The Long and Short (of) Quality Ladders*

Job Market Paper

Amit Khandelwal†

Yale University

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Abstract

Quality specialization may help insulate workers in developed countries from low-wage country competition by weakening the convergence in goods and factor prices implied by international trade. I develop a model in which vulnerability to low-wage country competition decreases with a product market's degree of vertical differentiation. To test the implications of this model, I measure countries' export quality by exploiting both price and market share information, which contrasts to earlier work that uses only price data. The quality estimates reveal that product markets vary widely in their degree of vertical differentiation, measured by the range of qualities observed in the market. The variation in the lengths of these products' "quality ladders" indicates that quality specialization is more feasible in some product markets than in others. Consistent with the model, the impact of low-wage import penetration on U.S. manufacturing employment is weaker in industries characterized by longer quality ladders. This evidence suggests that product quality is an important factor for understanding how international trade affects firms and workers.

Keywords: Quality Ladders; Import Competition; Quality Specialization; Product Differentiation

JEL Classification: F1, F2, L1

1 Introduction

The fear of globalization's impact on employment is rooted in the vulnerability or, to use Leamer's terminology, the "contestability" of jobs (Leamer, 2006). Recent attention in the media and political arena has

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†27 Hillhouse Avenue, Economic Growth Center, New Haven, CT 06520, *email:* amit.khandelwal@yale.edu, *website:* http://pantheon.yale.edu/∼ak389/.

elevated these fears by arguing that increased economic integration would result in today's American jobs being exported abroad tomorrow. As Leamer puts it, in an increasingly globalized world, the contestable jobs are those whose "wages in Los Angeles are set in Shanghai."[1] Proponents of increased protectionism have implicitly appealed to a factor price equalization argument: Wage arbitrage is possible when workers abroad can replicate–at a fraction of the cost–identical tasks performed in the United States. From a policy perspective, it is important to identify the types of industries that are likely to be contested by emerging economies.

But how does one identify the contestable jobs? Between 1980 and the mid-1990s, manufacturing's share of total U.S. employment fell from 21 to 14.5 percent while the share of low-wage imports simultaneously increased from .8 to 4 percent. Studies by Sachs and Shatz (1994) and Bernard, Jensen, and Schott (2006) provide formal evidence that contestability increases with the degree of import penetration, particularly from low-wage countries.[2] However, simple correlations suggest that some product markets are more vulnerable to foreign competition than others. For example, employment in both electronics and fabricated metals (e.g., metal cans and handtools) has declined annually by one percent even though low-wage import penetration has increased three times faster in electronics.

The hypothesis advanced in this paper is that the extent of quality specialization, as opposed to product specialization, allows the U.S. to reduce exposure to foreign competition. In a textbook Heckscher-Ohlin framework, factor prices equate through trade when countries produce identical goods using identical technologies. However, many studies reject this simple view of the world in favor of an equilibrium where countries specialize in goods tailored to their endowments.[3] Specialization leads to a breakdown of the factor price equalization prediction. Schott (2004) has found evidence against across-product specialization–62 percent of U.S. products in 1994 originated from trading partners that spanned the income distribution–in favor of within-product specialization because the distribution of unit values varies substantially within products according to exporter characteristics.

Like Flam and Helpman (1987) and Schott (2004), this paper demonstrates that specialization occurs in the vertical (i.e., quality) dimension. However, due to exogenous technology constraints, at least in the short- and medium-run, the ability to improve quality varies across product markets. A product's quality ladder, defined as the range of qualities within a product (Grossman and Helpman, 1991), may be *long* or *short*. For example, televisions, which range from tube receivers to high-tech plasma screens, are plausibly characterized by a longer quality ladder than footwear or basic metal objects.

I develop a model in which firms in a developed country (the North) are more vulnerable to competition in "short-ladder" products. Heterogenous firms compete by differentiating products in the vertical and

[1] Leamer (2006), page 5.

[2] Other studies that have found negative relationships between trade and employment include Freeman and Katz (1991) and Revenga (1992). Bernard et al. (2006) explicitly connect employment losses to exposure to low income countries, defined as countries with less than 5 percent of U.S. per capita GDP. The low-wage countries used in this paper are listed in Table 1.

[3] For example, see Leamer (1987), Davis and Weinstein (2001) and Schott (2003).

horizontal dimensions.[4] Like Flam and Helpman (1987), I assume that developed countries have a comparative advantage in producing higher-quality goods, and like Krugman (1980), I assume that differentiating in the horizontal dimension is costless. That is, moving up the quality ladder requires endowments abundant in developed countries while moving across a ladder rung is orthogonal to these comparative-advantage factors. The Northern firms use their comparative advantage to manufacture higher-quality goods along an exogenous quality ladder, but there exists a range of qualities along the ladder that overlaps with the low-cost Southern producers. The Northern firms that lie within this overlap are most vulnerable to import competition. However, the overlapping range of qualities declines as the quality ladder lengthens. Northern firms in long-ladder markets are therefore insulated from Southern competition because their comparative advantages enable them to position themselves further up the quality ladder.

Testing the implications of the model requires empirical measures of product quality. Since quality is unobserved, most studies in the international trade literature invoke a vertical-market assumption which allows observed unit values to perfectly proxy for unobserved quality.[5] However, the vertical-market assumption is inconsistent with the reality that most products possess both vertical and horizontal attributes. Horizontal differentiation allows products with high quality-adjusted manufacturing costs to remain in equilibrium because consumers have idiosyncratic preferences for such products. For example, some consumers may trade off comfort (a vertical attribute) for an expensive shoe style (a horizontal attribute) because of idiosyncratic preferences. The existence of horizontal differentiation therefore invalidates the "price = quality" assumption.

The empirical measures of quality follow from the theoretical model's demand structure, which embeds preferences for horizontal and vertical attributes. Quality represents the vertical component of the model and is structurally defined as the mean valuation that consumers attach to an imported product. I identify the quality of U.S. imports by estimating demand functions via a nested-logit framework. The procedure provides an adequate balance between computational feasibility, a necessary requirement since I estimate demand curves for approximately 850 markets that span the set of manufacturing imports, and maintaining flexible substitution patterns.[6] The intuition behind this approach is that an increase in a product's quality allows its price to rise without a loss in market share. A related paper by Hallak and Schott (2005) also uses this intuition to identify the quality of U.S. imports in a model with vertical and horizontal differentiation. The major difference between their approach and the one taken here, besides methodology, is that while Hallak and Schott (2005) estimate aggregate quality indexes, the procedure here

[4] Quality is a vertical attribute: at equal prices, all consumers prefer higher quality. Location, colors or patterns of a shirt are examples of horizontal differentiation since not all consumers agree on these attributes at equal prices. The international trade literature has largely ignored the interactions between vertical and horizontal differentiation. Two exceptions are Young (1998) and Hallak and Schott (2005).

[5] For example, see Brooks (2003), Schott (2004), Hummels and Skiba (2004), Hummels and Klenow (2005), Hallak (2006).

[6] In an earlier draft, I implement the random-coefficients model, developed by Berry et al. (1995), to infer the quality of a subset of apparel and footwear imports. This procedure, however, is not feasible to implement over hundreds of markets. See Khandelwal (2005).

recovers product quality at the finest level of aggregation.[7]

I empirically define a product's quality ladder as the range of estimated qualities within the product. Examples of short-ladder products include apparel, footwear, plastics and fabricated metals. Products with longer quality ladders lie in industries like transportation, machinery and professional equipment. I find that the average U.S. consumer attaches a relatively low valuation to expensive imports in products characterized by a short quality ladder. This occurs because this consumer is unwilling to pay for expensive imports that do not offer substantially better vertical attributes relative to cheaper substitutes. The expensive imports instead rely on horizontal differentiation to retain market share. The within-product substitutability of imports, measured by the cross-price elasticity, decreases with the length of the quality ladder, so imports into short-ladder products are more substitutable than imports into long-ladder products. As a result, developed countries, which export the expensive goods to the United States, have lower market shares in short-ladder products. These countries preserve market share in long-ladder products by upgrading their export quality at a relatively faster rate.

Having inferred the degree of quality differentiation across manufacturing markets, I aggregate the product-level quality ladders to match U.S. industry data in order to test the vulnerability hypothesis. Consistent with Bernard et al. (2006), I find that industry employment is negatively associated with exposure to imports, particularly from low-wage countries. The model here, however, predicts a differential impact across product markets according to ladder length. The results indicate that import penetration has a weaker effect on employment in industries with long quality ladders. A ten percentage point increase in low-wage penetration is associated with a 7 percent decline in employment in an industry characterized by the average quality ladder length. In comparison, employment in long-ladder industries (those with a quality ladder one standard deviation above the mean) is essentially insensitive to import penetration. Thus, I find evidence that industries characterized by a large degree of vertical differentiation are more insulated from import competition. Although direct evidence of a quality upgrading strategy is not available without micro-level data, there is weaker evidence that increased competition is associated with long-ladder industries accumulating skilled labor at a faster rate. This is consistent with a strategic response to import competition under the assumption that quality upgrading raises the demand for skilled labor.

Firms in short-ladder markets, by definition, are unable to use quality specialization to insulate themselves from foreign competition. Instead, I find evidence that these product markets impose higher tariff rates in order to remain competitive. Tariffs are 12 percent higher on imports into short-ladder products relative to imports into longer ladders, and the differential across ladders is even higher for imports originating from low-wage countries. The tariff results remain robust when controlling for alternative explanations of trade policy that have been proposed in the endogenous trade protection literature.

This paper contributes to the literature studying the importance of quality specialization in in-

[7] Hallak and Schott (2005) infer quality by decomposing observable price indexes into "pure" and "impure" components and relating the indexes to a country's net trade balance.

ternational trade for both developed and developing countries.[8] In particular, this paper establishes the importance of the type of product differentiation firms use to soften competition. Although both horizontal and vertical attributes can differentiate products, climbing the quality ladder lowers vulnerability to emerging economies. Given that certain products naturally possess longer quality ladders than others, increased globalization will likely continue to shrink U.S. industries like apparel, footwear and metal products, while firms in long-ladder industries adapt to the increased competition.

The remainder of the paper is organized as follows. Section 2 develops a model in which advanced nations are more vulnerable to import competition in product markets with short quality ladders. The empirical methodology that infers quality is discussed in Section 3. The data and quality estimation results are presented in Section 4. Section 5 explores the properties of the quality ladder. In section 6, I apply the quality ladders to U.S. industry data to test the implications of quality specialization for employment and trade policy. I conclude the paper in Section 7.

2 Theoretical Model

2.1 Model Setup

The model takes a partial equilibrium approach to illustrate the importance of quality ladders for competition between two regions, the North and South. The following assumptions are maintained throughout the model. I assume that unskilled wages are higher in the North: $w_L^N > w_L^S$. Skilled wages are denoted w_H^r, for $r = N, S$. Ricardian comparative advantage provides Northern firms with an ability distribution (see below) that stochastically dominates the ability distribution of Southern firms and has a higher bounded support: $\lambda_{\max}^N > \lambda_{\max}^S$.

2.1.1 Firms

Firms in the two regions compete by producing vertically and horizontally differentiated *varieties* within a monopolistically competitive product market. Firm heterogeneity is modeled as a draw from an ability distribution $G(\lambda)$, with associated pdf $g(\lambda)$, on the bounded support $[1, \lambda^{\max}]$. This draw enables a firm λ to design a quality, $\xi(\lambda)$, via the production function:[9]

$$\xi(\lambda) = \lambda h^{\gamma}, \qquad \gamma \in [0, 1). \tag{1}$$

Quality is increasing in skilled labor (h) and the firm's entrepreneurial ability. Although each variety in the product market is vertically and horizontally distinct, the cost of differentiation differs by type. Horizontal differentiation is costless so that in equilibrium, all firms choose a unique horizontal attribute (Krugman,

[8] For example, see Zhu and Trefler (2005), Bernard, Redding, and Schott (2006) and Verhoogen (2006).

[9] The quality production function is a simplified version of that considered in Verhoogen (2006). The model could easily be extended by allowing quality production to depend on capital, as well.

1980). There is a cost to vertical differentiation that varies proportionally with the amount of skilled labor. In order to manufacture the good, the firm requires 1 unit of unskilled labor and the marginal cost of production is $mc = hw_H + w_L$.

The exogenous and fixed parameter γ plays an important role in the model. It controls the returns to quality and is assumed to be less than one to ensure an interior solution. In order for the manufactured quality to be increasing in γ, I assume that $h > 1$; that is, for a given skill intensity, raising γ increases the manufactured quality. As is shown below, γ controls the "length" of the quality ladder. For a given length of the ladder, the firm's ability and its skilled labor allocation determine its position along the ladder.

2.1.2 Consumers

Northern consumers have unit demands and choose the variety that provides them with the highest utility.[10] The (indirect) utility that consumer n obtains from choosing variety λ is

$$V_n = \bar{\theta}\xi(\lambda) - p(\lambda) + \mu_n \xi(\lambda) + \epsilon_n(\lambda). \tag{2}$$

Consumers have a random taste for quality that is drawn from a distribution $P_\mu(\mu)$. The quality taste is decomposed into the mean component $\bar{\theta}$ and a consumer-specific-random deviation μ_n. There are alternative interpretations to the vertical component. It can measure physical characteristics like the clarity or sharpness of a television screen. Alternatively, it can capture the increase in perceived quality that results from marketing or advertising. In either case, the vertical component captures any attribute that enhances consumers' willingness-to-pay for this variety as opposed to competitor varieties. An alternative interpretation is that the vertical attribute represents a shift parameter in the variety demand schedule such that an increase induces a rightward shift in the demand curve (Sutton, 1991). The empirical identification of quality relies on this latter intuition (see below).

