Trade, competition and quality-upgrading: A theory with evidence from Colombia

Marcela Eslava, Ana Cecília Fieler and Daniel Xu

February 13, 2012

Abstract

Contrary to the predictions of a factor-proportions model, trade liberalization episodes in developing countries were followed by sharp increases in the skill-premium in a very short period. These increases are puzzling because the factor-proportions model describes cross-sectional data very well if it is reinterpreted to account for differences in factor intensities across quality levels within sectors. Specifically, a model of heterogeneous firms where high-quality goods are more skill intensive than low-quality goods explains well-documented facts about unit prices in the data on firms and bilateral trade. The standard channels of reallocation, export expansion and access to foreign inputs cannot quantitatively or qualitatively account for the rise in skill premium and changes in skill intensity. We then allow for the entry of high-quality alternatives during a trade liberalization to decrease the relative demand for low-quality goods. This effect, reminiscent of the Bertrand model, has long been used in theory to explain firm-level investments in productivity spurred by tightened competition. Here, this investment takes the form of quality-upgrading. Since higher-quality goods are more skill-intensive, the demand for skill increases. We use a panel data on manufacturing plants in Colombia to estimate the model and evaluate its predictions regarding a counterfactual decrease in tariffs.

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

A standard factor-proportions model of trade predicts that a country should export the goods whose production is intensive in its abundant factors: Oil rich countries should export oil. This model describes well bilateral trade data in manufactures if high-quality goods are more skill intensive than low-quality goods. While a diverse set of countries often exports goods to the same importer and in the same finely defined product category, skill-abundant countries systematically sell goods at higher unit prices.[1] A key prediction of this model is that, if a skill-scarce developing country liberalizes to trade, its production should shift toward its comparative advantage (low-quality) goods, thereby decreasing the demand for skilled workers and their wages relative to unskilled 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%.[2]

Well-documented facts about firms make these findings even more puzzling. Within the same sector and country, large firms are typically more skill-intensive and sell their goods at higher unit prices than average. So, the production of high-quality goods is probably not only skill-intensive but also involves economies of scale. Because demand from the domestic market decreases during a trade liberalization, costly fixed investments could provide further incentives for firms to downgrade. Yet, evidence suggests that quality upgrading was ubiquitous. Despite the rising skill-premium, skill intensity increased in manufacturing in general. It increased within firms and in particular in sectors with large tariff decreases, precisely in sectors where we should expect more quality downgrading as competition from imported high-quality goods shrinks the market share of domestic firms.[3]

We develop a two-country model of heterogeneous firms à la Melitz (2003) to address this

[1]Similar patterns hold for capital. See Schott for other patterns suggesting the skill and capital intensity of high quality goods.

[2]These increases have been documented for numerous countries, including India, Brazil, Argentina, Morocco. The increase in skill premium in Mexico was of 68%, but we exclude it from the range above because the peculiarities in its liberalization. See Feenstra and Hanson (1997).

[3]In line with the hypothesis of quality upgrading, capital-intensity and measured productivity also increased even though these features are associated with larger, high-unit-price firms in the cross-section. They also increased more in the same sectors and firms that became more skill intensive.
See Goldberg and Pavcnik (2004, 2007) for the findings on increases in skill premium and in skill intensity in sectors with large tariff reductions. For productivity and investment increases within firms see Eslava et al. (2011), Pavcnik (2002), Trefler (2004) and references there surveyed. For data on unit prices, see Kugler, Verhoogen (2009,2012), Manova, Zhang (forthcoming).

puzzle. Firms choose the quality of their products from a continuum. Production requires fixed labor costs that are increasing in quality. Since the costs of producing higher quality are fixed and the benefits are proportional to the firm's underlying productivity, more productive firms endogenously choose higher quality and become larger. Goods are used for final consumption and as intermediate inputs. Assuming the production of higher quality is more intensive in skilled-labor and in high-quality intermediates, larger more productive firms are also more skill-intensive and use higher-quality inputs.The model thus explains well the cross sectional correlations between size, skill-intensity and unit prices of inputs and outputs.

It also explains trade well. Firms incur fixed costs to import inputs or export output. If foreign inputs are of higher quality, high-quality producers benefit more from importing than low-quality producers of similar size. Then, importing firms are more skill intensive and pay higher wages than average even after controlling for size. Similarly, if the demand for high- relative to low-quality goods is higher abroad, exporters also pay higher wages.[4]

We [intend to] estimate this model structurally using pre-liberalization data of Colombian manufacturing plants. A counterfactual decrease in tariffs may potentially increase the skill premium in this model for at least three previously proposed reasons.[5] First, a trade liberalization reallocates resources from least productive unskill-intensive exiting firms to skill-intensive survivors. Second, exporters invest in quality upgrading both because their sales expand and to meet demand characteristics of high-income importing countries. Third, the relative cost of producing high-quality goods decreases with the entry of high-quality intermediates.

None of these explanations can explain the data quantitatively or qualitatively. Reallocations do not explain increases in skill-intensity within firms. Export expansion does not explain the correlation between increases in skill intensity and sectoral tariff decreases—tariff changes are associated with import penetration, not necessarily with export expansion. In addition, these liberalization episodes were often unilateral. Import penetration ensued immediately, while

[4]The case of larger relative supply and demand for high-quality goods in the foreign countries is reasonable since most imports and exports of developing countries at the time of their liberalization was with high-income countries. China is now changing this scenario.

