NBER WORKING PAPER SERIES

DEDUCTIONS FROM THE EXPORT BASKET: CAPABILITIES, WEALTH AND TRADE

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Working Paper 16834
http://www.nber.org/papers/w16834

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
February 2011

We are indebted to Daron Acemoglu, Philippe Aghion, Bernardo Blum, Kunal Dasgupta, Gilles Duranton, Penny Goldberg, Avner Grief, Elhanan Helpman, Amit Khandelwal, Peter Morrow, Nathan Nunn, Steve Redding, Peter Schott, Bob Staiger, and Eric Verhoogen as well as seminar participants at CIFAR, Columbia, CREI, Michigan, Toronto, Stanford, and Yale. Trefler gratefully acknowledges funding from the Social Sciences and Humanities Research Council of Canada (SSHRC) and the tremendous support of the Canadian Institute for Advanced Research (CIFAR). The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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NBER Working Paper No. 16834
February 2011
JEL No. F12,O10

ABSTRACT

This paper re-explores the relation between a country's level of wealth and the mix of products it exports. We argue that both are simultaneously determined by countries' capabilities i.e. by countries' productivity and quality levels for each good. Our theoretical setup has two features. (1) Some goods have fewer high-quality producers/countries than others i.e. there is Ricardian comparative advantage. (2) Imperfect competition allows high- and low-quality producers to coexist, which we refer to as 'product ranges'. These two features generate a very particular non-monotonic, general equilibrium relationship between a country's export mix and its wage (GDP per capita). We show that this non-monotonicity permeates the 1980-2005 international data on trade and GDP per capita. Our setup also explains two other facets of the data: (1) Product ranges are huge and (2) for the poorest third of countries, changes in export mix substantially over-predict growth in GDP per capita. This suggests that the main challenge for low-income countries is to raise quality and productivity in their existing product lines.

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1. Introduction

Rich and poor countries export very different baskets of goods. Our knowledge of this relationship between a country's mix of exports and its income dates back at least to the discussion of ladders of development by Chenery (1960) and Leamer (1984); and its implications for industrial policy have been fleshed out by Michaely (1984), Lall, Weiss and Zhang (2006), and most forcefully by Hausmann, Hwang and Rodrik (2007).

Running parallel to this literature, but disconnected from it, is a literature on the relationship between export quality and income. Schott (2004) observed that within finely disaggregated products, U.S. import prices are positively correlated with exporter incomes. The implication is that richer countries producer higher-quality goods. Related observations appear in Hallak (2006), Schott (2008), Hallak and Schott (2008), and Khandelwal (2010). Given that quality is an important component of productivity (e.g. Foster, Haltiwanger and Syverson 2008) and given that productivity is a key driver of the wealth of nations (e.g. Hall and Jones 1999 and Helpman 2004), there is most certainly a link between a country's wealth and its ability to produce high-quality goods.

This paper brings together these two literatures by introducing a model in which international differences in the capabilities of firms in different countries drive differences both in their export mix and their incomes. A firm's capability, though not directly observable, is revealed by three observable outcomes: the set of goods the firm produces, the quality of these goods, and productivity in their production.[1] In this paper, our primary focus is on quality and the product mix. Correspondingly, we suppress productivity differences across firms (and countries). The ideas here are closely related to work by Sutton (1991, 1998, 2007b). In that work there is a homogeneous good that is vertically differentiated i.e. differentiated only by quality. Equilibrium is characterized as a Nash equilibrium in quantities (Cournot equilibrium). The key feature of the equilibrium is that firms with differing levels of quality will co-exist in equilibrium and will set prices that are proportional

1. Productivity can be thought of as a 'cost shifter', and quality as a 'demand shifter', so that these two influences encompass all proximate determinants of current (gross) profits.

to qualities.

We graft this feature onto a Ricardian model of comparative advantage. Comparative advantage here means that quality capabilities are not only scarce, but scarcer for some products than others.[2] In particular, we assume that products can be ordered by the scarcity of capabilities, as reflected by product quality. If a country has high quality in good g then it has high quality in all goods ranked below g. Restated, low-g goods are ones for which most countries have high quality. These goods are 'easy' to make. In contrast, high-g goods are ones that are 'hard' to make.

For clarity, we summarize the two key features of our model:

1. There is Ricardian scarcity of quality capabilities; and,

2. Differing levels of quality will co-exist in equilibrium, with prices increasing in quality.

These two features generate a correlation between a country's income and its export mix. A country with high quality in just a few goods will only be able to survive in a few markets i.e. in the low-g or 'easy' markets. As a result, derived demand for its labour will be low and wages will be low. Thus, low-wage countries will export low-g goods. A country with high quality in many goods will have a high derived demand for its labour and have high wages. High wages will make the country a high-cost producer of low-g goods. Hence, a high-wage country will only be able to survive in high-g markets. Drawing together these observations about low- and high-wage countries, income will be correlated with the export mix and this correlation will be driven by underlying quality capabilities.

We use our two features to derive a host of implications about observables. That is, our analysis employs the minimal theoretical structure needed to generate a series of implications about observables. In particular, using 1980 and 2005 export data by exporter

2. We can motivate this idea of relatively scarce capabilities by reference to a key idea in the modern 'market structure' literature: if firms must incur fixed and sunk outlays to develop their capabilities, then the number of firms that find it profitable to develop these capabilities will be limited: the greater the elasticity of quality (or productivity) responses to R&D or other fixed outlays, the greater the degree to which firms 'escalate' their R&D spending in competing with rivals, and the fewer the number of producers that survive in the market. For a concise review, see Sutton (2007a). Thus, even if all firms in all countries were symmetric, some capabilities will remain scarce and valuable. In a world with inherited historical asymmetries, where firms in one country face different costs of building capabilities, then these effects may be accentuated. In this paper, we simply take as a given that some capabilities are relatively scarce; for a general equilibrium analysis of the mechanism of entry and R&D competition leading to this see Sutton (2007b).

and detailed product, we examine four predictions of the model.

First, when looking at a single finely disaggregated product, it will be produced both by rich and poor countries. Such *quality ranges* have been documented by Schott (2004); however, we take a different approach than Schott, one that is motivated by our theory, and show that quality ranges are more pervasive than previously understood.

Second, within a finely disaggregated product there will be a range of prices charged by exporters. Under our assumption of homogeneous goods and vertical (quality) differentiation, consumers care only about quality and thus care only about quality-adjusted prices. As a result, high-quality producers will charge high prices. Further, general equilibrium considerations discussed shortly imply that high-quality producers will be rich. Thus, high-quality countries will have high export quality, high export prices and, in general equilibrium, high incomes.

Predictions about markups are more subtle. Markups will be correlated with incomes, but only when looking *across* products. Looking across exporters of a single product, markups will first increase and then decrease in exporter income.

Third, for a single good g, there will be an inverted-U relationship between income and a country's share of world exports. Consider a country whose wages increase because its quality increases first in good g and then in good $g+1$. As the country's quality improves in good g the country grabs a larger share of the world good-g market. But as its quality then improves in good $g+1$ its wages continue to increase, thereby reducing the country's competitiveness in good g. This standard general equilibrium effect and the resulting non-monotonic relationship between income and export market shares has not been exploited in the quality-and-trade literature, but is a pervasive feature of the data.

Fourth, our framework highlights the conditions necessary to rigorously justify the product-mix diagrams that have been used to great effect by Hausmann et al. (2007). They use a country's export basket to predict its GDP per capita. They do this in two stages. First, pick a product and calculate the export-weighted average GDP per capita of exporting countries. Call this the product's 'score'. Second, pick a country and calculate the weighted average of the scores of the products that the country exports. The weights used are based on the country's export basket. Call this weighted average the country's 'implied GDP per capita'. A country's implied GDP per capita may be plotted against its actual GDP per capita and figure 4 below provides an example of such a 'product-mix' plot.

Two features of the figure 4 product-mix diagram are striking. First, the relationship is very 'flat' relative to the 45° line. Flatness can be explained easily by aggregation bias.[3] Second, the figure 4 relationship is 'diffuse'. By this we mean, for example, that even though Greece's GDP per capita is over 20 times that of the Philippines, the two countries have almost identical implied GDPs per capita. Diffuseness is most naturally explained by quality. A country can become rich in two ways: either by improving its capabilities and so the quality (and/or productivity) of its existing goods, or by moving to higher-g goods. Hausmann et al. (2007) have emphasized the role of moving to higher-g goods. But suppose a low-income country moves into higher-g goods at a low level of quality. Then the country will be inappropriately credited with the average score for that product. In terms of figure 4, the Philippines is such a country: its implied GDP per capita is much higher than its actual GDP per capita. Diffuseness, then, results when low-income countries produce high-g goods at low quality. This has important implications for industrial policy in developing countries.

Finally, we argue for some caution in making deductions from standard data sets in respect of the relation between the export mix and incomes across countries. For most products (four-fifths) in our data set, the range of countries (income levels) for whom the good is a significant export is so broad as to make its presence in a country's export basket almost wholly uninformative about the country's income.

We conclude by noting that our paper is part of a larger literature on trade and quality. Feenstra (1984), Schott (2004), Hummels and Klenow (2005), Hallak (2006), Verhoogen

3. Consider a product such as LCD modules that appear both in hand-held calculators (easy to make) and in 100-inch television screens (hard to make). Even the 10-digit Harmonized System classification does not distinguish between these so that there is only a single or average 'score' for LCD modules. Poor countries, which produce small LCDs, receive the average LCD score, thus raising their implied GDP per capita. Rich countries, which produce large LCDs, also receive the average LCD score, thus lowering their implied GDP per capita. As a result of this aggregation bias the figure 4 relationship is flatter than the 45° line.

(2008), Hallak and Schott (2008), Kugler and Verhoogen (2008) and Khandelwal (2010) have made important contributions to the measure of international differences in quality. We do not attempt to measure quality. These authors as well as Hummels and Skiba (2004), Schott (2008), Choi, Hummels and Xiang (2009), Johnson (2009) and Baldwin and Harrigan (forthcoming) examine the relationship between trade flows and quality. Verhoogen (2008) explores the relationship between quality, trade and inequality, as does Goldberg and Pavcnik (2007). Amiti and Khandelwal (2009) explore the impact of trade restrictions on quality upgrading. Hallak and Sivadasan (2009) and Bastos and Silva (2010) provide insights into the role of quality and productivity heterogeneity. Finally, Grossman and Helpman's (1991) quality-ladder model provides a dynamic link between quality, trade, and growth.

2. Theory I: A Baseline Model

2.1. *Consumer Choice*

All countries are of the same size and composed of a unit mass of workers. All individuals have identical Cobb-Douglas utility functions defined over G goods, indexed by g, and labour:

$$U = \prod_g (u_g x_g)^{\delta_g} - \frac{1}{2} l^2 \tag{1}$$

where $\sum_g \delta_g = 1$, l denotes hours of labour supplied, and u_g and x_g denote the quality and quantity of good g consumed. It follows from the form of the utility function that each consumer spends fraction δ_g of income on good g. We assume that all profits accrue to a separate group of individuals, who also have a utility function of the form (1) but with l constrained to zero. From this it follows that we can treat all firms in the global market for g as facing a unit-elastic market demand schedule, i.e. the total global expenditure on good g is a constant, which we denote as S_g, independently of equilibrium prices. We note that the S_g are proportional to the δ_g. We will assume throughout that all the δ_g, and so all the S_g, are equal, and so drop the product subscript, writing total expenditure on each good as S.

2.2. *Equilibrium in the Product Markets*

We characterize product market competition using the standard 'Cournot model with quality' introduced in Sutton (1991). In this model, firms are characterized by a level of capability, consisting of a quality level and a productivity parameter denoting the number of worker hours per unit of output produced,[4] together with a ('local') wage rate specific to the country in which the firm is located. At equilibrium, some subset of firms are active in the production of the good. For each active firm, indexed by i, its output level is related to its productivity c_i, its quality u_i, and its (local) wage rate w_i. Solving for a Nash equilibrium in quantities (Sutton, 1998, Appendix 15), we obtain the firm's quality-adjusted equilibrium price,

$$\frac{p_i}{u_i} = \frac{1}{N_g - 1} \sum_j \frac{w_j c_j}{u_j} \tag{2}$$

and its quality-adjusted output level,

$$x_i u_i = S \frac{N_g - 1}{\sum_j \frac{w_j c_j}{u_j}} \left\{ 1 - (N_g - 1) \frac{w_i c_i / u_i}{\sum_j \frac{w_j c_j}{u_j}} \right\} \tag{3}$$

where N_g (≥ 2) denotes the total number of firms that are active in the global market for good g, S is total expenditure on good g and the sum $\sum_j$ is taken over all active firms. One can see from equation (2) that p_i / u_i is the same for all active firms. The condition for firm i to be active, i.e. to have strictly positive output at equilibrium, is that

$$\frac{w_i c_i}{u_i} < \frac{1}{N_g - 1} \sum_j \frac{w_j c_j}{u_j} = \frac{N_g}{N_g - 1} (\overline{\frac{w_j c_j}{u_j}}) \tag{4}$$

4. Thus all costs are labour costs, and fixed costs are sunk, and so do not enter the present (short run) analysis. Materials cost, though of crucial importance in general, are here ignored in order to keep the analysis as clear as possible. This issue is examined in depth in Sutton (2007b) who shows that the key point is this: in the absence of material cost, low-wage countries can become viable in world markets even at low quality once their wage costs are sufficiently low: only the ratio of unit costs (wages times labour input) to quality matters to viability, and shortcomings in quality can be offset by a low value of the wage. But once material inputs as well as labour are required, a fall in the wage can only reduce unit costs to the world-market value of the material input. This places a floor on price, and so establishes a corresponding minimum quality level, independent of local wages, that is required for viability. Deficiencies in productivity can always be compensated for by low wages, but deficiencies in quality cannot. This is an important reason for emphasizing the role of quality in our present discussion.

where $(\overline{\frac{w_j c_j}{u_j}})$ denotes the mean capability of all active producers. (This condition is equivalent to requiring that equilibrium price p_i exceed marginal cost $w_i c_i$.) We will refer to $w_i c_i / u_i$ as firm i's 'effective cost level'.

In the special case where all the firms producing good g have the same w_j, c_j and u_j the output equation (3) takes the form

$$x_i = S \frac{N_g - 1}{N_g^2} \frac{1}{w_i c_i} \ . \tag{3'}$$

Finally, combining (2) and (3) we have the expression for the sales revenue of firm i,

$$R_i \equiv p_i x_i = \left\{ 1 - (N_g - 1) \frac{w_i c_i / u_i}{\sum_j \frac{w_j c_j}{u_j}} \right\} \cdot S \ . \tag{5}$$

We now state three properties of the output function that follow from inspection of (3); see Appendix A for proofs.

Lemma 1 *On the domain where inequality (4) holds, so that $x_i > 0$:*

1. $\dfrac{\partial x_i}{\partial w_i} < 0.$
2. $\dfrac{\partial x_i}{\partial u_i} > 0.$
3. *A rise in u_i and w_i that leaves u_i / w_i unchanged implies a fall in x_i.*

Note that the r.h.s. of equations (2) and (3) depend on u_i and c_i only through the ratio u_i / c_i, which we refer to as the 'capability' of firm i. It follows that all relationships between capabilities and wages developed below will depend only on firms' or countries' relative qualities and productivities in the production of each good, and not on their absolute levels. Since our empirical focus is on quality u_i, without loss of generality we set $c_i = 1$ for the remainder of the paper and periodically remind the reader that our comments about quality are also germane to productivity.

2.3. *Cross-Country Production Patterns: The Perfect Sorting Baseline*

We introduce a Ricardian model of comparative advantage. In our setup comparative advantage derives from the relative scarcity of the capabilities required for producing some goods; so that countries able to produce these goods tend to specialize in their production at equilibrium. This generates an equilibrium relation between a country's wealth and its export mix.

The model is as follows. The set of countries active in the production of each good g at equilibrium depends on the value of the quality parameters and on equilibrium wage rates. There are K countries. We divide these into T 'types' comprising identical countries, with N_k countries of type k so that $\sum_{k=1}^{k=T} N_k = K$. We divide the G goods into T equal-sized 'product groups', where m denotes the number of goods in each group, so $G = mT$.

We will construct a baseline case in which each country-type is associated at equilibrium with the production of exactly one 'product group'. In this special case, all producers of any good will share the same quality level for all goods, and so the same equilibrium wage level, and the same output level of each good. It follows that in this special case we may use the country index k to label, also, the set of goods produced at equilibrium by country k, which we denote as G_k, i.e. a good is produced by countries of type k iff $g \in G_k$.

We assume there is (at most) one firm capable of producing any particular good, in each country, so that if a good is produced (only) by countries of type k, then the number of active producers of that good is N_k. We further assume that $N_k \geq 2$ for all k, so that there are at least two producers of every good.[5]

We now introduce scarcity in capabilities i.e. in qualities. Countries in group k can produce all goods in product groups 1 to k at a 'standard' level of quality u; but not goods $k+1$ and upward; the interpretation, as noted above, is that goods of a higher index require capabilities that are 'scarcer'. We will, in what follows, place restrictions on the number of countries of type k, and so on the number of countries capable of producing goods in product group k. Specifically, we assume that $N_k \geq N_{k+1} + 4$ for all k. It is shown below that this restriction is sufficient to ensure that goods in group k are produced, at equilibrium, only by countries of type k; and that all countries producing goods in this product group are of type k.

