

The Quality and Variety of a Nation's Exports

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Abstract

Using 1990 data on U.S. imports from 119 countries in 14,572 product categories, we find that richer countries and countries with more workers export to the U.S. in many more categories. Within categories, richer countries export modestly fewer units at considerably higher unit prices, suggesting they are exporting higher quality products. If exports to the U.S. are representative of exporter production, then the estimates imply that one-half of country differences in income per worker arise from differences in the quality of goods produced. We find further that countries with more workers export greater quantities per category at no lower unit prices. This last finding coincides with Krugman-style models of differentiated products subject to fixed costs of production, and appears inconsistent with Armington-style models with a fixed number of country-specific varieties.

PRELIMINARY

1. Introduction

A central way in which models of trade differ is in their predictions for how countries employ marginal resources. There appear to be three broad approaches to this question. Expanding countries use added resources to do one or more of the following three things: increase output of goods already produced in the economy; add new varieties of goods not previously produced; produce better varieties of better quality.

Neoclassical models of trade and models that assume Armington (1969) national differentiation emphasize the first of these margins. In these models, doubling resources causes countries to produce exactly the same goods, only twice as much. Monopolistic competition models in the vein of Krugman (1981) capture the second margin – doubling country size doubles the number of goods produced in the economy. Vertical or quality differentiation models such as Flam and Helpman (1987) capture the third margin, allowing firms to invest resources in producing higher quality goods.

Identifying the empirical relevance of these three margins is important for three reasons. First, it provides insights into the fundamental questions of how and why countries specialize and trade. Second, it helps us to understand the welfare consequences of expansion. For example, countries that expand entirely by increasing output of existing goods will suffer a worsening of their terms of trade. This is a familiar concern for economists who work on large scale CGE models. They find that the simulated welfare changes associated with trade liberalization are dominated by terms of trade effects (see Brown, 1987). To the extent that countries increase the number of goods, or increase quality, adverse terms of trade effects are no longer a necessary consequence of trade expansion. Third, it helps us to understand how countries grow and to decompose differences in output and output per worker across countries. It enables us to attempt to answer an intriguing question: are countries rich because they produce more goods, or because they produce better goods?

To better address these questions we provide illustrative models that allow us to decompose these margins. We draw a primary contrast between two models. The first is an

Armington-style model in which firms choose between expanding output or increasing the quality of that output. The second is a Krugman-style model that adds a third margin to this choice, the possibility of adding a new variety. While these models look quite similar on many dimensions, they differ markedly in their predictions for the price-quantity relationship at the national level. Output expansion in the Armington model forces the firm down the consumers demand curve, lowering the goods price. More output at the national level is associated with a lower good's price. In the Krugman model, firms increase the number of varieties rather than output per variety. Because each firm produces a unique variety and faces its own demand curve, there is no relationship between national output and prices.

Of course, price variation across countries may arise from quality as well as quantity variation. Our simple static models provide a way to relate prices to quality, quantity, and number of varieties in general equilibrium. The associated empirical work is then able to answer two questions: Does an output expansion lead to lower quality-adjusted prices? Do countries expand output by increasing quality, quantity, or the number of goods produced?

Not surprisingly, countries with more workers tend to export more units of the typical product to the U.S.. But, less obviously, they do not export these greater quantities at lower prices. This suggests that countries with more workers export a greater number of varieties, rather than greater quantity per variety. Consistent with this interpretation, countries with more workers export in more categories. This observable extensive margin accounts for about a third of the additional exports of larger economies. This evidence comes down squarely in favor of Krugman-style models with multiple varieties produced by each country. Rather than slide down a demand curve for a single Armington variety, bigger countries export additional varieties.

Controlling for the type of product, richer countries tend to export higher-priced products to the U.S.. Despite selling at significantly higher prices, richer countries export modestly lower quantities of the typical product to the U.S.. These two facts together suggest that richer countries sell higher-quality products. Rather than a movement up a demand curve, the higher price reflects the higher demand for higher-quality products.

The rest of paper proceeds as follows. In Section 2 we outline the simple models that motivate our empirical specifications. Section 3 contains the empirical results. Using the 1990 cross-section, we document that countries with more workers export more units of the typical product to the U.S., and at no lower prices per unit. We also document that the unit price of a U.S. import tends to be higher the richer the source country in terms of GDP per worker. Just as important as these margins, we find that bigger economies export to the U.S. in more categories. In Section 4 (to be added) we show that the baseline results continue to hold over several ways of splitting the sample: consumer goods vs. capital goods plus intermediate goods, smaller vs. bigger exporting countries, poorer vs. richer exporters, and commodities vs. manufactured goods. In Section 5 we offer concluding comments.

2. Illustrative Models

2a. An Armington Model with Endogenous Quality

Armington (1969) modeled goods as differentiated by national origin. In a simple one-sector version of the model, bigger countries produce more output of their single national variety, thereby driving down the price of their varieties in the world market. Here we sketch a simple model that embodies this idea, extending it to include multiple sectors and quality variation across countries.

Suppose there are M categories of goods and J countries, with country j producing a unique variety in each category m . To keep things simple, consumer preferences are identical across countries. All workers within a country have the same income and preferences. A representative worker/consumer in each country i chooses $\{q_{ijm}, j = 1, \dots, J; m = 1, \dots, M\}$ to maximize

$$(1) \quad U_i = \prod_{m=1}^M \left(\sum_{j=1}^J Q_{jm} q_{ijm}^{1-1/\sigma} \right)^{\alpha_m}$$

subject to

$$(2) \quad \sum_{j=1}^J \sum_{m=1}^M p_{jm} q_{ijm} \leq w_i L_i = \sum_{m=1}^M p_{im} q_{im} = Y_i.$$

In (1) α_m is the nominal spending share of a category. q_{ijm} is the number of units of j 's variety in category m purchased by country i , Q_{jm} is the quality of country j 's variety in category m , and $\sigma > 1$ is the elasticity of substitution between varieties within each category. In (2) p_{jm} is the world price of country j 's variety in category m , w_i is the wage in country i , L_i is the number of workers in country i , q_{im} is the number of units that country i produces of its variety in category m , and Y_i is GDP in country i . We ignore price variation across destinations due to tariffs and transportation costs.

Since all consumers in the world face the same prices and have the same preferences, *world* demand reflects individual consumer demand.¹ From (1) and (2) we get

$$(3) \quad \frac{q_{jm}}{q_{im}} = \left(\frac{p_{jm}/Q_{jm}}{p_{im}/Q_{im}} \right)^{-\sigma}.$$

Expression (3) tells us that, within category m , relative demand is decreasing in quality-adjusted relative price.