The consumer's utility is decreasing in price where the price sensitivity has been set at one for simplicity. Horizontal differentiation is introduced through the consumer-variety-specific term, $\epsilon_n(\lambda)$, that is assumed to be independent and identically distributed type-I extreme value. This term explains why some consumers purchase varieties with high quality-adjusted prices. The two sources of variety differentiation distinguish this model from a purely horizontal model, as in Krugman (1980), or the purely vertical model of Flam and Helpman (1987).

The random coefficients model in (2) alleviates the Independence of Irrelevant Alternatives (IIA) property that plagues standard logit and CES frameworks.[11] IIA has the undesirable property that forces substitution patterns to be driven by market shares. For example, suppose the market shares for a high-quality plasma television variety and a low-quality tube variety were the same. Under IIA, the varieties

[10] While the discrete choice assumption is intuitive for some product markets (e.g., cars), it is less realistic for others (e.g., footwear). The discreteness of choice can be thought of an approximation to the true model in the same way that a constant elasticity of substitution (CES) framework approximates consumption choices by assuming nonzero demand for all alternatives.

[11] See Berry (1994) and Berry et al. (1995) for a discussion of the use of random coefficients to break IIA.

would have the same cross-price elasticity with respect to *any* third alternative. This would mean that a decrease in the price of another tube television would necessarily generate equal percentage declines in the demand for both varieties. IIA occurs because the covariance between the error components for two varieties, $\text{Cov}[\mu_n \xi(\lambda) + \epsilon_n(\lambda), \mu_n \xi(\lambda') + \epsilon_n(\lambda')]$, is equal to zero if $\mu_n \equiv 0$ because the ϵ draws are i.i.d. Allowing for consumer-taste interactions (i.e., $\mu_n \neq 0$) with quality implies that preferences for two similar quality goods are more highly correlated than varieties at two different quality segments.

The standard logit distributional assumption enables the ϵ error term to be integrated out of the model. Conditional on the μ_n draw, the probability that an *individual* chooses variety λ is given by the familiar logit formula

$$f_n(p, \xi, \bar{\theta}, \mu_n; \lambda) = \frac{e^{(\bar{\theta}+\mu_n)\xi(\lambda)-p(\lambda)}}{\int_\Lambda e^{(\bar{\theta}+\mu_n)\xi(\lambda)-p(\lambda)}\phi(\lambda)d\lambda}, \tag{3}$$

where $\phi(\lambda)$ denotes the *ex post* ability distribution of the firms that remain in the market and Λ denotes the support of this distribution. The overall market shares for variety λ are obtained by integrating over the distribution of the random coefficient:

$$s(p, \xi, \bar{\theta}; \lambda) = \int f_n dP_\mu(\mu). \tag{4}$$

2.2 Autarky in the North

The Northern firms draw their managerial ability from the distribution function $g^N(\lambda^N)$. Conditional on this draw, they choose the skilled labor and price to maximize profits, given the demand in (4). Under monopolistic competition, the behavior of competitors is taken as given so the denominator in (3) is fixed. The firm's maximization problem is given by

$$\pi^N = \max_{h,p}(p - hw_H^N - w_L^N)s - F^N, \tag{5}$$

where F^N is the fixed cost of production. Straightforward calculations provide the optimal price and factor input for a Northern firm of ability λ^N

$$p^N(\lambda^N) = 1 + w_L^N + w_H^N h^N(\lambda^N) = 1 + w_L^N + \left(\bar{\theta} + k\right)\gamma\xi^N(\lambda^N) \tag{6}$$

$$h^N(\lambda^N) = \left(\frac{\gamma\lambda^N\left(\bar{\theta}+k\right)}{w_H^N}\right)^{\frac{1}{1-\gamma}}, \tag{7}$$

where $k = \frac{\int \mu_n f_n dP_\mu(\mu)}{\int f_n dP_\mu(\mu)}$.[12] To ensure that the choice of h exceeds one, so that quality production is increasing in γ, let $\frac{\gamma(\bar{\theta}+k)}{w_H^N} > 1, \forall\gamma$. The firm's quality, $\xi^N(\lambda^N)$, is obtained by substituting (7) into (1)

$$\xi^N(\lambda^N) = \lambda^{N\frac{1}{1-\gamma}}\left(\frac{\gamma\left(\bar{\theta}+k\right)}{w_H^N}\right)^{\frac{\gamma}{1-\gamma}}. \tag{8}$$

[12]Because of the random coefficients, the parameter k implicity depends on h in a highly nonlinear fashion. Assuming this parameter to be constant across h does not change the intuition of the results but enables closed-form expressions.

Price, taking the usual form of a markup over marginal cost, is increasing in quality and manufacturing costs.[13] Firms choose higher skill intensity when skilled labor is cheaper, when the average preference for quality is higher or when the return to quality is greater.

2.2.1 Entry Conditions

Profits are increasing in the firms' ability so free entry implies that there is a unique cut-off, $\lambda^N_{\min}$, that determines the lowest ability firm that remains in the market. The zero-profit condition that defines the cutoff is

$$\pi^N(\lambda^N_{\min}) = 0 \Rightarrow \int \frac{e^{\left(\bar{\theta}+\mu_n\right)\xi^N(\lambda^N_{\min})-p^N(\lambda^N_{\min})}}{\int_{\lambda^N_{\min}}^{\lambda^N_{\max}} e^{\left(\bar{\theta}+\mu_n\right)\xi^N(\lambda^N)-p^N(\lambda)}\phi^N(\lambda^N)d\lambda^N} dP_\mu(\mu) = F^N. \tag{9}$$

Firms that draw below this ability exit the market. The *ex ante* probability of successful entry is given by $1-G^N(\lambda^N_{\min})$ so the *ex post* distribution of abilities, truncated at the zero-profit ability cutoff, is

$$\phi^N(\lambda^N) = \begin{cases} \frac{g^N(\lambda^N)}{1-G^N\left(\lambda^N_{\min}\right)} & \text{if} \quad \lambda^N \geq \lambda^N_{\min} \\ 0 & \text{otherwise.} \end{cases} \tag{10}$$

A firm must pay a sunk cost of entry, F^N_e, to obtain its ability draw. Upon learning λ^N, the firm decides whether to produce or exit the market. The free-entry condition is therefore

$$\left[1-G^N(\lambda^N_{\min})\right]\bar{\pi}^N = F^N_e, \tag{11}$$

where $\left[1-G^N(\lambda^N_{\min})\right]$ denotes the probability of survival and $\bar{\pi}^N$, the expected profit conditional on survival, is given by

$$\bar{\pi}^N = \frac{1}{1-G^N(\lambda^N_{\min})}\int_{\lambda^N_{\min}}^{\lambda^N_{\max}} \pi^N(\lambda^N)g^N(\lambda^N)d\lambda^N. \tag{12}$$

2.3 Quality Ladder Length

The bounded support determines the length of the market's quality ladder, defined as the range of qualities within the market

$$\begin{aligned} Ladder(\gamma;\lambda_{\min},\lambda_{\max}) &\equiv \xi(\lambda_{\max})-\xi(\lambda_{\min}) \\ &= \left(\frac{\gamma\left(\bar{\theta}+k\right)}{w_H}\right)^{\frac{\gamma}{1-\gamma}}\left[\lambda_{\max}^{\frac{1}{1-\gamma}}-\lambda_{\min}^{\frac{1}{1-\gamma}}\right]. \end{aligned} \tag{13}$$

Result 1–Quality Ladder Length: *Assuming that $h>1$, the quality ladder length is increasing in γ: $\frac{\partial Ladder(\gamma;\lambda_{\min},\lambda_{\max})}{\partial\gamma}>0$. Proof:* See Appendix. □

The γ parameter dictates the effectiveness of inputs in raising variety quality. For product markets with faster diminishing returns, the quality ladder is short and concentrated. Therefore, low γ markets are

[13] Note that price sensitivity has been set to one in the model for simplification. If a price sensitivity α is introduced, the optimal price becomes $\frac{1}{\alpha}+w^N_L+w^N_H h^N(\lambda^N)$ and the perfectly competitive market outcome is obtained with infinite price sensitivity.

those with a relatively higher degree of horizontal to vertical differentiation. Result 1 is related to the max-min models studied in the Industrial Organizational literature.[14] These models predict that firms maximally differentiate in the horizontal (vertical) dimension and minimally differentiate in the vertical (horizontal) space provided that the horizontal (vertical) dimension exceeds the vertical (horizontal) dimension. In the model here, when γ is small, firms rely on horizontal attributes to soften price competition.

The model treats the quality ladder length as fixed. Firms locate along the ladder given the range of qualities. The model therefore excludes the possibility that the quality ladder endogenously "lengthens" in response to competition, as in Grossman and Helpman (1991) or Sutton (1998). This assumption is reasonable in the short- and medium-term where technology determines the range of potential qualities within a given product market. The key point of the model is that comparative advantage will determine the quality segment where firms in each region produce.

2.4 Southern Exporters Enter the North

Now suppose the North allows Southern exporters to enter its market. The Southern firms costlessly differentiate their varieties in the horizontal space and locate along the quality ladder according to their entrepreneurial ability. Southern entrepreneurs draw their ability from the distribution $g^S(\lambda^S)$ on the bounded support $[1, \lambda^S_{\max}]$. Recall that $\lambda^N_{\max} > \lambda^S_{\max}$.

A Southern exporter faces the consumer demand functions given in (4). The firm receives its ability draw λ^S, and conditional on exporting, it sets the optimal skilled labor and price at[15]

$$p^S(\lambda^S) = 1 + w^S_L + \left(\bar{\theta} + k\right)\gamma\xi^S(\lambda^S) \tag{14}$$

$$h^S(\lambda^S) = \left(\frac{\gamma\lambda^S\left(\bar{\theta} + k\right)}{w^S_H}\right)^{\frac{1}{1-\gamma}}, \tag{15}$$

where w^S_i, $i = H, L$ are the skilled and unskilled wages in the South. The associated quality is given in (8) except that the Southern skilled wage replaces the Northern skilled wage. For a given quality, it is apparent from (14) that the lower unskilled wages give the South a cost advantage.

When Southern exporters enter the market, all Northern firms lose some market share because of the increased competition.[16] The lower the manufacturing wages in the South, the larger the decline in Northern market shares: $\frac{\partial s(\lambda^N)}{\partial w^S_L} > 0$. Empirical evidence for this derivative has been shown by Bernard et al. (2006): U.S. plant survival is negatively correlated with import competition, but the impact is much stronger from low-wage competition.

This model shows that the intensity of competition within a market depends on the quality ladder. Under the assumption that $\lambda^S_{\max} > \lambda^N_{\min}$, there exists a set of qualities that overlaps between the two regions.

[14]For example, see Neven and Thisse (1990) and Ansari et al. (1998).

[15]Trade costs are assumed to be zero for simplicity.

[16]The denominator in (3) increases to $\sum_{r=N,S}\int_{\Lambda^r} e^{(\bar{\theta}+\mu_n)\xi^r(\lambda^r)-p^r(\lambda^r)}g(\lambda^r)d\lambda^r$. Note that horizontal differentiation prevents any firm from exiting the market.

The random-coefficients utility implies that consumers of a Northern variety with a relatively high quality-adjusted price are now more likely to substitute towards a Southern variety with an identical quality but a lower quality-adjusted price.[17] As a result, the Northern firms that manufacture qualities within this overlapping set suffer the largest decline in market shares.

Denote the ability of the Northern firm that manufactures the quality of the most able Southern firm as $\tilde{\lambda}^N$.[18] The fraction of vulnerable Northern firms is illustrated in Figure 1. The shaded region delineates the area of qualities manufactured in both regions. The South can produce all qualities at or below $\xi^N(\tilde{\lambda}^N)$. The fraction of vulnerable firms is therefore given by

$$\Omega(\gamma; \lambda^N_{\text{min}}, \lambda^N_{\text{max}}) = \frac{\xi^N(\tilde{\lambda}^N) - \xi^N(\lambda^N_{\text{min}})}{\xi^N(\lambda^N_{\text{max}}) - \xi^N(\lambda^N_{\text{min}})}. \tag{16}$$

Result 2–Vulnerable Firms: *The fraction of vulnerable firms decreases with the ladder length:* $\frac{\partial\Omega(\gamma;\lambda^N_{\text{min}},\lambda^N_{\text{max}})}{\partial\gamma} < 0$. *Proof:* See Appendix. □

Result 2 states that the impact of allowing the South to enter the product market is greater in short-ladder markets. This is because a greater fraction of Northern firms overlap with Southern firms along the short quality ladder. In long-ladder markets, Northern firms retain market share by exploiting comparative-advantage factors to climb the quality ladder.

The result is related to models that predict a breakdown of factor price equalization when countries are fully specialized in production. In contrast to a single-cone equilibrium, where endowments are such that all countries produce all goods, the conditions required for factor price equalization are not met in multi-cone equilibrium because countries specialize in varieties tailored to their endowments.[19] This intuition emerges in Result 2. When Northern firms are able to utilize comparative advantages to specialize in increasingly higher-quality goods, they are less vulnerable to import competition.

3 Empirical Implementation

In order to test the implications of the model, I need measures of the degree of vertical differentiation for each manufacturing market. I obtain these measures using U.S. import data by empirically implementing the demand system above. However, it is not computationally feasible to estimate a fully random coefficients model over the entire manufacturing import data. I therefore adopt a nested-logit model that imposes a

[17]In a standard logit setup, all Norther market shares would fall by the exactly same percentage because of the IIA property.