5. If $N_k = 1$, the equilibrium (monopoly) price is undefined (i.e. goes to infinity).

2.4. *Labour Market Equilibrium in a Country of Type* k

The set of goods G_k produced by the firms in country k comprise the m goods in product group k, all of whose producers face the same country-specific wage rate, which we denote w_k, and have the same level of output (for each of the m products in product group k). We denote the equilibrium level of output of each product g by the single firm in each producing country k as x_{gk}. It follows from equation (3′), recalling that all productivity parameters c_i are set to unity, that

$$x_{gk} = \frac{N_g - 1}{N_g^2} \frac{S}{w_k} \tag{3''}$$

so the total demand for labour in a country of type k is

$$L_k^D = \sum_{g \in G_k} x_{gk} = \sum_{g \in G_k} \frac{N_g - 1}{N_g^2} \frac{S}{w_k} = m \frac{N_k - 1}{N_k^2} \frac{S}{w_k} \tag{6}$$

where the sum over $g \in G_k$ comprises the m products in G_k, and where N_k denotes the (common) value of the number N_g of producers of any good $g \in G_k$, which in the present special case equals the number of countries of type k, or N_k.

We now turn to labour supply: it follows from the form of equation (1) and the fact that there is a unit mass of workers in each country that the labour supply function for country k takes the form of a ray through the origin, viz.

$$L_k^S = w_k \prod_g \left(\delta \frac{u_g}{p_g} \right)^{\delta} \tag{7}$$

where w_k is the wage rate in country k and where δ corresponds, as before, to the share of expenditure devoted to good g (which we have assumed to be equal for all goods).

Since equations (3″) and (6) already incorporate product market equilibrium, we may characterize general equilibrium by equating the supply and demand for labour within each country (type).

Labour market equilibrium requires, given the form of the labour supply function (7), that for any two country types k and k',

$$\frac{L_k^S}{L_{k'}^S} = \frac{w_k}{w_{k'}} = \frac{L_k^D}{L_{k'}^D}$$

whence on substituting in equation (6) for any two country types k and k' we have

$$\frac{w_k}{w_{k'}} = \sqrt{\frac{N_k - 1}{N_{k'} - 1} \cdot \frac{N_{k'}}{N_k}} \, . \tag{8}$$

This equation serves to define the chain of wage ratios between country type k' and country type k.

Up to this point, we have *assumed* that firms from country group k are the sole producers of product group k. We now note that the restriction on the N_k introduced above, viz. $N_k \geq N_{k+1} + 4$, ensures this is so. To do this, note that a necessary and sufficient condition for this is that firms in each country $k + i$ have wages $w_{k+i} > w_k$ sufficiently high to render them unviable in the production of good k. Using equation (4) with the inequality reversed and recalling that u denotes the common standard of quality shared by all active firms in the market, this requires that[6]

$$\frac{w_{k+i}}{w_k} > \frac{N_k}{N_k - 1} \, .$$

From equation (8), a sufficient condition for this is that, for all k,

$$\frac{w_{k+1}}{w_k} = \sqrt{\frac{N_{k+1} - 1}{N_k - 1} \frac{N_k}{N_{k+1}}} > \frac{N_k}{N_k - 1} \, .$$

It is easy to verify that, given our assumption that $N_k \geq 2$ for all k, this inequality follows from our assumption that $N_k \geq N_{k+1} + 4$ for all k.[7]

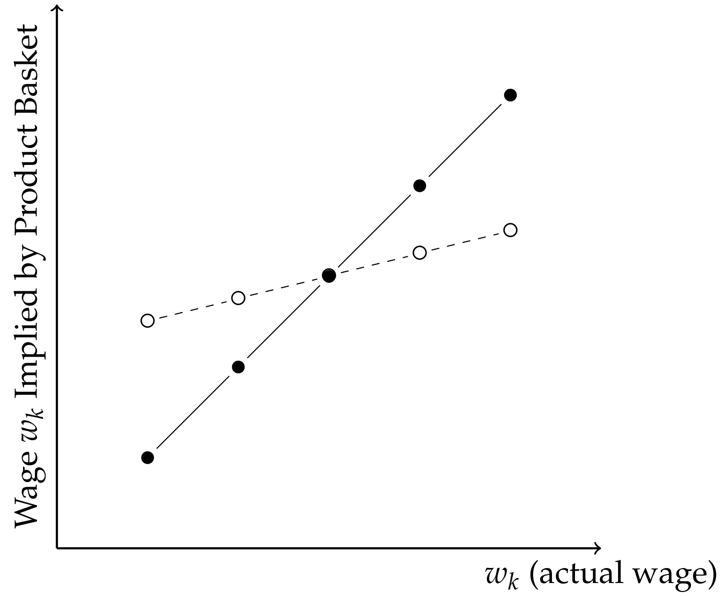
This establishes that under our restrictions on the N_ks there will be perfect sorting in equilibrium. That is, there will be a $1 : 1$ mapping between country types and product groups.

The interpretation of this restriction on the N_ks, as noted in the Introduction, is that higher-indexed products require relatively scarce capabilities; and that these higher-

6. To derive this, in equation (4) we replace N_g by $N_k + 1$ because there is now one additional producer that we must show is unviable. Also, $\sum_j w_j / u_j$ is replaced by $N_k w_k / u + w_{k+i} / u$ because all but one producer is from type-k countries. Finally, on the l.h.s. of inequality (4), w_i / u_i is replaced with w_{k+i} / u because we are looking at an unviable producer from country $k + 1$, not country i. With these changes, equation (4) with the inequality reversed can be simplified to $w_{k+i} > N_k^{-1}(N_k w_k + w_{k+i})$ or $w_{k+i} / w_k > N_k / (N_k - 1)$.

7. In fact, the restriction $N_k \geq N_{k+1} + 3$ is sufficient; but the stronger assumption is needed in the next section where we introduce one new entrant into some markets.

Figure 1: The 'Perfect Sorting' Benchmark and the Flatness Property



Notes: The wage implied by the product basket, shown on the vertical axis, is the weighted mean income of countries producing the products that are also produced by country k. The solid black dots on the 45° line represent countries in our benchmark case of perfect sorting i.e. in the case where all countries of a given type produce the same set of goods. The dashed line is explained later, in section 3.2.

indexed products are ones in which investment in capability building is relatively high, thus implying a high level of industry concentration at the global level.[8]

The first thing we do with our perfect sorting benchmark case is use it to provide analytical foundations for the product-mix diagram described in the Introduction. In the perfect sorting benchmark case, the product-mix plot coincides with the 45° line. This follows from the fact that the horizontal axis shows a country's wage rate w_k and the vertical axis shows, for that country, the (weighted) mean wage of the countries producing the goods produced by this country, which here are simply the goods in group k, all of whose producers have the same wage rate w_k. Here, the 'implied wage' coincides with the 'actual wage'. This is illustrated in figure 1. Each solid black dot represents a country type.

8. We are here dealing with short run analysis, in the sense of the Industrial Organization Literature, in which all costs of developing capabilities are sunk costs that were incurred in the past. The scarcity of capabilities reflects the equilibrium outcome from an earlier (unmodelled) stage of 'competing in capability building'. The industries with few players are those for which a given proportionate increase in a firm's investment in capability building yields a relatively large return in terms of (global) market share (Sutton, 1991, 1998, 2007b).

In this section we set up a perfect sorting equilibrium. Note that the Cournot model played no essential role in this. Its role is central however in the next section, where we introduce quality differences across different firms (countries) operating in each industry.

3. Theory II: Quality Differences

In this section, we relax the assumption characterizing the baseline model, that all producers in each industry have the same quality (and productivity.) The central aim is to characterize the band of countries, in terms of their real wage rate (GDP per capita), that will be active in a given industry at equilibrium. With this in mind, we examine a country initially producing good $k-1$, whose capability in the production of good k advances, in the sense that its quality, denoted v_k, rises from zero to the standard quality u. As v_k rises, the country's mix of output will gradually shift from the production of goods of group $k-1$ to goods of group k. This change will, in general, affect the equilibrium wage rate of all countries of adjacent types. The general solution in this setting is analytically intractable, and so we introduce a 'small' country approximation in order to permit a full solution. The idea is as follows: we begin from the benchmark model of last section, but we now introduce a new, additional, 'small' country ('country $K+1$') whose initial capability level is low. This country's population is very small compared to the unit mass of workers in every other country. Moreover, its capabilities are confined to only *one* of the m products in each product group. The result will be that, in the limit $m \to \infty$, this country's presence (or absence) from a single one of the m markets of type k will have a negligible influence on the equilibrium wage of other (large) countries. Hence, we may investigate the fortunes of this 'small developing country' while treating the wage rates of all other ('large') countries as being (approximately) constant.[9]

With this in mind, we proceed as follows: We begin from a situation in which the new country has the standard level of quality in the first of the m products in each of the product

9. We maintain here, as elsewhere, the assumption that the labour market faced by firms operating in country k is competitive, i.e. the firm is a price taker in the labour market.

groups 1 to $k-1$; and has zero quality in all other products. Since the small country's equilibrium wage falls monotonically as its worker population rises, we can choose its worker population so that its equilibrium wage, when v_k reaches the level u, coincides with the equilibrium wage of type k countries. At equilibrium, it will be active in, and only in, the first product of group k. Thus there are $N_k + 1$ producers in this market.

Phase I

We now examine the effect of allowing the small country's quality in the first product of group k, which we denote by v_k, to rise from zero to the standard quality level u of existing group-k producers. This is illustrated in the top panel of figure 2.

The rise in v_k has no effect on the new country's wage until v_k reaches the quality threshold at which the new country is viable in market k. This level of v_k, denoted v_k^c, is defined by the equation (4) viability condition

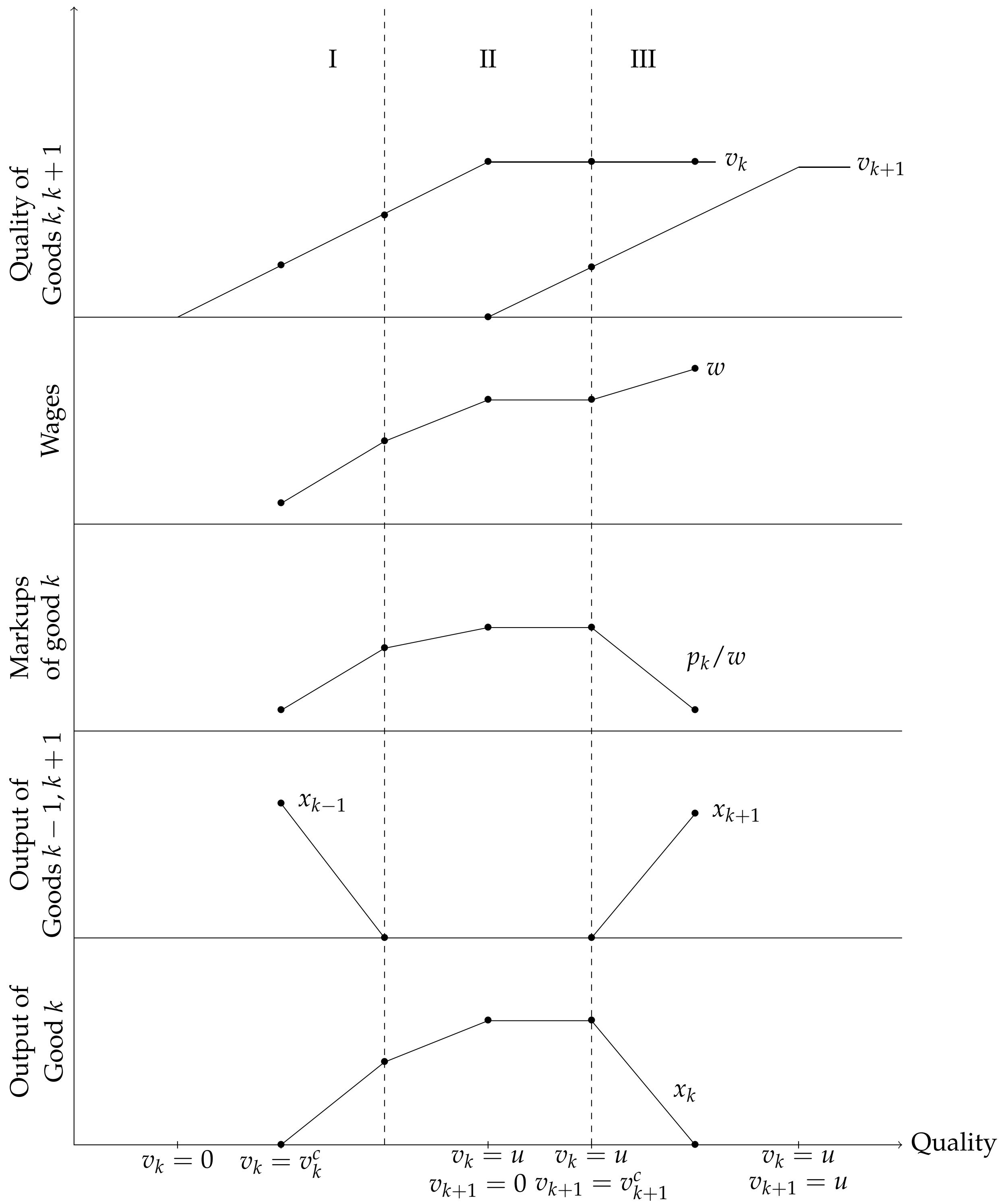
$$\frac{v_k^c}{w(v_k^c)} = \frac{N_k - 1}{N_k} \cdot \frac{u}{w_k}$$

where $w(v_k^c)$ is the small country's wage rate and w_k is the wage rate of group-k countries. v_k^c appears on the horizontal axis of figure 2.

We have thus established the following key result. For $v_k \in (v_k^c, u)$ there will be a 'quality' range, that is, type-k products will be produced at low quality v_k by the new country and at high quality u by all type-k countries.

Once v_k advances beyond v_k^c, the new firm becomes active in both market $k-1$ and market k; and this continues to be the case up to a critical level of v_k at which it ceases to be active in market $k-1$. (This corresponds to the boundary between phases I and II in figure 2.) Its wage in phase I can be deduced as follows. Note that there are now $N_{k-1} + 1$ producers in market $k-1$, all with quality u, where N_{k-1} producers have a local wage w_{k-1} and one has local wage $w(v_k) > w_{k-1}$. There are $N_k + 1$ producers in market k, of which N_k have quality u and local wage w_k, while one has quality v_k and local wage $w(v_k)$. The new

Figure 2: Advancing Quality



Notes: The top panel shows the new country's quality in good k advancing from $v_k = 0$ to $v_k = u$, and then its quality in good $k+1$ advancing from $v_{k+1} = 0$ to $v_{k+1} = u$. The critical value of v_k at which production of good k becomes viable is labelled v_k^c, and is marked by the first dot on the v_k schedule. The second and third panels show how the equilibrium wage and markup rise as qualities rise, while the bottom two panels show how the output of goods $k-1$, k, and $k+1$ change. In the diagram, for ease of notation we have suppressed the subscripts and arguments of $w(v_k,v_{k+1})$, $p_k(v_k,v_{k+1})$, $x_{k-1}(w(v_k))$, $x_k(w(v_k,v_{k+1}),v_k,v_{k+1})$, and $x_{k+1}(w(v_{k+1}),v_{k+1})$.

country's output of the first good of type $k-1$ is therefore (from equation 3)

$$x_{k-1} = \frac{1}{w(v_k)} S N_{k-1} \frac{w(v_k)/u}{N_{k-1}\frac{w_{k-1}}{u} + \frac{w(v_k)}{u}} \left\{ 1 - N_{k-1} \frac{w(v_k)/u}{N_{k-1}\frac{w_{k-1}}{u} + \frac{w(v_k)}{u}} \right\}$$

and its output of the first good of type k is

$$x_k = \frac{1}{w(v_k)} S N_k \frac{w(v_k)/v_k}{N_k \frac{w_k}{u} + \frac{w(v_k)}{v_k}} \left\{ 1 - N_k \frac{w(v_k)/v_k}{N_k \frac{w_k}{u} + \frac{w(v_k)}{v_k}} \right\} .$$

These expressions define a pair of functions $x_{k-1}(w(v_k))$ and $x_k(w(v_k), v_k)$ respectively. We note that x_{k-1} and x_k are monotonically decreasing in w (by property 1 of lemma 1).

We now note that labour demand in the new country equals (recalling that the productivity parameters have been set to unity),

$$L^D = x_{k-1}(w(v_k)) + x_k(w(v_k), v_k)$$

while labour supply is

$$L^S = \lambda w(v_k)$$

where λ is a constant, independent of v_k, by our small country assumption (i.e. m is large).