On the production side a single firm produces a country's variety in category m . The firm's production technology is

$$(4) \quad q_{jm} = A_j \exp\left(\frac{-Q_j}{Z_j}\right) L_{jm}.$$

A_j and Z_j are nonnegative *national* productivity indices.² Conditional on A_j and Z_j , producing at higher levels of quality Q_{jm} entails fewer units produced per worker, q_{jm}/L_{jm} . Higher A_j scales up productivity uniformly for all quality levels, whereas higher Z_j raises productivity proportionately more at higher quality levels.

The firm is a monopolistic competitor in the world market of J firms in category m , and is a price taker in the local (country) labor market. Subject to (4), the firm hires workers L_{jm} and chooses quality Q_{jm} to maximize profits given by

$$(5) \quad p_{jm} q_{jm} - w_j L_{jm}.$$

Using (3), (4) and (5), one can show that the profit-maximizing levels of L_{jm} and Q_{jm} satisfy

$$(6) \quad Q_{jm} = \frac{\sigma}{\sigma-1} Z_j$$

¹ Note we are assuming that all goods are perfectly tradable.

² The model has no physical capital.

and

$$(7) \quad \frac{L_{jm}}{L_{im}} = \left(\frac{Z_j/w_j}{Z_i/w_i} \right)^\sigma \left(\frac{A_j}{A_i} \right)^{\sigma-1}.$$

Expression (6) shows that the profit-maximizing level of quality is decreasing in σ (the responsiveness of demand to price). For a given economywide wage, a higher Z induces a higher Q , but in equilibrium does not affect the marginal cost of producing a physical unit of the good. Since Z , and therefore quality, is independent of m , hereafter we denote Q_j as the common quality level across categories within a country. Figure 1 shows how the choice of quality varies with the relationship between marginal cost of producing units and quality. Expression (7) shows that the profit-maximizing level of labor input is increasing in both productivity indices (Z_j and A_j) and decreasing in the wage (w_j). Because the productivity indices are the same across categories within a country, the category employment shares are the same across countries.

Combining (3), (4), (6) and (7) yields the familiar result of a fixed markup of price over marginal cost:

$$(8) \quad p_{jm} = \frac{\sigma}{\sigma-1} w_j / [A_j \exp(-\frac{Q_j}{Z_j})].$$

This is the profit-maximizing price conditional on the choice of quality. By (6), holding fixed w_j/A_j , Q_j is proportional to Z_j so the price does not vary with quality. As Z_j , Q_j , and p_j do not vary across categories within the country, we hereafter denote the price of each country's varieties as p_j . Equations (6) and (8) together imply that the relative price of country j versus country i varieties is

$$(9) \quad \frac{p_j}{p_i} = \frac{w_j/A_j}{w_i/A_i}.$$

Substituting (9) into (3) yields

$$(10) \quad \frac{q_{jm}}{q_{im}} = \left(\frac{Q_j A_j / w_j}{Q_i A_i / w_i} \right)^\sigma.$$

Equation (10) incorporates both preferences and technology and says that, conditional on wages, country j produces more units relative to country i in category m the higher its relative quality and the higher its relative "process productivity."

Using (7) we can pin down the market-clearing wage as

$$(11) \quad \frac{w_j}{w_i} = \left(\frac{L_j}{L_i} \right)^{-1/\sigma} \frac{Q_j}{Q_i} \left(\frac{A_j}{A_i} \right)^{1-1/\sigma}.$$

Substituting (11) into (9) and (10) yields

$$(12) \quad \frac{p_j}{p_i} = \left(\frac{A_j L_j}{A_i L_i} \right)^{-1/\sigma} \frac{Q_j}{Q_i}$$

$$(13) \quad \frac{q_j}{q_i} = \frac{A_j L_j}{A_i L_i}.$$

In turn, relative GDP's are

$$(14) \quad \frac{Y_j}{Y_i} = \left(\frac{A_j L_j}{A_i L_i} \right)^{1-1/\sigma} \frac{Q_j}{Q_i}.$$

These expressions say that having a large workforce drives down the relative price of a country's varieties (12) by driving up the quantities of each variety it produces (13). The price effect only partially offsets the quantity effect, however, because demand is elastic ($\sigma > 1$).

Thus a bigger workforce increases GDP (14), although it does lower GDP per worker. In this sense labor force growth is immiserating. Higher "process productivity" A , which increases

the effective size of the workforce, likewise expands GDP (and GDP per worker so it is *not* immiserating). But, like higher employment, higher process productivity lowers the prices of a country's varieties (12). In contrast, countries with higher "quality productivity" Z_j manufacture higher quality products rather than selling more units (13) and charge proportionately higher prices (12). This leads to higher GDP per worker in proportion to their higher quality (14). Taking logs, rearranging and again normalizing country i levels at 1, we get

$$(15) \quad \ln q_j = \frac{\sigma}{\sigma-1} \ln L_j + \frac{\sigma}{\sigma-1} \ln \frac{Y_j}{L_j} - \frac{\sigma}{\sigma-1} \ln Q_j$$

$$(16) \quad \ln p_j = \frac{-1}{\sigma-1} \ln L_j - \frac{1}{\sigma-1} \ln \frac{Y_j}{L_j} + \frac{\sigma}{\sigma-1} \ln Q_j$$

$$(17) \quad \ln q_j + \sigma \ln p_j = \sigma \ln Q_j$$

These results motivate testing the Armington model by looking at whether countries with larger workforces sell more quantities (15) but at lower prices per unit (16). Conditional on quality and employment, countries with higher GDP per worker (from higher process productivity) should likewise sell higher quantities (15) at lower prices per unit (16). But conditional on process productivity and employment, higher GDP per worker from higher quality will be associated with *higher* prices (16) and no higher quantities (15). Thus the sign and magnitude of the coefficients on GDP per worker depend on how much higher process productivity versus higher quality contribute to a country being richer. Expression (17) can be used to shed light on this issue: if a country sells many units of its varieties controlling for their price, the country must have higher quality products. We will use (17) to try to assess how much differences in quality contribute to differences in GDP per worker across countries.

2b. A Krugman Model with Endogenous Quality

Krugman (1980, 1981) modeled countries as producing an endogenous number of varieties.³ In these models, love of variety utility plus free entry by firms leads to a proliferation of varieties. This is tempered only by the fixed costs of production so that the number of varieties produced in a country is increasing with country size. Countries with larger workforces (or higher process productivity) produce more varieties rather than more quantity of each variety. As a result, output expansion does not necessarily worsen the terms of trade; unlike the Armington model, larger countries do not move down the world demand curve and reap a lower price for their varieties. In this subsection we write down a simple model with these predictions, again extending the model to multiple sectors and endogenizing quality choice by firms.