[5]See Bustos (2011b), Burstein, Cravino, Vogel (2012), Helpman, Itskhoki, Redding (2010), Verhoogen (2007). For related work, see Goldberg, Khandelwal, Pavcnik and Topalova (2009, 2010) on imported inputs and Aw, Roberts, Xu (2011) for investment in R&D.

exports expanded only several years later, often after the rise in skill premium.[6] Last, the decrease in the cost of high-quality inputs is predicted by the factor-proportions model and cannot account for the failure of developing countries to shift to their comparative advantage goods—namely, the unskill-intensive low-quality varieties. The relative price of high-quality inputs and skilled labor should be even lower in developed countries. Quantitatively, these mechanisms are not strong enough to offset the incentive for non-exporting firms to divest and shift toward unskill-intensive products.

Our novel mechanism is to allow for the entry of high-quality foreign goods to decrease the relative demand for low-quality goods. This effect is reminiscent of the Bertrand model—a special case of our model—where, holding prices fixed, the entry of a high-quality alternative drives demand of low-quality to zero. In our model, a trade liberalization has two effects in the domestic market that affect firms' quality choices in opposite directions. A decrease in residual demand through the price index leads to quality downgrading, and a decrease in the relative demand for low-quality goods leads to quality upgrading.[7] Investment due to the latter effect is the same across firms, but divestment due to the former effect is smaller for ex ante high-quality firms. Because high-quality firms are in a region where the residual demand is more elastic with respect to quality changes, small divestments in quality offsets large decreases in market size. As a result, the net effect on investment, which can be positive or negative, is strictly increasing in the firm's ex ante quality level (see section 2). Similarly, domestic sales decrease for all firms, but it decreases disproportionately for ex ante low-quality firms. These predictions are bore out by our data, where firms with higher pre-liberalization wages (proxy for skill intensity and quality) increase their sales, investment and wages per se relative to other firms.

Improved access to foreign markets provide additional incentives for exporters to invest in quality upgrading. As in Bustos (2011a) and Lileeva and Trefler (2010), these effects are larger for new exporters.

Discuss related literature.

[6] A unilateral trade liberalization expands exports through a general equilibrium effect. Relative wages must decrease (currency depreciate) in the liberalizing country to clear the trade balance. The Colombian trade balance did not return to its pre-liberalization levels until almost ten years after the trade liberalization. These patterns are not unusual.

[7] The use of Bertrand to explain investment when competition is tightened is not new. See Aghion et al. (2005) for example.

1 The Model

The environment is in section 1.1, preferences in section 1.2, technologies in section 1.3, the government in section 1.4 and equilibrium in section 1.5. Section 2 explains the workings of the model.

1.1 Environment

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.[8] There is a continuum of differentiated varieties that are used as final and intermediate goods. Firm ω is the only producer of variety ω, and it chooses its price and quality. Consumers observe prices and quality and choose quantities to maximize preferences. They own all firms and supply inelastically in a competitive market their endowment of skilled and unskilled labor L_s and L_u.

Labor is mobile across goods but not across countries. Differentiated goods are traded. The Home government charges a tariff on imports and transfers its revenues in a lump sum to consumers. Labor and goods markets clear in equilibrium.

1.2 Preferences

All consumers have the same homothetic preferences which are increasing in quality, quantity and variety. They take the price $p(\omega)$ and quality $q(\omega)$ of each good ω as given, and choose a reference quality $Q \in \mathbb{R}_+$ and quantities $\{x(\omega)\}_{\omega\in\Omega}$ to maximize

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

[8] In a monopolistic competition setting if we were to define countries symmetrically, Foreign would need to be of infinite size for its variables to be exogenous. But if Home firms had the option of accessing an infinitely large market they would get infinite profits. Below, a constant $y^* \in \mathbb{R}_+$ captures the size of Foreign. Following Arkolakis (2009), we interpret Home firms as paying a fixed cost to advertise their variety and access a finite portion of an infinitely sized market.

$\sigma > 1$ is the elasticity of substitution, Ω is the set of available varieties from Home and Ω^*, from Foreign, and function $\Phi : \mathbb{R}^2_+ \to \mathbb{R}_{++}$ is a demand shifter. We make specific assumptions on Φ in section 2, but for now, a minimal assumption is that Φ is strictly increasing in the first argument and decreasing in the second, so that a higher-quality input $q(\omega)$ increases utility and a higher-quality output Q is more costly to produce. Quality Q can be thought of as the perceived quality of the consumer's consumption bundle. Together with function Φ, it relaxes the independence of irrelevant alternatives by allowing the relative demand for goods of different quality levels to depend on the whole consumption bundle through Q. The consumer's choice of Q depends on function $h : \mathbb{R} \to \mathbb{R}_{++}$. Except for assuming h is strictly increasing, we remain agnostic about the shape of h and estimate Q directly from the data.

