manufacturing typically occur within the five years of the liberalization. Bustos studies the introduction of Mercosur, not the large Argentinean unilateral trade liberalization that preceded it.

[8]Decreases in the price of high-quality intermediates and capital is studied in Goldberg et al. (2010, 2012), though not in the context of the labor market.

[9]See Edwards (2003).

[10]The entry of low-quality goods in a developed country will not decrease the relative demand for high-quality goods depending on the interpretation of preferences. In addition, Bloom, Draka and Van Reenen (2011) find that only large firms in Europe invest with the penetration of imports from China. Firms in our model are infinitesimal, but large firms may endogenize consumer behavior. Heuristically, if a large high-quality American firm upgrades the quality of its output, it may decrease the relative demand for the low-quality goods of Chinese competitors. This case is studied theoretically in Aghion et al. (2005).

[11]Aghion and Howitt (2005) survey models of Bertrand competition. Holmes and Schmitz (2010) sur-

tition in these models should explain the efficiency of a country in making its comparative advantage good, not the failure to produce them after a trade liberalization. We present the model in section 1 and estimate it in section 2 and conclude in section 3.

1 The model

Preferences are in section 1.1, technologies in section 1.2, and equilibrium in section 1.3. The model is static. There are two countries, Home and Foreign. Foreign variables are denoted with an asterisk. With our empirical application to a small country—Colombia—in mind, we take all Foreign variables as exogenous and focus on Home. There is a continuum of goods indexed by ω. The set of goods in Home is Ω and in Foreign Ω^*, with $|\Omega| = |\Omega^*| = 1$. Consumers supply inelastically their endowments of skilled and unskilled labor.

1.1 Demand

Consumer take the price $p(\omega)$ and quality $q(\omega)$ of each good $\omega \in \Omega \cup \Omega^*$ as given, and choose quantities to maximize a CES demand function, where the value that the consumer attributes to good ω is a function $\Phi(q(\omega), Q)$ of the good's intrinsic quality $q(\omega)$ and a reference point Q:

$$X(Q) = \left[\int_{\Omega \cup \Omega^*} (x(\omega))^{(\sigma-1)/\sigma} \Phi(q(\omega), Q)^{1/\sigma} d\omega \right]^{\sigma/(\sigma-1)} \tag{1}$$

and $\sigma > 1$ is the elasticity of substitution. The reference point Q is fixed and depends on the interpretation of demand. It may be the overall quality of consumption in the previous period if there is habit formation, the set of goods available in the market under "keeping up with the Joneses" preferences, the consumer's level of utility if preferences are non-homothetic, and the overall quality of the consumer's consumption bundle if there are complementarities in the demand for high-quality goods. Throughout the paper, we take Q as an exogenous parameter and endogenize it in the appendix.

vey models with X-inefficiency or agency problems within firms. Caliendo and Rossi-Hansberg (2012) consider the organization of the firm. Models that interpret increases in competition as increases in the elasticity of substitution across products lead to increases in productivity only if the size of surviving firms increases (see Vives (2008) for a survey).

Assume Φ is strictly increasing in the first argument. Since Q is fixed, equation (1) represents CES preferences—quality can always be re-scaled to $q(\omega) = \Phi(q(\omega), Q)$. But we introduce parameter Q because, in section 2 below, we estimate the model with two cross-sections—one before and one after the trade liberalization—and we allow Q to change between these two cross-sections. Assume Φ is decreasing in Q and that the decrease is disproportionately large for low-quality goods. Figure 1 illustrates three examples of functions Φ satisfying these assumptions. For simplicity, we assume Φ takes the form of a logistic cumulative distribution, as illustrated in panel (c),

$$\Phi(q, Q) = \frac{\exp(q - Q)}{1 + \exp(q - Q)}. \tag{2}$$

This functional form is convenient because Q, the mode of the logistic distribution, captures in a single parameter the relative demand for low- versus high-quality goods. It also facilitates the introduction of intermediate inputs in section 1.2 below. Given Q, the consumer's problem is standard. Let I be the consumer income. The CES price index P and spending $r(q, p)$ on a good with price p and quality q are

$$P(Q) = \left[\int_{\Omega \cup \Omega^*} p(\omega)^{1-\sigma} \Phi(q(\omega), Q) d\omega\right]^{1/(1-\sigma)}, \tag{3}$$

$$r_c(q, p) = \left[\frac{p}{P(Q)}\right]^{1-\sigma} \Phi(q, Q) I. \tag{4}$$

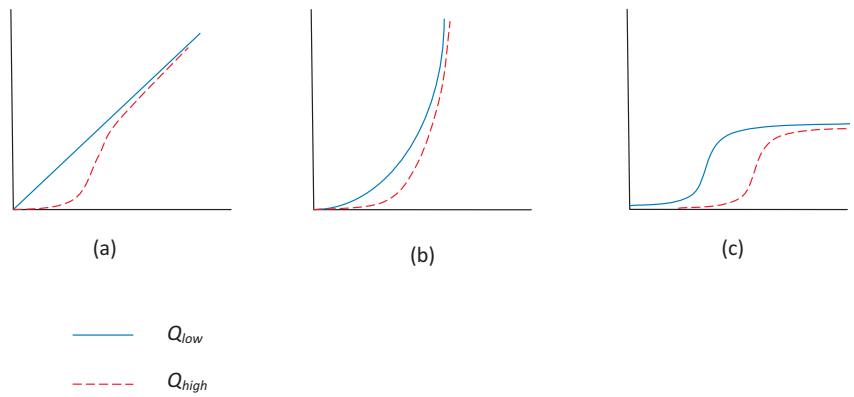
1.2 Production

Each good $\omega \in \Omega$ is potentially produced by a monopolistically competitive firm. The set of active firms is endogenous because, with fixed production costs, some firms may choose to exit. But the set of potentially active firms Ω is exogenous.[12] Firms use skilled and unskilled labor and inputs for production. To produce quality q, the firm pays a fixed cost of $f(q)$ units of a composite of labor, and to import Foreign varieties Ω^*, it pays f_I units of labor. We assume for simplicity that this composite contains one unit of skilled and one of unskilled labor.[13] After