[18]$\tilde{\lambda}^N$ satisfies the following equation

$$\xi^S(\lambda^S_{\text{max}}) = \lambda^{S\,\frac{1}{1-\gamma}}_{\text{max}} \left[\frac{\gamma(\bar{\theta}+k)}{w^S_H}\right]^{\frac{\gamma}{1-\gamma}} = \tilde{\lambda}^{N\,\frac{1}{1-\gamma}} \left[\frac{\gamma(\bar{\theta}+k)}{w^N_H}\right]^{\frac{\gamma}{1-\gamma}},$$

which simplifies to

$$\tilde{\lambda}^N = \left[\frac{w^N_H}{w^S_H}\right]^{\gamma} \lambda^S_{\text{max}}.$$

[19]For evidence in favor of the hypothesis that countries inhabit multiple cones of diversification, see Leamer (1987), Davis and Weinstein (2001) and Schott (2003).

slightly restricted version of the random coefficients framework in (2). The nested logit partially relaxes the IIA property by allowing preferences for alternatives within a nest, such as the type of clothing material, to be more correlated with each other.

Accounting for IIA is important because I infer quality from both price and market share data. To understand why, suppose a consumer chooses between a Japanese wool shirt and an Italian cotton shirt. Under a standard logit or CES framework, the market shares and inferred consumer valuation of both imports fall by an equal percentage if a Chinese cotton shirt enters the market. However, the Chinese shirt's "location" should be closer to the Italian shirt because of the similarity in material. The market share of the Italian shirt should adjust by more than the Japanese wool shirt. The nested logit allows for more appropriate substitution patterns by placing varieties into appropriate nests.

The U.S classifies imports according to the ten-digit Harmonized System (HS). Figure 2 provides a schematic representation of the data structure. Aggregates of the ten-digit *products* are classified at the five-digit Standard Industrial Trade Classification (SITC, Revision 2) level and are referred to as *sectors*. The map shows that within the men's knit-shirts sector, there are different types of shirt materials: cotton, wool, silk, etc. The HS codes therefore provide a natural delineation for the nests because the product descriptions classify imports along similar characteristics. A country's (c) export within a product k is referred to as a *variety* and is indexed by j in this section.

Consumer n obtains utility from purchasing variety j, which is classified in product k, at time t

$$V_{njkt} = \xi_{1j} + \xi_{2t} + \xi_{3jt} - \alpha p_{jt} + \sum_{k=1}^{K} \mu_{nkt} d_{jk} + (1-\sigma)\epsilon_{njt}. \tag{17}$$

The ξ terms represent the variety's valuation that is common across consumers. This is the empirical analog to quality in the theoretical model and is decomposed into three components. The first term, ξ_{1j}, is the time-invariant valuation that the consumers' attach to variety j. The second term, ξ_{2t}, controls for secular time trends common across all varieties. The ξ_{3jt} term is a variety-time deviation that is observed by the consumer but not the econometrician. This term is potentially correlated with the variety's unit value, p_{jt}, which includes all transportation and tariff costs.[20] Let $\delta_{jt} \equiv \xi_{1j} + \xi_{2t} + \xi_{3jt} - \alpha p_{jt}$.

The horizontal component of the model is captured by the expression $\sum_{k=1}^{K} \mu_{nkt} d_{jk}$ and the logit error ϵ_{njt}. The summation term reflects the random consumer tastes specified in the theoretical model. It interacts the valuation that consumer n places on product k, μ_{nkt}, with a dummy variable d_{jk} that takes a value of 1 if variety j lies in product k. Cardell (1997) has shown that the distribution of $\sum_{k=1}^{K} \mu_{nkt} d_{jk}$ is the unique distribution such that if ϵ is distributed extreme value, then the sum is also distributed type-I extreme value.[21]

[20] Unfortunately, non-tariff barrier data at the ten-digit level are unavailable.

[21] The degree of within nest correlation is controlled by $\sigma \in (0, 1]$ and is assumed to be identical across all products. As σ approaches one, the correlation in consumer tastes for varieties within a nest approaches one and as σ tends to zero, the nested logit converges to the standard logit model since the within group correlation tends to zero.

The consumer chooses variety j if $V_{njkt} > V_{nj'kt}$, $\forall\ j' \neq j, \forall k$.[22] The distributional assumptions imply the usual logit formulas: the conditional market share for variety j is

$$\bar{s}_{jt/k}(\delta,\sigma) = \frac{\exp[\frac{\delta_{jt}}{1-\sigma}]}{D_{kt}}, \tag{18}$$

where $\bar{s}_{jt/k}$ is variety j's share within product k and $D_{kt} = \sum_{j\in\mathcal{J}_{kt}} \exp[\frac{\delta_{jt}}{1-\sigma}]$. The notation $\mathcal{J}_{kt}$ denotes the total number of varieties within a product.

The probability of choosing product k amongst the set of all possible products within the sector (the product share) is given by

$$\bar{s}_{kt}(\delta,\sigma) = \frac{D_{kt}^{(1-\sigma)}}{\left[\sum_k D_{kt}^{(1-\sigma)}\right]}. \tag{19}$$

The unconditional market share for variety j is the product of (18) and (19):

$$\begin{aligned} s_j(\delta,\sigma) &= \bar{s}_{jt/k}(\delta,\sigma)\bar{s}_{kt}(\delta,\sigma) \\ &= \frac{\exp[\frac{\delta_{jt}}{1-\sigma}]}{D_{kt}^{\sigma}\left[\sum_k D_{kt}^{(1-\sigma)}\right]}. \end{aligned} \tag{20}$$

The denominator is composed of a product value, D_{kt}, which is common to all varieties in the product, and the total market value, $\sum_k D_{kt}$, which is common to all varieties within the sector.

An outside variety is required to complete the demand system. The outside variety allows consumers to substitute towards this variety if there is a homogenous increase in the inside variety prices. For example, the outside option captures the utility for purchasing a domestic U.S. variety.[23] The utility of the outside option is given by

$$u_{n0t} = \delta_{0t} + \mu_{n0t} + (1-\sigma)\epsilon_{n0t}, \tag{21}$$

and is normalized to zero by setting $\delta_0 = 0$ and $D_0 = 1$. The consumer chooses the outside option if his or her utility is greater than all the inside varieties. The outside market share is therefore

$$s_{0t}(\delta,\sigma) = \frac{1}{\left[\sum_k D_{kt}^{(1-\sigma)}\right]}. \tag{22}$$

Dividing (20) by (22) removes the market value term that is common across all varieties. Taking logs gives

$$\ln(s_{jt}) - \ln(s_{0t}) = \frac{\delta_{jt}}{1-\sigma} - \sigma \ln D_{kt}. \tag{23}$$

[22] The derivation of the nested logit follows Berry (1994).

[23] The outside variety market shares are not available at the sector-level. I therefore rely on import penetration measures at the slightly coarser four-digit Standard Industrial Classification (SIC, Revision 1987), which are taken from Bernard et al. (2006) and mapped to the SITC sectors using a concordance provided by Feenstra et al. (2002). I assume that all sectors within the four-digit SIC codes have the same import penetration shares. The outside variety market share is defined as one minus the import penetration ratio. Once the outside market share is known, the total market size, MKT_t is endogenously obtained through the formula $MKT_t = \sum_{j\in\mathcal{J}_{kt}, j\neq 0} m_{jt}/(1-s_{0t})$, where m_{jt} denotes the import quantity of variety j. Variety j's market share is then obtained by $s_{jt} = m_{jt}/MKT_t$.

Dividing (19) by (22) and taking logs simplifies to $\ln D_{kt} = [\ln(\bar{s}_{kt}) - \ln(s_{0t})] / (1-\sigma)$. Substituting this expression into (23) gives[24]

$$\delta_{jt} = \ln(s_{jt}) - \sigma \ln(\bar{s}_{jt/k}) - \ln(s_{0t}). \tag{24}$$

Using the definition of δ, the equation can be rewritten as

$$\ln(s_{jt}) - \ln(s_{0t}) = \xi_{1j} + \xi_{2t} - \alpha p_{jt} + \sigma \ln(\bar{s}_{jt/k}) + \xi_{3jt}. \tag{25}$$

The expression in (25) states that the relative market share of the variety will equal its mean valuation plus its significance within the nest it occupies, less its price. Typically, $\xi_{1j} + \xi_{2t}$ are approximated using the variety's characteristics. In the television market, these characteristics might include sharpness and screen size, but the trade data do not record characteristics. I therefore exploit the panel dimension of the data by estimating variety and year fixed effects. The third component of quality, ξ_{3jt}, is not observed and plays the role of the estimation error. Both this term and the nest share $(\bar{s}_{jt/k})$ are potentially correlated with the variety's price, so instrumental variables are required to identify the parameters.

Supply shifters are the ideal instruments in any demand regression. One set of cost shifters used are exchange rates and the interaction of distance to the U.S. with the price of oil.[25] However, there is insufficient variation in these instruments, even when they are interacted with product dummies, to identify the parameters. Additional cost shifters that vary at the ten-digit HS level for all countries, years and industries spanned by the trade data are not available. For example, country-specific raw cotton prices could instrument the price of cotton shirts. However, the detail of trade data is such that many knit-shirt products contain some amount of cotton material. As a result, country-specific instruments have insufficient variation to shift the price of each individual variety.

Under the assumption that ξ_{3jt} is serially uncorrelated, lagged competitor prices and lagged prices of varieties exported by the country serve to instrument variety j's price. Lagged prices will be correlated with j's price because of common marginal cost components (such as fabric prices for apparel).[26] One justification for using lagged rival prices as instruments is that the utility structure in (17) does not include competitor prices and is therefore uncorrelated with ξ_{3jt} by construction.

As noted in Berry (1994), characteristics of varieties within products can serve to instrument the nest share variable. Since characteristics data are unavailable, the number of varieties within the product nest and the number of observed varieties exported by the country are included as instruments to identify σ. Note that using the number of varieties is less restrictive than using product characteristics as instruments, which is a standard practice in the discrete choice literature. Validity of these instruments only requires that entry and exit occur prior to the revelation of the consumers' unobserved valuation.

[24] The nested logit provides a simple analytical expression to solve for the mean utility δ. In the random-coefficients model developed by Berry et al. (1995), obtaining this value is computationally intensive because it must be simulated. This is why the nested-logit procedure is adopted here.

[25] The great-circle distance information is taken from http://www.eiit.org/.

[26] Hausman (1996) and Nevo (2001) are also examples of discrete choice demand models that also rely on competitor prices as instrumental variables to identify demand parameters.

A second issue that arises in estimating (25) is that the market shares are likely to be an aggregation of even more finely classified imports. A country's large market share may simply reflect the fact that it exports more *unobserved* varieties within a product. For example, suppose that China and Italy export identically priced varieties that split the market equally at the (unobserved) twelve-digit level but that China exports more twelve-digit varieties. Aggregation to the observed ten-digit level would assign a larger market share to China, which from (25) would cause an upward bias in the fixed effects. One way to account for this problem is to allow the mean of the logit error distribution to vary across countries. For instance, a China dummy variable could capture the higher mean of the Chinese logit error. Country fixed effects, however, are not identified because of the variety fixed effects. Following the theoretical predictions of Krugman (1980), I therefore use a country's population to proxy the unobserved varieties. Allowing the (log of) population to shift the logit error mean implies that it becomes an additional covariate in (25).[27]

The estimating regression uses a fixed effect IV approach to estimate

$$\ln(s_{jt}) - \ln(s_{0t}) = \xi_{1j} + \xi_{2t} - \alpha p_{jt} + \sigma \ln(\bar{s}_{jt/k}) + \gamma \ln pop_{ct} + \xi_{3jt}, \tag{26}$$

where pop_{ct} is the population in country c at time t. I run (26) separately on the full set of manufacturing sectors which amounts to estimating approximately 850 demand curves. Quality is defined using the estimated parameters:

$$\xi_{jt} \equiv \hat{\xi}_{1j} + \hat{\xi}_{2t} + \hat{\xi}_{3jt}. \tag{27}$$

The quality measures are residuals of the demand systems. As noted in the theoretical section, it measures the consumers' willingness-to-pay; an increase in a product's quality allows its price to rise without losing market share. The lack of characteristics data implies that many factors could influence this measure, but it is important to note that this set is much smaller by controlling for prices. For example, a variety may have a large market share if the exporting country is geographically close to U.S. However, the price includes transportation costs and therefore the quality estimate is not capturing purely "gravity" effects such as distance. A similar argument can be made regarding free trade agreements. Even though Mexican and Canadian import shares are high because of NAFTA, this effect will operate through prices, which are inclusive of tariffs. Likewise, a low-wage country may have high market shares, but by conditioning on its low export price, the quality measure accounts for this.

The intuition behind the quality estimates is similar to Hallak and Schott (2005). In their model, quality is inferred by linking a country's export price index to its trade balance and defined as the sum of an estimated country fixed effect, a linear trend and deviations from the trend. Here, the quality measure is defined as the sum of a *country-product* fixed effect, year fixed effects and the deviation and therefore allows quality to be recovered at the variety level.

[27] In Krugman (1980), the number of varieties a country exports is proportional to its size given the production side of the model. Hallak and Schott (2005) deal with the unobserved varieties problem by assuming the number of varieties a country exports varies with its comparative advantage. This assumption, however, is problematic in the setup here because comparative advantage is likely to be correlated with the unobserved component of quality.