Country j produces N_{jm} varieties in category m , each selling for the same price and having the same quality. The representative worker/consumer in country i maximizes

$$(18) \quad U_i = \prod_{m=1}^M \left(\sum_{j=1}^J Q_{jm} N_{jm} (q_{ijm} / N_{jm})^{1-1/\sigma_m} \right)^{\alpha_m}$$

subject to

$$(2) \quad \sum_{j=1}^J \sum_{m=1}^M p_{jm} q_{ijm} \leq w_i L_i = \sum_{m=1}^M p_{im} q_{im} = Y_i.$$

In (18) q_{ijm} represents the total units purchased by country i of all country j varieties in category m . Units bought per variety are q_{ijm} / N_{jm} , the same for each of the N_{jm} varieties by symmetry. The budget constraint (2) is the same as in the Armington model.

From (18) and (2) relative demand satisfies

$$(19) \quad \frac{q_{jm}}{q_{im}} = \left(\frac{p_{jm}/Q_{jm}}{p_{im}/Q_{im}} \right)^{-\sigma} \frac{N_{jm}}{N_{im}}.$$

³ See also Ethier (1979, 1982).

Conditional on quality-adjusted relative prices, relative demand is proportional to the relative number of varieties produced.

On the production side a single firm produces a single variety. Its production technology is

$$(20) \quad q_{jm}/N_{jm} = A_j \exp\left(\frac{-Q_{jm}}{Z_j}\right) \left(\frac{L_{jm}}{N_{jm}} - \frac{\phi}{A_j}\right).$$

Each firm is a monopolistic competitor in the world market of $N_m (= N_{1m} + \dots + N_{Jm})$ firms in its category, and is a price taker in the local labor market. In (20) we are using the symmetry of firms within category m within country j : they choose the same number of workers and level of production, taking N_{jm} and N_m as given. In (20) there is a fixed cost of production equal to ϕ/A_j units of labor. Each firm chooses L_{jm}/N_{jm} workers and quality Q_{jm} to maximizes profits given by

$$(21) \quad p_{jm} q_{jm}/N_{jm} - w_j L_{jm}/N_{jm}.$$

Substituting (19) and (20) into (21), one can show that profit-maximization implies

$$(6) \quad Q_{jm} = \frac{\sigma}{\sigma-1} Z_j$$

This is the same as in the Armington model. We denote $Q_{jm} = Q_j \forall m$ since it does not vary with m . One can also show that profit maximization implies

$$(22) \quad \frac{L_{jm}/N_{jm}}{L_{im}/N_{im}} = \left(\frac{Z_j/w_j}{Z_i/w_i} \right)^\sigma \left(\frac{A_j}{A_i} \right)^{\sigma-1}.$$

This says that relative employment per firm is the same across all categories. As in the

Armington model, we also have

$$(8) \quad p_{jm} = \frac{\sigma}{\sigma-1} w_j / [A_j \exp(-\frac{Q_j}{Z_j})]$$

and

$$(9) \quad \frac{p_{jm}}{p_{im}} = \frac{w_j/A_j}{w_i/A_i}.$$

Substituting (9) into (19) gives

$$(23) \quad \frac{q_{jm}/N_{jm}}{q_{im}/N_{im}} = \left(\frac{Q_j A_j / w_j}{Q_i A_i / w_i} \right)^\sigma.$$

Setting (21) to zero (the zero profit condition) and using (9) and (20) we get

$$(24) \quad L_{jm}/N_{jm} = \frac{\phi\sigma}{A_j}$$

and therefore

$$(25) \quad \frac{L_{jm}/N_{jm}}{L_{im}/N_{im}} = \frac{A_i}{A_j}.$$

The result in (24) is familiar: the size of the fixed cost (ϕ/A_j), combined with the elasticity of substitution, pins down employment per firm. Using (24), a country's total varieties across all categories is proportional to its labor force times its process productivity:

$$(26) \quad N_j = \frac{A_j L_j}{\phi\sigma}.$$

Equating (25) to (22), relative wages are

$$(27) \quad \frac{w_j}{w_i} = \frac{Q_j}{Q_i} \frac{A_j}{A_i}.$$

Substituting (27) into (9) and (23), we obtain

$$\frac{p_j}{p_i} = \frac{Q_j}{Q_i} \quad \text{and} \quad \frac{q_j}{q_i} = \frac{A_j L_j}{A_i L_i}.$$

In turn relative GDP's are

$$\frac{Y_j}{Y_i} = \frac{A_j L_j Q_j}{A_i L_i Q_i}.$$

In contrast to Armington, here a large workforce does *not* drive down the relative price of a country's varieties. Likewise higher "process productivity" A . Bigger labor forces and higher process productivity increase the number of varieties (26) rather than quantity per variety.⁴

Taking logs, rearranging and normalizing country i levels at 1, we get

$$(28) \quad \ln q_j = \ln L_j + \ln \frac{Y_j}{L_j} - \ln Q_j$$

$$(29) \quad \ln p_j = \ln Q_j$$

$$(30) \quad \ln q_j + \sigma \ln p_j = \ln L_j + \ln \frac{Y_j}{L_j} + (\sigma-1) \ln Q_j$$

This model has roughly the same predictions for quantities (28) as the Armington model had: countries with bigger workforces and higher GDP per worker should export more proportionately greater quantities. Where this model diverges from the Armington model is in its predictions for prices (29): unlike in the Armington model, countries with larger workforces should not export at lower quality-adjusted prices.

⁴ An intermediate model between Armington and this one would have the fixed cost in terms of labor ϕL rather than in terms of efficiency units of labor $\phi L/A$. In this case variety would still be proportional to the labor force, but would no longer be affected by process productivity. Higher process productivity would increase quantity produced per variety, and the lower the price of varieties produced. In Section 3 we will present evidence distinguishing this intermediate model from the one in this section.

3. Baseline Results

3a. Data Description

The trade data are drawn from two sources. U.S. trade data are taken from the "U.S. Imports of Merchandise" CD-ROM for 1990, published by the U.S. Bureau of the Census. These data are drawn from electronically submitted Customs forms that report the country of origin, value, quantity, freight paid, duties paid, and Harmonized System (HS) classification code for each shipment entering the United States. The data include all countries shipping to the United States, a total of 203 in 1990. In combination with our factor endowments and output data, we employ 119 of these exporters. The 10-digit HS scheme includes 14,572 highly detailed goods categories. There are, for example, 13 separate lines covering motorcycles, and 140 lines covering various auto parts.