[12]Free entry is inconsistent with the increase in firm exit and decrease in firm size observed in the short and medium-term aftermath of trade liberalizations.

[13]The differential access to Foreign goods by consumers and firms can be eliminated by assuming all firms and consumers can access foreign markets, but they need to pay an additional markup for the

Figure 1: Examples of Φ function



incurring these fixed costs, the output of firm ω when producing quality q with import status $1_I \in \{0,1\}$ is

$$\tilde{\alpha} z(q,\omega) L(q)^{\alpha} X(q)^{1-\alpha} \tag{5}$$

$$\text{where} \quad X(q) = \left[\int_{\Omega \cup \Omega^*(1_I)} x(\omega')^{(\sigma-1)/\sigma} \Phi(q(\omega'), q)^{1/\sigma} d\omega' \right]^{\sigma/(\sigma-1)},$$

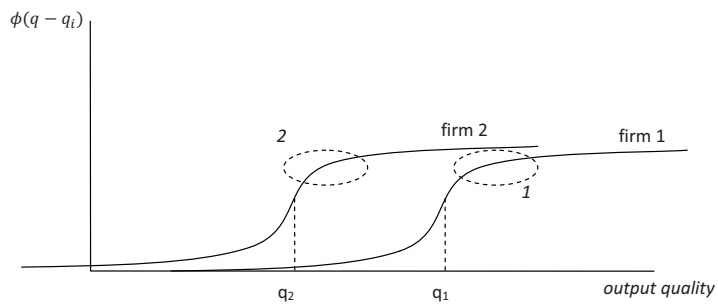
$$L(q) = \left[\sum_{i \in \{s,u\}} l_i^{(\sigma_L-1)/\sigma_L} \Phi_L(i,q)^{1/\sigma_L} \right]^{\sigma_L/(\sigma_L-1)},$$

$\tilde{\alpha} = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}$ is a constant, $z(q,\omega)$ is a firm- and quality-specific productivity parameter, $x(\omega')$ and $q(\omega')$ are the quantity and quality of variety ω', $\Omega^*(0) = \varnothing$ and $\Omega^*(1) = \Omega^*$, l_s and l_u are the quantities of skilled and unskilled labor. Production is a Cobb-Douglas aggregate between labor $L(q)$ and intermediate inputs $X(q)$.

The CES aggregate $X(q)$ is the same as in the utility function (1) but the consumer's reference quality Q is replaced with the firm's output quality q. By equation (2), firms are particularly sensitive to changes in the quality of inputs whose quality is close to its output. Figure 2 illustrates the demand shifter $\Phi(q, q_i)$ for two firms $i \in \{1,2\}$ with output qualities $q_1 > q_2$. If

distribution costs. Firms can alternatively pay a fixed cost to forgo these distribution costs.

Figure 2: Demand for intermediates from two firms with different output qualities



prices increase slowly with quality, firm 1 concentrates her purchases in oval 1 and demands on average inputs of higher quality than firm 2.

Function $\Phi_L : (\{s, u\} \times \mathbb{R}_+) \to \mathbb{R}_+$ governs how skill intensity changes with quality. Denote with w_s and w_u the wages of skilled and unskilled labor, respectively. A firm's skill-intensity is its demand for skilled relative to unskilled workers:

$$\frac{l_s}{l_u} = \left(\frac{w_s}{w_u}\right)^{-\sigma_L} \frac{\phi_L(s, q)}{\phi_L(u, q)}.$$

It decreases in the skill premium $\frac{w_s}{w_u}$ and increases in output quality if $\frac{\phi_L(s,q)}{\phi_L(u,q)}$ is increasing in q.

Firms pay a fixed cost f_X units of composite labor to access the Foreign market with demand

$$r^*(q, p) = p^{1-\sigma} \Phi(q, Q^*) I^*.$$

As in Melitz (2003), more productive firms are more likely to export. And if $Q^* > Q$, the relative demand for high-quality goods is higher in Foreign, firms with higher output quality are also more likely to export. The cost of labor and material inputs for producing quality q

with import status 1_I is

$$c(q, 1_I) = w(q)^{\alpha} P_M(q, 1_I)^{1-\alpha},$$

where $w(q) = [\sum_{i=s,u} w_i^{(1-\sigma_L)} \Phi_L(i, q)]^{1/(1-\sigma_L)}$ is the CES price of labor, $P_M(q, 1) = P(q)$ is in equation (3) and $P_M(q, 0) = P_\Omega(q)$ is the corresponding index for Home goods only (subscript M stands for materials). Importing decreases variable costs of production—$P_M(q, 1) < P_M(q, 0)$ for all q. Since this benefit is proportional to size and the cost f_I is not, large firms are more likely to import. If, in addition, the quality of Foreign goods is high, high-quality firms gain more from importing. The decision to import and export cannot be disentangled—exporting increases the scale of production rendering imports more profitable, and importing decreases variable costs rendering exports more profitable. Similarly intertwined is the decision of output quality since importing and exporting yield higher profits from quality upgrading.