4 Data and Quality Estimation Results

U.S. product-level import data, compiled by Feenstra et al. (2002), track a country's export in ten-digit HS products between 1989-2001. The sample is restricted to the manufacturing sectors. The data record the fob value, transportation costs and customs duties paid. The unit value is defined as the sum of the three components divided by the quantity and deflated to real values.[28] Table 2 reports basic summary statistics by two-digit SIC industry. The apparel and leather industries have the lowest average per capita GDP while transportation, industrial machinery and chemicals receive imports from the richest set of countries.[29]

The estimating equation in (26) is run separately on 848 manufacturing sectors. Summary statistics of the regressions are shown in Table 3. Approximately 74 percent of the 1.1 million observations are associated with a negative and statistically significant price coefficient. Although the average p-value testing the overidentifying restrictions is low, the IV price coefficient is almost four times the magnitude of the OLS coefficient (rows 2 and 3), indicating that instruments are working in the intuitive direction. The average own-price elasticity (row 4) is low, but this is expected because the fixed effect regressions exclude across-variety variation. Approximately 80 percent of the estimations report a statistically significant σ parameter, indicating that the nested structure is important. In addition, 90 percent of the estimations report that $\hat{\sigma}$ lies within the unit interval, which is a necessary and sufficient condition for random utility maximization (McFadden, 1978).[30] The standard errors for the quality estimates are obtained by simulating draws from the asymptotic distribution of the estimated parameters ($\hat{\alpha}$, $\hat{\sigma}$ and $\hat{\gamma}$).[31] The average t-statistic is 12, indicating that the quality estimates are precisely estimated.

4.0.1 Factor Endowments and Quality Specialization

The parameters of interest in (26) are the estimated fixed effects and residuals that constitute the quality measure. The inferred qualities offer support for previous studies that have found, using prices to proxy for quality, that more capital- and skill-intensive countries export higher quality varieties.[32] The relationship

[28] Values are deflated using the CPI. The import data are extremely noisy (General Accounting Office, 1995), so the data is trimmed along two dimensions. All varieties that report a quantity of one or a total value of less than $10,000 are excluded. I also exclude varieties with unit values below the 5th percentile and above the 95th percentile within the sector. 12 percent of the sectors report multiple units across products. For these sectors, the products of the majority unit are kept (which comprise about 80 percent of the observations within a multiple-unit sector). The sample is restricted to chemicals (SITC 5), manufactured goods (SITC 6), machinery (SITC 7) and miscellaneous manufactured goods (SITC 8). All homogenous goods are excluded since these goods, by definition, have no quality differences (Rauch, 1999).

[29] Dollar-denominated GDP per capita, population and real exchange rate data are taken from World Bank's World Development Indicators.

[30] Specifications tests proposed by Hausman and McFadden (1984) indicate that nesting at the ten-digit HS product level is more appropriate than an alternative specification which nests at the eight-digit HS level.

[31] The bootstrap, which is an alternative method to obtain the standard errors, may be inappropriate in this context since sampling varieties may alter the market equilibrium.

[32] See Hummels and Klenow (2005) and Hallak (2006).

between quality and level of development is illustrated by regressing variety quality on GDP per capita:

$$\xi_{ckt} = \alpha_{kt} + \beta \ln Y_{ct} + \nu_{ckt}, \tag{28}$$

where ξ_{ckt} is the estimated quality of country c's export in product k at time t and Y_{ct} is country c's per capita GDP. The inclusion of a product-year dummy, α_{kt}, indicates that the regression considers the cross-sectional relationship between quality and income within products. Table 4 reports that the coefficient on exporter income is positive and significant. Richer countries, on average, export higher quality products within narrowly defined industries.

Columns two and three are re-run (28) using capital-labor ratios and the fraction of a country's workforce with tertiary education, which provides a more appropriate test of the factor proportions hypothesis.[33] The coefficients are also positive and significant; countries abundant in skill and capital export higher quality varieties within the narrowly classified products. Thus, the quality measures inferred from a model that allows products to possess both vertical and horizontal attributes indicate evidence of within-product quality specialization.

Below, I demonstrate that although more advanced countries export higher quality varieties within products, this "distance" between developed and developing countries' exports varies substantially across products. This means that quality specialization is more pronounced in some products and not others. To the extent that quality specialization decreases vulnerability to competition, as predicted by the model, the scope for quality differentiation will have important implications for developed countries are affected by import competition.

5 Properties of the Quality Ladders

This section documents the properties of the quality ladder. The quality ladder is defined as the range of the estimated qualities within a product:[34,35]

$$Ladder_{kt} = \xi_{kt}^{\max} - \xi_{kt}^{\min}. \tag{29}$$

The quality ladder possesses some intuitive properties. First, quality ladders are positively correlated with factor intensities. UNIDO (2005) provides productivity, skill and capital intensities at the three-digit In-

[33] Capital-labor ratios and tertiary education percentages are obtained from the World Bank's World Development Indicators.

[34] I define the quality ladder as the inter-decile range which is more robust measure than the range. However, the results, including those reported in Section 6, are robust to defining the quality ladder as the full range, the inter-quartile range or the standard deviation of qualities within a product.

[35] Despite the data trimming procedures described in footnote 28, a small fraction of quality ladders heavily skews the distribution of quality ladders. This is likely due to the noisy trade data or to imperfect aggregation within products. For example, HS 8543190000 ("particle accelerators, nes") contains imports ranging from a couple dollars to over three-hundred thousand dollars which generates a quality ladder 200 times greater than the median. I therefore trim the top 1 percent of the quality ladder distribution, of which 43 percent of the trimmed products contain the phrases "not elsewhere specified" or "other" in their description.

ternational Standard Industrial Classification (ISIC) industry level. These measures are plotted against the industry quality ladder in Figure 3.[36] On average, industries that are more factor intensive are associated with longer quality ladders. For example, apparel, footwear, and fabricated metals are short-ladder industries while long-ladder industries include machinery, iron and steel, chemicals and transport equipment. There are, however, exceptions to this pattern. For example, the low-skilled textile industry is characterized by a long quality ladder, presumably because the industry is relatively capital intensive (see second panel).[37]

In Figure 4, I plot the industry quality ladder against the coefficient of variation of factor intensities across countries. Greater *intra*-industry heterogeneity is associated with longer quality ladders. This is consistent with countries using varying degrees of factor intensities to manufacture varieties of different qualities within the same product. As in the previous figure, there are some exceptions. For example, the variation in skill intensity for apparel and footwear is large, although its estimated quality ladder is short. I demonstrate below that this can be explained by the fact that apparel and footwear are types of goods that possess a smaller scope for vertical differentiation. As a result, the quality variation within these industries is small despite differences in cross-country factor intensities used to manufacture these goods.

The next set of results verifies that long quality ladders are characterized by a greater degree of vertical relative to horizontal differentiation. I appeal to the definitions of horizontal and vertical markets to demonstrate this claim. In a vertical product market, export prices and quality are isomorphic since consumers agree on the rankings of goods. The mapping between prices and quality is less clear in horizontal markets because idiosyncratic preferences influence purchasing behavior. The inferred qualities are used to test if prices are better proxies for quality in long-ladder products. Consider the following regression that relates a variety's quality to its price, allowing the coefficient to vary according to the product's quality ladder:

$$\xi_{ckt} = \alpha_{kt} + \beta_1 \ln p_{ckt} + \beta_2 \left(\ln p_{ckt} \times Ladder_{k0}\right) + \nu_{ckt}. \tag{30}$$

Product-year fixed effects are denoted by α_{kt}, and p_{ckt} is the unit value of country c's export in product k. The coefficient of interest is β_2. A positive β_2 implies that the relationship between price and quality is (relatively) stronger in long ladders. This would provide evidence that long ladders possess characteristics that are more vertical than horizontal.

I mitigate concerns of an endogenous quality ladder by relying on the product's baseline quality ladder, $Ladder_{0k}$. Note that using the baseline quality ladder may still be problematic if the errors are serially

[36] The ISIC quality ladder is a weighted average of the product-level quality ladders defined in (29). A concordance from HS to ISIC codes is obtained from http://www.eiit.org. Skill intensity is the average compensation per worker. Capital intensity is the ratio of capital stock, computed using the perpetual inventory method, to employment. Productivity is captured by value added per worker.

[37] It should also be noted that the quality ladders for more factor-intensive industries are arguably biased downwards. Accounting for the selection bias would increase the quality ladders in more factor-intensive industries. For industries like textiles, footwear and apparel, the selection bias is arguably non-existent. The selection bias works against the results below by underestimating the quality ladder in factor-intensive industries. Correcting for zero trade flows (e.g., Helpman et al. (2006)) would strengthen the arguments below.

correlated, but the baseline nevertheless serves as a more appropriate measure than the contemporaneous quality ladder. Table 5 shows that the ladder coefficient is positive and statistically significant at the 10.6 percent level.[38] Longer quality ladders are therefore indicative of a larger degree of vertical differentiation because of the closer relationship between unit values and quality.

Specification (30) casts doubt on the vertical-market assumption that is commonly used in the international trade literature. The findings indicate that the *average* consumer does not attach a high valuation to expensive imports into short-ladder products. For example, although Canadian footwear is 29 percent more expensive than the average footwear import, it has a lower than average estimated quality. Horizontal differentiation explains why these high quality-adjusted varieties remain in the product market. Some consumers purchase Canadian footwear not because its ξ is high but because these consumers obtain a high logit draw for the Canadian shoes. In the aggregate, however, the *average* consumer attaches a low valuation to the expensive Canadian shoes because these exports do not offer better vertical attributes to justify its high price. Inferring quality from just prices would instead place Canada in the top of the footwear quality distribution under the assumption that *all* consumers agree that Canadian shoes are high quality. The results of (30) suggest that this assumption may appropriate for some product markets and not others.

Two graphs further illustrate this point. Figure 5 plots the relationship between quantities, unit values and the estimated qualities for two products: "Transmission Receivers Exceeding 400 MHZ" (HS 8525203080) and "Footwear with Plastic Soles, Leather Uppers" (HS 6403999065). The figures are ordered by unit values, which also roughly correspond to exporter per capita GDP. For transmission receivers (top panel), unit values and quality are positively correlated, indicating that the average consumer assigns a higher valuation to more expensive varieties. For this product, it appears that the vertical market assumption to use prices to proxy unobserved quality is tenable.

The bottom panel plots leather shoes. Here, exporters of expensive varieties, like Belgium, are associated with relatively low quality. The reason lies in the export quantities (square dots). Belgium has a very low market share, even conditioning on its price. Taking into account Belgium's market share and export price, the quality estimates reveal that the average consumer attaches a low valuation to Belgian leather shoes. On the other hand, France exported the second most expensive variety in this HS classification and obtained a relatively high market share given its price. It is therefore assigned a high quality estimate. There are other notable exceptions that accord with intuition. Spain, Italy and Germany export expensive footwear, but they also secure large market shares given their export prices. As a result, these countries are associated with relatively high quality shoes.

Varieties in short-ladder products are more substitutable than varieties that enter into long-ladder products. Using the estimated parameters from (26), the cross-price elasticities between any two countries'

[38]Note that the negative β_1 coefficient is a consequence of how quality is defined (see (26)). *Conditional* on market shares, price and the estimated quality measures are positively correlated.

exports into product k at time t is given by

$$\eta_{cc',k} = \frac{\partial s_c}{\partial p_{c'}} \frac{p_{c'}}{s_c} = -\hat{\alpha} p_{c'} s_{c'} \left(\frac{\hat{\sigma}}{1-\hat{\sigma}} \frac{s_{c'|k}}{s_{c'}} + 1 \right), \quad \text{if } c \neq c' \in k. \tag{31}$$

$\eta_{cc',k}$ is the percent change in the market share of country c in product k if the price of c' increases by one percent. I calculate the (within-product) bilateral cross-price elasticities for all varieties in 1995, which amounts to more than 1 million elasticities. These elasticities are regressed on the quality ladder to compare substitutability of varieties across products

$$\eta_{cc',k} = \alpha + \beta Ladder_{0k} + \nu_{cc',k}. \tag{32}$$

If varieties within short-ladder products are more substitutable then they should exhibit larger cross-price elasticities and β should be negative. Table 6 confirms that β is negative and statistically significant. The results are robust to including two-digit SIC (column two) and sector fixed effects (negative, but not significant). Using the point estimates in column one, the cross-price elasticity between any two varieties in an average-ladder product is 2.6 percent. This number falls to 2.2 percent in a long ladder (one standard deviation above the mean). This finding is consistent with the hypothesis that imports of similar quality are more substitutable.[39]

Since varieties in short-ladder products rely on horizontal differentiation and are more substitutable, developed countries should have lower market shares in short-ladder products. Establishing this fact provides initial evidence that developed countries are more vulnerable to competition in markets characterized by a greater degree of horizontal differentiation. Define the import market share of OECD countries by $s_{kt}^{OECD} = \sum_{c \in \text{OECD}} m_{ckt} / \sum_c m_{ckt}$, where m_{ckt} denotes the import quantity from country c in HS product k at time t. I compare the OECD market shares across across long- and short-ladder products in the following regression:[40]

$$s_{kt}^{\text{OECD}} = \alpha_t + \beta Ladder_{k0} + \nu_{kt}. \tag{33}$$

Table 7 reports a positive and significant β coefficient. The second and third column include two-digit SIC industry-year and sector-year controls, respectively. The findings show that even within industries and sectors, OECD countries have larger market shares in longer products. Using the point estimates in column one, OECD countries have a 4.9 percentage point (11 percent) greater market share in long ladder products (one standard deviation above the mean) relative to a product with an average ladder.

[39]A stronger test of this hypothesis is to demonstrate that the cross-price elasticity is inversely related to the quality "difference" between the varieties within a product. However, because of the IIA property (i.e., $\eta_{cc',k} = \eta_{\tilde{c}c',k}, \forall c \neq \tilde{c} \in k$), this comparison is not meaningful in this context. For example, the cross-price elasticity of the highest- and lowest-quality variety with respect to the second lowest-quality variety is the same. Using a random-coefficients estimation framework to break IIA, Khandelwal (2005) finds evidence that cross-price elasticities are decreasing in the distance between exporting countries' income levels for a sample of footwear and apparel goods.