We construct prices as a unit value = value/quantity for a shipment. Quantity (and therefore price) data are missing from approximately 18 percent of our observations for 1990. To the extent that the data include multiple shipments from an exporter in a good, we aggregate these together. The resulting price data is thus a quantity weighted average of prices found within shipments from that exporter in that good. For robustness, we re-do all regressions with samples restricted to those observations consisting of only a single shipment so as to avoid averaging. Results in these cases are similar.

Worldwide trade data are taken from UNCTAD's Trade Analysis and Information System (TRAINS) CD-ROM for 1995. The TRAINS project combines bilateral imports data collected by the national statistical agencies of 76 importing countries, covering all exporting countries (227 in 1995). Combined with our factor data, we employ 117 of these exporters. The data are reported in the Harmonized System classification code at the 6 digit level, or 5,027 goods, and include shipment values. Note that the 76 importers represent the vast majority of world trade so that total shipments for each exporter reported in TRAINS closely approximates the worldwide shipments for that exporter.

3b. Exports Within Categories

In comparing the section 2 models to the data described in the previous subsection we are making several assumptions. First, when we are using the U.S. import data, we are assuming that country j 's exports *to the U.S.* are representative of country j 's overall exports to the rest of the world. For evidence on exports across categories in the next subsection, we are able to test this assumption using data that covers exports to many more countries. Second, we are assuming that all goods are tradable so that a country's exports are representative of its production.

Table 1 presents basic regressions of export quantities and prices on the employment and GDP per worker of the exporting country. Column (1) shows that, controlling for their income per worker, countries with more workers export higher quantities per category. The elasticity is 0.41 with a standard error of only 0.07 (t-statistic 6.3), highly significant both economically and statistically. This is not surprising given that both theories in section 2 predict more units exported by countries with more workers (Armington because of higher quantity per variety; and Krugman because of more varieties). Indeed, it is more surprising that the coefficient is so far below unity. We return to this issue in the next subsection, where we ask whether bigger and richer populations export in more categories, not just more per category. Column (1) also shows that, conditional on the number of workers, countries with higher GDP per worker actually export modestly lower quantities per category (elasticity – 0.11), but the relationship is not statistically significant (standard error 0.13). To the extent that countries are richer because they have higher process productivity, both theories in section 2 predict export quantities to be increasing in GDP per worker.

Column (2) of Table 1 regresses the average unit price of a country's exports on its own employment and GDP per worker. The coefficient on employment (0.01, standard error 0.03) is neither economically or statistically significant. This does not support the Armington prediction that higher employment will drive down the price of a country's varieties. According to the Armington hypothesis (as embodied in equation 16 in section 2a) the

coefficient should be $-1/(\sigma-1)$. If $\sigma = 4$, a typical estimate in the literature (Feenstra, 1995), then the Armington hypothesis would predict a coefficient of $-1/3$. Even conditional on the quantity elasticity of 0.4 in column (1), Armington might suggest a coefficient of -0.14 or so, 5.1 standard deviations below the point estimate. In contrast, an insignificant coefficient is precisely what the Krugman model predicts. The estimates are consistent with bigger workforces exporting more varieties within a typical category at no lower average prices.

The Armington story could explain column (2) in Table 1 if countries with more workers export higher quality products, masking the lower quality-adjusted prices. This would have to be true *conditional* on income per worker, however, since income per worker is also a regressor. The evidence in column (2) suggests that income per worker of the exporter may be highly correlated with quality: the price elasticity with respect to income per worker is 0.50 (standard error 0.05, t-statistic 10.1). Thus 1% richer countries charge 0.5% higher prices but sell insignificantly fewer quantities, not the 2% less one would expect with $\sigma = 4$. We return to this issue in Table 3 below, where we estimate the elasticity of quality with respect to income per worker implied by several values of σ .

Columns (3) and (4) of Table 1 break income per worker into its ingredients of TFP, the ratio of physical capital to output, and human capital per worker.⁵ Column (3) shows that quantity exported per category is lower in physical capital intensive countries (elasticity -1.33, standard error 0.59, marginally significant), higher in human capital intensive countries (elasticity 1.53, standard error 0.74, marginally insignificant), and modestly lower in higher TFP countries (elasticity -0.13 , standard error 0.22, insignificant). Column (4) shows that the average unit price of exports is higher in physical capital intensive countries (elasticity 0.76, standard error 0.22, significant), a little higher in human capital intensive countries (elasticity

⁵ The aggregate production function $Y_j = TFP_j K_j^\theta H_j^{1-\theta}$ can be expressed as $Y_j/L_j = TFP_j^{\frac{1}{1-\theta}} (K_j/Y_j)^{\frac{\theta}{1-\theta}} H_j/L_j$. K_j/Y_j is the physical capital-output ratio in country j . We constructed the physical capital stock data from Penn World Tables data using the methodology in Klenow and Rodriguez-Clare, 1997. H_j/L_j is human capital per worker in country j , measured as $\exp(0.1*s_j)$, where s_j is the average schooling attainment of the population 15 years and older. The 0.1 exponential coefficient is based on micro estimates of the Mincerian return to education in many countries (Bils and Klenow, 2000). The attainment data is from Barro and Lee (2000).

0.14, standard error 0.29, insignificant), and higher in higher TFP countries (elasticity 0.60, standard error 0.09, highly significant).

By entertaining several possible values for σ , we will try to infer what the Table 1 results imply for the variety and quality of exports in Table 3 below. But first we address whether our data allow us to obtain a consistent estimate of σ . Rearranging (19) from section 2b and taking out m -means, one can show that the Krugman model implies

$$(31) \quad \ln q_{jm} = -\sigma \ln p_{jm} + \sigma \ln Q_{jm} + \ln N_{jm}.$$

as well as the reverse

$$(32) \quad \ln p_{jm} = -\frac{1}{\sigma} \ln q_{jm} + \ln Q_{jm} + \frac{1}{\sigma} \ln N_{jm}.$$

This model nests the Armington model, for which $\ln N_{jm} = \ln 1 = 0 \forall jm$ pairs. Table 2 presents regressions motivated by (31) and (32). Column (1) of Table 2 regresses prices on quantities as in (32) and obtains a coefficient of -0.28 (standard error 0.01), suggesting $\sigma = 3.6$. There are several possible biases in this estimate, going in opposite directions. Average unit prices are constructed by dividing nominal imports by units exported: $p_{jm} = v_{jm}/q_{jm}$. As a result measurement error in $\ln q_{jm}$ will transmit measurement error with the opposite sign to $\ln p_{jm}$. This would bias the coefficient toward -1 and the estimate of σ toward 1. On the other hand, q_{jm} may be positively correlated with the quality and/or variety of j 's exports in category m . Based on (32), this would bias the coefficient upward and the estimate of σ toward ∞ .