The remaining specification of the model is standard. Let $\bar{w} = w_1 + w_2$ be the cost of the composite labor, $\mu = \frac{\sigma}{\sigma-1}$ be the markup, $r(q, p)$ be the home demand function (equation (7) below), and $r_T(\omega) = [r(q(\omega), p(\omega)) + 1_X(\omega) r^*(q(\omega), p(\omega))]$ be the firm's total revenue. Then, firm ω's demand for skilled and unskilled labor is

$$w_i l_i(\omega) = \left(\frac{w_i}{w(q(\omega))} \right)^{1-\sigma_L} \phi_L(i, q(\omega)) R_L(\omega) \qquad \text{for } i = s, u$$

where $R_L(\omega) = (\alpha/\mu) r_T(\omega)$ is the firm's total spending on labor. The firm's spending on an input with quality q and price p is

$$r_M(q, p, \omega) = \left(\frac{p}{P_M(q(\omega), 1_I(\omega))} \right)^{1-\sigma} \Phi(q, q(\omega)) R_M(\omega) \tag{6}$$

where $R_M(\omega) = [(1-\alpha)/\mu] r_T(\omega)$ is total spending on inputs. Aggregating over consumers and firms (equations (4) and (6)), spending on a variety with price p and quality q in Home is

$$r(q, p) = r_c(q, p) + \int_\Omega r_M(q, p\omega) d\omega = p^{1-\sigma} \chi(q) \tag{7}$$

$$\text{where} \quad \chi(q) = \Phi(q, Q) P(Q)^{\sigma-1} I + \int_\Omega \Phi(q, q(\omega)) P_M(q(\omega), 1_I(\omega))^{\sigma-1} R_M(\omega) d\omega.$$

Function $\chi(q)$ summarizes the country-wide demand for quality q: Each type of spending, consumers' I and firms' $R_M(\omega)$, is weighted by its own relative demand for quality q. If Φ is constant in its second argument, all agents have the same relative demand for high- and low-quality goods, and $\chi(q)$ reduces to a function of aggregate prices, aggregate absorption and a demand shifter associated with q.

Firm ω sets $p = \mu c(q, 1_I)/z(q, \omega)$ and chooses quality q, entry 1_E, import status 1_I and export status 1_X to maximize profits:

$$\pi(\omega) = \max_{q, 1_E, 1_I, 1_X} 1_E \left\{ \sigma^{-1} \left[r(q,p) + 1_X r^*(q,p) \right] - \bar{w} \left[f(q) + 1_I f_I + 1_X f_X \right] \right\}. \tag{8}$$

A firm's operating profit $\sigma^{-1} \left[r(q,p) + 1_X r^*(q,p) \right]$ is proportional to the firm's productivity, $z(q,\omega)^{\sigma-1}$, while the cost of quality upgrading $\bar{w} f(q)$ is fixed. As a result, more productive firms endogenously choose higher quality.

1.3 Tariffs, trade and equilibrium

The price $p(\omega)$ that agents at Home pay for $\omega \in \Omega^*$ includes ad valorem tariff τ imposed by the Home government: $p(\omega) = (1+\tau) p^*(\omega)$ where $p^*(\omega)$ is the unit price of a Foreign variety $\omega \in \Omega^*$ after trade costs.[14] Home's imports from Foreign is $R_{HF} = R^{\tau}_{HF}/(1+\tau)$ where R^{τ}_{HF} is after-tariff spending on Foreign goods:

$$R^{\tau}_{HF} = \left[\frac{P_{\Omega^*}(Q)}{P(Q)} \right]^{1-\sigma} I + \int_{\Omega} 1_I(\omega) \left[\frac{P_{\Omega^*}(q(\omega))}{P(q(\omega))} \right]^{1-\sigma} R_M(\omega) d\omega.$$

where $P_{\Omega^*}(Q)$ is the CES price index in equation (3) corresponding only to Foreign goods Ω^*. Home's exports to Foreign:

$$R_{FH} = \int_{\Omega} 1_X(\omega) r^*(q(\omega), p(\omega)) d\omega.$$

Following Dekle, Eaton and Kortum (2008), we admit trade deficits but take them as exogenous. Denoting this Home's trade deficit with D_H, trade is in equilibrium if $R_{HF} = R_{FH} + D_H$.

[14] We make the standard assumption that Foreign factors are used to transport Foreign goods.

The government redistributes tariff revenues $T = \tau R_{HF}$ to consumers through a lump sum transfer. Consumer spending is

$$I = w_s L_s + w_u L_u + \int_\Omega \pi(\omega) d\omega + T + D_H.$$

The labor markets clear if

$$L_i = \int_\Omega \left[l_i(\omega) + f(q(\omega)) + 1_I(\omega) f_I + 1_X(\omega) f_X \right] d\omega \qquad \text{for } i = s, u. \tag{9}$$

To summarize, an economy is defined by Home's endowments L_s and L_u, firm-specific technologies $z(q, \omega)$, economy-wide fixed costs $f(q)$, f_I and f_X, tariffs τ and deficit D_H, and by Foreign's demand shifters Q^* and I^* and the set of firm prices and quality levels $\{p^*(\omega), q(\omega)\}_{\omega \in \Omega^*}$. An equilibrium is a set of wages w_s and w_u that clears the labor markets in equation (9). More productive firms choose higher quality and become larger. They demand relatively more skilled labor and high-quality goods, and they are more likely to import and export.