[40]Products with $s_{kt}^{OECD} = 1$ are excluded from this regression. Consistent with within-product quality specialization, products comprised of only OECD imports have a discontinuously shorter quality ladder because of the absence of developing countries.

Industrialized countries preserve market shares in long-ladder products because they upgrade quality at a (relatively) faster rate. Table 8 reports the coefficients of a difference-in-difference specification to demonstrate this claim. Using only within-variety variation, the table regresses a variety's quality on a linear time trend, an OECD country dummy, the product's quality ladder and the full set of interactions. The coefficient of interest is the time trend-OECD dummy-ladder interaction. This interaction captures the differential rate at which OECD nations improve export quality across ladder lengths. Although OECD countries improve export quality at a slower rate, they ascend the quality ladder relatively more rapidly in long-ladder products. The point estimates indicate that the quality growth differential between non-OECD and OECD countries is 28 percent higher in an average ladder compared to a long-ladder product (one standard deviation above the mean). The findings provide an explanation as to why industrialized countries remain competitive in these products.

The next section formally tests the vulnerability prediction by applying these quality ladders to U.S. industry data. Although the quality ladders are inferred from imported varieties, the maintained assumption is that they provide information on the U.S. market's scope for vertical differentiation. This is a reasonable assumption since the ladders are constructed from other highly developed countries' imports, such as Japan and Canada, that are similar to the U.S. It is assumed that the U.S. firms can manufacture qualities within the quality ladder. One potential caveat is that non-tariff barriers, such as voluntary export restraints or quotas, may results in higher quality imports but not domestic varieties. The major non-tariff barrier operating during this period was the Multifiber Arrangement (MFA) which imposed quotas on apparel and textile articles.[41] However, the quotas were only relevant for developing economies, so they should not have directly influenced developed countries' apparel and textile quality, which presumably is similar to U.S quality.

6 The Vulnerable Jobs

6.1 Quality Ladders and U.S. Manufacturing Employment

The empirical strategy to demonstrate that developed countries are more vulnerable to import competition in short-ladder industries modifies the approach taken by Bernard, Jensen, and Schott (2006). Using detailed U.S. plant-level data, they show that the probability of plant death increases in industries with greater exposure to low-wage imports. In response, plants switch towards more capital-intensive products in high exposure industries. While indicative of a quality-upgrading strategy, the theoretical and empirical evidence above suggests that this strategy may be limited only to a subset of industries.

[41] Brambilla, Khandelwal, and Schott (2006) examine the effects of the Multifiber Arrangement on textile and clothing export quality using a unique dataset that records the details of all bilateral MFA arrangements signed by the United States. For evidence of quota-induced quality upgrading, using prices to proxy for quality, see Aw and Roberts (1986), Feenstra (1988) and Evans and Harrigan (2005).

I decompose four-digit SIC industry import penetration into imports originating from countries with less than 5 percent of U.S. per capita GDP ($LWPEN$) and the rest of the world ($OTHPEN$).[42] Total import penetration is defined as $I_{mt}/(I_{mt}+Q_{mt}-X_{mt})$, where I_{mt} is the value of imports in industry m at time t, Q_{mt} is the industry's domestic production and X_{mt} represents U.S. exports. $LWPEN$ is the product of total import penetration and the value share of imports originating from low-wage countries:

$$LWPEN_{mt} = \frac{I_{mt}^{\text{low}}}{I_{mt}+Q_{mt}-X_{mt}}.$$

$OTHPEN$ is defined analogously as

$$OTHPEN_{mt} = \frac{I_{mt}-I_{mt}^{\text{low}}}{I_{mt}+Q_{mt}-X_{mt}}.$$

The industry's quality ladder, $IndLadder_m$, is obtained by weighting the *baseline* product ladders by their importance within the industry:

$$IndLadder_m = \sum_{k=1}^{K_m} w_{0k} Ladder_{k0}, \tag{34}$$

where K_m denotes the number of ten-digit HS products in SIC industry m, $Ladder_{k0}$ is the product's baseline ladder and w_{0k} is its baseline weight within the industry.

The industry ladders are matched to the NBER manufacturing database (Bartelsman et al., 1996) from 1989-96. The data contain four-digit SIC industry employment, skill composition and capital-labor ratios.[43] The following regression assesses the relationship between employment, import penetration and the industry's quality ladder:

$$\ln Emp_{mt} = \alpha_m + \alpha_t + \beta_1 OTHPEN_{mt} + \beta_2 LWPEN_{mt} + \beta_3 \left(LWPEN_{mt} \times IndLadder_m\right) + \nu_{mt}. \tag{35}$$

The specification includes four-digit industry and year fixed effects. The regression should find $\beta_1, \beta_2 < 0$; higher import penetration is negatively correlated with industry employment. The coefficient of interest is the interaction between $LWPEN$ and $IndLadder$, which quantifies the differential impact of low-wage penetration on employment across ladders. The vulnerability hypothesis predicts $\beta_3 > 0$; long-ladder industries with high low-wage exposure suffer smaller employment declines.

Column one of Table 9 reports the baseline results. The coefficients are statistically significant and have the predicted signs. Import penetration negatively affects employment, and the impact of low-wage penetration is stronger. The interaction coefficient is positive and precisely estimated, supporting the model's prediction that vulnerability to low-wage penetration declines in industries with longer quality ladders.

The point estimates are also economically significant. If low-wage penetration increases by ten percentage points, employment in an average ladder industry declines by 7 percent. In contrast, low-wage

[42] The $LWPEN$ and $OTHPEN$ variables are provided by Bernard et al. (2006).

[43] Skill intensity is measured as the ratio of non-production to production workers. Capital intensity is the ratio of capital stock to total employment.

penetration is not associated any employment declines in a long-ladder industry (one standard deviation above the mean). The finding that long-ladder industries are essentially insensitive to import penetration is not evident without considering differences across product markets. As a specific example, if $LWPEN$ were to increase by ten percentage points in the household audio and video equipment industry (SIC 365), employment would fall 6.6 percent compared to a 12.2 percent decline in footwear (SIC 314), an industry with one-third the ladder length.

The point estimates imply large changes in employment resulting from import competition. However, as argued by Leamer (2000), even low import volumes can have a significant impact on U.S. firms if international trade equalizes product prices. This is particularly relevant for products with short quality ladders. Indeed, the extent to which domestic goods overlap with foreign goods, and the source of the foreign imports, is precisely what determines which industries are vulnerable to competition. The magnitude of the employment effects are consistent with Bernard et al. (2006), whose conservative estimates indicate that a ten percentage point increase in $LWPEN$ raises the probability of U.S. plant death by 17 percent.

In column two, I include a ladder-$OTHPEN$ interaction to determine if the effects of imports originating from more-advanced countries are also dampened in long-ladders. Although positive, the ladder-$OTHPEN$ interaction is not significant. Note that the ladder-$LWPEN$ interaction remains statistically significant.

One concern with the previous regressions could be that the quality ladder just captures observable factor intensities. If this were true, then the results in columns one and two simply confirm the findings of previous studies that have argued that higher skill- and capital-intensive industries are less susceptible to import competition. Columns three and four therefore include interactions of an industry's baseline skill and capital intensities with $LWPEN$. More capital-intensive industries are less vulnerable to low-wage imports, although the effect does not vary with skill intensity. The coefficient on the quality ladder interaction remains statistically significant implying that the quality dimension is a relevant metric in assessing an industry's vulnerability. Moreover, the magnitudes of the point estimates are comparable. Using the point estimates in column three, *ceteris paribus*, a ten percentage point increase in $LWPEN$ results in a 6 percent larger employment decline in a short-ladder industry (one standard deviation below the mean). Similarly, a low capital-intensive industry (one standard deviation below the mean) suffers a 6.8 percent larger decline relative to an industry that uses the average capital intensity.

The OLS regressions are problematic because, while using the baseline ladder and factor intensities mitigates endogeneity concerns, the import penetration measures are likely to be endogenous. International trade may be filling a void created by a decline in domestic industries caused by other factors, such as structural changes in the economy. The simultaneity would bias the import penetration coefficients downward in (35). I therefore instrument the penetration measures with industry-year weighted averages of exchange rates, tariffs and freight rates for low-wage countries and the rest of the world.[44]

[44] As weights, I use the country's share of total industry value in 1989.

Table 10 presents the IV results. The first column shows the baseline specification. Instrumenting actually causes the coefficient on $LWPEN$ to increase in magnitude, which suggests measurement error in the variable.[45] The quality ladder now becomes even more important. For example, a ten percentage point increase in $LWPEN$ leads to a 20 percent employment decline in a short-ladder industry (one standard deviation below the mean) compared to no employment losses in the average industry. These magnitudes are large but again are plausible if trade leads to a convergence in product prices. For example, the raw data indicate that low-wage import penetration into the footwear industry (SIC 314) increased by 35 percentage points and employment simultaneously fell by almost 50 percent between 1989-96. Import competition therefore can have large impacts on domestic firms in short-ladder industries, particularly those at the competitive fringe.

Column two includes the interaction of the ladder with $OTHPEN$, and the main results do not change. Columns three and four add the interactions of factor intensities and the ladder-$LWPEN$ interaction remains robust to these controls, as well. Moreover, the results are robust to including two-digit SIC-year fixed effects as shown in Table 11. As expected, the magnitudes of the coefficients decline, but ladder interaction remains statistically significant in each of the four regressions.

Although the precise adjustment mechanism firms use to respond to import competition is difficult to uncover from industry-level data, there is weak evidence that high exposure in long-ladder industries is associated with a faster accumulation of skilled labor. Columns one and two of Table 12 report the analogous OLS and IV regression with skill intensity as the dependent variable in (35). The coefficient from OLS is not significant, but the $LWPEN$-ladder interaction is positive and significant at the 12 percent level in the IV regression. The IV point estimates imply that in the industry with the mean ladder length, a ten percentage point rise in $LWPEN$ corresponds to a 9 percent accumulation of skilled labor. An analogous increase is correlated with a 21 percent rise in skill intensity in a long-ladder industry. Under the assumption that quality upgrading raises the demand for skilled labor, this result is consistent with a quality response to import competition.

Columns three and four report the evolution of capital intensity associated with increased import penetration. Here, an increase in import penetration results in faster growth in capital-labor ratios for shorter ladder industries, which appears counterintuitive. This is likely a consequence of the aggregate data. Given that employment and import penetration are negatively associated in short-ladder industries, the industry-level capital-labor ratio may mechanically rise within increased import penetration.

The quality ladder metric identifies the types of industries most likely to survive competition. Consistent with the model's predictions, differences in the scope for vertical differentiation across product markets are important in understanding the survival and future of U.S. manufacturing. The future of industries like apparel and footwear appears bleak if firms are unable to vertically differentiate their products from the flood of cheap imports. On the other hand, the entrance of emerging economies like China into relatively

[45] Bernard et al. (2006) also find that instrumenting import penetration causes the magnitude of the coefficients to increase.

sophisticated product lines, such as laptops and television, is likely to represent a smaller threat to electronic firms in developed countries.[46]

6.2 Quality Ladders and Trade Policy

While quality specialization may be a strategy to reduce exposure in long-ladder markets, it is by definition ineffective in short-ladder product markets. This subsection offers evidence that short-ladder industries instead insulate themselves by imposing higher tariff barriers on imports.

Since tariffs are observed at the variety level, I can compare how tariffs vary across products that differ in ladder lengths. Consider the following specification that regresses ad-valorem tariff rates on the product-level quality ladders, a low-wage country indicator and its interaction with the ladder

$$\ln\left(1+\tau_{ckt}\right)=\alpha_t+\beta_1 LOW_c+\beta_2 Ladder_{k0}+\beta_3\left(LOW_c\times Ladder_{k0}\right)+\nu_{ckt}. \qquad (36)$$

The tariff rate levied on country c's exports in product k at time t is denoted τ_{ckt}. As before, the product's baseline quality ladder is used to avoid endogeneity problems. The coefficients of interest are β_2 and β_3. β_2 captures the extent to which tariffs vary with the quality ladder and should be negative. A negative interaction coefficient, β_3, measures the extent to which tariffs are lower on low-wage imports into longer ladders relative to shorter ladders. Column one in Table 13 reports the baseline results. The coefficients have the predicted signs and are economically and statistically significant. An import from a non-low-wage country into a long-ladder product (one standard deviation above the mean) faces a .7 percentage point (12 percent) lower tariff relative to the mean. On average, low-wage imports face a 3 percentage point higher tariff, and the quality ladder has an even greater impact on the differential tariff across products. Low-wage countries face a 1.2 percentage point (14 percent) lower tariff in a product with a long quality ladder relative to an average-ladder product.

The specification in column one is incomplete because the endogenous trade protection literature has identified additional variables that influence trade protection.[47] The literature has found that trade barriers are higher in industries that have lower factor intensities and in industries that are more organized. Trade barriers also tend to be lower on intermediate products as opposed to final consumer goods. Column two controls for these additional factors by including four-digit SIC industry factor intensities, two-digit SIC union employment figures and an (admittedly crude) indicator if the product is an intermediate good.[48] All the variables have the expected signs and the ladder coefficients remain statistically significant. Products that enter skill- and capital-intensive industries face lower tariffs, as do intermediate goods. There is also a positive association between unionization and tariff rates.

[46]See Rodrik (2006) for a discussion of the sophistication of China's exports given its position in the income distribution.

[47]For a survey of the literature, see Rodrik (1995).

[48]Union employment figures are constructed from the NBER Consumer Population Survey (Merged Outgoing Rotation Groups). Intermediate goods are identified as any HS code that contains the phrases "parts", "prts", "pts" and "component" in its description (Ng and Yeats, 1999).