The aggregate CES price index associated with quality Q is

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

Denote by $P(Q)$ the price index of only Home varieties Ω and by $P^*(Q)$ of Foreign varieties Ω^*. For any income y, $X(Q) = y/P_I(Q)$. So, all consumers choose the same quality $Q = \arg\max\{h(Q)/P_I(Q) : Q \in \mathbb{R}_+\}$, which we assume exists. Then, there is a representative consumer with aggregate income y whose spending on a variety with quality q and price p is

$$x_c(q, p) = \left[\frac{p}{P_I(Q)}\right]^{1-\sigma} \Phi(q, Q) y. \tag{2}$$

1.3 Technologies

We describe a firm's technology, derive its demand and set its profit maximization problem. Firm ω chooses the price and quality $(p, q) \in \mathbb{R}^2_+$ of its output $\omega \in \Omega$. To produce quality q, the firm pays a fixed cost of $F(q)$ units of a composite of labor, and to access Foreign varieties Ω^*, it pays F_I units of labor. We assume for simplicity that this composite contain one unit of skilled and one of unskilled labor.[9] After incurring these fixed costs, the production function of

[9] An alternative is to use Cobb-Douglas. 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 distribution costs. Firms can alternatively pay a fixed cost to forgo these distribution costs.

firm ω when producing quality q with import status 1_I is

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

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

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

$\tilde{\alpha} = \alpha^{\alpha}(1-\alpha)^{1-\alpha}$ is a constant, $z(q,\omega)$ is a firm- and quality-specific productivity parameter, $m(\omega')$ 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, and function $\Phi_L : (\{s,u\} \times \mathbb{R}_+) \to \mathbb{R}_+$. The assumptions on Φ above imply that the aggregate intermediate quantity $M(q)$ is strictly increasing in the quality of the intermediate $q(\omega')$ and decreasing in the quality of output q. Analogous to function Φ for intermediates, function Φ_L allows for the productivity of skilled and unskilled labor to depend on output quality. The firm's unit cost is

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

where $w(q) = [\sum_{i=s,u} w_i^{(1-\sigma_L)} \Phi_L(i,q)]^{1/(1-\sigma_L)}$ is the CES price index of labor, w_s and w_u are the wages of skilled and unskilled labor, respectively, $P_M(q,0) = P(q)$ and $P_M(q,1) = P_I(q)$. Importing decreases variable costs of production—$P_I(q) < P(q)$ for all q. Since this benefit is proportional to size and the cost is not, large firms are more likely to import. In addition, the assumptions on Φ below are such that, if the quality of Foreign goods is high, the cost reductions from importing are larger for high- than for low-quality firms. Firm ω's spending on labor for production is

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

where $X_L(\omega) = (\alpha/\mu)x(q(\omega), p(\omega))$ is the firm's total spending on labor, $x(q(\omega), p(\omega))$ is its revenue and $\mu = \left(\frac{\sigma}{\sigma-1}\right)$ the markup. The ratio of skilled to unskilled workers is

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

The production of high-quality goods is skill intensive relative to low-quality if $\frac{\phi_L(s,q)}{\phi_L(u,q)}$ is strictly increasing: Given the same wages, a high-quality firm demands relatively more skilled labor. The firm's spending on a variety with quality q and price p is

$$x_M(q,p,\omega) = \left(\frac{p}{P_M(q(\omega), 1_I(\omega))}\right)^{1-\sigma} \Phi(q, q(\omega)) X_M(\omega) \tag{3}$$

where $X_M(\omega) = [(1-\alpha)/\mu]x(q(\omega), p(\omega))$ is total spending on inputs. Aggregating over consumers and firms (equations (2) and (3)), spending on a variety with price p and quality q in Home is

$$x_H(q,p) = x_C(p,q) + \int_\Omega x_M(q,p,\omega)d\omega = p^{1-\sigma}\chi(q) \tag{4}$$
$$\text{where } \chi(q) = \Phi(q,Q)P_I(Q)^{\sigma-1}y + \int_\Omega \Phi(q, q(\omega))P_M(q(\omega), 1_I(\omega))^{\sigma-1}X_M(\omega)d\omega.$$

Function $\chi(q)$ summarizes the country-wide demand for quality q. If Φ is constant in its second argument—as in standard models—$\chi(q)$ reduces to a function of aggregate prices, aggregate absorption and a demand shifter that depends exclusively on q. But in the general case, the demand for a good of quality q relative to other goods depends on the set of goods available in the market through Q and $q(\omega)$. Firms may also pay a fixed cost F_X units of labor (one of each type for simplicity) to export and access Foreign demand

$$x^*(q,p) = p^{1-\sigma}\Phi(q, Q^*)y^*. \tag{5}$$

Compared to Home demand in equation (4), equation (5) simplifies the aggregation of firms and consumers in function χ to a single quality Q^*. Parameter y^* summarizes total absorption, price index, trade costs and Foreign tariffs. For simplicity, we assume below that each firm produces

only one quality level.[10]

Firms with higher productivity and quality are more likely to export. In addition to the standard effect of productivity, Foreign relative demand for high-quality goods may be larger than Home's if Q^* is large. The decision to import and export cannot be disentangled—exporting increases the scale of production rendering importing more profitable, and importing decreases variable costs rendering exporting more profitable.