We now turn to the empirical analysis. Section 2.1 presents a background of the Colombian trade reforms and the data, and sections 2.2 and 2.3 estimate the model.

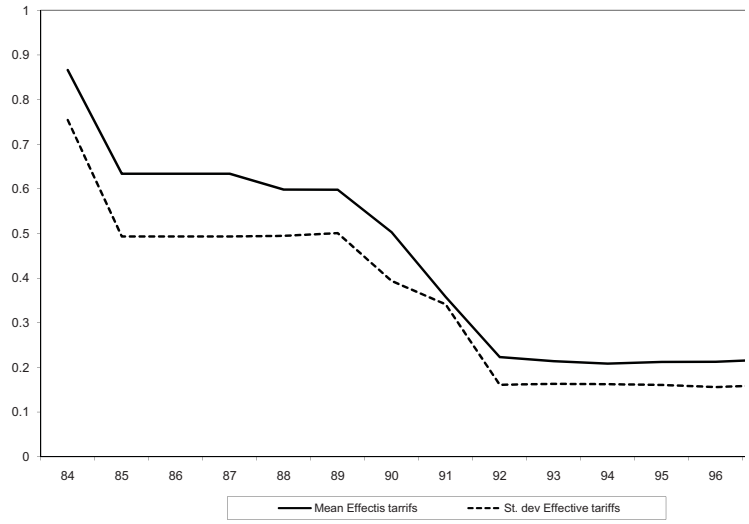
2 Empirical Analysis

2.1 Background of the Colombian trade liberalization

Following international trends, Colombia significantly reduced trade barriers in a broad range of industries between 1985 and 1991 after a long period of import substitution policies.[15] Non-tariff barriers, which affected 99.6% of industries in 1984, were removed, and the average tariff decreased from 27% to 10%. Figure 3 shows the evolution of effective tariff rates between 1984 and 1996. Most decreases were concentrated in 1991. Arguably, they were also unexpected. In 1990, the newly-elected Gaviria administration designed a four-year plan to reduce trade bar-

[15] Attanasio et al (2004) and Edwards (2001) describe reforms in Colombia. The trade liberalization was accompanied by reforms in the labor and financial markets, but these were less comprehensive because they stalled for political reasons. See also Lora (2001).

Figure 3: Effective tariffs, mean and standard deviation 1984-1996



riers, but after a few months under the impression that uncertainty was holding back changes in firms, the government decided to abruptly implement the whole plan.

We use the Colombian Annual Manufacturing Survey which comprises all manufacturing plants in Colombia with 10 or more workers. We use two sample years: 1988 as pre-liberalization and 1994 as post-liberalization.[16] For each plant, the data in 1988 contain the value of domestic sales and export sales, and the value of domestic and imported inputs. The number of workers and wage bill is reported separately for managerial, white-collar and blue-collar workers. We define the share of skilled workers is as the number of managerial plus white-collar workers divided by total number of workers. The survey changed during the years of interest. In 1994, there is no plant-specific data on imports and exports. We use only total imports and exports aggregated by sector. The firm identification numbers changed in 1990. So, our estimation will only use the joint distribution of firm characteristic in each cross-section, not information on firm exit or within-firm changes. Last, the classification of employees changed in 1995, preventing us from using a longer time horizon for our analysis of skill intensity.

[16]In the appendix, we plan to repeat the exercise for 1987 for robustness.

2.2 Pre-liberalization cross-section

We estimate the model to the chemical sector, which includes final goods sub-sectors such as pharmaceutical, cosmetics and household cleaning products.[17] We choose the chemical sector merely because it has more firms than other sectors. Its cross-sectional and time-series patterns are similar to other sectors, as presented in the appendix **??**. This is consistent with other papers that find that systematic variations occur mostly within sectors and are similar across sectors.[18] The purpose of our empirical exercise is twofold. First, the model provides a unified framework delivering well-documented correlations between firm size, wages, skill-intensity, input and output prices and import and export behavior. This section describes its parametrization, identification issues and its ability to quantitatively match the joint distribution of these firm characteristics, and thereby quantify the importance of economies of scale and high-quality intermediate inputs in the production of skill-intensive high-quality goods, and their relative demand abroad. Section 2.3 below allows for few parameters to change to match the import penetration, export expansion, changes in the distribution of firm size and skill intensity.

2.2.1 Estimation procedure and identification

We use the simulated method of moments. For each guess of the parameter estimates and each guess of wages, we simulate the behavior of 5000 firms who choose quality levels from a quality grid with 400 choices $q \in [0, 8]$. We iterate over wage guesses until equilibrium equations (9) hold. Table 4 lists the parameters to be estimated. There are 16 parameters to be matched with 47 moments describing the joint distribution of firm characteristics. We set $\tau = 20\%$ the average tariff on chemicals in 1988, use foreign prices as the numeraire, $p^*(\omega) = 1$ for all $\omega \in \Omega^*$, and set the input share $\alpha = 0.3$ in the production function (5). We discuss the identification of our parameters as we present their parametrization below.

[17] Sectors in Colombian manufacturing are classified according to their raw materials, for example, "plastics" and "metal products" contain goods of final and intermediate usage.