Column three includes interactions of factor intensities with the low-wage dummy since low-wage imports in low skill- and capital-intensive industries should face higher tariffs. The results find evidence for this and the ladder variables remain negative and significant. For a sense of the relative magnitudes, a low-wage import into a industry with high capital intensity faces a 22 percent lower tariff relative an industry at the average capital intensity. *Ceteris paribus*, a low-wage import into a long ladder faces an 11 percent lower tariff relative to an average ladder.

Columns four through six re-run the regressions but now include two-digit SIC-year fixed effects to account for potentially unobserved factors. For example, the fixed effects control for the fact that some industries, such as textiles and iron and steel, are themselves intermediate components for other industries, such as apparel and machinery, and therefore might have lower tariff barriers. This would not be captured by the intermediate product indicator. The table shows that the ladder coefficients are also robust to these additional controls.

The results suggest that when industries are unable to vertically differentiate their products from cheaper imports, they pursue an alternative strategy of using trade policy to insulate from import competition. Thus, the quality ladders appear relevant for the political economy of trade protection.

7 Conclusion

Product specialization can weaken the convergence in goods and factor prices predicted to result from international trade. It therefore allows developed countries to reduce exposure to emerging economies. This paper uses an alternative measurement of quality to demonstrate that product specialization occurs in the quality dimension. Departing from traditional use of prices as sufficient statistics for quality, I infer the quality of imports in a framework that incorporates both vertical and horizontal differentiation.

Although factor-abundant countries export higher-quality varieties within products, the scope for quality differentiation varies substantially across products. I develop a model establishing that developed countries are less vulnerable to import competition in products that possess a large degree of vertical differentiation, or a long quality ladder. In such products, developed countries can successfully exploit comparative-advantage factors to differentiate their products in the vertical dimension.

The quality ladders are matched to U.S. industry data to test the implications of the model. Industries that face higher import penetration, particularly from low-wage countries, are associated with larger employment declines. However, consistent with the model, in markets characterized by a large scope for vertical differentiation, or a long quality ladder, the effects of import penetration on employment are weak. This suggests that quality differentiation is an important dimension that enables countries to weaken the effects of factor price equalization. As an alternative means to protect against foreign competition, markets characterized by short quality ladders impose higher tariff rates on imports, particularly those originating from low-wage countries.

This paper contributes to the growing literature describing how firms use product markets to respond to import competition (e.g., Eckel and Neary (2005), Nocke and Yeaple (2005), and Bernard, Redding, and Schott (2006)). The findings here suggest that product switching resulting in a movement up the quality ladder, as opposed to across a ladder rung, has implications for firm survival. Thus, the paper highlights the importance of the interaction of both vertical and horizontal product differentiation, a feature that is typically not addressed in trade models.

In addition to the effects on firm survival, quality upgrading in response to import competition may have important implications for rising income inequality within developed countries.[49] Climbing the existing quality ladder, or investing in innovative resources to lengthen the quality ladder (Grossman and Helpman, 1991), presumably raises the demand for skilled labor. If so, this would suggest a channel through which globalization increases income inequality in addition to other factors, such as the offshoring of manufacturing activity to developing countries (Feenstra and Hanson, 1999). Understanding the firm-level mechanisms of quality specialization resulting from increased import competition, and its subsequent impact on workers, is left for future research.

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A Appendix

Result 1–Quality Ladder Length: *Assuming that* $h > 1$*, the quality ladder length is increasing in* γ*:* $\frac{\partial Ladder(\gamma;\lambda_{\min},\lambda_{\max})}{\partial\gamma} > 0$. *Proof:* See Appendix. □

I suppress the superscript N to reduce clutter. The quality ladder height is given in (8) by

$$Ladder(\gamma;\lambda_{\min},\lambda_{\max}) = \left(\frac{\gamma\left(\bar{\theta}+k\right)}{w_H}\right)^{\frac{\gamma}{1-\gamma}} \left[\lambda_{\max}^{\frac{1}{1-\gamma}} - \lambda_{\min}^{\frac{1}{1-\gamma}}\right]. \tag{A-1}$$

The derivative of the quality range with respect to γ is

$$\frac{\partial Ladder}{\partial\gamma} = B\left\{\left(\lambda_{\max}^{\frac{1}{1-\gamma}} - \lambda_{\min}^{\frac{1}{1-\gamma}}\right)\left[1-\gamma+\ln\left(\frac{\gamma\left(\bar{\theta}+k\right)}{w_H}\right)\right] + \left(\lambda_{\max}^{\frac{1}{1-\gamma}}\ln\lambda_{\max} - \lambda_{\min}^{\frac{1}{1-\gamma}}\ln\lambda_{\min}\right)\right\} > 0,$$

where $B = \frac{1}{(1-\gamma)^2}\left(\frac{\gamma(\bar{\theta}+k)}{w_H}\right)^{\frac{\gamma}{1-\gamma}}$. The derivative is greater than zero under the assumption that $h > 1$ (i.e., $\frac{\gamma(\bar{\theta}+k)}{w_H} > 1, \forall \gamma$). □

Result 2–Vulnerable Firms: *The fraction of vulnerable firms is decreasing in the ladder length:* $\frac{\partial \Omega(\gamma;\lambda_{\min},\lambda_{\max})}{\partial \gamma} < 0$.

Again, the superscript N is suppressed. The fraction of vulnerable firms is given by

$$\Omega(\gamma;\lambda_{\min},\lambda_{\max}) = \frac{\xi(\tilde{\lambda}) - \xi(\lambda_{\min})}{\xi(\lambda_{\max}) - \xi(\lambda_{\min})}, \tag{A-2}$$

where $\lambda_{\min} < \tilde{\lambda} < \lambda_{\max}$. Using the optimal quality choice in (8), the expression simplifies to

$$\begin{aligned} \Omega(\gamma;\lambda_{\min},\lambda_{\max}) &= \frac{\tilde{\lambda}^{\frac{1}{1-\gamma}} - \lambda_{\min}^{\frac{1}{1-\gamma}}}{\lambda_{\max}^{\frac{1}{1-\gamma}} - \lambda_{\min}^{\frac{1}{1-\gamma}}} && \text{(A-3)} \\ &= \frac{\lambda_1^{\frac{1}{1-\gamma}} - 1}{\lambda_2^{\frac{1}{1-\gamma}} - 1}, && \text{(A-4)} \end{aligned}$$

where $\lambda_1 = \frac{\tilde{\lambda}}{\lambda_{\min}}, \lambda_2 = \frac{\lambda_{\max}}{\lambda_{\min}}$ and $\lambda_1 < \lambda_2$. The derivative of $\Omega(\gamma)$ with respect to γ is

$$\frac{\partial \Omega}{\partial \gamma} = \frac{(\ln \lambda_2)\,\lambda_2^{\frac{1}{1-\gamma}} - (\ln \lambda_1)\,\lambda_1^{\frac{1}{1-\gamma}} + (\ln \lambda_1)\,\lambda_1^{\frac{1}{1-\gamma}}\lambda_2^{\frac{1}{1-\gamma}} - (\ln \lambda_2)\,\lambda_1^{\frac{1}{1-\gamma}}\lambda_2^{\frac{1}{1-\gamma}}}{(1-\gamma)^2\left(\lambda_2^{\frac{1}{1-\gamma}} - 1\right)^2}. \tag{A-5}$$

It remains to be shown that the numerator in (A-5) is less than zero. Note that for $\lambda_1 = \lambda_2$, the numerator is equal to zero. Denote the numerator as $N(\lambda_1,\lambda_2)$. To show that this expression is less than zero, I exploit the fact that $\lambda_2 > \lambda_1 > 1$. Take the derivative of the expression with respect to λ_2, and evaluate at $\lambda_2 = \lambda_1$

$$\begin{aligned} \frac{\partial N}{\partial \lambda_2}\Big|_{\lambda_2=\lambda_1} &= \frac{\lambda_2^{\frac{\gamma}{1-\gamma}}\left(1-\gamma+\ln\lambda_2 - \lambda_1^{\frac{1}{1-\gamma}}\left(1-\gamma+\ln\lambda_2-\ln\lambda_1\right)\right)}{1-\gamma}\Big|_{\lambda_2=\lambda_1} && \text{(A-6)} \\ &= \frac{\lambda_1^{\frac{1}{1-\gamma}}\left(1-\gamma+\ln\lambda_1 - (1-\gamma)\,\lambda_1^{\frac{1}{1-\gamma}}\right)}{1-\gamma} < 0. && \text{(A-7)} \end{aligned}$$

Since $\lambda_2 > \lambda_1 > 1$, the numerator in (A-5) is less than zero, which means that it is decreasing away from 0. Therefore, $\frac{\partial \Omega}{\partial \gamma} < 0$. □

B Tables

Low-Income Countries

Afghanistan	Chad	Haiti	Niger
Albania	China	India	Pakistan
Angola	Congo	Kenya	Rwanda
Armenia	Equitorial Guinea	Lao PDR	Samoa
Azerbaijan	Ethiopia	Madagascar	Sierra Leone
Bangladesh	Gambia	Malawi	Sri Lanka
Benin	Georgia	Mali	Sudan
Burkina Faso	Ghana	Mauritania	Togo
Burundi	Guinea	Moldova	Uganda
Cambodia	Guinea-Bissau	Mozambique	Vietnam
Central African Republic	Guyana	Nepal	Yemen

Table 1: The table provides the list of low-wage countries used in the paper. Low-wage countries are defined as countries with a less than 5 percent of US per capita GDP.
Source: Bernard et al. (2006).

Summary Statistics

Industry	Sectors	Products	Varieties	Vty/Pdct	Share	GDP
20 Food	5	32	507	15.8	0%	16,381
22 Textile	68	1,623	21,766	13.4	1%	12,901
23 Apparel	53	2,531	48,437	19.1	9%	6,937
24 Lumber	14	267	3,705	13.9	1%	13,242
25 Furniture	2	62	2,103	33.9	1%	11,572
26 Paper	26	224	4,147	18.5	2%	19,724
27 Printing	10	49	1,909	39.0	0%	17,708
28 Chemicals	160	2,508	31,716	12.6	6%	20,278
29 Petroleum	3	15	262	17.5	0%	14,152
30 Rubber & Plastic	22	434	7,110	16.4	2%	13,507
31 Leather	13	420	8,985	21.4	3%	5,802
32 Stone & Ceramic	36	324	7,558	23.3	1%	14,793
33 Primary Metal	74	1,348	20,054	14.9	4%	16,644
34 Fabricated Metal	55	610	14,463	23.7	3%	17,389
35 Industrial Machinery	122	1,598	29,895	18.7	15%	20,332
36 Electronic	66	1,321	27,364	20.7	18%	15,066
37 Transportation	30	399	6,012	15.1	25%	22,996
38 Instruments	47	703	9,826	14.0	3%	21,716
39 Miscellaneous	39	311	6,340	20.4	3%	10,653

Table 2: The table provides summary statistics for the two-digit SIC (1987 revision) industries. Column seven reports the weighted average of exporter per capita GDP.
Source: Feenstra et al. (2002) and author's calculations.

Estimation Results

Remark	Statistic
Obs. with $\hat{\alpha}$ significant at 10 percent	74%
OLS price coefficient	-0.04
IV price coefficient	-0.15
Own price elasticity	-1.20
T-statistic of quality estimates	12.4
Within-product correlation (σ)	0.55
Overidentifying restrictions p-value	0.094
1st stage F-statistic, price	3.4
1st stage F-statistic, nest share	2.3
R-squared	0.69
Observations per estimation	960
Number of estimations	848
Total Observations	1,135,016

Table 3: Table reports estimation statistics of running equation (26) separately for each of the 848 manufacturing sectors. All statistics are mean values.

Quality and Factor Endowments

	Quality		
Regressors	(1)	(2)	(3)
Log (GDP per Capita)	3.22***		
	(0.73)		
Log (Capital-Labor)		3.16***	
		(0.70)	
Tertiary Education Percentage			0.09***
			(0.03)
Product-Year FEs	yes	yes	yes
R-squared	0.234	0.227	0.45
Obs.	1,134,527	1,069,406	465,902

Table 4: Table regresses the quality estimates on (log) per capita GDP, (log) capital-labor ratios and percentage of workforce with tertiary education. Regressions include product-year fixed effects. Robust standard errors are clustered by exporting country. Significance levels: *** .01 ** .05 * .1.

Source: The World Bank's World Development Indicators.

Vertical vs. Horizontal Products

Regressors	Quality
Log Price	-1.20***
	(0.20)
Log Price $\times Ladder_0$	0.007
	(0.004)
Product-Year FEs	yes
R-squared	0.254
Obs.	1,125,776

Table 5: Table regresses variety quality on (log) price and its interaction with the product's baseline quality ladder. Robust standard errors are clustered at the product level. Significance levels: * .1 ** .05 *** .01.

Cross-Price Elasticities and Quality Ladders

	Cross-price Elasticity		
Regressors	(1)	(2)	(3)
$Ladder_{0k}$	-0.010***	-0.007***	-0.002
	(0.002)	(0.002)	(0.003)
Constant	0.031***	0.029***	0.027***
	(0.002)	(0.002)	(0.001)
Fixed Effects		Two-digit SIC	Sector
R-squared	0.002	0.022	0.208
Obs.	1,331,586	1,331,586	1,331,586

Table 6: Table regresses the bilateral cross-price elasticities of varieties within products (excluding own-price elasticities) on the product's baseline quality ladder using data from 1995. The cross-price elasticities are defined in (31). Robust standard errors are clustered at the product level. Significance levels: * .1 ** .05 *** .01.