We do several things to address these potential biases. First, we run the reverse regression, (31). Measurement error should again bias the estimate of σ down toward 1. But simultaneity bias should now go in the same direction, rather than the opposite direction. The true price is likely be positively correlated with quality, biasing the $\ln p_{jm}$ coefficient in (31) upward and the estimate of σ downward. Column (2) has a coefficient on $\ln p_{jm}$ of -1.32 (standard error 0.02). Since both biases push the estimate down, it is not surprising that this estimate ($\sigma = 1.3$) falls considerably below the estimates in the literature. Columns (3) and (4)

add exporter GDP per worker to the regressions to try to reduce the upward bias on the coefficients from simultaneity with the quality residual. The effects are minimal (implied σ 's of 3.68 and 1.34 rather than 3.55 and 1.32).

The final column in Table 2 instruments for $\ln q_{jm}$ with $\ln L_j$. From Table 1 we know exporter employment predicts some of the variation in quantities. And country employment is arguably uncorrelated with the measurement error in its export quantities (its mean, not its variance). If quality is also uncorrelated with employment conditional on GDP per worker, then under Armington this should provide a consistent estimate of σ . As column (5) of Table 2 shows, the estimate is actually positive and statistically insignificant (0.02, standard error 0.07). This implies an essentially infinite value for σ , far above estimates in the literature and at odds with the whole Armington notion of distinct country varieties. Rescuing the Armington hypothesis would seem to require that, even conditional on its GDP per worker, an exporter's employment is positively correlated with the quality of its exports. In contrast, a Krugman model could interpret column (5) as resulting from higher varieties being exported by countries with more workers. No correlation between quality (or mismeasurement) and employment need be invoked. This is a way of restating the result in column (2) of Table 1 and how it seems to favor Krugman over Armington.

Rearranging (31) slightly, we have

$$(33) \quad \ln q_{jm} + \sigma \ln p_{jm} = \sigma \ln Q_{jm} + \ln N_{jm}.$$

The left-hand-side is the "price-adjusted quantity" of exports by country j in category m , that is, how much a country exports in a category relative to what one would expect from the average unit price of its exports in the category. The right-hand-side shows that high quality and high variety are possible contributors to a high price-adjusted quantity. As an example consider Japanese versus Swedish car exports to the U.S. in 1990. Japan exported 10 times as many cars to the U.S. as Sweden did, and at an average price 15% lower than the average price

of the Swedish cars exports to the U.S.. If $\sigma = 4$ is the elasticity of substitution between Japanese and Swedish cars, then one would have expected Japan to export twice as many cars than Sweden, not 10 times as many. The factor of five discrepancy represents a high "price-adjusted quantity" for Japanese car exports to the U.S. relative to Swedish car exports to the U.S.. The interpretation in (33) is that Japanese cars are typically higher quality than Swedish cars and/or Japan exports more distinct models than Sweden does.

Because we do not possess a consistent estimate of σ , we construct price-adjusted quantities under different assumed values for σ . In Table 3 we report regressions of these price-adjusted quantities on exporter employment and either GDP per worker or its ingredients (physical capital, human capital and TFP). Columns (1) and (2) use $\sigma = 1$. This is below the typical estimates in the literature, but usefully gives elasticities for *nominal* exports. Column (1) shows elasticities of nominal exports with respect to both employment and GDP per worker of around 0.4 (0.42 for employment, t-statistic 9.4; 0.39 for GDP per worker, t-statistic 4.2). Column (2) says that countries with higher average schooling attainment and higher TFP have notably higher nominal exports, but the relationships are not very precise.

Columns (3) and (4) use $\sigma = 4$ to construct the price-adjusted quantities. Because $\sigma = 4$ is near estimates in the literature this is the case of greatest interest.⁶ In column (3) the elasticity with respect to employment is 0.45 (t-statistic 6.3), and with respect to GDP per worker it is 0.48 (t-statistic 17.0). These might reflect quality, variety, or both. In terms of the Krugman model in section 2b, we have reason to expect bigger workforce countries to produce more varieties. And Table 1 showed that higher employment countries export more quantity at no higher prices, consistent with higher variety. We have reason to expect richer countries to export both more varieties and higher quality ones. Table 1 showed that richer countries export modestly lower quantities at considerably higher prices. In terms of the Krugman model, this would suggest richer countries produce higher quality rather than higher variety.

⁶ Neither we nor the literature maintain that there is a common σ across all categories. Each category surely has a distinct σ_m . The elasticities estimated in Table 3 are still consistent, however, so long as $(\sigma - \sigma_m)\ln p_{jm}$ is uncorrelated with $\ln L_j$ and $\ln(Y_j/L_j)$, respectively.

For this reason, we actually scaled income per worker (and component variables) by σ in Table 3 so that, according to (33), its coefficient is in terms of a quality elasticity.

Column (4) of Table 3 shows that, like income per worker, physical capital intensity, human capital intensity, and TFP all have "quality" elasticities of around 0.5. The elasticity with respect to TFP is the strongest statistically (t-statistic 9.5), followed by the elasticity with respect to physical capital intensity (t-statistic 5.1) and then by the elasticity with respect to human capital (t-statistic 3.5). But there is no evidence that producing quality is more intensive in, say, human capital than physical capital.

Columns (5) and (6) in Table 3 use $\sigma = 7$ to construct the price-adjusted quantities. This at the high end of estimates in the literature. The elasticities remain around 0.5 for employment and GDP per worker (latter scaled by σ), with the former elasticity estimated less precisely than with lower values of σ . The elasticities with respect to components of GDP are also less precise, but continue to show a pattern of statistically favoring physical capital intensity and TFP as predictors of high price-adjusted quantities.

3c. Exports Across Categories

All of the size elasticities in the previous subsection were *conditional* on a country exporting in a category. In this subsection we present direct evidence on the variety channel by looking at elasticities of *categories exported* with respect to exporter size. We start with simple counts: in how many 10 digit categories does a country export to the U.S., and how does this vary with the exporter's size? Figure 2 shows that these counts are highly positively correlated with exporter GDP (correlation 0.82). Column (1) of Table 4 estimates elasticities of counts with respect to exporter employment and GDP per worker at 0.65 (standard error 0.03) and 1.47 (standard error 0.05).