We measure the wage of the new country relative to the equilibrium wage of group-k countries. We have, on equating L^D to L^S,

$$\lambda w(v_k) = x_{k-1}(w(v_k)) + x_k(w(v_k), v_k) \ . \tag{9}$$

We begin by showing that, as v_k increases, w increases. To see this, differentiate (9) with respect to v_k to obtain

$$\lambda \frac{dw}{dv_k} = \frac{\partial x_{k-1}}{\partial w} \cdot \frac{dw}{dv_k} + \frac{\partial x_k}{\partial w} \cdot \frac{dw}{dv_k} + \frac{\partial x_k}{\partial v_k}$$

whence

$$\frac{dw}{dv_k}[\lambda - \underbrace{\frac{\partial x_{k-1}}{\partial w}}_{(-)} - \underbrace{\frac{\partial x_k}{\partial w}}_{(-)}] = \underbrace{\frac{\partial x_k}{\partial v_k}}_{(+)}$$

where the indicated signs on the derivatives follow from properties 1 and 2 of lemma 1. It follows that dw/dv_k is positive. This is illustrated in the second panel of figure 2.

We next show that as v_k, and hence $w(v_k)$ rise, the ratio $v_k/w(v_k)$ rises i.e. the proportionate rise in w is less than the proportionate rise in v. To show this, suppose the contrary viz. that w rises proportionally more than v_k. By property 1 of lemma 1, this implies a fall in x_{k-1}. By properties 1 and 3 of lemma 1, this also implies a fall in x_k. Thus, the r.h.s. of (9) falls. However, the l.h.s. of (9) rises, a contradiction. It follows that, as v_k increases, w rises, but by a smaller proportional amount, so v_k/w rises.

Since w is rising, property 1 of lemma 1 implies that x_{k-1} falls. See the second-to-bottom panel of figure 2. Since w is rising, but by less than v_k, properties 2 and 3 of lemma 1 imply that x_k rises. See the bottom panel of figure 2.

Finally, we examine how the price-cost markup for good k varies with v_k. To see this, note that for our small developing country all its competitors are k-type countries with quality u and wage rate w_k. The price-quality ratio, which is the same for our small developing country and its rivals, can be written using equation (2) as

$$\frac{p_k(v_k)}{v_k} = \frac{p_k(u)}{u} = \frac{1}{N_k}\sum_j \frac{w_j}{u_j} = \frac{1}{N_k}\left\{N_k \frac{w_k}{u} + \frac{w(v_k)}{v_k}\right\}$$

where $p_k(v_k)$ is the small developing country's price and $p_k(u)$ denotes the price set by the rival k-type firms, and so, multiplying through by $v_k/w(v_k)$, we obtain the markup

$$\frac{p_k(v_k)}{w(v_k)} = \frac{w_k}{u}\frac{v_k}{w(v_k)} + \frac{1}{N_k}\ . \tag{10}$$

Since our small country approximation implies that w_k/u is (approximately) constant, and we have just seen that $v_k/w(v_k)$ is rising, it follows that the markup rises with v_k. This is illustrated in the third panel of figure 2.

Phase II

The first phase, labelled phase I in figure 2, ends when $w(v_k)$ rises to the critical value at which the new country is no longer viable in the production of goods of type $k-1$. As v_k increases further, the new country specializes in the production of good k. Now labour market equilibrium requires

$$\lambda w(v_k) = x_k(w(v_k), v_k)$$

and $w(v_k)$ rises to w_k as v_k rises to u.[10]

This is an important observation: all the type-k countries with quality u have a common wage $w_k > w(v_k)$. Thus, even though our new country produces the same product as type-k countries, it is poorer. Restated, the new country is poor not because of what it produces, but because of the quality of what it produces.

Finally, since w is rising, $x_k = \lambda w(v_k)$ must also be rising. This is shown in the bottom panel of figure 2 in the phase II region.

Phase III

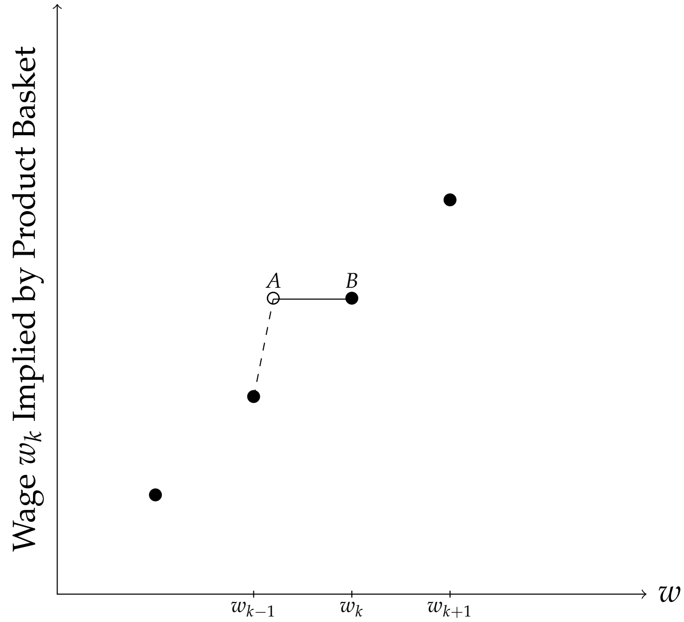
We now extend the analysis by allowing our small developing country to build capabilities in the next group of products, i.e. in group $k+1$. Specifically, we now denote by v_{k+1} the new country's quality level in the first product of group $k+1$, holding its quality in products of group k at the standard quality level u. As before, there is no effect until its quality rises to a threshold level, corresponding to the boundary between phases II and III in figure 2. Thereafter, following the same argument as set out above, its wage rises with v_{k+1} and output in market k now declines to zero as it becomes a 'high quality' but 'high wage' producer relative to incumbent firms (phase III of figure 2).

Finally, the markup earned by the small developing country in market k falls as we move through phase III. (This can be confirmed by noting that, in the final term in the markup equation (10), v_k is constant at u and $w(v_k)$ is replaced by $w(v_{k+1})$, which is rising in v_{k+1}.)

This completes our discussion of the several observable implications of the model. For a

10. Differentiating the previous equation yields $\lambda \frac{\partial w}{\partial v_k} = \frac{\partial x_k}{\partial w}\frac{\partial w}{\partial v_k} + \frac{\partial x_k}{\partial v_k}$ or $\frac{\partial w}{\partial v_k} = \left[\lambda - \frac{\partial x_k}{\partial w}\right]^{-1} \frac{\partial x_k}{\partial v_k}$. $\frac{\partial w}{\partial v_k} > 0$ follows from this and properties 1 and 2 of lemma 1.

Figure 3: The Diffuseness Property



Notes: The hatched and solid lines correspond, respectively, to phases I and II of figure 2. A country that was initially in group $k-1$ experiences an increase in v_k, that is, in the quality of its group-k good. In phase I, it produces decreasing amounts of good $k-1$ and increasing amounts of good k so that its wage implied by its product basket is increasing. This explains why the hatched line is upward sloping. In phase II, it only produces good k so that, even though its quality (and wage) are improving, its wage implied by its product basket is unchanged. This explains why the solid line is flat. Point A corresponds to the point at which production of good $k-1$ ceases i.e. the border between Phases I and II. Point B corresponds to the point at which $v_k = u$.

broader discussion of our choice of model, see on-line appendix E.[11]

11. Some readers will have noticed that the output-quality relationship in the bottom two panels of figure 2 look like the Heckscher-Ohlin output-capital or cones-of-diversification relationship (see Leamer, 1984; Schott, 2003). One might wonder, then, why was our theory needed? For one, improvements in quality are very different empirically from capital deepening. More importantly, this prediction is just one of several predictions that arise in our model, and all these predictions flow from the fact that there is imperfect competition. Imperfect competition is needed to ensure that different qualities co-exist, that prices are a non-constant markup over marginal cost, that prices are correlated with quality, and that export shares are correlated with income in ways that reflect quality . In short, our output-quality relationship is just one of several predictions. The output prediction in isolation can be modelled more simply; however, we are interested in a bundle of predictions that require us to append an imperfectly competitive market structure onto a trade model. Thus, a cones-of-diversification Heckscher-Ohlin model delivers at best only a small part of what is needed and a more natural trade model in our setting, one that emphasizes the role of technological capability for delivering quality, is the Ricardian model.

3.1. *Diffuseness*

We can now re-consider the product-mix diagram (figure 1) in the light of the addition of this new country. Consider the critical value of v_k at which the new country ceases to produce good $k-1$ (the boundary between phases I and II). Its product basket will now coincide with that of type k countries, so that its product basket index, or implied wage, equals w_k, but its actual wage $w(v_k)$ will lie strictly below w_k. This is illustrated as point A in figure 3. The country's actual wage will advance to w_k only when v reaches the standard quality level u (point B in figure 3.) This provides an explanation for the diffuseness feature of empirical product-mix diagrams: a horizontal movement across the diagram corresponds to an advance in quality (and/or productivity) in the country's existing basket of goods. In our empirical work we will show this process in the time-series data.

3.2. *The Flatness Property*

We return to the perfect sorting benchmark of figure 1, in which the product-mix diagram was a 45° line, and ask: what would happen to this plot if industries were aggregated in a way that lumped low-index industries and high-index industries in the same composite (aggregate) industry? (See the LCD industry example described in footnote 3 of the Introduction). With this in mind, recall that we have m products (or industries) in each product group $k = 1, \ldots, T$. We construct a 'data set' in which a single product drawn from each of the T product groups is placed in a single newly defined industry. In other words, this new industry comprises goods from both low-end product groups (k close to 1) and high-end product groups (k close to T).

Note that the mean wage rate of countries producing the 'product' of this new industry is simply the global average wage, which we denote as $\overline{w}$. Now we re-compute the wage implied by a country's product basket. The only difference introduced into the calculation is that the wage assigned to the group-k good which has been placed in our new composite industry is no longer the wage w_k associated with k-type countries, but rather the global average wage $\overline{w}$. The result is that the 45° line of figure 1 swivels towards the horizontal.

See the dashed line in figure 1. To the left lie low-wage countries who produce low-end products within the composite good, yet are 'credited' with the average wage $\overline{w}$. They thus receive too much 'credit' and lie above the 45° line. In contrast, to the right lie high-wage countries who produce high-end products within the composite good. They thus receive too little 'credit' and lie below the 45° line. This provides an interpretation of the empirically observed 'flatness' property found in product-mix diagrams.

We now turn to a comprehensive examination of the predictions of the model.

4. Data

Trade data are from COMTRADE for the years 1980 and 2005. It will be important to find a balance between a long time series, a detailed commodity breakdown, and wide country coverage. We thus use the 4-digit SITC Revision 2 classification (henceforth SITC4), which allows us to go back to 1980 for a large number of countries. To verify that *all* of our cross-sectional results hold for more detailed commodity breakdowns we also use the 2005 COMTRADE data at the 6-digit HS level (1996 revision, henceforth HS6) and 2005 U.S. import data at the 10-digit HS level (henceforth HS10). We exclude countries whose population was less than two million in 2005 and/or whose territorial integrity changed substantially between 1980 and 2005 e.g. the USSR. The exception is Germany (we use West Germany in 1980 and unified Germany in 2005). This leaves us with the 94 countries listed in Appendix B. GDP per capita and population data are from the United Nations. We do not use a PPP adjustment because we are interested in nominal price competition in world product markets.

A missing link between our theory and empirics is that the theory deals with production while the data deal with exports. Given our assumptions of homothetic demand and internationally identical prices, consumption patterns are the same in all countries (up to a scale). Hence production and export predictions are qualitatively identical. Specifically, the production predictions in the bottom two panels in figure 2 also hold for exports. We will need notation for exports. In the theory x_k denoted production; in the empirical sections

x_{kg} will denote exports of good g by country k. We also note that the theory deals with quantities while the export data deal with values. However, it is easy to show that the quantity predictions in the bottom two panels of figure 2 continue to hold with quantities replaced by values.[12]

5. Product-Mix Diagram

The conventional way of representing the relation between a country's product mix and its GDP per capita is in terms of a product-mix diagram which shows actual GDP per capita on the horizontal axis and the level of GDP per capita implied by its export basket on the vertical axis. The latter is constructed in two stages. First, a product *score* is calculated based on the weighted average GDP per capita of countries that export the product. Following Hausmann et al. (2007) we use weights that depend on the relative importance of the good in each country's export basket. Specifically, let $x_k \equiv \Sigma_g x_{gk}$ be country k's total exports so that x_{gk}/x_k is the share of good g in country k's export basket. Let y_k be the GDP per capita of country k. The score of good g is defined as

$$\sigma_g \equiv \frac{\Sigma_k \frac{x_{gk}}{x_k} \ln y_k}{\Sigma_k \frac{x_{gk}}{x_k}}. \tag{11}$$

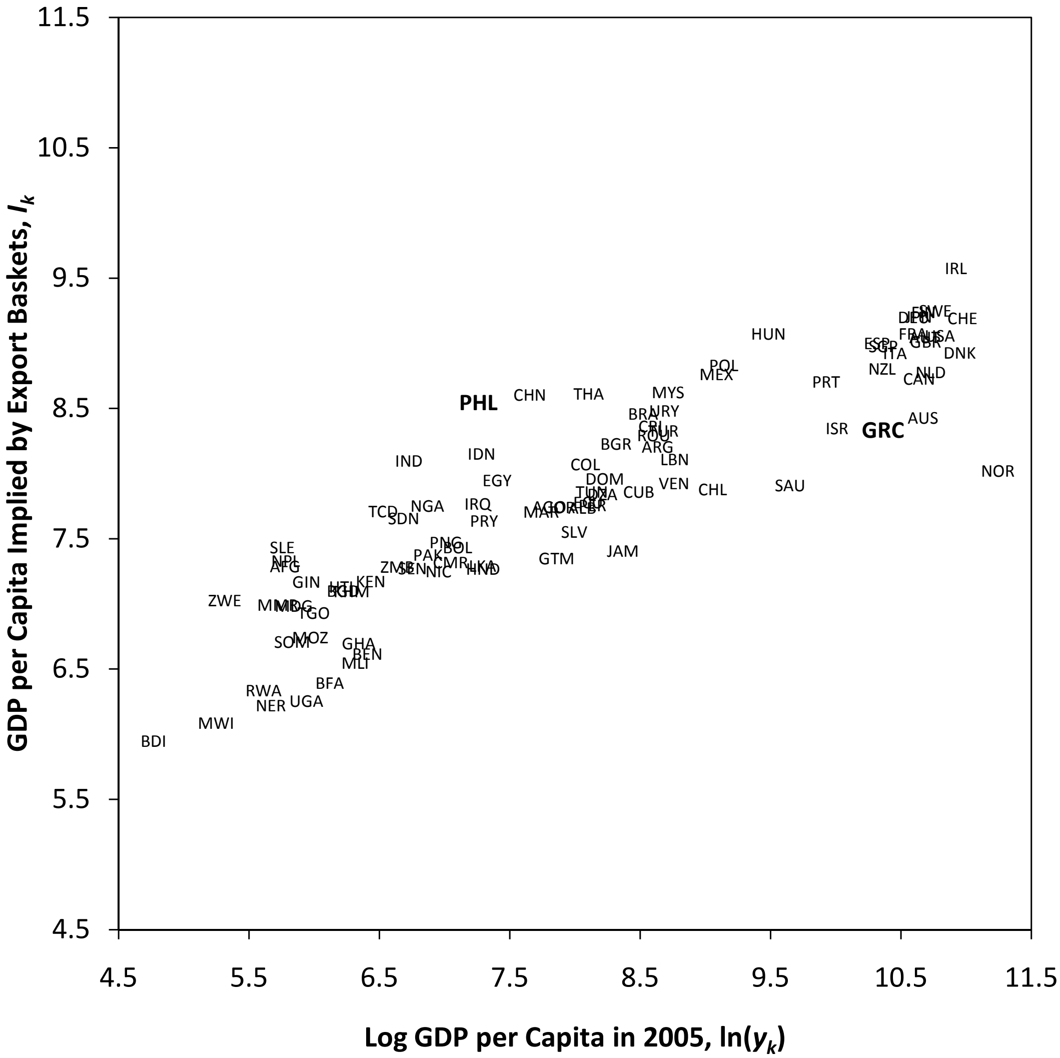
Next, an *index* of a country's implied GDP per capita is constructed from these scores:

$$I_k \equiv \Sigma_g \frac{x_{gk}}{x_k} \sigma_g. \tag{12}$$

Figure 4 plots I_k against $\ln y_k$ for 2005. Each of the 94 points is a country. The figure shows the twin features of 'flatness' and 'diffuseness' noted in sections 3.1 and 3.2. As we showed in our perfect sorting benchmark equilibrium, (*a*) if goods can be grouped based on the scarcity of the required quality capabilities, (*b*) if countries can be grouped into types with identical quality capabilities, and (*c*) if each country is fully specialized in a single product group, then the product-mix diagram takes the form of a 45° line. See figure 1.

12. The proof of this can be had directly from figure 2. In phases I and II, $w(v_k)$, $p_k(v_k)/w(v_k)$ and hence $p_k(v_k)$ are all rising. Since x_k is rising, $p_k(v_k)x_k$ must be rising. In phase III, v_k is fixed at u and x_k is falling so that $p_k(u)x_k$ must be falling. Thus, quantities and values behave in the same way.