Since the elasticity of substitution σ is the same in Home and Foreign, firms charge a constant markup $\mu = \left(\frac{\sigma}{\sigma-1}\right)$. Firm ω chooses price p, quality q, and entry 1_E, import 1_I and export status 1_X to maximize profits:

$$\begin{aligned} \pi(\omega) = & \max_{p,q,1_E,1_I,1_X} 1_E \left\{\sigma^{-1}\left[x_H(q,p) + 1_X x^*(q,p)\right] - \bar{w}\left[F(q) - 1_I F_I - 1_X F_X\right]\right\} \\ & \text{subject to} \quad p = \mu c(q, 1_I, \omega). \end{aligned} \tag{6}$$

where $\bar{w} = w_1 + w_2$.

1.4 Government

The price $p(\omega)$ that agents at Home pay for $\omega \in \Omega^*$ includes ad valorem tariff τ imposed by the Home governemnt: $p(\omega) = (1+\tau)p^*(\omega)$ where $p^*(\omega)$ is the unit price of a Foreign variety $\omega \in \Omega^*$ after trade costs and before tariffs.[11] Home's imports from Foreign is $X_{HF} = X_{HF}^{\tau}/(1+\tau)$ where X_{HF}^{τ} is after-tax spending on Foreign goods,

$$X_{HF}^{\tau} = \left[\frac{P^*(Q)}{P_I(Q)}\right]^{1-\sigma} y + \int_{\Omega} 1_I(\omega)\left[\frac{P^*(q(\omega))}{P_I(q(\omega))}\right]^{1-\sigma} X_M(\omega)d\omega,$$

The government redistributes tariff revenues $T = X_{HF}\tau$ to consumers through a lump sum transfer, and consumer income is

$$y = T + w_s L_s + w_u L_u + \int_{\Omega} \pi(\omega)d\omega.$$

[10]Evidence Hummels and Skiba (2004) and Manova and Zhang (2010) suggests that firms export their higher-quality goods. Although our model may deliver this pattern, our data do not report prices separately by destination, rendering identification of this phenomenon difficult.

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

1.5 Equilibrium

Following Dekle, Eaton and Kortum (2008), we admit trade deficits but take them as exogenous.[12] Trade is in equilibrium if

$$X_{HF} = X_{FH} + D_H \tag{7}$$

where D_H is Home's trade deficit with Foreign and X_{FH} is Home's exports to Foreign,

$$X_{FH} = \int_{\Omega} 1_X(\omega)[x^*(q(\omega), p(\omega))]d\omega.$$

The labor market clears if

$$L_i = \int_{\Omega} [l_i(\omega) + F(q(\omega)) + 1_I(\omega)F_I + 1_X(\omega)F_X]\, d\omega \quad \text{for } i = s, u. \tag{8}$$

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 y^* and the set of firm prices and quality levels $\{p^*(\omega), q(\omega)\}_{\omega \in \Omega^*}$.

Definition 1 *An **equilibrium** is a set of wages w_s and w_u and aggregate prices $P(q)$ and $P_I(q)$; a set of choices by firms on entry, import and export participation, quality and prices $\{1_E(\omega), 1_I(\omega), 1_X(\omega), q(\omega), p(\omega)\}_{\omega \in \Omega}$ and demand for intermediates $\{m(\omega, \omega')\}_{\omega \in \Omega, \omega' \in \Omega \cup \Omega^*}$, and a set of choices by consumers Q and $\{x(\omega)\}_{\omega \in \Omega \cup \Omega^*}$ such that:*

(i) Firms maximize profits. For all ω, $\{1_E(\omega), 1_I(\omega), 1_X(\omega), q(\omega), p(\omega)\}$ solves problem (6), and the demand for inputs $p(\omega')m(\omega, \omega') = x_M(q(\omega'), p(\omega'), \omega)$ satisfies equation (3).

(ii) Consumers maximize utility. Quality Q maximizes $Q/P_I(Q)$ and demand $p(\omega)x(\omega) = x_c(q(\omega), p(\omega))$ satisfies equation (2).

(iii) The labor market clears as per equation (8).

(iv) The government's budget constraint clears, $T = X_{HF}\tau$.

(v) Home's trade deficit in the goods market is D_H as per equation (7).

[12] Our model is static and thus does not speak to deficits.

2 Function Φ

The key deviation of the model from a standard one is function $\Phi(q, Q)$, a demand shifter attributed to a variety of quality q by a firm whose output quality is Q or a consumer whose aggregate good has quality Q. Assume

$$\Phi(q, Q) = \bar{\phi}(q)\phi(q - Q) \tag{9}$$

where $\bar{\phi} : \mathbb{R}_+ \to \mathbb{R}_+$ is increasing and $\phi : \mathbb{R} \to \mathbb{R}_{++}$ is strictly increasing and twice continuously differentiable. Function $\bar{\phi}$ is the component of the demand shifter that is common for firms and consumers of all quality levels Q, and function ϕ captures their relative demand. If $\lim_{x\to\infty} \phi(x) = 1$, then $\phi(q - Q)$ is the demand shifter of a consumer of quality Q relative to a consumer with infinitely lower quality Q.[13] The decomposition in equation (9) presumes the existence of a quality metric such that the the ratio of relative demand of any two varieties with quality levels q and q' by any two consumers with quality levels Q and Q' depends only on the distance between quality levels: $\frac{x(p,q;Q)/x(p,q';Q)}{x(p,q;Q')/x(p,q';Q')} = \frac{\phi(q-Q)/\phi(q'-Q)}{\phi(q-Q')/\phi(q'-Q')}$. Except for the case where ϕ is constant, it is easy to see that this metric is unique up to a linear transformation.[14] So, although quality is an ordinal concept, it makes sense to talk about the curvature of ϕ:

Assumption 1 *$\phi''(x) > 0$ if $x < 0$ and $\phi''(x) < 0$ if $x > 0$.*

The consumer whose reference quality Q is far away from q is less sensitive to changes in q than the consumer whose quality is close to q—$|\phi'|$ decreases with $|q - Q|$. Similarly, firms do not value much changes in the quality of intermediates whose quality is either far below or far above the quality of its final output. We believe that this is an appealing property that is well captured by smooth cumulative distribution functions with unimodal densities and mode at zero. Assumption 1, however, is very weak because even linear functions ϕ can be arbitrarily well approximated by functions satisfying it. Assuming that ϕ is bounded is equally weak because boundedness is a property of the tail and the function be approximately linear in an arbitrarily large interval. We thus assume:

[13] Assuming $\lim_{x=\infty} \phi(x) = 1$ only eliminates the case (not of our interest) where ϕ is unbounded.

[14] The case where ϕ is exponential is equivalent to ϕ constant. For example, if $\phi(x) = e^x$, then $\Phi(q - Q) = \bar{\phi}(q)e^q e^{-Q}$, and we can redefine $\bar{\phi}$ as $\bar{\phi}(q)e^q$ and $z(Q, \omega)$ as $z(Q, \omega)e^{-Q(1-\alpha)}$ so that $\phi = 1$.

Assumption 2 $\left|\frac{\Phi''(x)}{\Phi'(x)}\right|$ *is strictly increasing in* $|x|$.

The expression $\frac{\Phi''(x)}{\Phi'(x)} = \frac{d\log(\phi'(x))}{dx}$ is the familiar notion of concavity from Pratt's (1964) measure of risk aversion.[15] Assumption 2 requires $|\phi'(x)|$ not only to decrease with $|x|$, but to decrease at an increasing rate. It is satisfied everywhere by the normal and the logistic distribution, used in the empirical analysis.[16] Next, we discuss a firm's choice of quality q in section 2.1 and the consumer's choice of quality Q in section 2.2.

2.1 Firms' choice of output quality

Our model has the property that the entry of high-quality Foreign varieties shifts the demand of firms and consumers toward higher-quality goods and induces an unequal investment in quality upgrading within the group of firms that do not export before or after the trade liberalization. This group is of interest because a trade liberalization decreases the size of their market, and so they divest in standard models. To understand this demand effect, we isolate it considering the simplest case: (i) There are no intermediate goods ($\alpha = 1$), (ii) $\frac{\Phi_L(s,q)}{\Phi_L(u,q)}$ is constant in q so that $w(q) = w$ for all q, (iii) F' is constant, and (iv) $z(q,\omega) = \bar{z}(q)z(\omega)$ and $\left[\bar{\phi}(q)^{1/(\sigma-1)}\bar{z}(q)\right]$ is constant in q.

In utility function (1), $[\Phi(q-Q)]^{1/(\sigma-1)}$ is a quantity-equivalence measure of quality q and $[\bar{\phi}(q)]^{1/(\sigma-1)}$ is its component that is independent from Q. So, assumption (iv) states that increases in the quantity-equivalence measure of the quality of a good are exactly offset by decreases in the per unit productivity z. There is no reason to believe either assumption (iii) or (iv)—we simply do not know how fixed costs $F(q)$ and $\bar{\phi}(q)^{1/(\sigma-1)}\bar{z}(q)$ evolve. But clearly, firms are more likely to invest in regions where F' is small or $\left[\bar{\phi}(q)^{1/(\sigma-1)}\bar{z}(q)\right]$ increases, and our purpose is to isolate the demand effect. Similarly, assumptions (i) and (ii) preclude potential reductions in the relative cost of producing high-quality goods. Accordingly, the results below should be interpreted only as a general tendency for ex ante high-quality firms to invest more

[15] As in Pratt, the magnitude of the first derivative has no meaning here because the quality metric is unique only up to a linear transformation.

[16] The cumulative distribution function of all unimodal distributions trivially satisfy assumption 2 in the region close to the mode. Since this is the region where most (if not all) domestically-oriented firms locate their quality q, deviations in the tail do not concern us. We need to confirm this conjecture when we do the empirics.

and lose proportionately less revenue following a trade liberalization. Shifts in demand quality Q are to be interpreted broadly as coming not only from consumers but also from high-quality firms—exporters and non-exporters alike—that upgrade the quality of their products and expand relative to low-quality firms that downgrade quality or exit.