OECD Market Shares and Quality Ladders

	OECD Market Share		
Regressors	(1)	(2)	(3)
$Ladder_{k0}$	0.0009***	0.0004***	0.0001*
	(0.0001)	(0.0001)	(0.0001)
Constant	0.417***	0.439***	0.454***
	(0.004)	(0.003)	(0.004)
Fixed Effects	Year	Industry-Year	Sector-Year
R-squared	0.021	0.294	0.534
Obs.	99,843	99,843	99,843

Table 7: Table regresses OECD market share in product k on the product's baseline quality ladder. Columns one, two and three include year, two-digit SIC-year and sector-year fixed effects, respectively. Regressions exclude products where OECD market shares are equal to one. Robust standard errors are clustered by product. Significance levels: * .1 ** .05 *** .01.

Quality Upgrading and Quality Ladders

Regressors	Quality
Trend	0.748***
	(0.073)
OECD × Trend	-0.484***
	(0.087)
$Ladder_{0k}$× Trend	-0.004***
	(0.001)
$Ladder_{0k}$× OECD × Trend	0.002***
	(0.001)
Variety FEs	yes
R-Squared	0.945
Obs.	1,125,744

Table 8: Table regresses variety quality on a linear time trend, an OECD country dummy, the product's baseline quality ladder and the full set of interactions. The regression includes variety fixed effects. Robust standard errors are clustered by exporting country. Significance levels: * .1 ** .05 *** .01.

Industry Employment and Quality Ladders: OLS

	Log Employment			
Regressors	(1)	(2)	(3)	(4)
$OTHPEN$	-0.495***	-0.679**	-0.466***	-0.596**
	(0.162)	(0.327)	(0.139)	(0.290)
$IndLadder \times OTHPEN$		0.003		0.002
		(0.004)		(0.004)
$LWPEN$	-1.503***	-1.520***	-4.231**	-4.086**
	(0.305)	(0.349)	(1.872)	(1.855)
$IndLadder \times LWPEN$	0.014**	0.013**	0.013*	0.013*
	(0.006)	(0.007)	(0.007)	(0.007)
Initial Skill $\times LWPEN$			-0.222	-0.221
			(0.305)	(0.271)
Initial Capital Intensity $\times LWPEN$			0.816*	0.762*
			(0.432)	(0.440)
Industry, Year FEs	yes	yes	yes	yes
R-Squared	0.12	0.12	0.13	0.13
Obs.	2499	2499	2499	2499

Table 9: The dependent variable for each regression is the four-digit SIC industry (log) employment. The first column regresses employment on import penetration from the rest of the world ($OTHPEN$), low-wage import penetration ($LWPEN$) and the interaction of $LWPEN$ with the industry quality ladder. Column two includes the $OTHPEN$-ladder interaction. Columns three and four include interactions of $LWPEN$ with the industry's baseline factor intensities. Robust standard errors are clustered at the two-digit SIC level. Significance levels: * .1 ** .05 *** .01. Source: Employment, skill and capital-labor intensities are taken from Bartelsman et al. (1996) for 1989-1996. Import penetration variables are provided by Bernard et al. (2006).

Industry Employment and Quality Ladders: IV

	Log Employment			
Regressors	(1)	(2)	(3)	(4)
$OTHPEN$	-0.517	-1.056	-0.467	-0.751
	(0.621)	(0.776)	(0.527)	(0.692)
$IndLadder \times OTHPEN$		0.009		0.005
		(0.008)		(0.008)
$LWPEN$	-3.011***	-2.596***	-6.719**	-6.123*
	(0.733)	(0.703)	(3.411)	(3.238)
$IndLadder \times LWPEN$	0.058***	0.050***	0.052***	0.047***
	(0.019)	(0.019)	(0.019)	(0.018)
Initial Skill $\times LWPEN$			0.312	0.370
			(0.927)	(0.888)
Initial Capital Intensity $\times LWPEN$			1.514**	1.401*
			(0.772)	(0.755)
Overidentification p-value	0.24	0.25	0.32	0.23
F-test $OTHPEN$	4.73 [0]	4.73 [0]	238 [0]	238 [0]
F-test $IndLadder \times OTHPEN$		3.75 [0]		23 [0]
F-test $LWPEN$	1.85 [.12]	1.85 [.12]	26 [0]	26 [0]
F-test $IndLadder \times LWPEN$	23.05 [0]	23.05 [0]	103 [0]	103 [0]
F-test Skill $\times LWPEN$			30 [0]	30 [0]
F-test Capital Intensity $\times LWPEN$			19 [0]	19 [0]
Industry, Year FEs	yes	yes	yes	yes
Obs.	2499	2499	2499	2499

Table 10: The dependent variable for each regression is the four-digit SIC industry (log) employment. The first column regresses employment on import penetration from the rest of the world ($OTHPEN$), low-wage import penetration ($LWPEN$) and the interaction of $LWPEN$ with the industry quality ladder. Column two includes the $OTHPEN$-ladder interaction. Columns three and four include interactions of $LWPEN$ with the industry's initial factor intensities. Import penetration measures are instrumented using industry-year exchange rates (weighted by countries' share in 1989), tariffs and freight rates for low-wage countries and the rest of the world. First-stage F-statistics and p-values (in brackets) are reported at the bottom of the table. Robust standard errors are clustered at the two-digit SIC level. Significance levels: * .1 ** .05 *** .01.

Industry Employment and Quality Ladders: Within-Industry IV

	Log Employment			
Regressors	(1)	(2)	(3)	(4)
$OTHPEN$	-0.109	-0.359	-0.206	-0.485
	(0.846)	(1.246)	(0.748)	(0.941)
$IndLadder \times OTHPEN$		0.003		0.004
		(0.009)		(0.008)
$LWPEN$	-1.199	-1.248	-2.646	-2.474
	(1.451)	(1.369)	(3.795)	(4.017)
$IndLadder \times LWPEN$	0.053**	0.049*	0.049**	0.044*
	(0.025)	(0.027)	(0.025)	(0.023)
Initial Skill $\times LWPEN$			0.196	0.299
			(1.356)	(1.208)
Initial Capital Intensity $\times LWPEN$			0.531	0.527
			(1.390)	(1.363)
Overidentification p-value	0.49	0.33	0.46	0.37
F-test $OTHPEN$	10.9 [0]	10.9 [0]	78 [0]	78 [0]
F-test $IndLadder \times OTHPEN$		11.5 [0]		50 [0]
F-test $LWPEN$	4.37 [.003]	4.37 [.003]	290 [0]	290 [0]
F-test $IndLadder \times LWPEN$	10.1 [0]	10.1 [0]	95 [0]	95 [0]
F-test Skill $\times LWPEN$			92 [0]	92 [0]
F-test Capital Intensity $\times LWPEN$			714 [0]	714 [0]
Industry, Two-digit SIC-Year FEs	yes	yes	yes	yes
Obs.	2499	2499	2499	2499

Table 11: The dependent variable for each regression is the four-digit SIC industry (log) employment. All regressions include two-digit SIC-year fixed effects. The first column regresses employment on import penetration from the rest of the world ($OTHPEN$), low-wage import penetration ($LWPEN$) and the interaction of $LWPEN$ with the industry quality ladder. Column two includes the $OTHPEN$-ladder interaction. Columns three and four include interactions of $LWPEN$ with the industry's initial factor intensities. Import penetration measures are instrumented using industry-year exchange rates (weighted by countries' share in 1989), tariffs and freight rates for low-wage countries and the rest of the world. First-stage F-statistics and p-values (in brackets) are reported at the bottom of the table. Robust standard errors are clustered at the two-digit SIC level. Significance levels: * .1 ** .05 *** .01.

Industry Skill and Quality Ladders

	Log Skill		Log Capital	
	OLS	IV	OLS	IV
Regressors	(1)	(2)	(2)	(4)
$OTHPEN$	-0.081	-0.834	0.381***	0.819*
	(0.055)	(0.667)	(0.129)	(0.470)
$LWPEN$	-0.252**	-0.671	0.690***	1.548*
	(0.126)	(0.686)	(0.238)	(0.884)
$IndLadder \times LWPEN$	0.003	0.027	-0.007**	-0.029**
	(0.003)	(0.017)	(0.003)	(0.014)
Industry, Year FEs	yes	yes	yes	yes
Obs.	2499	2499	2499	2499

Table 12: The dependent variable in columns one and two is the ratio of non-production to production workers. The dependent variable in columns three and four is the industry capital-labor ratios. Each column regresses the dependent variable on import penetration from the rest of the world ($OTHPEN$), low-wage import penetration ($LWPEN$) and the interaction of $LWPEN$ with the industry quality ladder. IV regressions are presented in columns two and four. Robust standard errors are clustered at the two-digit SIC level. Significance levels: * .1 ** .05 *** .01.

Tariffs and Quality Ladders

Regressors	Log Tariff (1)	(2)	(3)	(4)	(5)	(6)
LOW	0.032***	0.014***	0.019***	0.012***	0.011***	0.023***
	(0.002)	(0.001)	(0.005)	(0.001)	(0.001)	(0.005)
$Ladder_{k0}$	-0.135***	-0.048***	-0.049***	-0.078***	-0.066***	-0.068***
	(0.020)	(0.012)	(0.012)	(0.011)	(0.011)	(0.011)
$Ladder_{k0} \times LOW$	-0.092***	-0.061***	-0.044***	-0.075***	-0.072***	-0.059***
	(0.022)	(0.017)	(0.016)	(0.017)	(0.017)	(0.016)
Capital Intensity		-0.006***	-0.006***		-0.003**	-0.003*
		(0.001)	(0.001)		(0.001)	(0.001)
Capital Intensity $\times LOW$			-0.003***			-0.003***
			(0.001)			(0.001)
Skill Intensity		-0.023***	-0.023***		-0.016***	-0.016***
		(0.001)	(0.001)		(0.002)	(0.002)
Skill Intensity $\times LOW$			-0.003*			-0.0002
			(0.002)			(0.002)
Union		0.179***	0.179***			
		(0.010)	(0.010)			
Intermediate Product		-0.001	-0.001		0.002	0.002
		(0.003)	(0.003)		(0.003)	(0.003)
Constant	0.062***	0.035***	0.034***	0.062***	0.055***	0.054***
	(0.002)	(0.005)	(0.005)	(0.001)	(0.007)	(0.007)
Year FEs	yes	yes	yes	no	no	no
Two-digit SIC-Year FEs	no	no	no	yes	yes	yes
R-squared	0.047	0.323	0.323	0.389	0.396	0.397
Obs.	1125744	1119749	1119749	1125744	1119749	1119749

Table 13: The dependent variable is the (log) ad-valorem equivalent tariff for country c's import into product k at time t. Column one regresses tariffs on a low-wage country indicator (see Table 1), the product's baseline quality ladder and the interaction of the two. Column two includes skill and capital intensities, an indicator if the product is an intermediate good (i.e., HS description includes the phrases "parts", "prts", "pts" and "component") and the share of two-digit SIC employment that is under a union contract. Column three includes interactions of factor intensities with the low-wage indicator. Columns four through six re-run the regressions using two-digit SIC-year fixed effects. Robust standard errors are clustered at the eight-digit HS level (the U.S. tariff line). Significance levels: * .1 ** .05 *** .01.

Source: Union figures are constructed from the NBER Consumer Population Survey (Merged Outgoing Rotation Groups).

Quality Ladder

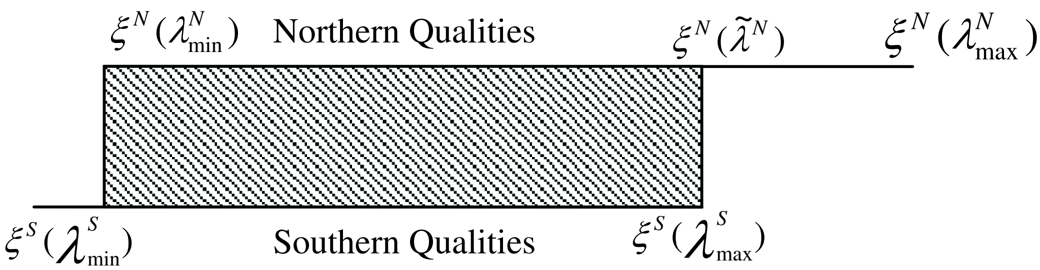

Figure 1: A graphical representation of the vulnerable Northern firms within a market's quality ladder. $\xi^N(\tilde{\lambda^N})$ $(= \xi^S(\lambda^S_{\max}))$ is the highest quality a Southern exporter can manufacture. All Northern firms within the quality range $[\xi^N(\lambda^N_{\min}), \xi^N(\tilde{\lambda^N})]$ suffer larger market share declines when the South enters the North market.