Figure 4: Product-Mix Diagram



Notes: The horizontal axis is log GDP per capita. The vertical axis is I_k of equation (12) i.e. log GDP per capita implied by a country's export basket. Data are for 2005 at the SITC4 level of aggregation.

We also showed that if industries are classified in such a way as to aggregate goods from different quality capability groups, then 'flatness' results. See section 3.2. Consistent with this, poor countries lie well above the 45° line and rich countries lie well below the 45° line.[13] Figure 4 is based on SITC4 data (746 products). The corresponding figure using HS6 data (4,932 products) looks virtually identical. See on-line appendix figure A11.

Finally, we showed that 'diffuseness' would result if firms from different countries operating within each industry have different quality levels (section 3.1). This diffuseness is a major feature of figure 4: countries with very different GDP per capita have very similar I_k. For example, the export baskets of the Philippines and Greece imply similar GDP per capita despite the fact that Greece is 20 times richer than the Philippines.[14] [15] [16]

The strong correlation in figure 4 ($\rho = 0.89$) has been used to support the view that effective development policy focuses primarily on the mix of goods that is produced and only secondarily on the quality of the goods produced. Our theory section provided conditions under which figure 4 can be used in this way; however, for the remainder of this paper we show that those conditions are not likely satisfied in the data. In product-mix diagrams each industry is given a score based on the 'average' GDP per capita of exporting countries. Our main point of departure from product-mix diagrams lies in focussing instead on the *range* of GDP per capita levels of countries exporting the product.

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13. Another way of making this point is to consider an OLS regression of I_k on $\ln y_k$ — with the major caveat that the OLS estimator looses all of its nice properties because I_k and $\ln y_k$ are jointly determined endogenous variables. Using the data in figure 4, the OLS slope estimate is 0.43 with a tight standard error of 0.023. That is, the OLS slope estimate is much less than unity.

14. In this section we used weights $x_{gk}/\sum_g x_{gk}$ i.e. shares in country k's exports. Michaely (1984) and Lall et al. (2006) use weights $x_{gk}/\sum_k x_{gk}$ i.e. shares in world exports of good g. Flatness and diffuseness are even more prominent using such world export weights. See on-line appendix figure A11. However, in our theoretical setting, what matters is the impact of exporting on the derived demand for labour and so on the equilibrium wage rate. As such, the Hausmann et al. export-basket shares (which are typically large when employment shares are large) provide the appropriate weights for us.

15. The main conclusions of this section hold when we replace GDP per capita with manufacturing value added per worker (a much noisier data series). This brings resource-rich countries such as Norway and Saudi Arabia closer to the 45° line, but otherwise does not alter our conclusions.

16. We also calculated product scores σ_g separately for each country which excluded the country's trade, and used these to calculate the country index I_k. This had no effect on figure 4 because no country carries a large enough weight in the calculation of the product scores.

6. Product Ranges

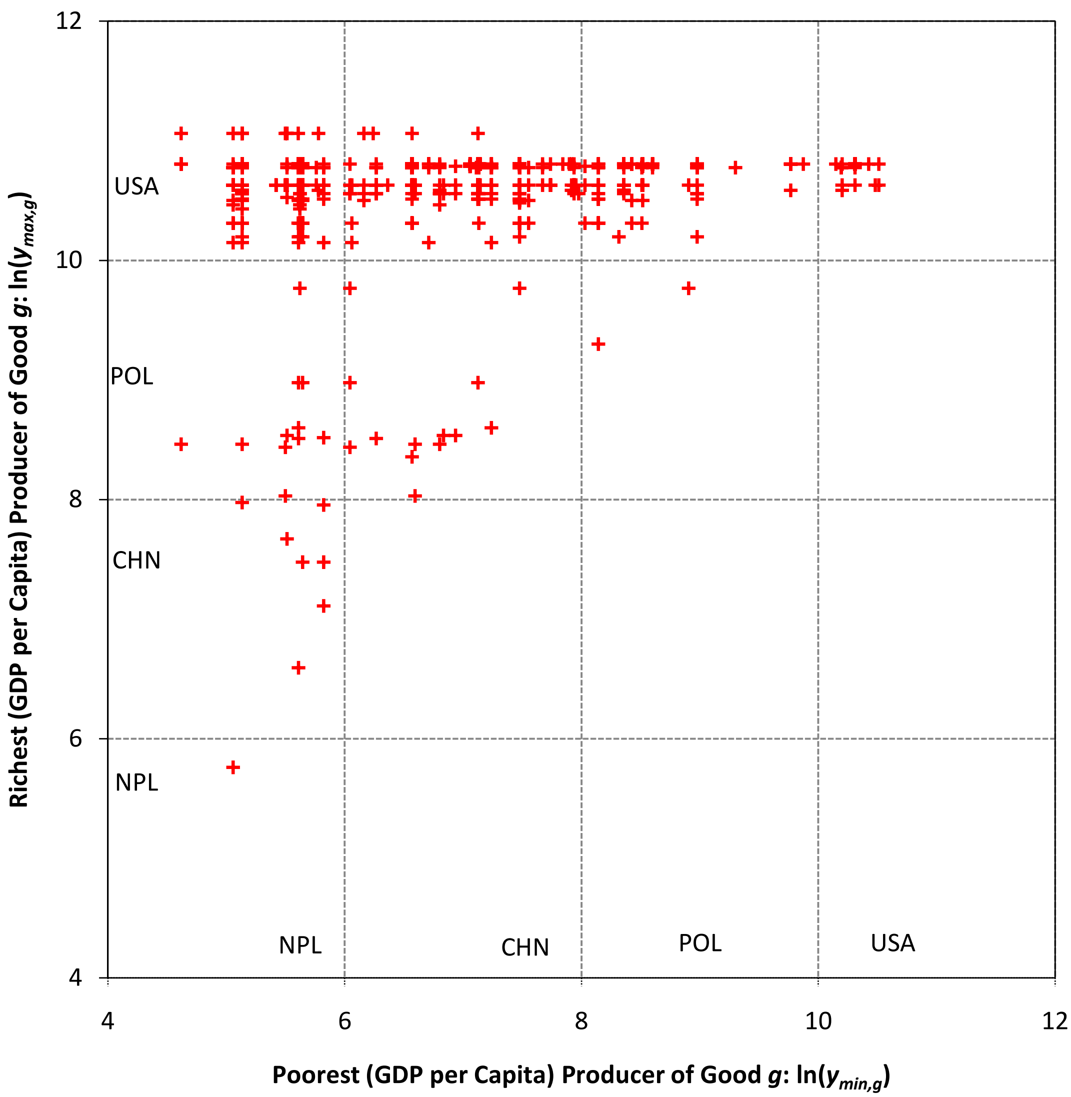
A key prediction of our theory is that in general equilibrium countries with different quality capabilities may nevertheless export the same good. While we do not observe quality, an observable implication is that at least some goods will be produced both by rich and poor countries. To investigate, for each product g we identify the poorest and richest exporters of the product. Denote these by $y_{min,g}$ and $y_{max,g}$, respectively. To avoid 'noise' associated with small reported export values, a problem to which trade data are notoriously prone, for each good we look only at the set of countries for whom the good is a 'significant' export, in the sense that the value of its exports in that good constitute at least 1% of the value of exports of the country's principal export good.[17] An important theoretical reason for using this 1% cut-off is that it ensures that the good is sufficiently important to the exporter to generate the general equilibrium wage impacts upon which our theory rests.

Product ranges are displayed in figure 5. Each point corresponds to a unique SITC4 good (g) and the figure plots ($y_{min,g}$,$y_{max,g}$). A point therefore shows the range of income levels of countries for which g is a significant export. All the points necessarily lie above the 45° line. For reference, along the axes we show the log GDP per capita of Nepal, China, Poland and the United States.

The truly remarkable feature of figure 5 is the preponderance of points in the top left corner, i.e. the preponderance of products for which the income range is very wide. To get a clearer sense of magnitudes, consider the points lying in the top left corner where $\ln y_{min,g} < 8.25$ and $\ln y_{max,g} > 10$. If a product is in this region then its richest significant exporter is *at least* 5.8 times richer then its poorest significant exporter ($e^{10-8.25} = 5.8$). For the median product in the region the corresponding difference is 79-fold ($e^{4.4} = 79$). These are huge differences. And there are a lot of goods in this region: the region contains 81% of all products displayed in the figure and accounts for 70% of world trade.

17. More formally, for each g, let $K(g)$ be the set of countries for which $x_{gk}/x_k \geq 0.01 \max_{g'} x_{g'k}/x_k$. g is a significant export of country k iff $k \in K(g)$, thus we only use (g,k) pairs for which $k \in K(g)$. Further, let $\underline{k}(g)$ be the poorest and $\overline{k}(g)$ the richest countries in $K(g)$. Then $y_{min,g} = y_{\underline{k}(g)}$ and $y_{max,g} = y_{\overline{k}(g)}$.

Figure 5: Product Ranges



Notes: Each point represents an SITC4 product. The horizontal axis is $\ln y_{min,g}$, the poorest country for which the product is a significant export. The vertical axis is $\ln y_{max,g}$, the richest country for which the product is a significant export.

We will shortly show the reader that this observation about wide product ranges is robust, and holds even in the most detailed trade data (HS10). However, we first draw three economic insights from the wideness of product ranges. The first deals with the Hausmann et al. (2007) product-mix exercise of figure 4. Their exercise uses *all* goods in a country's export basket even though products with wide ranges are 'uninformative' about a country's income in the sense that knowing that a wide-range product is a significant contributor to a country's export basket tells us little about the country's income. Figure 5 shows that such 'uninformativeness' is the norm rather than the exception.

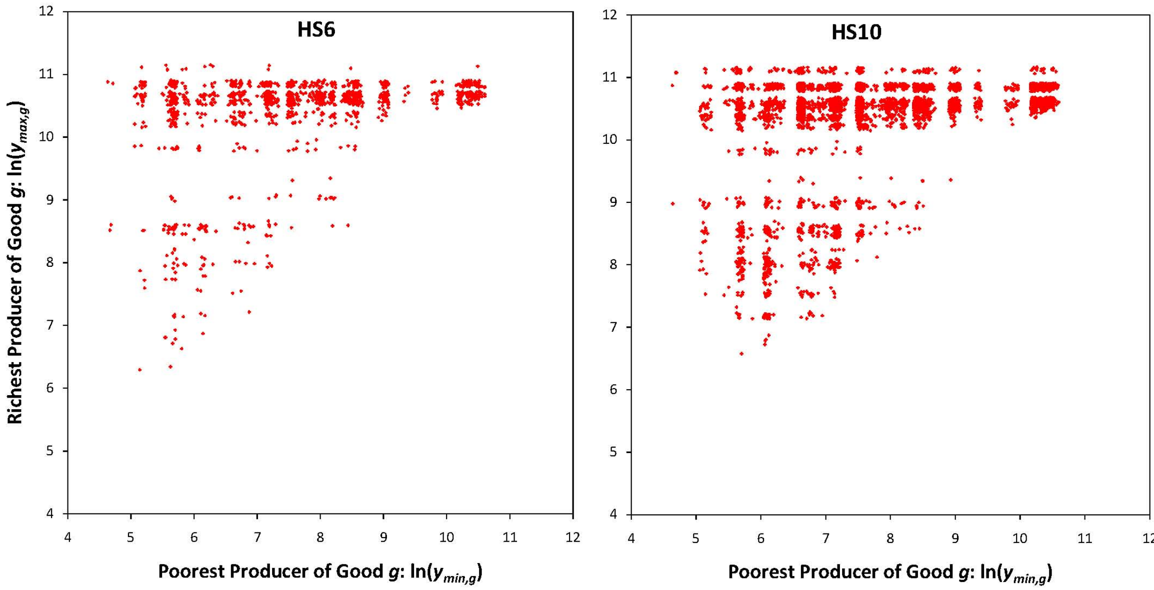
Second, our theory emphasizes that for each product, multiple quality levels can coexist in equilibrium. One can therefore interpret the wide ranges as support for the theory *provided* that one is willing to accept that product ranges are the result of quality differences. As is well known, quality is difficult to identify without detailed data about product characteristics. Since we do not have this information we refer to the ranges as product ranges rather than as quality ranges and take the weaker position that wide product ranges are implied by the theory but do not imply the theory.

Third, there are two distinct groups of points that lie far from the top-left corner in figure 5. These are 'informative' products. The first group lies to the bottom left ($\ln y_{max,g} < 10$) and consists of those goods exported only by relatively low- and middle-income countries (the 'L group'). The second group lies to the top right ($\ln y_{min,g} > 8.25$) and consists of those goods exported only by relatively high-income countries (the 'H group'). On our present interpretation, L-group goods are not produced by high-income countries because these countries' wage costs are too high, whereas H-group goods are not produced by low-income countries because their quality capabilities are too low.

The reader will and should be skeptical about the wide product ranges in figure 5. For the remainder of this section we anticipate five possible objections to the figure.

1. It is all aggregation bias: One would expect that the large product ranges displayed in figure 5 would become much narrower with finer product-level data. This is not the case. In figure 6 we repeat the exercise using HS6 data (world trade data from COMTRADE)

Figure 6: Product Ranges: Insensitivity to Aggregation



Notes: Each panel in this figure is constructed in the same way as figure 5, but with different data. Figure 5 used the SITC4 classification and COMTRADE (world) data. The left-hand panel of the current figure uses the HS6 classification and COMTRADE data. The right-hand panel uses the HS10 classification and U.S. import data.

and using HS10 data (U.S. import data). The distribution of product ranges in figures 5 and 6 are very similar. In particular, product ranges remain large and in both panels just over 70% of total exports are accounted for by the uninformative products in the top left ($\ln y_{min,g} < 8.25$ and $\ln y_{max,g} > 10$).[18]

2. *Finer disaggregation is always better:* The fact that nothing changes when moving to finer levels of product disaggregation may seem puzzling, since if the move to a finer level of aggregation involved the breaking up of technologically disparate sub-industries into individual industries, we might expect the range to narrow as we move to this new level of aggregation. An examination of the way in which industries are broken up in the HS6 and HS10 data throws light on why disaggregation beyond SITC4 does not alter the

18. In figure 6 there are thousands of points, many of which lie on top of each other. To make the figure clearer, instead of plotting $\ln y_{max,g}$ on the vertical axis we have plotted $\ln y_{max,g} + \epsilon$ where ϵ is a uniformly distributed random variable on $(-0.05, 0.05)$. This adds a *tiny* random vertical shift to the data, which helps the reader see where the bulk of points are located. Likewise, we have added a tiny random horizontal shift to $\ln y_{min,g}$.

distribution of ranges. In some cases the SITC4 industry is as disaggregated as the HS6 and even the HS10 industries e.g. 'New tires for motor cars' is a single category in both SITC4 and HS6. In other cases, the disaggregation is based only on size or value, without any reference to capabilities e.g. 'New tires for motor cars' feeds into seven HS10 codes that distinguish between technology-irrelevant differences in the diameter of the tire. In yet other cases the SITC4 code is disaggregated only by introducing a capability-irrelevant 'parts of' HS6 or HS10 code. This is pervasive e.g. SITC4 7817 'Nuclear reactors.' Finally, in those cases where a technology-based disaggregation of products is introduced it is often unclear whether this disaggregation conveys any information about differences in required capabilities: for example, SITC4 7252 'Machinery for making paper pulp, paper, paperboard; Cutting machines' is disaggregated in HS10 into a number of industries, including 'Machines for making paper bags etc.' and 'Machines for making paper cartons etc.' Thus, finer disaggregation is typically not more informative about quality capabilities. Were an ideal disaggregation of industries to be constructed on the basis of the quality capabilities required, this would doubtless lead to some narrowing in the relevant ranges. However, the limitations of the published data are quite serious even at the most disaggregated level.[19]

3. Estimation error: Another possible objection to our wide product ranges is that we have not reported standard errors. Let N_g^{sig} be the number of countries for which g is a significant export.[20] It is possible that products with wide ranges are products for which N_g^{sig} is small i.e. for which there are very few observations and hence large standard errors. This is not the case; indeed, the opposite is true. The correlation between N_g^{sig} and the product range $\ln y_{max,g} - \ln y_{min,g}$ is positive (0.57) and, for example, products with $N_g^{sig} \geq 20$ (one quarter of all products) *all* have large product ranges. However, to deal with this objection in the simplest way possible, in figures 5–6 we have only displayed those products for which

19. For what we are doing, the relevant market is never equatable with an item in a government commodity classification, be it SITC4, HS6 or HS10. Sometimes the relevant market is more detailed than HS10 (as in many electronic parts) and sometimes the relevant market is less detailed than SITC4 (as in many apparel products). Thus, all of our conclusions must be thought of relative to a definition of the market that is determined by the commodity classification, not the actual product producers.

20. N_g^{sig} is the dimension of $K(g)$ in footnote 17.

there are at least three significant exporters ($N_g^{sig} \geq 3$). That is, we displayed only 547 of the possible 746 SITC4 goods. These 547 products account for 98.3% of world trade so that we are only excluding very minor products. We conclude from this that wide product ranges are not an artifact of statistical uncertainty. To be safe though, we will continue throughout this paper to restrict attention only to products for which $N_g^{sig} \geq 3$.