Consider non-exporters. Under assumptions (i)-(iv), the profit of firm ω with productivity $z(\omega) = z$ producing quality q is

$$\pi(q, \omega) = z^{\sigma-1} Y \phi(q - Q) - \bar{w} F(q)$$

where $Y = \beta w^{(1-\sigma)} P(Q)^{\sigma-1} y$ is a country-wide variable capturing the size of the market and $\beta = \sigma^{-\sigma}(\sigma - 1)^{\sigma-1} \bar{\phi}(q) z(q^{\sigma-1})$ is a constant. Differentiating by q, the first-order necessary condition (FONC) is:

$$z^{\sigma-1} Y \phi'(q - Q) - \bar{w} F'(q) = 0 \tag{10}$$

The firm's choice is illustrated in figure 1. The bell-shaped curve is the derivative of gross profits $G' = \beta z^{\sigma-1} P(Q)^{\sigma-1} y \phi'(q - Q)$, which attains a maximum at $q = Q$ by assumption 1, and the horizontal line is $F' = \bar{w} F'(q)$. The first intersection of the two curves is a local minimum and the second, $\hat{q}$, the only interior maximum. The profit of the firm is the shaded area minus $F(0)$. If it is negative, the firm exits, otherwise it chooses $\hat{q}$. An increase in z is a proportional upward shift in G' that increases $\hat{q}$, as shown in figure 1b. Hence, more productive firms choose higher q. This result arises because the gains from investing in quality are proportional to productivity and the cost is fixed.[17]

Figure 1c shows an increase in Q by ΔQ holding Y fixed. It is a uniform rightward shift in G'. The interior optimal $\hat{q}$ of all firms increase by ΔQ, the profit decreases by $\bar{w} F'(q) \Delta Q$ and the least productive firms exit. From the perspective of firms that never export, a unilateral trade liberalization in a developing country is an increase in Q and a decrease in Y, through a decrease in the price index. So, the direction of investment in q is unclear since these changes have opposing effects (figures 1b and 1c). We then apply the implicit function theorem to

[17] This result is independent of our assumptions on G and F. It is also in Harrigan and Reshef (2011).

equation (10) and recall $F''(q) = 0$:

$$\frac{\delta \hat{q}}{\delta Q} = 1 \quad \text{and} \quad \frac{\delta \hat{q}}{\delta Y} = -\frac{\phi'}{\phi''}$$

where the argument $(\hat{q} - Q)$ is omitted from ϕ for compactness. Then, the total derivative of $\hat{q}$ with respect to tariffs τ is

$$\frac{d\hat{q}}{d\tau} = \frac{\delta \hat{q}}{\delta Q}\frac{dQ}{d\tau} + \frac{\delta \hat{q}}{\delta Y}\frac{dY}{d\tau} = \frac{dQ}{d\tau} - \frac{\phi'}{\phi''}\frac{dY}{d\tau} \tag{11}$$

The first term $\frac{dQ}{d\tau}$ is positive and common for all firms and the second term is negative ($\phi'' < 0$, $dY/d\tau < 0$) and decreasing in $\hat{q}$ in absolute value by assumption 2. Since the derivative is larger for ex ante more productive firms everywhere, the result extends to large changes in τ: More productive firms choose higher quality and invest more under a trade liberalization. From appendix A, the percentage change in revenue is

$$\frac{dx/d\tau}{x} = \frac{dY}{d\tau}\left[\frac{1}{Y} - \frac{(\phi')^2}{\phi\phi''}\right], \tag{12}$$

which is always negative since $\frac{dY}{d\tau} < 0$ and $\frac{(\phi')^2}{\phi\phi''} < 0$. The term $\left[-\frac{(\phi')^2}{\phi\phi''}\right]$ is strictly decreasing in $\hat{q}$ (see appendix A) so that the relative loss in revenue decreases with the quality of the firm.

Example Let $\phi(x) = \frac{\exp(x)}{1+\exp(x)}$. Then, equations (11) and (12) become

$$\frac{d\hat{q}}{d\tau} = \frac{dQ}{d\tau} + \left(\frac{e^{(\hat{q}-Q)}+1}{e^{(\hat{q}-Q)}-1}\right)\frac{dY}{d\tau}$$
$$\frac{dx/d\tau}{x} = \frac{dY}{d\tau}\left[\frac{1}{Y} + \frac{1}{e^{(\hat{q}-Q)}-1}\right]$$

$\frac{d\hat{q}}{d\tau}$ is positive if $(\hat{q} - Q)$ is large enough, but $\frac{dx/d\tau}{x}$ is always negative. So, ex ante high-quality firms may invest and experience revenue losses, while ex ante low-quality firms divest and loose proportionately more revenue.

Now consider existing and new exporters. Under assumptions (i)-(iii) above, the profit and

FONC of an exporting firm ω with productivity $z(\omega) = z$ producing quality q are

$$\pi(q,\omega) = z^{\sigma-1}\left[Y\phi(q-Q) + Y^*\phi(q-Q^*)\right] - \bar{w}F(q) - \bar{w}F_X \qquad \text{(profit)}$$

$$z^{\sigma-1}[Y\phi'(q-Q) + Y^*\phi'(q-Q^*)] - \bar{w}F'(q) = 0 \qquad \text{(FONC)}$$

where $Y^* = \beta w^{(1-\sigma)} y^*$ reflects the size of the Foreign market. In figure 2, curves $G = z^{\sigma-1}Y\phi'(q-Q)$ and $G^* = z^{\sigma-1}Y\phi'(q-Q)$ refer to the Home and Foreign markets, respectively, and $G' = G + G^*$ is the derivative of gross profits. The FONC is satisfied in the intersection of G' and F'. Since $Q^* > Q$, curve G' now has two peaks and may present two interior maxima, $\hat{q}_1$ and $\hat{q}_2$, both of which may be the global maximum (see figure 2b). And since $\hat{q}_1$ and $\hat{q}_2$ both lie above the optimum for the Home market, firms upgrade the quality of their products when they enter the export market.[18] Following the same steps as before, we get

$$\frac{d\hat{q}}{d\tau} = \frac{dQ}{d\tau} - \frac{\phi'(\hat{q}-Q)}{\phi''(\hat{q}-Q)}\frac{dY}{d\tau} \underbrace{- \frac{\phi'(\hat{q}-Q^*)}{\phi''(\hat{q}-Q^*)}\frac{dY^*}{d\tau}}_{(*)}$$