[18] See for example Bernard et al. (2003) for cross-sectional patterns and Helpman et al. (2012) for changes in the labor market.

Table 1: List of parameters

variable	description	# param.
$z(0,\omega)$	productivity levels at $q=0$	2
$f(q)$	fixed cost of production (mean)	3
$\Phi_L(q,s)$	productivity of skilled workers	2
f_M	fixed cost of importing (mean)	1
f_X	fixed cost of exporting (mean)	1
q^*	quality of Foreign firms	1
Q^*	reference quality of Foreign demand	1
D_H	trade deficit of Home	1
sources of noise		
$z(q,\omega)$	normal with mean zerop	1
f_M	fixed cost of importing (variance)	1
f_X	fixed cost of exporting (variance)	1
σ_s	measurement error of skill-intensity (variance)	1
total		**16**

Quality scale, $f(q)$, Q. Let $Q=0$. Then, the assumption $\Phi(q,Q)=\frac{\exp(q-Q)}{1+\exp(q-Q)}$ normalizes the quality scale, by eliminating the variance and mean of the logistic distribution. Assume

$$f(q)=f_1+f_2q+f_3q^2.$$

The fixed cost of production $f(q)$ governs the dispersion of quality choices across firms. If qualities choices are very similar, firms' choices of inputs will be independent of firm size, and their decision on import and export status and intensity would depend only on firm size, not on skill intensity. Hence, the dispersion in input prices and on import and export intensities, controlling for size, provide information on $f(q)$.

Firm size, $z(q,0)$, I^*, σ, L_u, L_s^*. Firms' productivity parameters at quality $q=0$, $z(q,0)$, are independently drawn from a log-normal with mean and variance parameters μ_1, σ_1, respectively. They capture primarily the unconditional distribution of sales across firms. Our moments below refer only to the distribution of normalized sales (divided by total sales in the sector in Colombia), not to sales in Colombian pesos or dollars. Hence, in the model, we also need to fix the size of the domestic or of the foreign market. We set $I^*=1$. Then, the mean productivity parameter μ_1 governs the size of the domestic relative to the foreign market, thus

governing the overall level of export intensity. We also normalize total employment by setting $L_u = 1$ and $L_s = 1.04$ to match the ratio of skilled to unskilled workers in the data.

The elasticity of substitution σ is not separately identified from productivity. A decrease in the elasticity of substitution makes the distribution of sales more dispersed across firms with different prices and the same quality. But such dispersion can always be offset with increases in the variance of $z(q, 0)$ and quality-adjusted prices are not observed. We set $\sigma = 5$ following Broda and Weinstein (2004) and experiment with different values in the appendix.[19]

Skill premium, skill intensity, $\Phi_L(q, i)$, σ_L Assume

$$\Phi_L(q, u) = \bar{\phi}_L(q)$$
$$\Phi_L(q, s) = \bar{\phi}_L(q)(l_1 + l_2 q)$$

where l_1 and l_2 are parameters to be estimated and $\bar{\phi}(q)$ is judiciously adjusted for every guess of l_1 and l_2 so that the CES price of labor $w(q)$ is constant. Without $\bar{\phi}_L$, l_1 and l_2 increase the productivity of producing high-quality goods. With $\bar{\phi}_L$, l_1 and l_2 have only an effect on skill premium and skill intensity, not on a firm's profit or quality choice. The elasticity of substitution across skilled and unskilled labor is not identified in our data set. So, we set $\sigma_L = 1.6$ following Katz and Murphy (1992) and Acemoglu and Autor (2010).[20]

Import and export behavior, $\bar{f_M}$, $\bar{f_X}$, q^*, Q^*, D_H The average fixed costs of importing $\bar{f_M}$ and exporting $\bar{f_X}$ govern the share of firms that import and export, respectively. Given the size of the domestic and foreign markets (above), the trade deficit D_H controls the aggregate import intensity. The quality of foreign imports $q(\omega) = q^*$ governs how the share of imported inputs varies with firm size and skill intensity, and analogously, the shifter of Foreign demand Q^* governs how export intensity varies with firm size and skill intensity.

[19]To identify σ, we would need to observe changes in prices holding a firm's quality fixed. Studies such as Broda and Weinstein (2004) that measure the elasticity of substitution across goods within product categories assume goods within a product category have the same quality.

[20]Unlike these papers, we do not observe the level of education of workers and cannot infer σ_L from variations in the wage premium and skill intensity. See more below (subsection on noise) on the crudeness of our skill measure.

Sources of noise, $z(q,\omega)$, σ_s, $f_M(\omega)$, $f_X(\omega)$ Our measure of skill-intensity, managers plus technical workers divided by total number of workers, is rather crude. In the data, the correlation of firm size and skill intensity is only 0.06 and of firm size and average wages is 0.29. Our interpretation is that firms observe skill better than we econometricians and that wages reflect actual ranking of skill intensity across firms.[21] Since wages are not perfectly correlated with firm size, we allow firms productivity parameters to vary not only in their levels but also in their slopes:

$$z(q,\omega) = \max\{0, z(0,\omega) + z_2(\omega)q\}$$

where $z(0,\omega)$ has a log-normal distribution, and $z_2(\omega)$ has a normal distribution with mean zero and variance parameter σ_2. To match weaker link between skill intensity and sales, we also assume that skill intensity is observed with noise. The observed skill intensity of firm ω is[22]

$$\frac{l_s(\omega)\mu(\omega)}{l_s(\omega)\mu(\omega) + l_u(\omega)} \tag{10}$$

where $l_s(\omega)$ and $l_u(\omega)$ is the firm's actual demand for skilled and unskilled labor and $\mu(\omega)$ is a measurement error distributed according to a log-normal with parameters $\mu = 0$ and σ_s to be estimated.