That bigger economies export in more categories does not establish that they export nontrivial amounts in the added categories. An indirect way of addressing this is to ask whether the distribution of a bigger economy's exports across categories is more dispersed and, in particular, more left-skewed (as if they are adding categories comprising small shares of its exports). For each country j we calculate the standard deviation of v_{jm}/v_j across the categories in which $v_{jm} > 0$ in 1990, where v_{jm} is country j 's nominal exports to the U.S. in category m and v_j is country j 's nominal exports to the U.S.. In the case when a country's exports are distributed uniformly across the categories in which it exports, the shares are equal across m 's and their standard deviation is zero. We calculate the standard deviation and skewness of these shares for each country, and then correlate them with the country's $\ln$ GDP. We find that higher GDP countries have *less* dispersed export shares (correlation -0.76 between $\ln \text{GDP}_j$ and the standard deviation of v_{jm}/v_j) and *less* left-skewness (correlation 0.80 between $\ln \text{GDP}_j$ and the skewness of v_{jm}/v_j).

Although bigger economies appear to have more balanced export shares across their exporting categories, it could be that they are more balanced among the categories in which smaller economies tend to export as well. The *additional* categories may still have trivial quantities, if the shares of other categories are sufficiently more equal for bigger economies. To more directly address the issue of whether bigger economies export

meaningfully more varieties, we calculate "Feenstra Ratios" based on Feenstra (1994). To compare the variety of U.S. imports over time, Feenstra compared the growth rate of U.S. imports between two periods to the growth rate of U.S. imports between two periods *in those categories in which the U.S imported in both periods*. The net growth rate measures the importance of new import varieties relative to disappearing import varieties compared to importance of additional imports of varieties present in both periods. For comparing the variety of two country's exports at a point in time, we construct an analogous Feenstra Ratio:

$$(34) \quad FR_{i,j} = \left[\frac{v_j}{v_i} \right] / \left[\frac{\sum_{m \in M_{j,i}} v_{jm}}{\sum_{m \in M_{j,i}} v_{im}} \right]$$

where $M_{j,i}$ is the set of m 's for which $v_{jm} > 0$ and $v_{im} > 0$. We construct this for all pairs of countries among the 119 countries exporting to the U.S. in 1990 for which we have data on employment and GDP per worker. Interestingly, the set $M_{j,i}$ is actually empty (and the Feenstra Ratio undefined) for 8% of the country pairs; these pairs have no common 10 digit categories in which they exported to the U.S. in 1990. Using the 6,580 pairs with some categories in common, column (2) of Table 4 gives the results from regressing the ln of the Feenstra Ratio on the country size variables. The estimated elasticities with respect to employment and GDP per worker are economically and statistically significant (0.45 with a standard error of 0.03 and 0.46 with a standard error of 0.05, respectively). They are notably smaller than the count elasticities in column (1) of Table 4 (2/3 and 1/3 as big, respectively), suggesting that the added categories are less important than the typical category.

For comparison purposes, column (3) of Table 4 reports the elasticity of exports with respect to country size for the same sample. This elasticity is unity for employment and around 1.5 for GDP per worker (both highly significant statistically). Since column (3) is the numerator of the Feenstra Ratio, one can decompose the overall export elasticity in column (3) into the Feenstra Ratio elasticity and the elasticity for the denominator of the Feenstra Ratio.

That is, one can decompose the overall elasticity into an extensive (across category) margin and an intensive (within category) margin. Column (4), the ratio of the column (2) coefficient to the column (3) coefficient, indicates the importance of the extensive margin. The extensive margin represents 45% of the export elasticity for employment, 31% of the export elasticity for GDP per worker, and 41% of the export elasticity for GDP.

To the extent that larger workforces export more varieties within categories, as suggested by results in the previous subsection, the external margin in Table 4 understates the importance of the external margin in the overall export elasticity with respect to employment. Table 4 covers exports to the U.S. only, however, so it is possible that the extensive margin is more important bilaterally (or with respect to the U.S. in particular) than overall. To address this question, we employ UNCTAD TRAINS (1995) data on exports to 76 countries comprising the overwhelming majority of worldwide imports. We did not employ this data in the previous subsection because its quantity units are not comparable across countries, making unit price and quantity comparisons impossible. For *nominal* exports as in Table 4, however, the units in the TRAINS data are comparable across countries (current dollars).

Table 5 repeats the Table 4 regressions with the TRAINS data. Column (1) of Table 5 shows that larger economies export in substantially more categories. The elasticities are remarkably close to those in column (1) of Table 4. Column (2) of Table 5 provides elasticities of the Feenstra Ratio with respect to exporter size. These are large economically and statistically significant (0.24 standard error 0.02 for employment, 0.55 standard error 0.03 for GDP per worker). The elasticity with respect to employment is markedly smaller than in the U.S. data (0.24 vs. 0.45), whereas that with respect to GDP per worker is somewhat higher (0.55 vs. 0.46). Column (4) shows that, as a share of the overall export elasticity, the external margin represents 28% for employment, 37% for GDP per worker, and 31% for GDP alone. These TRAINS elasticities might be lower bounds on the importance of the external margin, however, since the external margin may be operating within TRAINS categories (of which there are around 5,072, compared to 14,572 in the U.S. data).

4. Robustness (to be added)

4a. Consumption Goods vs. Intermediate and Capital Goods

Table 6 (like Table 1)

4b. Small vs. Large

Table 7 (like Table 1) bottom vs. top half of L

Figure 3 kernel.

Table 8 (like Table 1) bottom vs. top half of Y/L

Figure 4 kernel.

4c. Commodities vs. Manufactured Goods

Table 9 (like Table 1)

Table 10 minerals (like Table 1)