4. Wide product ranges are an artifact of using a 1% cut-off for 'significant exporters': Again, this is not the case. On-line appendix figure A12 shows that the inference we have drawn from figures 5–6 is not sensitive to the choice of cut-offs. It repeats figure 5 for a low percentage cut-off (0.1%), a high percentage cut-off (10%), and cut-offs based on mixtures of percentages and dollar values ($x_{gk} >$ \$5 million and $x_{gk} >$ \$50 million). In every single case the pattern displayed in figures 5–6 is repeated.[21]

5. Wide product ranges are driven by China: Omitting China does not alter the impression that product ranges are wide. Indeed, the reader can omit China from these figures simply by deleting all points for which either $\ln y_{min,g} = 7.5$ or $\ln y_{max,g} = 7.5$. (China's log GDP per capita is 7.5.)

Having established the robustness of figure 5, we can now restate our conclusion. Our theory implies that there will be product ranges: the empirical surprise is that product ranges are often so large.

7. Price Ranges

The theory predicts that, for a single good, all producers of the good will share the same price-quality ratio. Since richer countries have higher quality, they should have higher prices. That is, prices should be increasing in the income of the exporter. Since price data are not available, we follow Schott (2004) in proxying for prices using HS10 unit values

21. There is a minor technical point about figure 6 that should be reviewed. Since the United States is far from most countries and since trade costs increase in distance we expect that countries' exports to the United States will be more concentrated on a few goods than their exports to the world. This is indeed the case. Therefore, for the HS10 panel of figure 6, which is based on U.S. data, we use a 0.1% cut-off instead of a 1% cut-off. This results in far more points in the figure, but does not alter the distribution of points in the figure. See on-line appendix figure A12 for the HS10 figure using a 1% cut-off.

from the 2005 U.S. import file. We emphasize that unit values are extremely noisy so that caution must be exercised in interpreting them as prices. See Appendix B for a discussion of the data.

Let p_{gk} be the unit value of good g exported by country k to the United States. We are interested in how the p_{gk} vary as we move through product ranges. The most familiar way of doing this is Schott's (2004, table V) famous regression $\ln p_{gk} = \alpha_g + \beta \ln y_k$ where α_g is an HS10 product fixed effect. Re-estimating Schott's regression using 2005 U.S. imports from our 94 exporters (187,363 observations), the OLS estimate of β is 0.29 (clustered $t = 8.05$) so that, as in Schott, there is indeed a statistically significant positive correlation between unit values and exporter incomes.

A sharper prediction of our theory is as follows. Consider a single HS10 good g. Recall that in the HS10 panel of figure 6 we plotted the income of the poorest and richest countries that had significant exports of g i.e. we plotted $(\ln y_{min,g}, \ln y_{max,g})$. Since for each g we know the identity of the poorest and richest countries, we know these countries' unit values. We denote them in obvious fashion by $p_{min,g}$ and $p_{max,g}$. We expect that

$$\Delta_g \equiv \ln p_{\max,g} - \ln p_{\min,g} > 0.$$

This inequality is sharp in that it is directly related to our product ranges, that is, to the poorest (min) and richest (max) exporters that define the boundaries of our product ranges. It is also an inequality that is unlikely to hold because we are examining two *specific* unit values ($p_{\max,g}$ and $p_{\min,g}$) even though we know that such unit values are extremely noisy.

$\Delta_g > 0$ defines one inequality for each product range in the HS10 panel of figure 6. A nonparametric test of $\Delta_g > 0$ is the sign test, which easily rejects the null hypothesis that the signs of the Δ_g are random (p-value of less than 0.0001). The mean value of Δ_g is 0.63 ($t = 27.23$) and, more robustly with noisy data, the median value of Δ_g is 0.45. Since $e^{0.45} - 1 = 0.57$, this implies that the richest significant exporter of the median product has a unit value that is 57% higher than the corresponding unit value of the poorest significant exporter. Cautiously interpreting unit values as prices, this means that prices are increasing as one moves through a product range in figure 6.

It is tempting to examine an even stronger prediction, namely, that unit-value ranges Δ_g are large when product ranges $\ln y_{\max,g} - \ln y_{\min,g}$ are large. While this is not a prediction of the model, it can be generated by adding more restrictions on how scarcity varies across countries and products. To examine this prediction we estimate the following regression:

$$(\ln p_{\max,g} - \ln p_{\min,g}) = 0.15 + 0.18(\ln y_{\max,g} - \ln y_{\min,g}) \qquad \text{(clustered } t = 11.23\text{)}.$$

Thus, large product ranges in figure 6 are associated with large unit-value ranges.

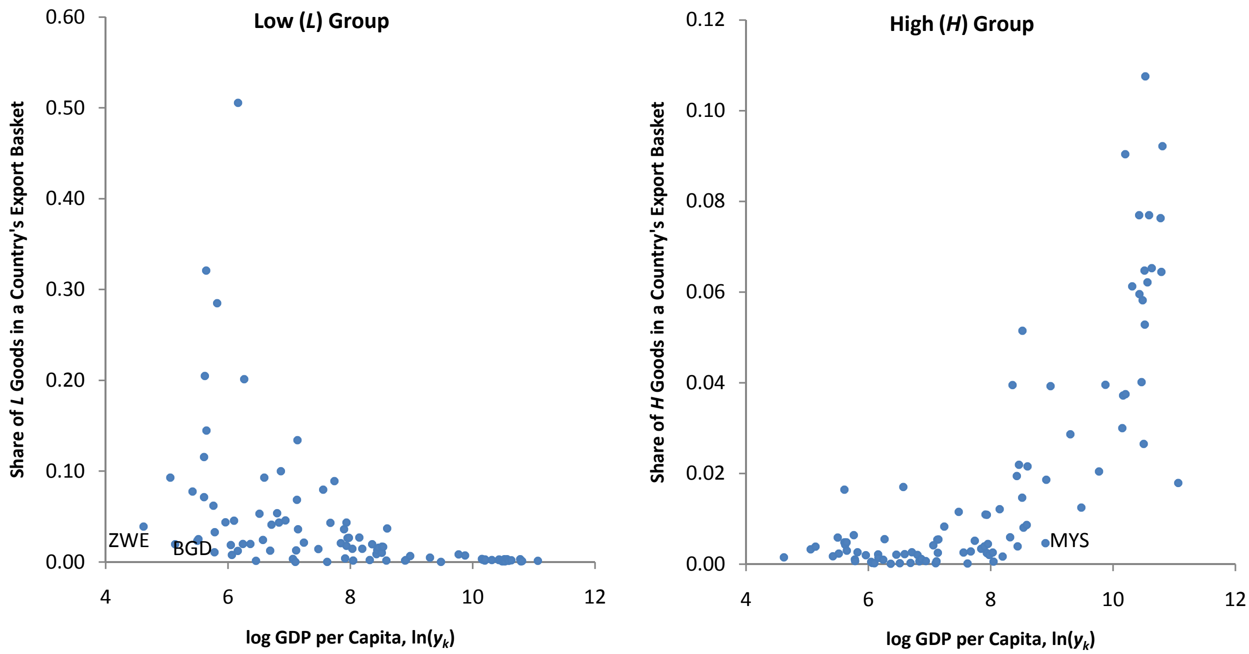
8. Development Ladders in the Cross-Section: The Role of Product Ranges

The Hausmann et al. (2007) product-mix diagrams only use information about the mean characteristic of each good (σ_g of equation 11). Wide product ranges and their correlation with unit values suggest that a country's wealth depends not just on what goods it produces, but also on the quality of the goods produced. To investigate further, return to figure 5 and, as before, divide goods into three groups: (*i*) the L group to the lower left ($\ln y_{max,g} < 10$); (*ii*) the H group to the upper right ($\ln y_{min,g} > 8.25$); and, (*iii*) the 'uninformative' group, comprising the remaining goods. In what follows we confine attention to the L and H goods because these are the only ones that are informative.[22]

We show in figure 7 the relationship of a country's GDP per capita with (*a*) the share of L goods in its export basket (left panel) and (*b*) the share of H goods in its export basket (right panel). We see a clear fall in the share of L goods and a rise in the share of H goods as GDP per capita increases. But an important feature of figure 7 lies in the fact that the relation between the product mix and income is not bi-directional: while significant exporters of H goods are necessarily rich, it is not the case that rich countries are necessarily significant exporters of H goods. A very low contribution of H goods is consistent with a relatively high level of GDP per capita. (See Malaysia in the right-hand panel). Similarly, while a

22. The conclusions of this section are in no way sensitive to the choice of 8.25 and 10 as cut-offs: we have chosen these because they represent break points in figure 5. Also, in figure 5 there is one good that is in both the L and H groups. This is cameras (SITC4 8732). It lies at the point $(\ln y_{min,g}, \ln y_{max,g}) = (8.9, 9.8)$. We place this in the H group, though where it goes makes no difference because it is only one of hundreds of goods.

Figure 7: The Share of L and H Goods in Each Country's Export Basket



Notes: Each point represents a country (there are 94 points in each panel). The horizontal axis is log GDP per capita in 2005. The vertical axis is a country's exports of L goods (right panel) or H goods (left panel) as a share of the country's total exports. Using the product ranges in figure 5, a good is an L good if $\ln y_{max,g} < 10$ and an H good if $\ln y_{min,g} > 8.25$.

high share of L goods necessarily implies that a country is poor, many poor countries have a low share of L goods. (See Zimbabwe or Bangladesh in the left-hand panel.)

We can restate this in a way that makes one of the key points of our thesis crystal clear. *A poor country can advance out of L goods and still remain poor: this happens when the country enters as a low-quality producer into uninformative goods i.e. goods with wide quality ranges.* Since most goods are uninformative, we might expect this type of no-growth shift in product mix to be common. *By the same token, a country may move from being poor to being rich without changing its product mix: this happens when it improves the quality of the uninformative, wide-quality-range goods that it already exports.*

9. Market Share Predictions

The two bottom panels of figure 2 presented our predictions about each country's share of world exports. Underlying that figure is a comparative static in which a country that previously specialized in producing good $k-1$ first sees its quality in good k rise up from a very low level to that of the world standard and then sees its quality in good $k+1$ rise up from a very low level to that of the world standard. This comparative static highlighted two mechanisms affecting world export shares. First, as capabilities rise in good k, the country produces more of k and grabs an increasing share of world exports. This is the 'quality effect'. Second, as quality rises for good $k+1$ wages are pushed up, which erodes the country's competitiveness in good k. This is the general equilibrium 'wage effect'. These two mechanisms lead to the world export share predictions in figure 2. For middle-capability goods (k), world export shares display an inverted-U shaped relationship with income as first the quality effect and then the wage effect come into play. For low-capability goods ($k-1$), only the wage effect is relevant and world export shares decline in income. For high-capability goods ($k+1$) only the quality effect is relevant and world export shares are increasing in income. See the bottom two panels of figure 2.

We operationalize these distinct export-share predictions of goods $k-1$, k, and $k+1$ as follows. We associate good $k+1$ with H goods (goods for which $\ln y_{min,g} > 8.25$) and goods $k-1$ and k with L goods (goods for which $\ln y_{max,g} < 10$). To distinguish between $k-1$ and k goods, we split the L group in half: $k-1$ is associated with L goods that are exported by very poor countries ($\ln y_{min,g} < 6$); k is associated with the remaining L goods ($\ln y_{min,g} > 6$). This gives us three groups: the 'High' group ($k+1$), the 'Middle' group (k), and the 'Low' group ($k-1$).[23]

Since we must pool across exporters and products, we will need to consider normalizations of export shares that are designed to control for country and product size.

23. If this is not clear, the reader is encouraged to draw the boundaries of the three groups on figure 5. Also, there is potential for notational confusion: g indexes goods and k indexes countries, yet we have been referring to k as a good. As in the theory sections, references to good k are an abbreviation for 'a good that is produced by a type-k country'.

Consider country k's share of world exports of good g. We normalize the income level of k by reference to the income levels $\underline{y}_g$ and $\overline{y}_g$ of the poorest and richest exporters, respectively, of g; we represent the position of log GDP per capita within this range as $(\ln y_k - \ln \underline{y}_g)/(\ln \overline{y}_g - \ln \underline{y}_g)$.[24]

We also need to adopt some normalization for the level of exports. This will be affected, as the theory indicates, by product-market size and country size. The global market size for product g is given by S_g (or equivalently δ_g) in the theory. To control for S_g, we scale x_{gk} by world exports of g, $x_g \equiv \Sigma_k x_{gk}$. Country size also figures into the theory. Recall that each product group k consists of m products and that our small developing country only produces one of these m products. More generally, larger countries will produce a larger subset of these m products. To control for this we scale x_{gk}/x_g by its average $\Sigma_g(x_{gk}/x_g)/N_k$ where N_k is the number of goods exported by country k i.e. the number of goods for which $x_{gk} > 0$. Summarizing, we plot

$$(\text{Normalized GDP per Capita})_{gk} \equiv \frac{\ln y_k - \ln \underline{y}_g}{\ln \overline{y}_g - \ln \underline{y}_g} \tag{13}$$

against

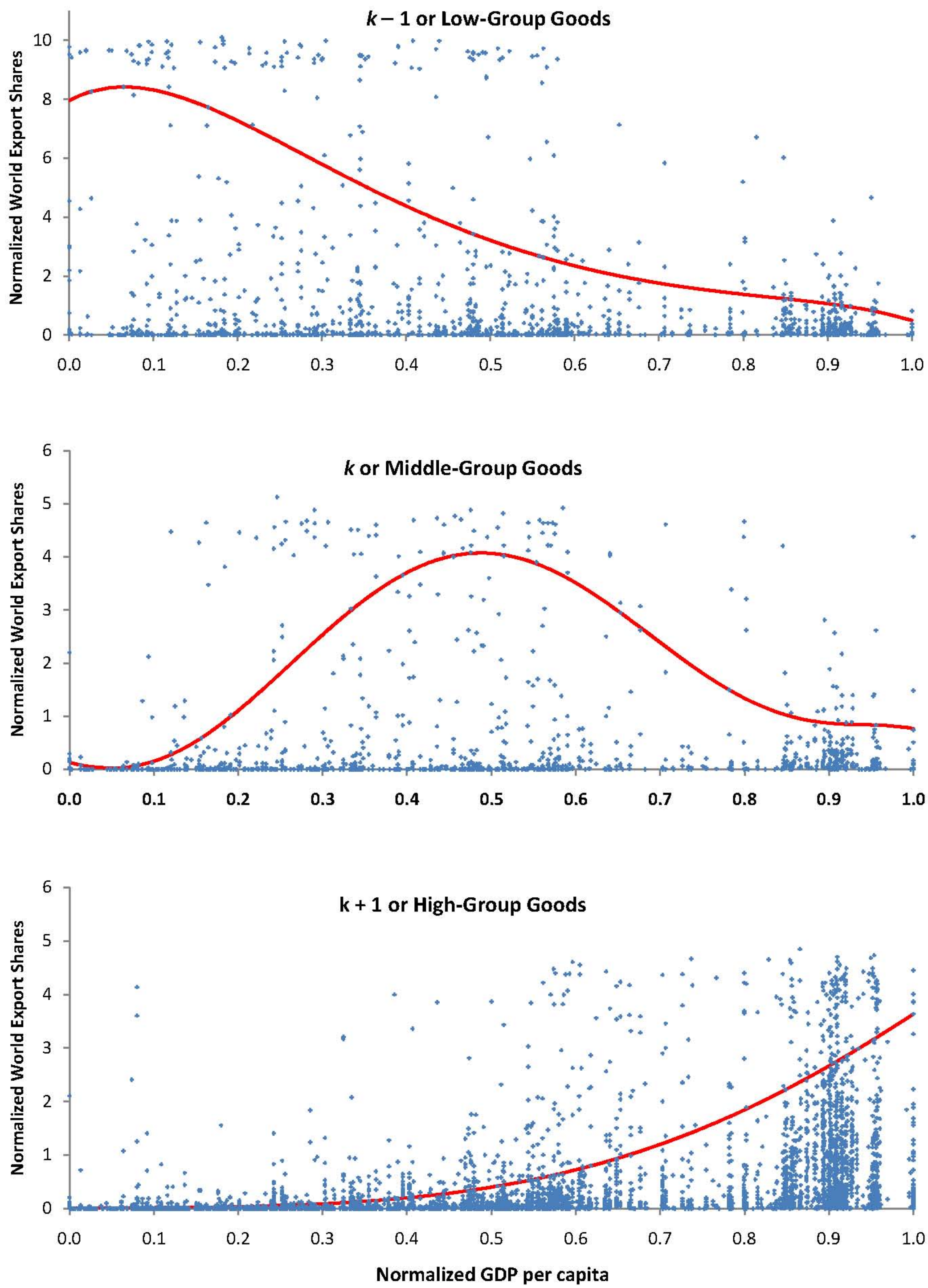
$$(\text{Normalized World Export Share})_{gk} \equiv \frac{(x_{gk}/x_g)}{\frac{1}{N_k}\Sigma_g(x_{gk}/x_g)} \tag{14}$$

where the numerator is country k's share of world exports of g and the denominator is country k's average share of world exports.