Data Structure

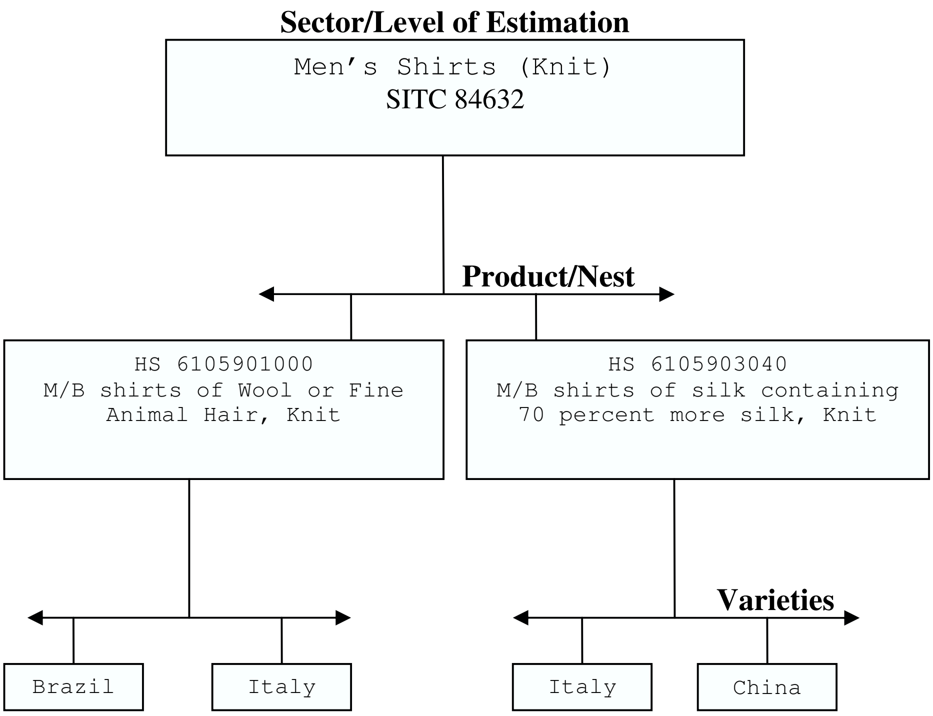

Figure 2: The figure depicts the U.S. import data structure. The estimation equation in (26) is run for each sector. Products are nested within a sector according to the HS product classification. A country's export within a product is called a variety.

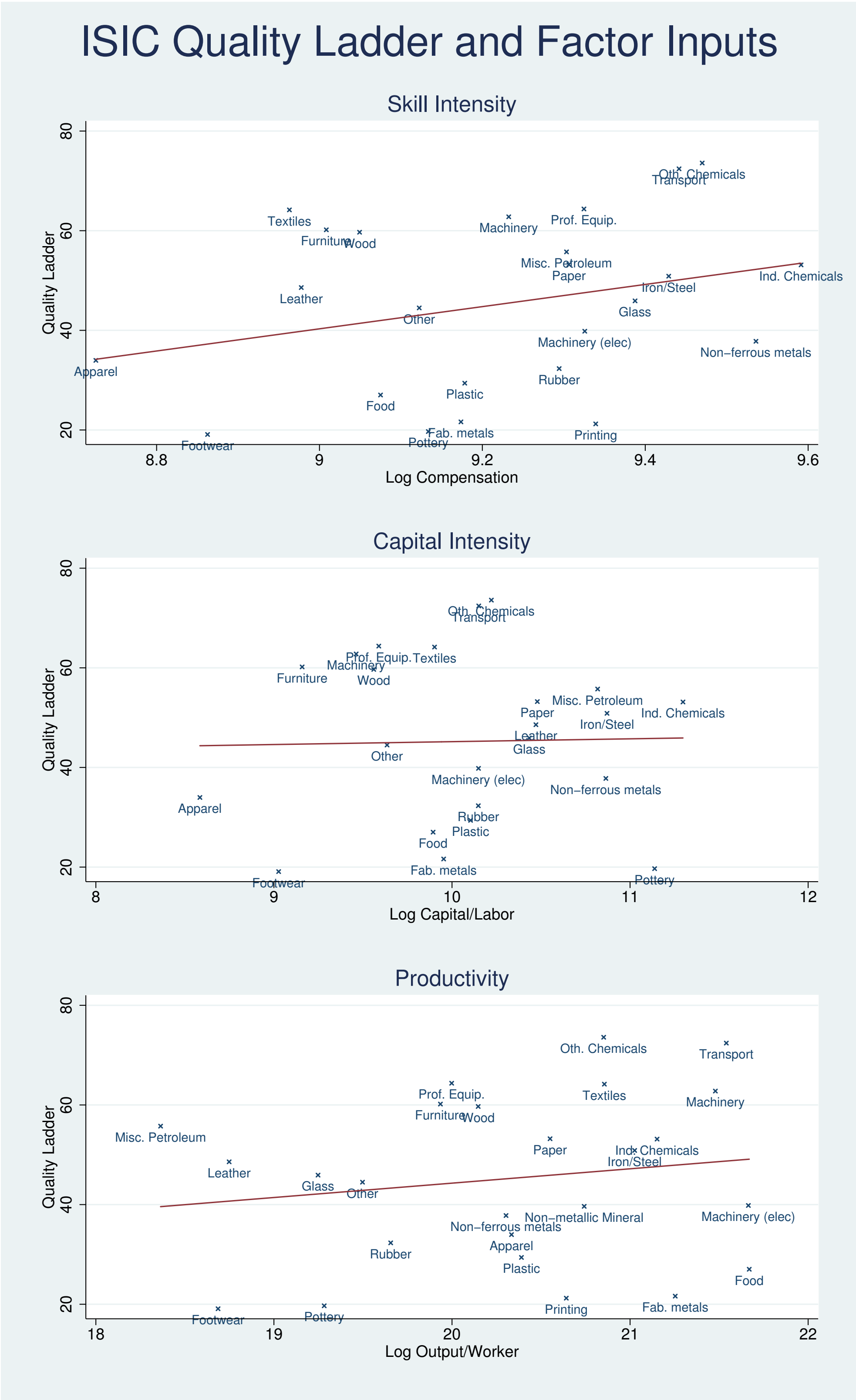

Figure 3: The figure plots the three-digit ISIC industry quality ladder against average factor intensities across countries. Skill intensity is measured as the cross-country average compensation per worker. Capital intensity is the capital stock divided by total employment. Productivity is measured as the value added per worker. Source: UNIDO (2005) and author's calculations.

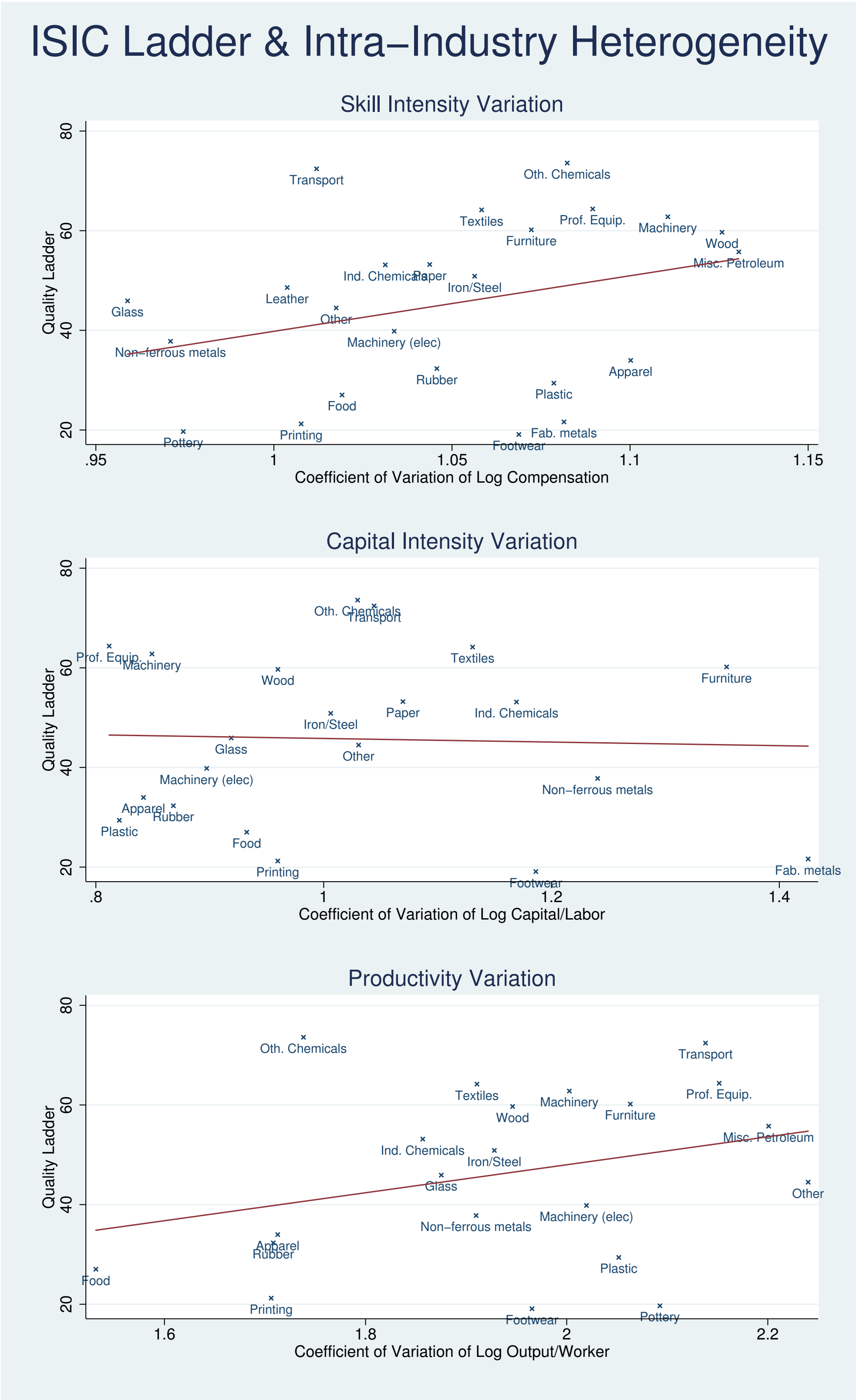

Figure 4: The figure plots the three-digit ISIC industry quality ladder against intra-industry heterogeneity of factor inputs. Intra-industry heterogeneity is measured as the coefficient of variation within an industry's factor inputs across countries. Skill intensity is measured as the cross-country average compensation per worker. Capital intensity is the capital stock divided by total employment. Productivity is measured as the value added per worker. Source: UNIDO (2005) and author's calculations.

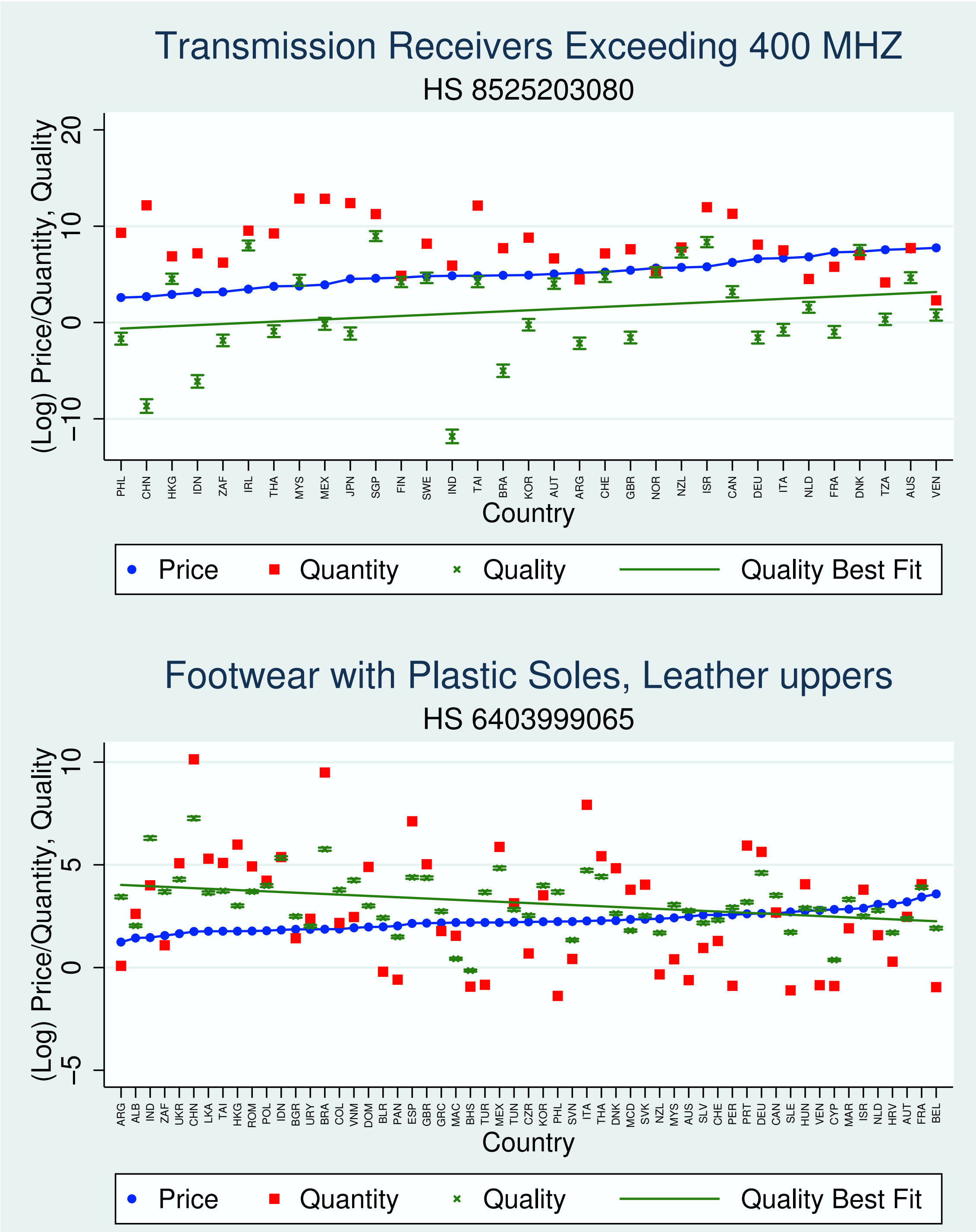

Figure 5: The graphs show the price, quantity and estimated quality (and 95 percent confidence interval) for countries for HS 8525203080 ("Transmission Receivers Exceeding 400 MHZ") and HS 6403999065 ("Footwear with Plastic Soles, Leather Uppers") in 2001. Countries are ordered by unit value.