4d. Tariffs and Freight Costs

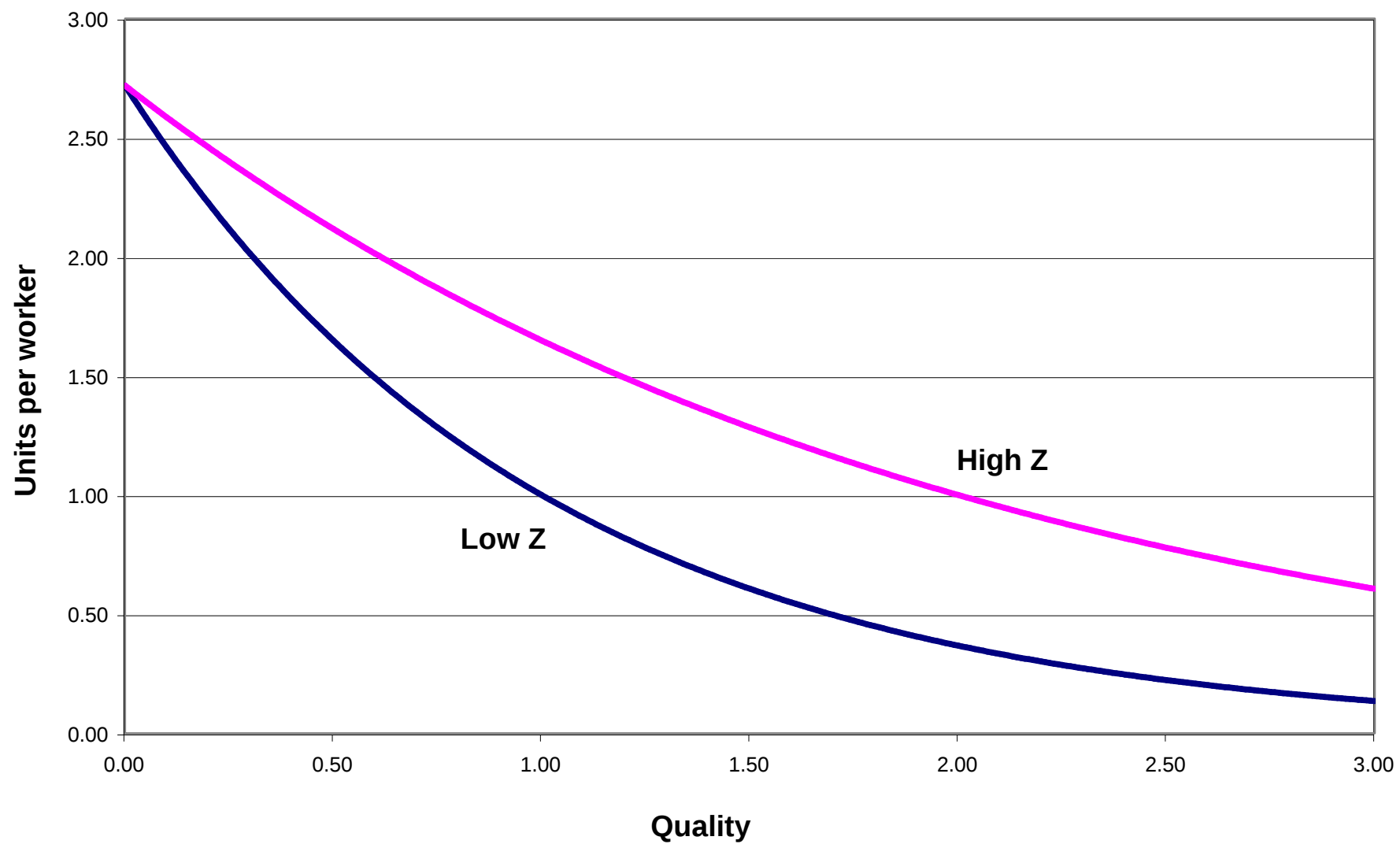
Table 11 (like Table 1)

5. Conclusion

In examining U.S. import data from 119 countries in 14,572 product categories in 1990, we found that richer countries exported in more categories. Within categories, richer countries exported lower quantities but at much higher prices. For reasonable price elasticities (e.g., above 0.2) the quantities are too high to be consistent with the prices, suggesting that richer countries export higher quality products to the U.S. than poorer countries do.

We found further that countries with more workers export to the U.S. in more categories, in higher quantities per category, and at no lower unit prices. The observably greater number of varieties favors Krugman-style models over Armington one-variety-per-country models. The higher quantities per category at no lower unit prices suggests an endogenous number of varieties within even narrowly-defined categories.

Figure 1



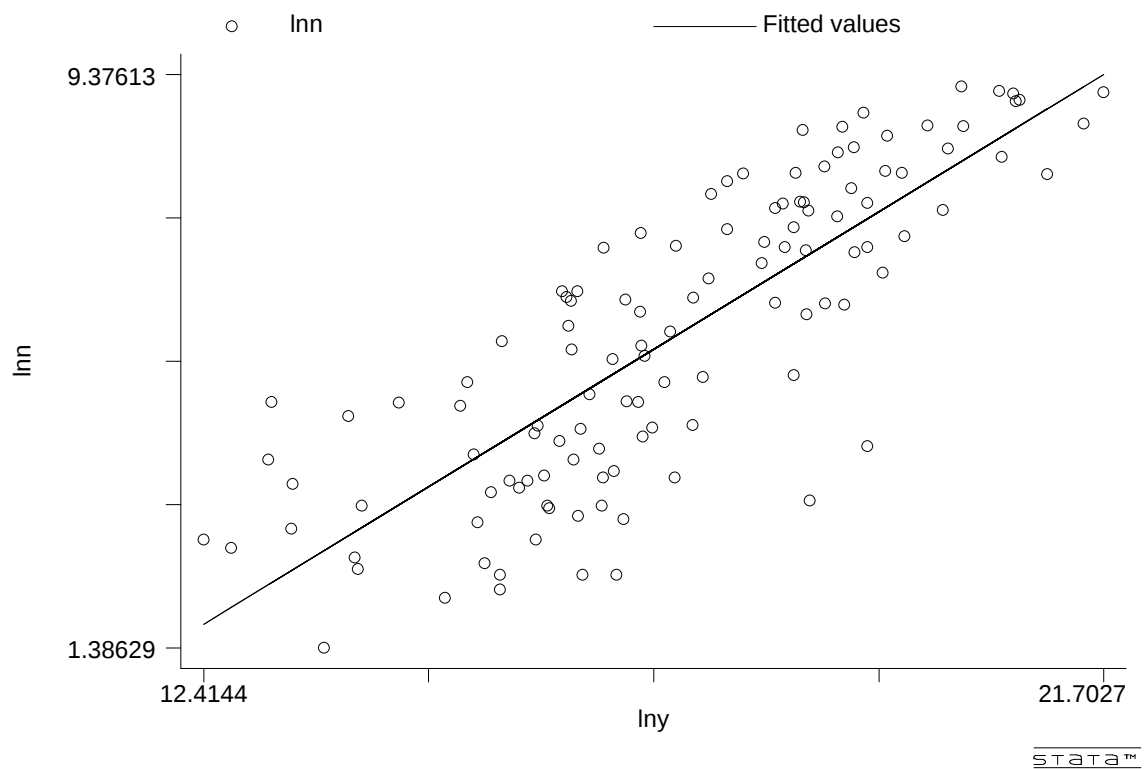


Table 1: Armington vs. Krugman

Dependent Variable [®]	(1)	(2)	(3)	(4)
Independent Variables [—]	$\ln q_{jm}$	$\ln p_{jm}$	$\ln q_{jm}$	$\ln p_{jm}$
$\ln L_j$	0.41 (0.07)	0.01 (0.03)	0.47 (0.09)	-0.02 (0.03)
$\ln(Y_j/L_j)$	-0.11 (0.13)	0.50 (0.05)		
$\ln(K_j/Y_j)$			-1.33 (0.59)	0.76 (0.22)
$\ln(H_j/L_j)$			1.53 (0.74)	0.14 (0.29)
$\ln(TFP_j)$			-0.13 (0.22)	0.60 (0.09)
Number of Observations	145,198	145,198	143,650	143,650
Number of Countries	119	119	98	98
Adjusted R ²	0.048	0.066	0.062	0.077

Notes: All data is for 1990. Variables are deviations from m (category) means. Robust standard errors, in parentheses, are adjusted for clustering (regressors varying by j but not by m). q_{jm} = Units exported to the U.S. by country j in category m . p_{jm} = Average unit price of exports to the U.S. by country j in category m . L_j = Employment in country j . Y_j/L_j = GDP per worker in country j . K_j/Y_j = Ratio of physical capital to output in country j . H_j/L_j = human capital per worker in country j , measured as $\exp(0.1 \cdot s_j)$, where s_j is average schooling attainment of the 15+ population.