Figure 8 plots normalized world export shares against normalized GDP per capita for our three groups of goods. The first thing to note about the plots is the preponderance of points on or very near the horizontal axis. This reflects the fact that poorer countries have zero exports of many goods. This fact is built into the model – our small country produced only one of m possible products in group k. It is also a feature of the Eaton and Kortum (2002) model. There, a country can potentially produce all goods but draws high

24. Note that $\underline{y}_g$ differs from $y_{min,g}$. The former is the minimum across all countries that export any positive amount of good g while the latter is the minimum across any country for which g is a significant export. Likewise for the difference between $\overline{y}_g$ and $y_{max,g}$.

Figure 8: Normalized World Market Shares



Notes: Each point in the plot corresponds to a product-country (g,k) pair. The vertical axis is country k's share of world exports of good g, normalized as in equation (14). The horizontal axis is country k's income, normalized as in equation (13). The curves are the 90th quantile regressions.

productivity for only a subset of goods. Hence in interpreting these scatters, our focus of interest lies not on means — which tend to be dominated by the many (g,k) pairs with near-zero exports — but on the upper bound of the scatter. With this in mind, we estimate a quantile regression (the 90th quantile). This appears as the curve shown in each of the panels of figure 8.[25]

The upper, middle, and lower panels correspond to Low-group goods $(k-1)$, Middle-group goods (k), and High-group goods $(k+1)$, respectively. The panels bear out the world-export-share predictions of the model. World export shares are decreasing in income for the Low group, increasing in income for the High group, and display an inverted-U relationship for the Middle group. This is exactly as predicted in the two bottom panels of figure 2.

We round out this section with a discussion of specification issues. In constructing figure 8 we made five choices. First, we defined the low, middle and high groups by reference to the cut-offs $\ln y_{min,g} = 6$, $\ln y_{min,g} = 8.25$ and $\ln y_{max,g} = 10$. The choice of cut-offs does not matter. Figure 8 is not substantially altered by lowering the $\ln y_{min,g} = 6$ cut-off to 5.25 or raising it to 6.75; by lowering the $\ln y_{min,g} = 8.25$ cut-off to 7.25 or raising it to 9.25; or by lowering the $\ln y_{max,g} = 10$ cut-off to 9. See on-line appendix figure A13. Changing the cut-offs beyond these ranges results in groups that either (1) contain too few observations or (2) include too many wide product-range, uninformative goods.[26] Second, we chose the normalization $(\ln y_k - \ln \underline{y}_g)/(\ln \overline{y}_g - \ln \underline{y}_g)$. This choice of normalization plays almost no role empirically because $\overline{y}_g - \underline{y}_g$ does not vary much across goods i.e. it is not much different than normalizing by a constant. Specifically, across all goods its maximum is 6.4, its median is 6.0 and its 5th percentile is 5.2. Third, in equation (14) we normalized world export shares x_{gk}/x_g by average world export shares $N_k^{-1}\Sigma_g(x_{gk}/x_g)$. We have experimented extensively with alternative normalizations of (x_{gk}/x_g), including the 50th, 75th, 90th, and 99th percentiles of each country's world export shares.[27] All of

25. We use the SAS QUANTREG procedure with a 6th order polynomial.

26. When $\ln y_{min,g} = 6$ is raised to 6.75, the Low group contains so many Middle group goods that it has an interior peak, but this peak is far to the left, at 0.2.

27. For each country k these are percentiles of the vector $(x_{1k}/x_1, \ldots, x_{gk}/x_g, \ldots, x_{Gk}/x_G)$.

these normalizations produce curves with the same shapes as those in figure 8. Fourth, we reported quantile regressions based on the 90th quantile. The curves do not change when using the 85th, 95th, or 99th quantiles. Fifth, we used SITC4 data. The figures look virtually identical using HS6 data. See on-line appendix figure A14.[28]

10. The Dynamics of Development Ladders: The Role of Product Ranges

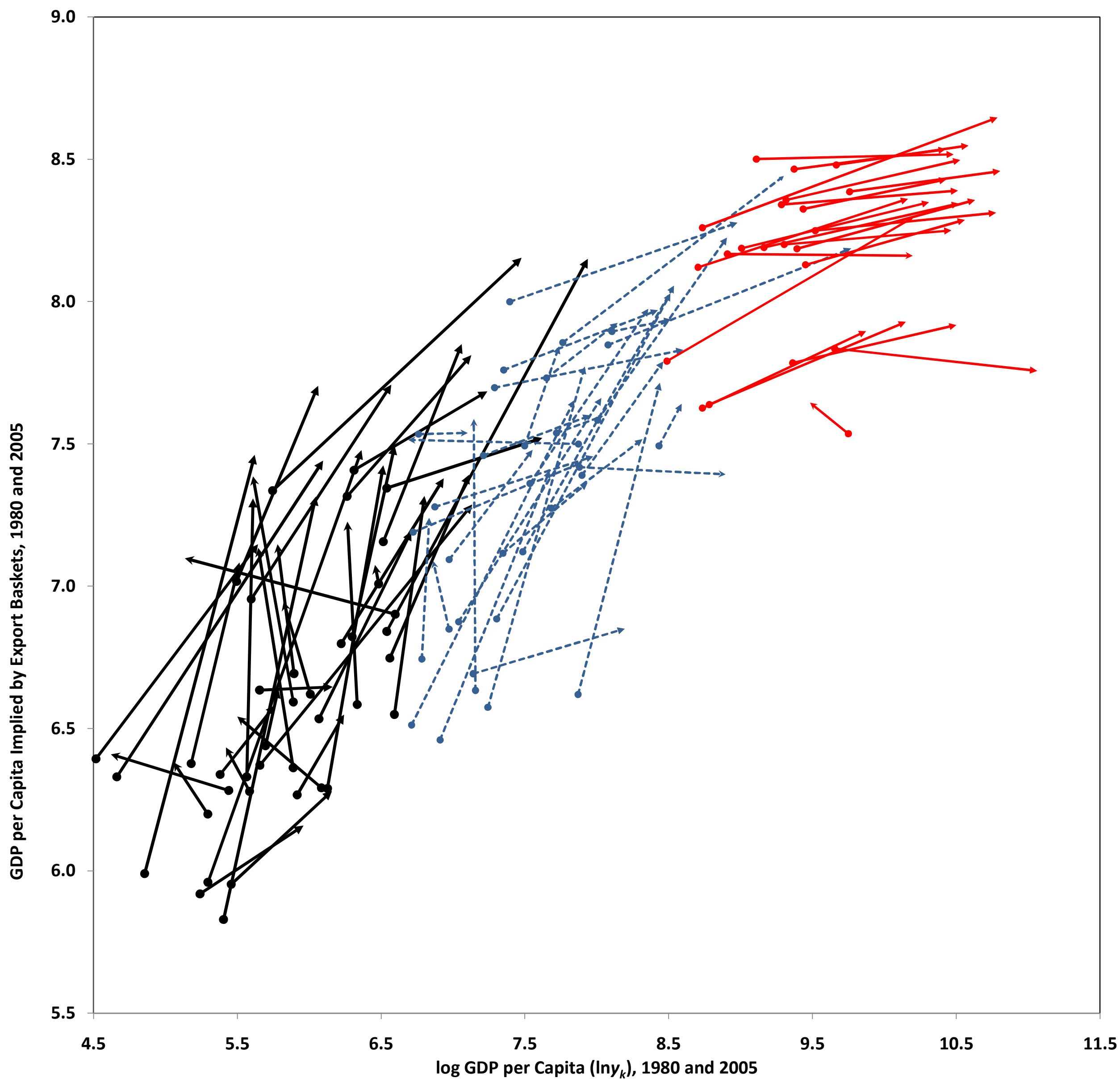
The preceding investigations of the range of exporter incomes associated with each industry raise certain questions as to what we can infer from a country's product mix. The basic point is that advances in income are in general associated *both* with changes in the product mix and with the advance of quality (or productivity) within a given set of industries. Now one point already noted is that we cannot fully separate these two contributions by reference to available data across the general run of industries; we acknowledge that some movements, especially in the wide product-range or 'uninformative' goods may involve *either* a quality improvement, or a shift from one set of products to another more demanding set of products within the industry. With that caveat in mind, we return to the conventional product-mix diagram of figure 4, and we now examine how countries have moved on this diagram over the 25-year period 1980 to 2005.[29]

Figure 9 overlays two product-mix diagrams, one for each year. Each country is represented by an arrow. At the tail of the arrow is the point $(\ln y_{k,1980}, I_{k,1980})$ and at the head is the point $(\ln y_{k,2005}, I_{k,2005})$. The striking feature of this figure is best seen by

28. There are a few extreme 'vertical' outliers that would 'squash' figure 8 down to the horizontal axis if displayed. Rather than leave them off the figure entirely, we shrink them towards the horizontal axis as follows. In the top panel, if a vertical point y exceeds 9, then it is replaced by $9 + f(\Delta)$ where $\Delta = y - 9$ and $f(\Delta) = \ln(1 + \Delta)/5$ so that $f(0) = 0$ and $f' > 0$. Likewise for the middle and bottom panels, but with 4 instead of 9. This has no effect on the position of the quantile regressions.

29. Introducing time subscripts t, we are interested in how the figure 4 points $(\ln y_{kt}, I_{kt})$ have moved over time. (I_{kt} was defined in equation 12.) $I_{k,2005} - I_{k,1980}$ can be decomposed into within and between changes i.e. into a change due to changing product scores and a change due to changing export weights. Since we are only interested in the latter, we compute I_{kt} ($t = 1980, 2005$) using 1980 scores ($\sigma_{g,1980}$) and period-t exports. That is, in equation (12) we use $I_{kt} \equiv \Sigma_g \frac{x_{gkt}}{x_{kt}} \sigma_{g,1980}$, $t = 1980, 2005$. The results are almost identical using 2005 scores.

Figure 9: Dynamic Arrow Diagram



Notes: The arrows in this diagram link the point corresponding to actual and implied GDP per capita in 1980 to the corresponding point in 2005. That is, each arrow connects the point $(\ln y_{k,1980}, I_{k,1980})$ to the point $(\ln y_{k,2005}, I_{k,2005})$. 1980 is the tail of each arrow and 2005 is the head. The three different types of arrows correspond to low-, middle- and high-income country groups.

splitting countries into low-, middle- and high-income groups.[30] It is clear a priori that for high-income countries, an initial concentration on high-end products limits the extent to which the product mix, and hence the implied GDP per capita, can rise further; so here the arrows are necessarily flat.

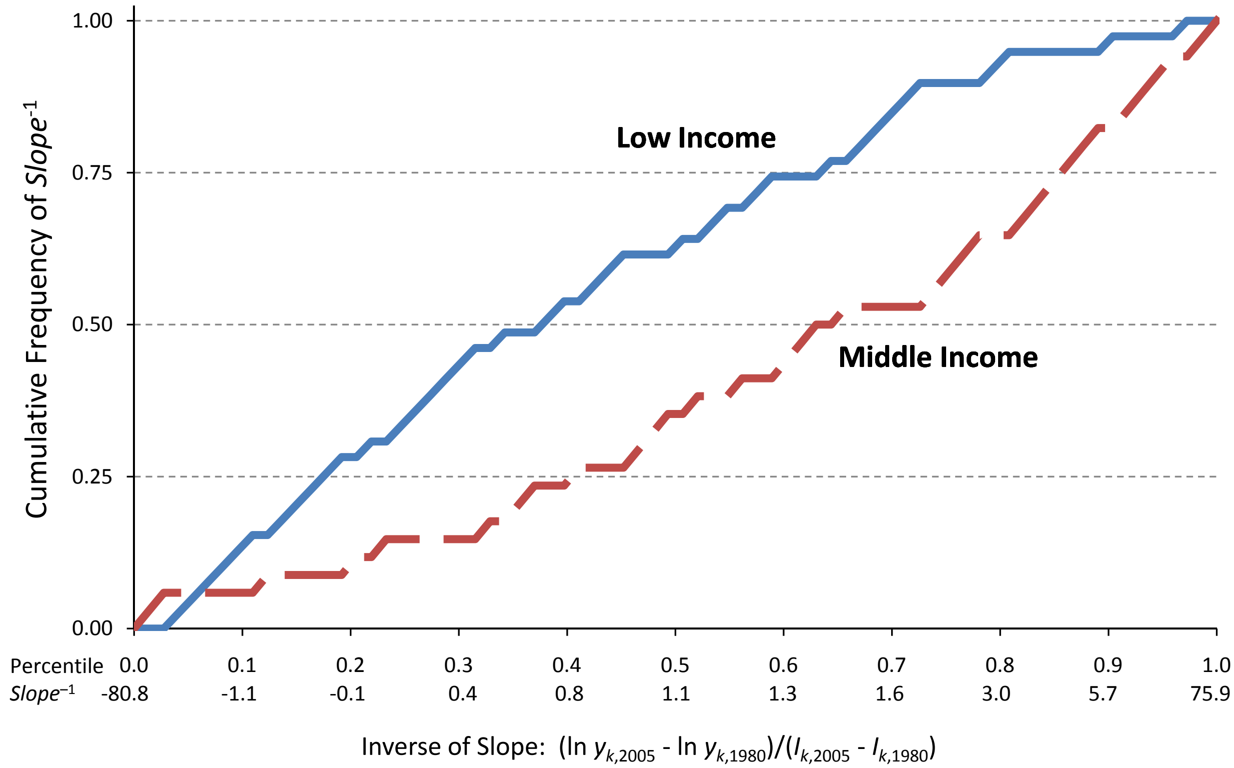
The point of interest in figure 9 relates to the difference in experience between the low- and middle-income groups: the arrows are flatter for middle-income countries than for low-income countries. Figure 3 provided a partial explanation of this. Steep arrows occur when GDP per capita rises without a commensurate increase in I_k. This can happen for two reasons. First, as in figure 3, a country may advance into a new product but only produce it with atypical, below-average quality; in which case there is limited world demand for the product and only slight upward pressure on wages. Second, as in figure 1, the SITC4 good may be an aggregate of low- and high-capability goods and the country may advance into the lower-capability sub-aggregates of the SITC good; in which case exports are limited by competition from other low-capability countries and thus there is very little upward pressure on wages. In short, low-income countries exhibit a very steep slope because they typically moved into the bottom end of 'wider range' industries, which can be interpreted either as becoming low-quality producers, or as producing low-end products within these industries. In contrast, middle-income countries have flatter slopes because they advanced through the figure 9 cloud by becoming typical or average producers within the new industries they entered, whether in terms of product quality or in terms of the products they offer within their industries.

This difference in average slopes between the low- and middle-income groups can be confirmed more formally as follows. Since $I_{k,2005} - I_{k,1980} > 0$ for almost every country, we work with

$$slope_k^{-1} = \frac{\ln y_{k,2005} - \ln y_{k,1980}}{I_{k,2005} - I_{k,1980}} \tag{15}$$

30. The cut-off between low- and middle-income countries is 1980 log GDP per capita of 6.7. This corresponds to a break-point in the GDP per capita series. There are 39 low-income countries below this and 34 middle-income countries above this. The high-income group consists of countries with a 1980 log GDP per capita in excess of 8.5. These are primarily OECD countries, with Spain being the poorest country in the group.

Figure 10: Cumulative Distributions of $Slope_k^{-1}$



Notes: This figure plots the cumulative distribution of $slope_k^{-1}$ (equation 15) for the low- and middle-income countries that appear in figure 9. The horizontal axis reports both the value of $slope_k^{-1}$ and the percentile of its rank. The 'Low Income' curve reports the proportion of low-income countries for which $slope_k^{-1}$ is less than or equal to the number on the horizontal axis. Likewise for the middle-income curve. In essence, the figure shows that low-income countries have steeper figure 9 arrows than do middle-income countries.

and ask whether poor countries have had small gains in GDP per capita relative to their gains in I_{kt}.

Figure 10 reports the cumulative distribution of $slope_k^{-1}$ for our low- and middle-income groups of countries. The distribution cumulates faster for the low-income group, which means that low-income countries as a group have smaller values of $slope_k^{-1}$.

Figure 10 establishes that for comparable changes in I_k, a low-income country experiences a smaller increase in GDP per capita than does a middle-income country. We can interpret this in a purely arithmetic sense as follows: if a low-wage country that hitherto produced L goods enters new markets where it produces goods for which the product range is very wide, so that the product score is close to world average income, the country's implied income I_k rises. In economic terms, we interpret this by saying that the developing country enters at the 'low-quality' end of the product range, and so achieves only a small increase in GDP per capita.

While it would be dangerous to draw strong inferences here, this does emphasize our basic point that advances in GDP per capita involve both changes in product mix and improvements in quality and productivity; and the trajectory followed by this group of countries suggests that the key challenges to development may be on improving quality and productivity within existing activities.