Finally, to match the joint distribution of firm size and import and export status, we assume

[21] We rule out the hypothesis that larger firms pay higher wages because of profit-sharing as in Helpman et al. (2009). See also Eeckhout and Kircher (2009) on issues with identifying this premium. We use moments only referring to the rank of wages across firms because the model with just two skill types is too stylized to match the distribution of wages—wages are much more dispersed in the data than a variation in skill intensity from 0 to 100% would imply.

[22] It is important to match these the unconditional distribution of skill intensity because a key moment comparing the pre- to the post-liberalization data is the overall change in skill intensity. The distribution of skill intensity with size, in turn, disciplines the extent of economies of scale in the production of high-quality goods. As firm size changes with the trade liberalization, firms adjust quality choices accordingly.

fixed costs f_M and f_X are firm specific:[23]

$$f_M(\omega) = \bar{f_M}\mu_M(\omega)$$
$$f_X(\omega) = \bar{f_X}\mu_X(\omega)$$

where $\mu_M(\omega)$ and $\mu_X(\omega)$ are independently distributed across firms according to log-normal distributions with mean parameters zero and variance parameters σ_M and σ_X, respectively.

Prices We have not yet gotten the moments related to input and output prices from Colombia. To match these prices, we plan to redefine $\Phi(q, Q)$ and $z(q, \omega)$ as

$$\Phi'(q, Q) = \bar{\phi}(q)\Phi(q, Q)$$
$$z'(q, \omega) = \bar{z}(q)z(q, \omega)$$

where $\Phi(q, Q)$ and $z(q, \omega)$ are defined as above. It is easy to see that firms' choices of quality levels and importing and exporting behavior remain unchanged if $\bar{\phi}(q)\bar{z}(q)^{\sigma-1} = 1$ for all q. That is, potential decreases in productivity $\bar{z}(q)$ with quality q are exactly offset with an increase in the demand shifter $\bar{\phi}(q)$. Then, although the other predictions do not change, a firm's unit price is $\frac{C(q,1_I(\omega))}{\bar{z}(q)z(q,\omega)}$ depends on $\bar{z}(q)$ and so do systematic variations of unit prices with firm size.

Moments Most moments are displayed on tables 4 and 3. On table 2, we classify firms according to their quartile of domestic sales. For each group of firms, we match the total skill intensity, the percentage of firms importing and exporting, the spending on imported inputs divided by total spending on inputs pand the export revenue divided by total revenue. On table 3, we match five percentiles of the unconditional distribution of domestic sales (normalized by total sales in the chemical sector) and export sales. The moment of the model corresponding to these distributions of skill intensities is the observed skill intensity by firm in equation 10. We then classify firms by their quartile of domestic sales and their quartile of average wage in

[23]The variation of firm size with skill intensity governed by $z_2(\omega)$ generates some variation in the firm's choice of importing and exporting even after controlling for size. But the variations in the data are larger. We find that without these firm-specific costs, the estimates of q^* and Q^* are distorted because the moments that reflect import and export intensity are aggregated across firms of similar size (below).

Table 2: Joint distributions of firm size with other characteristics (quartile 4 is the largest)

	quartiles of domestic sales			
	1	2	3	4
skill intensity				
data	0.38	0.40	0.49	0.51
model	0.47	0.46	0.48	0.53
share of importing plants				
data	0.25	0.49	0.72	0.90
model	0.05	0.22	0.79	0.99
share of exporting plants				
data	0.02	0.09	0.19	0.66
model	0.00	0.08	0.09	0.73
spending on imported inputs/total				
data	0.07	0.20	0.25	0.50
model	0.01	0.16	0.46	0.55
export sales/total sales				
data	0.02	0.01	0.01	0.09
model	0.00	0.00	0.01	0.09

Table 3: Unconditional distribution of firm size and of skill intensity

				percentiles	
	10%	25%	50%	75%	90%
ln(normalized domestic sales)					
data	-13.3	-12.6	-11.5	-10.1	-8.9
model	-13.7	-12.2	-10.3	-8.3	-6.7
skill intensity					
data	0.18	0.30	0.46	0.61	0.73
model	0.15	0.27	0.47	0.66	0.80

the data. This forms a grid of 16 potential bins classifying firms. We match the percentage of firms in each bin. The classification of firms by quartile of wage in the model reflects the firm's true skill intensity, without measurement error. Finally, we match the overall skill premium in the sector, $\frac{\text{average wage of skilled workers}}{\text{average wage of unskilled workers}} = 1.92$. There are 30 moments on tables 4 and 3, 16 moments in the joint distribution of domestic sales and wages, and the skill premium, yielding a total of 17 moments.[24]

[24]We take the weights to be the inverse of the variance of each moment, where the variance is calculated by randomly drawing the set of firms with replacement and recalculating the moments.