The effects on the domestic market do not change—a tariff change induces changes in $\hat{q}$ that are strictly increasing in the productivity and ex ante quality of a firm. But the effect of the Foreign market is ambiguous. In general equilibrium, Y^* increases in a unilateral trade liberalization (decreases in τ) because the relative wage of Home w has to decrease in order for Foreign demand for Home goods to increase and trade to balance. Then, by assumptions 1 and 2, the Foreign term (*) is increasing in q, it is negative if $\hat{q} < Q^*$ and positive otherwise. So, for small continuing exporters ($\hat{q} < Q^*$), Foreign markets have a negative effect on investment whose magnitude is increasing in ex ante quality $\hat{q}$, and for large exporters ($\hat{q} > Q^*$), the effect is positive and decreasing in q. A discontinuous large investment in q occurs for firms that switch maxima from $\hat{q} < Q^*$ before the liberalization to $\hat{q} > Q^*$ afterwards. These firms gain proportionately more sales in Foreign than Home. Similar ambiguous effects occur to percentage in sales (see appendix ??).

To summarize, more productive firms choose higher output quality. A trade liberalization

[18] Evidence for this phenomenon has been documented in several papers—see Bustos (2011), Verhoogen (2008) and Lileeva and Trefler (2010) for example.

decreases the size of the domestic market and shifts demand toward high-quality goods. Domestically oriented firms all loose sales, but high-quality firms loose proportionately less. Investment in quality is an increasing function of the firm's ex ante quality. Entry to the export market requires a discrete investment in quality. Small exporters may also incur large investments in quality that significantly increases their sales abroad but has a modest effect domestically.

2.2 Quality Q

We refer to the first argument of Φ with small q and to the second with capital Q even though Q may refer to a firm with quality $q(\omega) = Q$. In understanding the link between the reference quality Q of the buyer (firm or consumer) and the quality of the seller q there are two relevant questions: Does a higher consumer Q imply a higher relative demand high-quality goods, and conversely does the increase in the availability of high-quality goods increase the consumer's choice of Q? The answer to both questions is a qualified yes. And the reason for the qualification is the difference between assumptions 1 and 2 and supermodularity.

The demand of a buyer with quality Q for a variety with price p and quality q is

$$x(p, q, Q) = [p^{1-\sigma}\bar{\phi}(q)]\phi(q - Q)X$$

where X is the total absorption of differentiated goods. Figure 3 plots $\phi(q - Q)$. If the term $[p^{1-\sigma}\bar{\phi}(q)]$ changes slowly, the buyer concentrates her purchases in the region highlighted with the oval. Figure 3b plots $\phi(q-Q)$ for two buyers with $Q_1 < Q_2$ and highlights two quality levels $q_1 < q_2$. If demand were supermodular, then the relative demand for the high-quality variety q_2 would be larger for the high-quality buyer 2, which is clearly not the case in the figure since $\phi(q - Q_2)$ is flat for $q \in [q_1, q_2]$. To take a numerical example, again let $\phi(x) = \frac{\exp(x)}{1+\exp(x)}$, and $(Q_1, Q_2, q_1, q_2) = (0, 100, -1, 1)$. Then, the demand for variety 2 relative to variety 1 is greater for buyer 1:

$$\frac{x(q_2, p_2, Q_1)/x(q_1, p_1, Q_1)}{x(q_2, p_2, Q_2)/x(q_1, p_1, Q_2)} \approx 2.7.$$

In sum, the relative demand for high-quality goods is not necessarily larger for the buyer with a higher Q *everywhere*, but to the extent that the buyer with a higher Q concentrates his purchases

in a region of higher quality, his basket will typically have higher-quality goods on average (see figure 3b). This lack of complementarity everywhere is not necessarily an undesirable feature of the model. In the textile industry, for example, a low-quality firm may be very sensitive to the changes in the quality of polyester, while a high-quality firm barely buys polyester of any quality. So, the relative demand for high- versus low-quality polyester will be larger for the former than for the latter firm.

References

[1] Aghion, P., N. Bloom, R. Blundell, R. Griffith, P. Howitt (2005), "Competition and Innovation: An Inverted-U Relationship," *The Quarterly Journal of Economics*, **120**, 701-728.

[2] Aw, B.Y., M. Roberts, D. Xu (2011), "R&D Investments, Exporting, and Productivity Dynamics," *American Economic Review*, **101**, 1312-1344.

[3] Burstein, A., J. Cravino, J. Vogel (2012), "Importing Skill-Bias Technology," mimeo, Columbia University.

[4] Bustos, P. (2011a), "The Impact of Trade Liberalization on Skill Upgrading: Evidence from Argentina," mimeo, Universitat Pompeu Fabra, CREI.

[5] Bustos, P. (2011b), "Trade Liberalization, Exports and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinian Firms," *American Economic Review*, **101**, 304-340.