11. Conclusions

The aim of this paper has been to explore the way in which advances in wealth are associated both with changes in the product mix and with changes in quality (and productivity) within a given set of industries. The central point relates to the fact that the range of wealth levels of significant exporters of most products is very wide. This is true for products defined at the conventional SITC4, HS6 and HS10 levels, and moving to more disaggregated data does not change this. At a theoretical level, one reason for the wide product ranges lies in aggregation of disparate sub-industries; another reason lies in the fact that within any industry, there will, in a general equilibrium multi-country setting, be a viable range of producer wealth levels. In this viable range, poor low-quality exporters compete with rich high-quality exporters.

The central property of this producer-wealth range is that, in a multi-market general equilibrium setting, the relation between quality and price on the one hand, and output and global market share on the other, is non-monotonic. There is at equilibrium a range of producer qualities (and so wealth levels) that are viable in a given industry. As quality rises, the country moves into the production of higher-ranked goods, and its equilibrium wage (or GDP per capita) rises. But this means that its output and global market share all exhibit an inverted-U relationship with quality, and so with GDP per capita. As quality rises, market share rises, and wages rise also. As the country advances into the production of higher-ranked products, the rise in wage causes its effective cost level to rise, and its global market share in this industry to fall. It is this inverted-U relation that is the basis of the selection effect that links a country's wealth to its product-mix.

References

Amiti, Mary and Amit K. Khandelwal, "Import Competition and Quality Upgrading," Working Paper No. 15503, National Bureau of Economic Research, November 2009.

Baldwin, Richard and James Harrigan, "Zeros, Quality, and Space: Trade Theory and Trade Evidence," *American Economic Journal: Microeconomics*, forthcoming.

Bastos, Paulo and Joana Silva, "The Quality of a Firm's Exports: Where you Export to Matters," *Journal of International Economics*, November 2010, *82* (2), 99–111.

Bernard, Andrew B., Jonathan Eaton, Bradford Jensen, and Samuel Kortum, "Plants and Productivity in International Trade," *American Economic Review*, September 2003, *93* (4), 1268–1290.

Chenery, Hollis B., "Patterns of Industrial Growth," *American Economic Review*, 1960, *50* (4), 624–654.

Choi, Yo Chul, David Hummels, and Chong Xiang, "Explaining Import Quality: The Role of Income Distribution," *Journal of International Trade*, April 2009, *77* (2), 265–275.

Eaton, Jonathan and Samuel Kortum, "Technology, Geography, and Trade," *Econometrica*, September 2002, *75* (5), 1741–1779.

Feenstra, Robert C., "Voluntary Export Restraint in U.S. Autos, 1980-81: Quality, Employment, and Welfare Effects," in Robert E. Baldwin and Anne O. Krueger, eds., *The Structure and Evolution of Recent U.S. Trade Policy*, Chicago: University of Chicago Press, 1984, pp. 35–66.

Foster, Lucia, John Haltiwanger, and Chad Syverson, "Reallocation, Firm Turnover, and Efficiency: Selection on Productivity or Profitability?," *American Economic Review*, March 2008, *98* (1), 394–425.

Goldberg, Pinelopi Koujianou and Nina Pavcnik, "Distributional Effects of Globalization in Developing Countries," *Journal of Economic Literature*, March 2007, *45* (1), 39–82.

Grossman, Gene M. and Elhanan Helpman, *Innovation and Growth in the Global Economy*, Cambridge, Mass. and London: MIT Press, 1991.

Hall, Robert E. and Chad Jones, "Why Do Some Countries Produce So Much More Output per Worker than Others?," *Quarterly Journal of Economics*, February 1999, *114* (1), 83–116.

Hallak, Juan Carlos, "Product Quality and the Direction of Trade," *Journal of International Economics*, January 2006, *68* (1), 238–65.

__ **and Jagadeesh Sivadasan**, "Firms' Exporting Behavior under Quality Constraints," Working Paper No. 14928, National Bureau of Economic Research, April 2009.

__ **and Peter Schott**, "Estimating Cross-Country Differences in Product Quality," Working Paper No. 13807, National Bureau of Economic Research, February 2008.

Hausmann, Ricardo, Jason Hwang, and Dani Rodrik, "What You Export Matters," *Journal of Economic Growth*, March 2007, *12* (1), 1–25.

Helpman, Elhanan, *The Mystery of Economic Growth*, Cambridge, MA: Harvard, 2004.

Hummels, David and Alexander Skiba, "Shipping the Good Apples Out: An Empirical Confirmation of the Alchian-Allen Conjecture," *Journal of Political Economy*, December 2004, *112* (6), 1384–1402.

_ **and Peter Klenow**, "The Variety and Quality of a Nation's Exports," *American Economic Review*, June 2005, *95* (3), 704–23.

Johnson, Robert C., "Trade and Prices with Heterogeneous Firms," 2009. Mimeo, Dartmouth College.

Khandelwal, Amit, "The Long and Short (of) Quality Ladders," *Review of Economic Studies*, October 2010, *77* (4), 1450–1476.

Kugler, Maurice and Eric Verhoogen, "The Quality-Complementarity Hypothesis: Theory and Evidence from Colombia," Working Paper No. 14418, National Bureau of Economic Research, October 2008.

Lall, Sanjaya, John Weiss, and Jinkang Zhang, "The "Sophistication" of Exports: A New Trade Measure," *World Development*, February 2006, *34* (2), 222–37.

Leamer, Edward E., *Sources of International Comparative Advantage: Theory and Evidence*, Cambridge, MA: MIT Press, 1984.

Melitz, Marc J., "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, November 2003, *71* (6), 1695–1725.

Michaely, Michael, *Trade, Income Levels, and Dependence*, Amsterdam, North-Holland and New York: Elsevier Science Pub. Co, 1984.

Schott, Peter, "One Size Fits All? Heckscher-Ohlin Specialization in Global Production," *American Economic Review*, June 2003, *93* (2), 686–708.

_ , "Across-Product versus Within-Product Specialization in International Trade," *Quarterly Journal of Economics*, May 2004, *119* (2), 647–678.

_ , "The Relative Sophistication of Chinese Exports," *Economic Policy*, 2008, *53*, 5–49.

Sutton, John, *Sunk Costs and Market Structure*, Cambridge: MIT Press, 1991.

_ , *Technology and Market Structure*, Cambridge: MIT Press, 1998.

_ , "Market Structure: Theory and Evidence," in Mark Armstrong and Robert Porter, eds., *Handbook of Industrial Organization, Volume III*, Amsterdam: North-Holland, 2007, pp. 2301–2368.

_ , "Quality, Trade and the Moving Window: The Globalisation Process," *Economic Journal*, November 2007, *117* (524), F469–F498.

Verhoogen, Eric, "Trade, Quality Upgrading and Wage Inequality in the Mexican Manufacturing Sector," *Quarterly Journal of Economics*, May 2008, *123* (2), 489–530.

Appendix A. Proof of Lemma 1

Proof of Part 1. Using equation (3), note that $\sum_j \frac{w_j c_j}{u_j}$ is increasing in w_i, and $\frac{w_i c_i / u_i}{\sum \frac{w_j c_j}{u_j}}$ is increasing in w_i, whence the r.h.s. of the equation rises.

Proof of Part 2. From equation (3) it follows on re-arranging that

$$x_i = \frac{S}{w_i c_i}(N_g - 1)\frac{w_i c_i / u_i}{\sum_j \frac{w_j c_j}{u_j}}\left\{1 - (N_g - 1)\frac{w_i c_i / u_i}{\sum_j \frac{w_j c_j}{u_j}}\right\}.$$

We aim to examine how x_i varies with u_i, holding w_i, c_i and the w_j, c_j and u_j constant, over the relevant domain (where inequality (4) is satisfied, to be defined precisely below).

With this in mind, define the function

$$z(u_i) = \frac{w_i c_i / u_i}{\sum_j \frac{w_j c_j}{u_j}} = \frac{1}{1 + \frac{u_i}{w_i c_i}(\sum_{j \neq i} \frac{w_j c_j}{u_j})}$$

and note that $z(u_i)$ is strictly decreasing. Note that

$$x_i = \frac{S}{w_i c_i}(N_g - 1) \times z[1 - (N_g - 1)z]$$

The relevant domain can be written in terms of z as

$$\frac{1}{N_g} < z \leq \frac{1}{N_g - 1}$$

where the right hand inequality corresponds to the threshold at which u_i reaches the level at which firm i's effective cost level $w_i c_i / u_i$ makes the firm just viable, while the left hand inequality corresponds to the point at which firm i's effective cost level $w_i c_i / u_i$ becomes equal to that of its $N_g - 1$ identical rivals, so that $z(u_i) = 1/[1 + (N_g - 1)] = 1/N_g$.

To establish that x_i is increasing in u_i on the relevant domain, we note that the function $z[1 - (N_g - 1)z]$ is strictly decreasing on the domain

$$\frac{1}{2}\frac{1}{N_g - 1} < z \leq \frac{1}{N_g - 1}.$$

Recall that $N_g \geq 2$, whence this domain includes the relevant domain

$$\frac{1}{N_g} < z \leq \frac{1}{N_g - 1}.$$

It follows that $\partial x_i / \partial u_i > 0$ on the relevant domain.

Proof of Part 3. Consider equation (3). Since u_i/w_i and hence $w_i c_i / u_i$ are constant, the r.h.s. of equation (3) is constant. Hence so is $x_i u_i$. Since u_i is rising, it must be that x_i is falling.

Appendix B. Trade Data

COMTRADE reports each bilateral transaction twice, once by the importer and once by the exporter. We always use the importer's data as this is known to be more reliable for most countries.

The countries in our sample are (using ISO codes for brevity[31]): AFG, AGO, ALB, ARG, AUS, AUT, BDI, BEN, BFA, BGD, BGR, BOL, BRA, CAN, CHE, CHL, CHN, CMR, COL, CRI, CUB, DEU, DNK, DOM, DZA, ECU, EGY, ESP, FIN, FRA, GBR, GHA, GIN, GRC, GTM, HND, HTI, HUN, IDN, IND, IRL, IRQ, ISR, ITA, JAM, JOR, JPN, KEN, KHM, LBN, LKA, MAR, MDG, MEX, MLI, MMR, MOZ, MWI, MYS, NER, NGA, NIC, NLD, NOR, NPL, NZL, PAK, PER, PHL, PNG, POL, PRT, PRY, ROU, RWA, SAU, SDN, SEN, SGP, SLE, SLV, SOM, SWE, TCD, TGO, THA, TUN, TUR, UGA, URY, USA, VEN, ZMB, and ZWE. The only major countries not included in our list are Taiwan and Honk Kong. Taiwan is excluded because there are no 1980 data. Hong Kong is excluded because, for our purposes, it should be merged with China in 2005 and be by itself in 1980. None of our 2005 cross-section results are affected by the inclusion of Taiwan and Hong Kong (the latter either by itself or merged with China).

We exclude live animals, meat, fish and dairy. These goods account for only 2.1% of trade and including them does not affect our results at all; however, it is hard to relate trade in these goods to the issues raised in this paper.

Price data p_{gk} are from the U.S. historical imports CD, 2001–2005. This CD only reports what is called the 'first quantity' and 'first value' so that all observations within an HS10 product have the same quantity units. We sum U.S. imports and quantities by HS10 product and trading partner (exporter to the United States). We calculate unit values with

31. See on-line appendix table A1 for a full list of country names and GDPs per capita.

the summed data. In addition, we winsorize the unit values below the 10th within-HS10 percentile and above the 90th within-HS10 percentile. Winsorizing makes virtually no difference to our results.

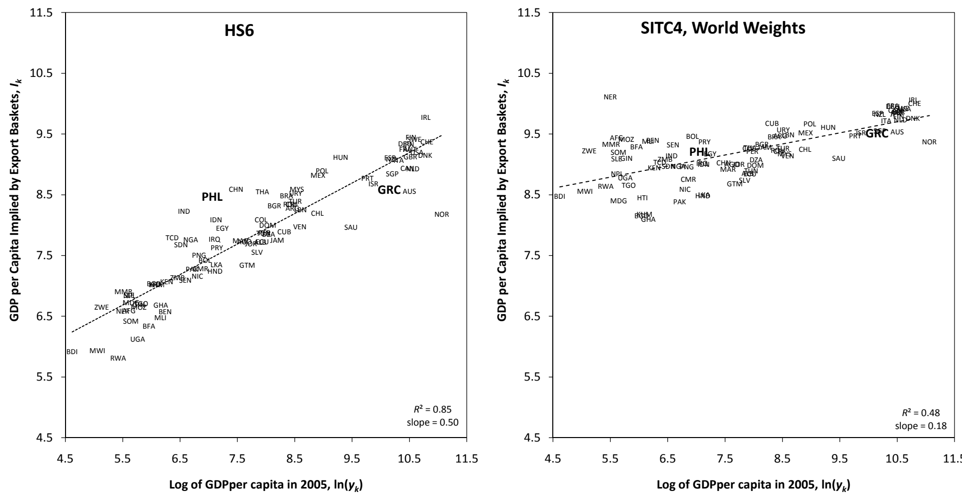
Online Appendix to

"Deductions from the Export Basket: Capabilities, Wealth and Trade"

by

John Sutton and Daniel Trefler

Figure A11: Product-Mix Diagrams: HS6 and World Weights



Notes: This figure displays two variants of the figure 4 product-mix diagram. The left-hand panel uses HS6 data for 2005. The right-hand panel uses SITC4 data for 2005, but constructs predicted GDP per capita using world weights as in Michaely (1984). That is, the weights $x_{gk}/\sum_g x_{gk}$ in equation (11) are replaced by world weights $x_{gk}/\sum_k x_{gk}$. See section 5 for details.

On-Line Appendix A. Robustness of Product-Mix Diagrams

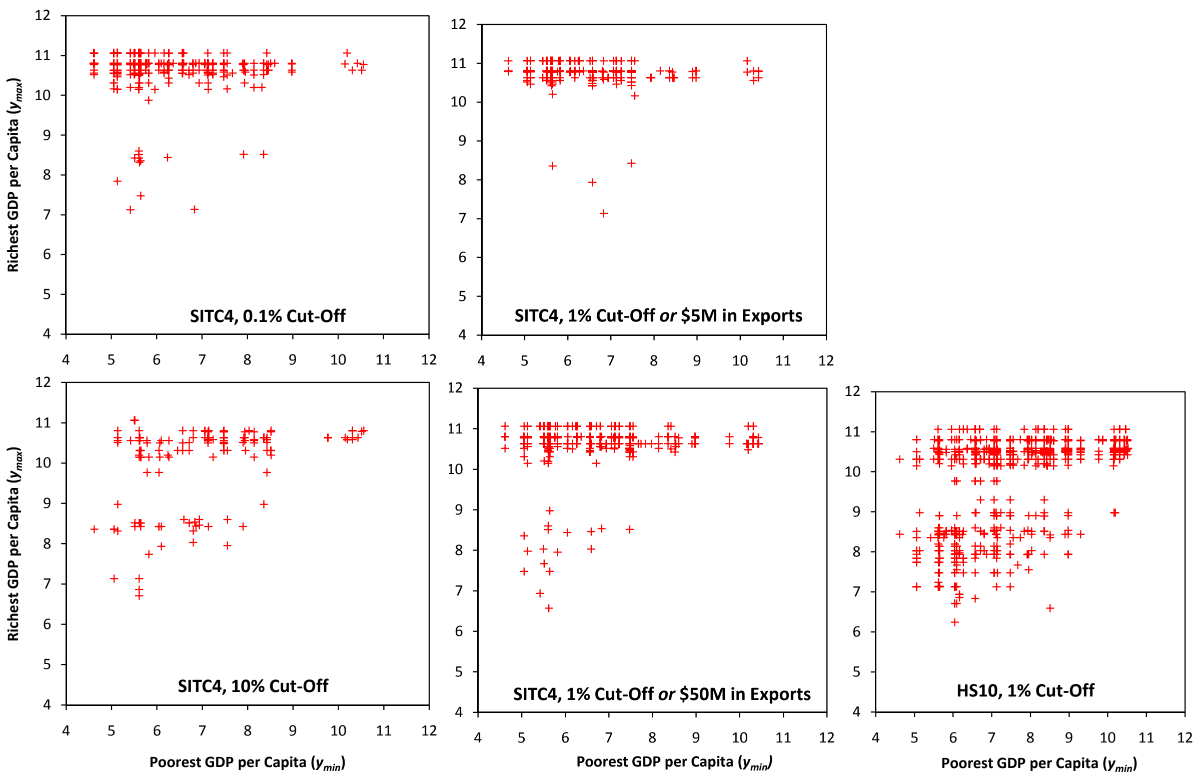
Figure A11 displays two product-mix diagrams: (1) using HS6 data (left panel) and (2) using Michaely (1984) and Lall et al. (2006) world export shares rather than own export shares (right panel). Both panels display 'flatness' and 'diffuseness'.

On-Line Appendix B. Robustness of Product Range Diagrams

There were several choices made in constructing the product ranges of figures 5–6. When defining the product ranges we only looked at country-product pairs for which the product accounted for a significant share of the country's exports. As in the main text, let x_{gk}/x_k be the share of country k's exports accounted for by product g. We considered country-product pairs with $x_{gk}/x_k \geq \alpha \max_{g'} x_{g'k}/x_k$ where $\alpha = 0.01$. In the top left and bottom left panels of figure A12 we choose $\alpha = 0.001$ and $\alpha = 0.10$, respectively. As is apparent, the impression of the pervasiveness of wide product ranges does not change.