Table 4: List of parameters

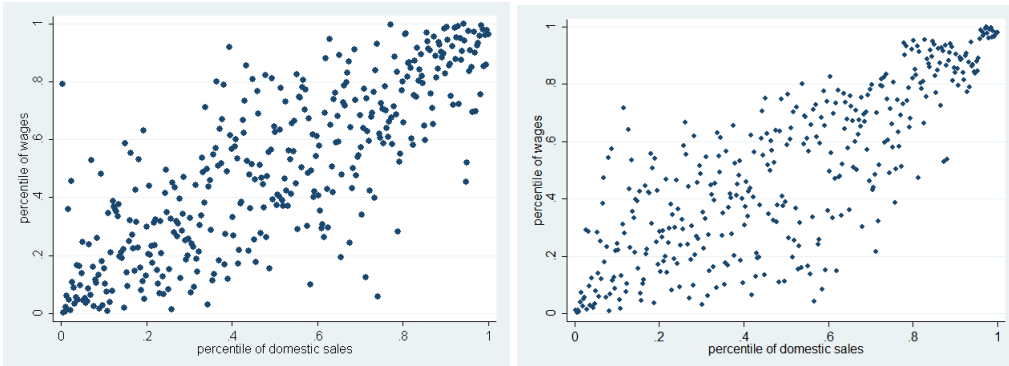
model parameter	variable	estimate
$z(0,\omega)$	μ_1	-1.6
	σ_1	0.84
$f(q)$	f_1	5e-5
	f_2	3e-6
	f_3	4e-11
$\Phi_L(q,s)$	l_1	0.017
	l_2	0.696
f_M	$\bar{f}_M$	0.002
f_X	$\bar{f}_X$	0.008
q^*		4.95
Q^*		5.09
D_H		1.21
sources of noise		
$z(q,\omega)$		0.0035
f_M	var	1.0
f_X	var	1.0
σ_s	var	1.1

2.2.2 Results

Table displays the parameter estimates (standard errors are not yet available). In equilibrium, all firms choose quality between 2.1 and 4.8. So, the quality of the foreign goods at $q^* = 4.95$ is comparable to the highest-quality firms in Colombia, and the Foreign reference quality $Q^* = 5.1$ is well above the reference point for the Colombian consumer and firms. Tables 2 and 3 show moments on the distribution of firm characteristic in the data and in the model. The model is able to replicate quite well the joint distribution of firm size, skill intensity, and import and export status and intensity. The model does not replicate well the right tail of the unconditional distribution of firm size—the data exhibits a thicker tail than that implied by the log-normal distribution of technologies.[25] As shown in figure 4, the model is also able to replicate well the tight correlation between a firm's wage and its domestic sales.

Firms' choice of quality, import and export behavior Consider the problem of a non-exporting firm ω in choosing its output quality. For simplicity, assume its productivity is

[25]We tried a Pareto distribution and it does very badly on left tail. A distribution like the double exponential that combines both should do better.



(a) Data (b) Model

Figure 4: Distribution of firm domestic sales and wage

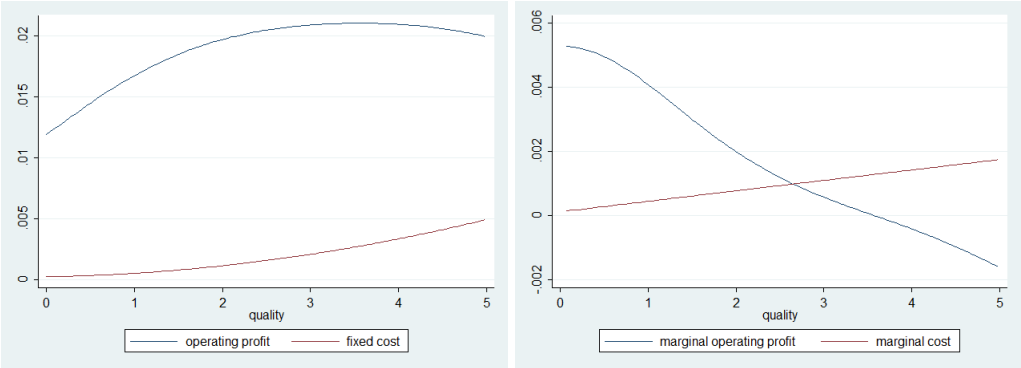
$z(q,\omega) = z$ for all q and its import status is $1_I = 0$. Its profit will then be:

$$z^{\sigma-1}\left[(c(q,0)/\mu)^{1-\sigma}\chi(q)/\sigma\right] - \overline{w}f(q) \tag{11}$$

The first term is the firm's operating profit and the second, the fixed cost. Figure 5(a) illustrates the two terms for a fictitious firm, where the terms $\left[c(q,0)^{1-\sigma}\chi(q)/\mu\right]$ and $\overline{w}f(q)$ are taken from the estimates in section 2 below.[26] The operating profit is initially increasing, peaks at $q = 3.6$ and then declines. The demand term $\chi(q)$ is always increasing but the cost $c(q,0)$ increases in q as high-quality inputs become expensive or unavailable in the domestic market. Figure 5 illustrates the firm's first order conditions—i.e., the derivative of equation (11) with respect to q. The firm will choose quality $q = 2.6$, where marginal operating profit equals marginal profit. The firm's total profit is the area between the marginal operating profits and cost (minus the production cost at $q = 0$).