[6] Eslava, M., J. Haltiwanger, A. Kugler, M. Kugler (2011), "Trade Reforms and Market Selection: Evidence from Manufacturing Plants in Colombia," *NBER Working Paper*, #14935.

[7] Feenstra, R, G. Hanson (1997), "Foreign Direct Investment and Relative Wages: Evidence from Mexico's Maquiladoras," *Journal of International Economics*, **42**, 371-393.

[8] Goldberg, P., A. Khandelwal, N. Pavcnik, P. Topalova (2009), "Trade Liberalization and New Imported Inputs," *American Economic Review Papers and Proceedings*.

[9] Goldberg, P., A. Khandelwal, N. Pavcnik, P. Topalova (2010), "Imported Intermediate Inputs and Domestic Product Growth: Evidence from India," *Quarterly Journal of Economics*, forthcoming.

[10] Goldberg, P., N. Pavcnik (2004), "Trade, Inequality, and Poverty: What Do We Know? Evidence from Recent Trade Liberalization Episodes in Developing Countries," *Brookings Trade Forum*, 223-269.

[11] Goldberg, P., N. Pavcnik (2007), "Distributional Effects of Globalization in Developing Countries," *Journal of Economic Literature*, **45**, 39-82.

[12] Helpman, E., O. Itskhoki, S. Redding (2010), "Inequality and Unemployment in a Global Economy," *Econometrica*, **78**, 1239-1283.

[13] Kugler, M., E. Verhoogen (2009), "Plants and Imported Inputs: New Facts and an Interpretation," *American Economic Review Papers and Proceedings*, **99**, 501-507.

[14] Kugler, M., E. Verhoogen (2012), "Prices, Plants and Product Quality," *The Review of Economic Studies*, **79**, 307-339.

[15] Lileeva, A., D. Trefler (2010), "Improved Access to Foreign Markets Raises Plant-Level Productivity...For Some Plants," *Quarterly Journal of Economics*, **125**, 1051-1099.

[16] Manova, K., Z. Zhang. (2011), "Export Prices across Firms and Destinations," *Quarterly Journal of Economics*, forthcoming.

[17] Melitz, M. (2003), "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, **71**, 1695-1725.

[18] Pavcnik, N. (2002), "Trade Liberalization, Exit, and Productivity Improvements: Evidence from Chilean Plants," *The Review of Economic Studies*, **69**, 245-276.

[19] Schott, P. (2004), "Across-Product versus Within-Product Specialization in International Trade," *Quarterly Journal of Economics*, **119**, 647-678.

[20] Thoenig, M., T. Verdier (2003), "A Theory of Defensive Skill-Biased Innovation and Globalization," *American Economic Review*, **93**, 709-728.

[21] Trefler, D. (2004), "The Long and Short of the Canada-US Free Trade Agreement," *American Economic Review*, **94**, 870-895.

[22] Verhoogen, E. (2007), "Trade, Quality Upgrading and Wage Inequality in the Mexican Manufacturing Sector," *Quarterly Journal of Economics*, **123**, 489-530.

A Proofs

We first derive the expression for the percentage change in revenue $\frac{dx/d\tau}{x}$ under a trade liberalization:

$$\begin{aligned} x &= \sigma^{-1} z^{\sigma-1} Y \phi(q^* - Q) \\ \sigma \frac{dx}{d\tau}(q^*, p^*) &= z^{\sigma-1} \left[\phi \frac{dY}{d\tau} + Y\phi' \left(\frac{dq^*}{d\tau} - \frac{dQ}{d\tau} \right) \right] \\ &= z^{\sigma-1} \frac{dY}{d\tau} \left[\phi - Y \frac{\phi'}{\phi''} \right] \\ \frac{dx/d\tau}{x} &= \frac{dY}{d\tau} \left[\frac{1}{Y} - \frac{(\phi')^2}{\phi\phi''} \right] \end{aligned}$$

where $\frac{dY}{d\tau} < 0$ and the term in brackets is positive since $(\phi, \phi') \gg 0$ and $\phi'' < 0$. To show that losses are proportionately smaller for higher-quality firms, we need to show that $-\frac{(\phi')^2}{\phi\phi''}$ is strictly decreasing:

$$\begin{aligned} \frac{\delta((\phi'(x))^2/\phi(x)\phi''(x))}{\delta x} &= -\frac{2\phi\phi'(\phi'')^2 - (\phi')^2[\phi'\phi'' + \phi\phi''']}{(\phi\phi'')^2} \\ &= -\frac{\phi'}{(\phi\phi'')^2} \left[2\phi(\phi'')^2 - (\phi')^2\phi'' - \phi\phi'\phi''' \right] \\ &< -\frac{\phi'}{(\phi\phi'')^2} \left[\phi(\phi'')^2 - (\phi')^2\phi'' \right] \qquad \text{(A.1)} \\ &< \frac{-\phi'\phi''}{(\phi\phi'')^2} \left[\phi\phi'' - (\phi')^2 \right] < 0 \qquad \text{(A.2)} \end{aligned}$$

where line (A.1) comes from assumptions 1 and 2 that $\phi'\phi''' < (\phi')^2$ and $(\phi\phi'' - (\phi')^2) < 0$ because $\frac{\phi}{\phi'}$ is increasing.