An alternative to choosing cut-offs based on $x_{gk}/x_k \geq \alpha \max_{g'} x_{g'k}/x_k$ is to use a dollar value cut-off: $x_{gk} > \$5{,}000{,}000$ or $x_{gk} > \$50{,}000{,}000$. This has the advantage that it keeps more of the trade of rich countries, and the disadvantage that it eliminates more of the trade of poor countries. We therefore combine this dollar criterion with our previous α (or percentage) criterion. That is, an observation (g,k) is included if it meets *either* of the two criteria. The results appear in the right-hand panels of figure A12. The top and bottom panels use \$5,000,000 and \$50,000,000, respectively.

Figure A12: Product Ranges: Sensitivity to Cut-offs



On-Line Appendix C. Robustness of Market-Share Diagrams

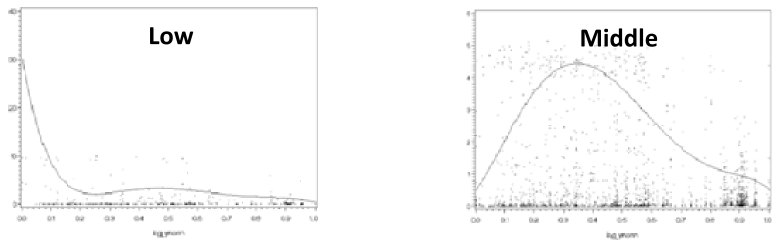
In section 9 we claimed that the figure 8 market-share diagram was not very sensitive to the choice of cut-offs $\ln y_{min,g} = 6$, $\ln y_{min,g} = 8.25$ and $\ln y_{max,g} = 10$. Figure A13 shows the basis for this claim. In the top pair of panels, $\ln y_{min,g} = 6$ is lowered to 5.25. In the second pair of panels, $\ln y_{min,g} = 6$ is raised to 6.75. Here the monotonicity of the Low group is lost, but only because the Low group now absorbs so many Middle-group goods. It remains true that the Low-group peak is far to the left of the Middle-group peak. In the third pair of panels, $\ln y_{min,g} = 8.25$ is lowered to 7.25. Monotonicity is lost for the High group, but only because it now includes so many Middle-group goods. (Also, the downturn at the far right of the High panel is entirely associated with Norway.) In the fourth pair of panels, $\ln y_{min,g} = 8.25$ is raised up to 9.25. In the bottom pair of panels, $\ln y_{max,g} = 10$ is lowered to 9. From figure A13 it is clear that the market-share predictions of figure 8 are not sensitive to the choice of cut-offs, or where they are, this 'sensitivity' is entirely explainable.

The market-share diagram (figure 8) was drawn using SITC4 data. In figure A14 the figure is redrawn using HS6 data. Because there is much more data, we report the 95th quantile rather than the 90th quantile that was used for the SITC4 data. As is apparent, figures 8 and A14 are almost identical. The only difference lies in the Low group where the peak of the quantile is no longer at the far left; however, its peak remains close to the extreme left and certainly much further left than for the middle group.[32]

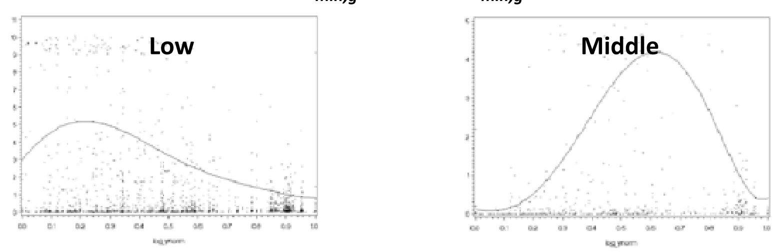
32. On a minor technical note, at the HS6 level there are a few goods that meet the criteria for being in both the Medium and High groups. Where this is the case the goods are put in the High group; however, since there are so few of these goods it makes no difference where they are put.

Figure A13: Normalized World Market Shares, Sensitivity to Cut-Offs

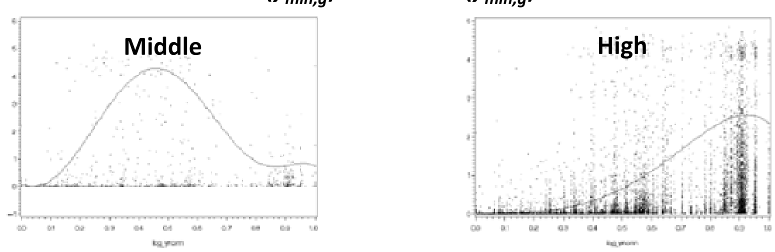
Lower $\ln(y_{min,g}) = 6$ to $\ln(y_{min,g}) = 5.25$



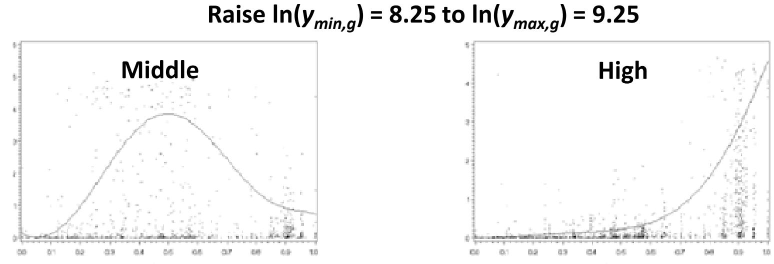
Raise $\ln(y_{min,g}) = 6$ to $\ln(y_{min,g}) = 6.75$



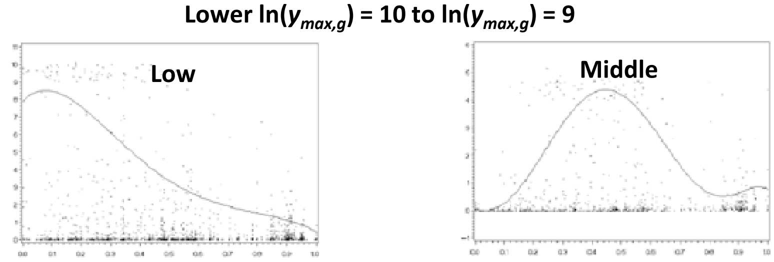
Lower $\ln(y_{min,g}) = 8.25$ to $\ln(y_{min,g}) = 7.25$



Raise $\ln(y_{min,g}) = 8.25$ to $\ln(y_{max,g}) = 9.25$

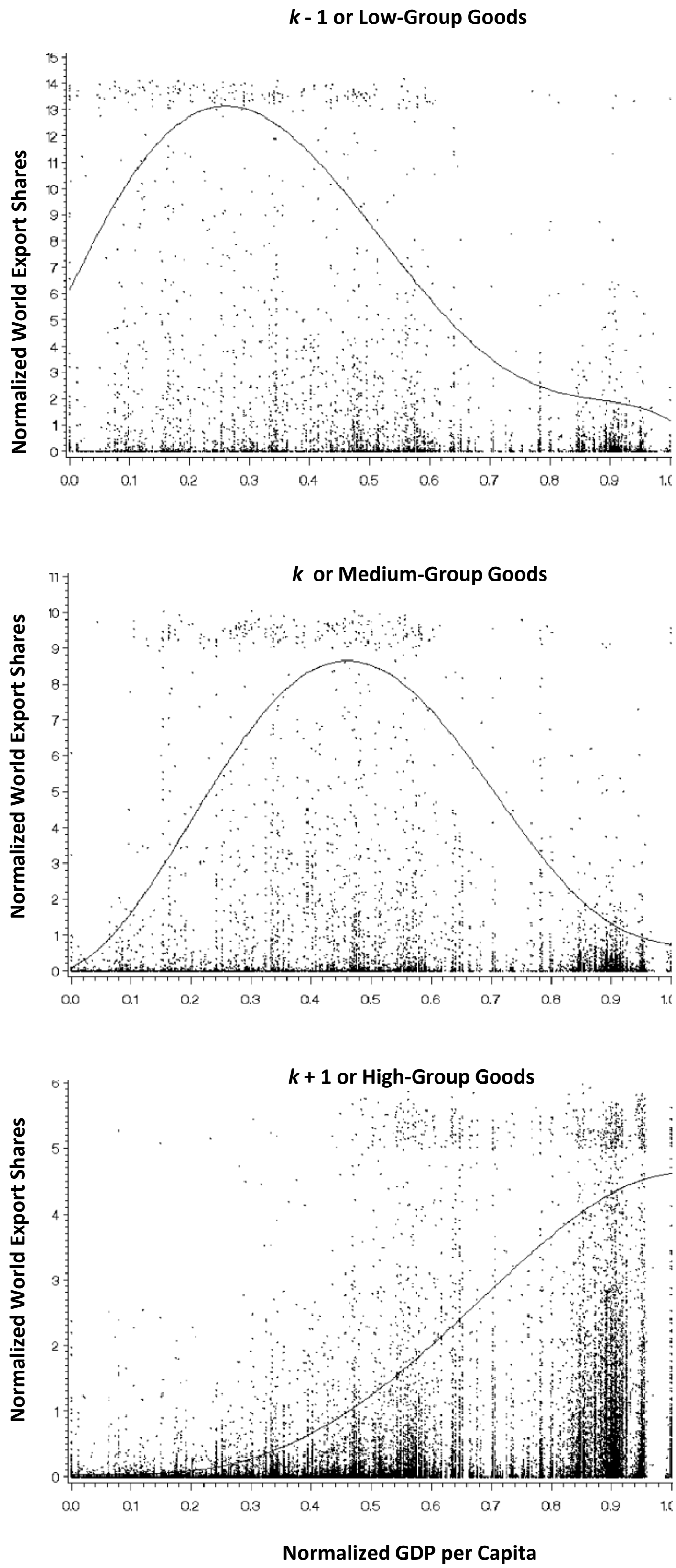


Lower $\ln(y_{max,g}) = 10$ to $\ln(y_{max,g}) = 9$



Notes: This figure reports the sensitivity of figure 8 to the choice of cut-offs defining the Low, Middle and High groups of goods. SITC4 data are used.

Figure A14: Normalized World Market Shares, HS6 Data



Notes: This figure repeats figure 8, but using HS6 COMTRADE data and the 95 quantile (since the HS6 data are much finer than the SITC4 data).

Table A1: List of Countries

Code	Country	GDP per Capita (2005) $US	$\ln y_k$	Code	Country	GDP per Capita (2005) $US	$\ln y_k$
BDI	Burundi	101	4.62	ALB	Albania	2,691	7.90
MWI	Malawi	157	5.06	COL	Colombia	2,739	7.92
ZWE	Zimbabwe	170	5.13	ECU	Ecuador	2,794	7.94
RWA	Rwanda	226	5.42	THA	Thailand	2,797	7.94
NER	Niger	245	5.50	TUN	Tunisia	2,846	7.95
MMR	Myanmar	248	5.51	PER	Peru	2,911	7.98
SLE	Sierra Leone	273	5.61	DOM	Dominican Rep.	3,073	8.03
AFG	Afghanistan	273	5.61	DZA	Algeria	3,115	8.04
NPL	Nepal	276	5.62	BGR	Bulgaria	3,441	8.14
SOM	Somalia	283	5.64	JAM	Jamaica	3,622	8.19
MDG	Madagascar	283	5.65	CUB	Cuba	4,093	8.32
UGA	Uganda	317	5.76	BRA	Brazil	4,260	8.36
MOZ	Mozambique	323	5.78	ROU	Romania	4,557	8.42
GIN	Guinea	325	5.78	CRI	Costa Rica	4,616	8.44
TGO	Togo	337	5.82	ARG	Argentina	4,728	8.46
BFA	Burkina Faso	387	5.96	TUR	Turkey	4,969	8.51
BGD	Bangladesh	422	6.05	URY	Uruguay	4,996	8.52
HTI	Haiti	429	6.06	MYS	Malaysia	5,098	8.54
KHM	Cambodia	444	6.10	VEN	Venezuela	5,374	8.59
MLI	Mali	473	6.16	LBN	Lebanon	5,436	8.60
GHA	Ghana	475	6.16	CHL	Chile	7,297	8.90
BEN	Benin	513	6.24	MEX	Mexico	7,365	8.90
KEN	Kenya	526	6.27	POL	Poland	7,923	8.98
TCD	Chad	580	6.36	HUN	Hungary	10,942	9.30
ZMB	Zambia	637	6.46	SAU	Saudi Arabia	13,119	9.48
SDN	Sudan	675	6.52	PRT	Portugal	17,457	9.77
IND	India	713	6.57	ISR	Israel	19,389	9.87
SEN	Senegal	730	6.59	GRC	Greece	25,562	10.15
NGA	Nigeria	803	6.69	ESP	Spain	25,947	10.16
PAK	Pakistan	820	6.71	NZL	New Zealand	26,789	10.20
NIC	Nicaragua	899	6.80	SGP	Singapore	26,968	10.20
PNG	Papua New Guinea	928	6.83	ITA	Italy	30,053	10.31
CMR	Cameroon	955	6.86	DEU	Germany	33,718	10.43
BOL	Bolivia	1,028	6.94	FRA	France	33,862	10.43
PHL	Philippines	1,163	7.06	CAN	Canada	35,071	10.47
IRQ	Iraq	1,213	7.10	JPN	Japan	35,646	10.48
HND	Honduras	1,225	7.11	AUS	Australia	36,321	10.50
IDN	Indonesia	1,244	7.13	AUT	Austria	36,760	10.51
LKA	Sri Lanka	1,253	7.13	GBR	United Kingdom	36,954	10.52
PRY	Papua New Guin.	1,266	7.14	FIN	Finland	37,307	10.53
EGY	Egypt	1,392	7.24	NLD	Netherlands	38,512	10.56
CHN	China	1,766	7.48	SWE	Sweden	39,539	10.59
MAR	Morocco	1,906	7.55	USA	USA	41,348	10.63
AGO	Angola	2,039	7.62	DNK	Denmark	47,839	10.78
GTM	Guatemala	2,147	7.67	IRL	Ireland	48,373	10.79
JOR	Jordan	2,293	7.74	CHE	Switzerland	49,282	10.81
SLV	El Salvador	2,545	7.84	NOR	Norway	63,704	11.06

On-Line Appendix D. Full Country Names and GDP per Capita

Table A1 provide full country names for the ISO codes listed in appendix Appendix B.

On-Line Appendix E. Additional Justification of Our Modelling Approach

E.1. Alternative Models Used in the International Trade Literature

There are a number of models of international trade that could have been used to deliver our results e.g. Eaton and Kortum (2002), Bernard, Eaton, Jensen and Kortum (2003) and Melitz (2003). Why have we not used these? The core of our model has two components. First, we assumed that quality capabilities are scarce and asymmetrically distributed across countries. Second, in equilibrium wages adjust to changes in quality capabilities so that rich countries are priced out of low-k goods. One could obtain our main results in these other models, but it would be less straightforward.

For one, in these other models, scarcity is described by the distribution of productivities ($G(a)$ in Melitz, 2003; the Type II extreme value distribution in Eaton and Kortum, 2002 and Bernard et al., 2003). To use these other models one would have to provide a detailed specification of how these distributions vary across both countries and industries. This can be done, but it would require so much asymmetry that the elegance of these models would be lost. Re-stated, these other models are designed to handle within-industry heterogeneity and are less concerned with standard between-industry comparative advantage. In contrast, we have made the extreme assumption that there is at most one firm per country and focussed instead on the cross-country, cross-industry distribution of capabilities that are central to our Ricardian logic.

For another, in these other models wage adjustment plays a role in determining entry thresholds. Beyond this, there is little discussion of the comparative advantage implications of wages or of why some countries are rich and others poor. It is these latter issues that are our main concern.

In short, we have chosen the simplest model possible that focuses on (1) Ricardian asymmetries in the distribution of quality capabilities and (2) the role of wages as an adjustment mechanism in a multi-industry world populated by rich and poor countries.

E.2. The Endogeneity of Quality Capabilities

The driving assumptions on this paper are that (*a*) some capabilities are relatively scarce, and (*b*) the relatively scarce capabilities are distributed asymmetrically across countries. (We have chosen to take (*a*) and (*b*) as given, and explore their consequences.) It might seem natural to endogenize the entry process, and so derive (*a*) and (*b*) from more primitive assumptions. We have chosen not to do this for the following reasons. Endogenizing (*a*) is straightforward, and has been done elsewhere (Sutton, 1991, 1998, 2007b). To model (*b*), however, requires that some assumption be made regarding asymmetries between countries. This could be done by assuming that the (unobservable) relationship between the fixed and sunk costs of product development, and product quality, differ across countries; but to do this would simply beg the question, why? This leads, then, into the broad economic history of industrial development, and so to the issues that lie far beyond our present scope; no single way of modelling the origin of these cross-country differences could hope to command general acceptance. And so we have chosen to present the theory in its simplest form, staying close to the empirical observables, by taking (*a*) and (*b*) as our primitives.