More productive firms choose higher quality because the cost $\overline{w}f(q)$ is fixed and the operating profit is proportional to the firm's productivity. Graphically, an increase in the firm's productivity z shifts the marginal profit curve upwards and increases the firm's quality choice. Figure 6 illustrates the firm's choice of quality for different import and export status. The marginal operating cost of the domestically-oriented firm is the same as in figure 5. Importing and exporting both shift the marginal profit curve to the right. Importing decreases the cost

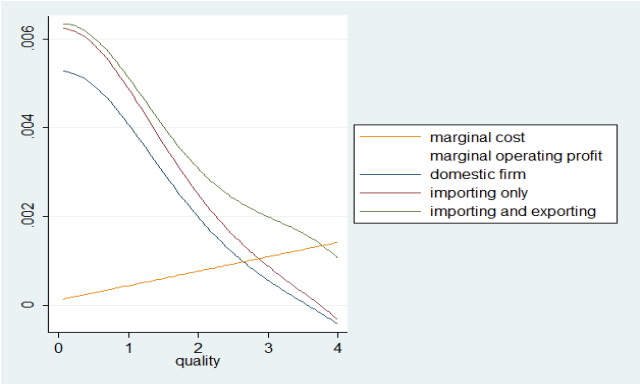
[26]The firm in figure 5 has productivity $z(0,\omega)$ at the 25th percentile.



(a) profit (b) first order conditions

Figure 5: A firm's choice of output quality

Figure 6: Choice of output quality and international trade



of producing high-quality, $c(q)$ as higher-quality inputs become available, and exporting increases the relative demand for high-quality goods. Both activities increase the firm's choice of output quality and its operating profit. The firm engages in international trade if the increase in profit offsets the fixed cost of importing and exporting.

2.3 Pre- versus post-trade liberalization

Figure 7(a) displays the kernel density of the distribution of firm size in 1988 and 1994, where firm size is a firm's total sales (domestic plus exports) divided by the total sales in the sector where the firm operates, and figure 7(b) displays the distribution of skill-intensity.[27] There

[27] The normalization of firm size by the size of the market is standard (see Tybout (2003)). It purges the effect of inflation and growth between 1988 and 1994, which are not associated with trade liberalizations. We realize the figures need cleaning and the title of panel (a) is wrong. We plan to correct it, but we are waiting for new graphs from Colombia. We are also waiting for the distribution of firm size, where size

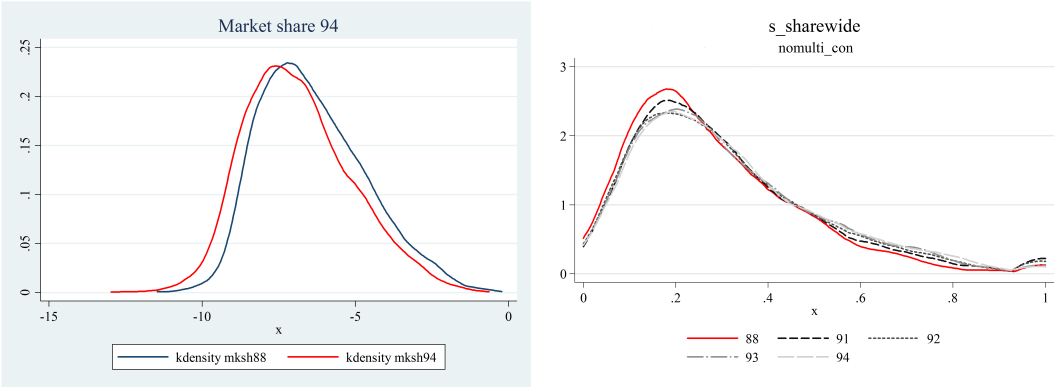


Figure 7: Distribution of firm size and skill intensity in 1988 and 1994

is a shift to the left in the distribution of firm size and to the right in the distribution of skill intensity. Firms generally decreased their scale of production and increased their skill intensity. These patterns are difficult to reconcile in standard models and in the special case of our model where preferences are CES.

3 Conclusion

Even among countries of very different endowments and income levels, specialization in trade occurs largely within sectors. High-income countries typically export high-quality versions of the same products exported by poor countries. We have extended a recent literature that combines the classic model of factor proportions with new trade theory to explain these production patterns in a quantitative framework. But this production set up alone does not change the prediction from classic models that import competition should shift a developing country's production toward its comparative advantage, unskill-intensive goods. In contrast, trade liberalizations in developing countries are marked with increases in demand for skilled labor—the skill premium and skill intensity in manufacturing both increase—suggesting a shift toward the comparative disadvantage, high-quality goods. Firm-level data make this shift even more intriguing because the size of plants generally decreases and the production of high-quality goods is associated with larger plants in the cross-section, suggesting economies of scale.

is measured in number of employees.

We generalize CES preferences to allow for the entry of high-quality goods during a trade liberalization to disproportionately decrease the relative demand for high-quality goods. This effect explains quantitatively the increase in the demand for skilled workers following trade liberalizations in developing countries. It is rationalized in preferences, widely used in macroeconomics, that feature habit formation and status considerations, or complementarities in demand. We hope that such a generalization finds its way to other applications and that future research furthers our understanding of demand in the presence of horizontal- and vertical-product differentiation.

The proposed model bears a clear resemblance with other models where competition induces productivity growth—models of creative destruction à la Schumpeter that study the effect of competition on economic growth.[28] While the new model is static, models of creative destruction account for economic growth but are highly stylized, typically featuring only one active firm. Combining the two approaches may render viable a quantitative study of the effects of competition on growth or the effects of international trade on growth.

[28]See Aghion and Howitt (2005) for a survey.

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