Data Sources: U.S. Bureau of the Census (1990) for export prices and quantities. Summers and Heston (2001) for employment and GDP, and for capital stocks using the methodology in Klenow and Rodriguez-Clare (1997). Barro and Lee (2000) for schooling attainment data.

Table 2: Estimating σ

Dependent Variable [®]	(1)	(2)	(3)	(4)	(5)
Independent Variables [—]	$\ln p_{jm}$	$\ln q_{jm}$	$\ln p_{jm}$	$\ln q_{jm}$	$\ln p_{jm}$
$\ln q_{jm}$	-0.28 (0.01)		-0.27 (0.01)		
$\ln p_{jm}$		-1.32 (0.02)		-1.34 (0.02)	
$\ln(Y_j/L_j)$			0.36 (0.05)	0.17 (0.16)	0.51 (0.06)
$\ln q_{jm}$ instrumented by L_j					0.02 (0.07)
Implied value of σ	3.6	1.3	3.7	1.3	∞
Number of Observations	148,285	148,285	145,198	145,198	145,198
Number of Countries	152	152	119	119	119
Adjusted R ²	0.37	0.37	0.407	???	0.0033

Notes: All data is for 1990. Variables are deviations from m (category) means. Robust standard errors, in parentheses, are adjusted for clustering (regressors varying by j but not by m). q_{jm} = Units exported to the U.S. by country j in category m . p_{jm} = Average unit price of exports to the U.S. by country j in category m . L_j = Employment in country j . Y_j/L_j = GDP per worker in country j .

Data Sources: U.S. Bureau of the Census (1990) for export prices and quantities. Summers and Heston (2001) for employment and GDP, and for capital stocks using the methodology in Klenow and Rodriguez-Clare (1997). Barro and Lee (2000) for schooling attainment data.

Table 3: Price-Adjusted Quantities

Dependent Variable = $\ln q_{jm} + s \ln p_{jm}$	(1) $s = 1$	(2) $s = 1$	(3) $s = 4$	(4) $s = 4$	(5) $s = 7$	(6) $s = 7$
Independent Variables –						
$\ln L_j$	0.42 (0.05)	0.45 (0.06)	0.45 (0.07)	0.40 (0.07)	0.48 (0.15)	0.34 (0.16)
$\ln(Y_j/L_j)/s$	0.39 (0.09)		0.48 (0.03)		0.49 (0.04)	
$\ln(K_j/Y_j)/s$		-0.56 (0.39)		0.45 (0.09)		0.58 (0.14)
$\ln(H_j/L_j)/s$		1.68 (0.49)		0.53 (0.15)		0.36 (0.20)
$\ln(TFP_j)/s$		0.47 (0.16)		0.57 (0.06)		0.58 (0.12)
Number of Observations	145,198	143,650	145,198	143,650	145,198	143,650
Number of Countries	119	98	119	98	119	98
Adjusted R ²	0.055	0.062	0.077	0.080	0.074	0.080

See the Notes to Table 1. See also equation (33) in the text.

Table 4: The External Margin in Exports to the U.S.

Dependent Variable [®]	(1) lnN _j	(2) lnFR _{j,i}	(3) lnv _{j,i}	(4) % External = (2)/(3)
Independent Variables [–]				
lnL _j	0.65 (0.03)	0.45 (0.03)	1.00 (0.03)	45%
ln(Y _j /L _j)	1.47 (0.05)	0.46 (0.05)	1.48 (0.06)	31%
Adjusted R ²	0.81	0.32	0.69	
lnY _j	0.82 (0.03)	0.45 (0.03)	1.10 (0.03)	41%
Adjusted R ²	0.67	0.32	0.67	
# of Observations	119	6,580	6,580	

Notes: All data is for 1990. Number of countries = 119. Robust standard errors are in parentheses. N_j = Number of 10 digit categories in which country *j* exported to the U.S.. v_j exports to the U.S. of country *j*. v_{jm} exports of country *j* to the U.S. in category *m*. v_{j,i} = v_j/v_i. FR_{j,i} = (v_j/v_i)/(v_j/v_i) $\forall$ *m* in which v_{jm} > 0 and v_{im} > 0) – see equation (34) in the text. L_j = Employment in country *j*. Y_j/L_j = GDP per worker in country *j*.

Data Sources: U.S. Bureau of the Census (1990) for exports to the U.S.. Summers and Heston (2001) for employment and GDP.

Table 5: The External Margin in Exports to All Countries

Dependent Variable [®]	(1) lnN _j	(2) lnFR _{j,i}	(3) lnv _{j,i}	(4) % External = (2)/(3)
Independent Variables [–]				
lnL _j	0.67 (0.05)	0.24 (0.02)	0.84 (0.03)	28%
ln(Y _j /L _j)	1.48 (0.08)	0.55 (0.03)	1.47 (0.03)	37%
Adjusted R ²	0.79	0.37	0.80	
lnY _j	0.88 (0.06)	0.31 (0.02)	0.98 (0.03)	31%
Adjusted R ²	0.66	0.29	0.72	
# of Observations	117	5,558	5,558	

Notes: All data is for 1995. Number of countries = 117. Robust standard errors are in parentheses. N_j = Number of 6 digit categories in which country *j* exported. v_j exports of country *j*. v_{jm} exports of country *j* in category *m*. v_{j,i} = v_j/v_i. FR_{j,i} = (v_j/v_i)/(v_j/v_i ∀ *m* in which v_{jm} > 0 and v_{im} > 0) – see equation (34) in the text. L_j = Employment in country *j*. Y_j/L_j = GDP per worker in country *j*.

Data Sources: UNCTAD (1995) for exports to all nations. Summers and Heston (2001) for employment and GDP.

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