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OPENNESS IS A MATTER OF DEGREE: HOW TRADE COSTS REDUCE DEMAND ELASTICITIES

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Abstract

The relative costs of trading different goods vary independently of the relative costs of producing them. The costs of trade are also often high. As a result, producer price elasticities of demand in economies that trade are usually much lower than purchaser price elasticities. Trade costs could thus explain why cross-country variation in the composition of output is much less sensitive to variation in relative production costs (or comparative advantage) than is predicted by standard open-economy models, in which demand elasticities are infinite. However, this sensitivity is greater in countries with lower trade costs – which are consequently 'more open'.

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1. Introduction

Why and how does the commodity composition of output, exports and imports vary among countries that trade with one another? The standard short answer to this question is 'comparative advantage' or, more fully, 'variation among countries in the relative costs of producing different goods in the absence of trade'. To be useful, this answer needs to be extended to include an explanation of why relative production costs vary among countries (different endowments, for instance). The answer also needs to be extended to specify more precisely how variation in the composition of output and trade is shaped by variation in relative costs of production.

This paper focuses on the second sort of extension of the standard answer, taking cross-country variation in relative production costs as given. It asks how much the relationship between relative production costs and the composition of output in an open economy differs from that in a closed economy. The usual answer in trade theory, common to models with widely varying assumptions about the determination of comparative costs, is 'greatly'. The answer proposed by this paper is 'moderately, and to a degree that depends (inversely and fairly continuously) on the height of trade barriers in the economy concerned'.

The proposition, in other words, is that it is analytically more helpful, as well as empirically more realistic, to treat openness as a matter of degree, determined by the level of a country's trade costs, than to assume – as almost all trade models do – that there is a qualitative difference on the demand side between closed and open economies. Integrating trade costs into the analysis of trade in this way could make trade models work better: it is attractive also because it brings trade costs into the core of trade theory, rather than adding them on as an afterthought.

Elasticities in theory and reality

The context is the real world of many countries (rather than the analytically useful two-country world from which trade theory starts). In most theoretical trade models with many countries, on the grounds that countries are usually small in relation to the world market, each country is assumed to be a price taker. It can sell (or buy) unlimited amounts of all goods at given world prices.

The relationship between output composition and comparative costs in the standard open-economy model differs greatly from the relationship in a closed economy, where producers face inelastic sectoral demand curves and outputs rise continuously as costs fall. In an open economy, if a country's cost of production for a particular good is above the world price, it produces none of it and relies on imports. If a country's cost of production for a good is at or below the world price, it produces as much of it as is permitted by the availability of resources (national supplies less use in other sectors), supplying all of its home demand and exporting any surplus.

In practice, however, elasticities are far from infinite. As trade economists recognise, the composition of output in particular countries is not nearly so specialised, nor so sensitive to cost variation, as this assumption implies (Deardorff, 2006). International macroeconomists, too, cannot reconcile this assumption with the evidence (Obstfeld and Rogoff, 2000). And to achieve realistic outcomes, CGE modellers need to damp elasticities heavily, mainly by treating imported and locally produced varieties of each good as distinct goods, but also assuming imperfect substitutability for firms between home and export sales, and sometimes world prices that decline with export sales.

The issue is how to explain this inelasticity of demand in an economically plausible way. The commonest explanation is that consumers regard local and foreign varieties of goods as imperfect substitutes (Armington, 1969). CGE models thus treat imports and local production of the same good as two distinct goods, and use a CES function to combine them into a composite good. Trefler (1995) invokes Armington as part of the reason for 'missing trade'. Obstfeld and Rogoff (2000) likewise assume imperfect substitutability in consumption as part of their explanation of puzzles in international macroeconomics (the field in which Armington's original article was written).

Trade theorists, however, have for nearly four decades been unwilling to incorporate this explanation into their standard models (e.g. Deardorff, 2006: slides 29-31). The basic reason appears to be a concern about magnitudes. Trade theorists accept that local and foreign goods are usually less than perfect substitutes, but the substitution elasticities in CGE models (rarely more than 5, and usually less)[1] are far lower than is suggested by their own preferences and casual observation, which imply a degree of substitutability high enough to make infinite elasticity a reasonable approximation. Trade theorists, to be clear, accept the empirical evidence that elasticities are low: they are just unpersuaded that the main explanation is consumer preferences.

Rethinking the costs of trade

Another explanation for low demand elasticities is trade costs. Obstfeld and Rogoff (2000) advance precisely this argument, noting that it goes back to Samuelson (1954) and implementing it by coupling their Armington elasticity with iceberg trade costs. Trefler (1995), too, suggests that trade costs are part of the explanation for missing trade. Relatedly, Rauch and Trindade (2003) argue that elasticities of substitution are lowered by information costs, even though goods may be perfect substitutes. Aldaz-Carroll (2003) suggests that elasticities are reduced by unit costs of trade that rise with the quantity sold (at the margin, sales must be made in ever more distant and difficult markets). Rising trade costs are suggested as a possible way of improving the realism of Heckscher-Ohlin models also by Deardorff (2006).

As yet, none of these trade cost explanations has found its way into standard theory. Part of the reason may be lack of knowledge of them, because of their newness, but this is not credible for Obstfeld and Rogoff (2000), which is widely known. My guess is that trade theorists tacitly reject this approach because they see it as combining an element that is not new (iceberg trade costs) with an element that is not true (a low substitution elasticity). The Aldaz-Carroll approach is basically an explanation of low supply elasticities, rather than low demand elasticities (providing a better behavioural foundation for the CET export functions used in CGE models). In Deardorff (2006), too, rising trade costs act on supply functions rather than on demand functions – and serious doubt is expressed about the validity of this assumption.

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[1] Of the elasticities in the 42 material-goods sectors in the current version of the widely used GTAP model, 31 are below 4 (Dimaranan et al., 2007: table 20.2). Harrison et al. (1997), in their well-known modelling analysis of the Uruguay Round, take 4 as their base elasticity. Obstfeld and Rogoff (2000: 345) cite typical values 'in the neighborhood of 5 to 6.'

This paper is in the same spirit as that of Obstfeld and Rogoff, arguing that trade costs reduce demand elasticities, but the suggested mechanism is different from theirs. It differs also from that of most of the many other models that include trade costs (since the survey of Anderson and van Wincoop, 2004, notable contributions include Melitz, 2003, Bernard *et al*., 2007, and Markusen and Venables, 2007). In these models, as in Obstfeld and Rogoff, the variable cost of trading a good is usually taken to be a fixed proportion of its world price or production cost, like an ad valorem tariff.[2] Countries whose cost of production of a good lies above or below the world price by less than this proportion produce it only for home use (in amounts that vary along the relevant segment of the closed-economy demand curve). Other countries stay in the 'produce nothing' or the 'produce as much as resources permit' ranges of the standard model. So demand remains infinitely elastic, except within the 'non-traded' range.

To assume ad valorem trade costs is reasonable for some purposes, such as explaining the volumes and directions of total trade flows among countries in gravity models, but is misleading for the traditional purpose of explaining the commodity composition of trade. In this context, the ad valorem assumption is not just somewhat inaccurate, but is as far as it is possible to get from the truth, which is that variation among countries in the relative costs of trading any pair of goods is basically independent of variation in the relative costs of producing them. Most obviously, physical attributes of goods tend to make relative trade costs similar for all countries: a good which is heavier than some other good is heavier in every country, and thus the cost of moving it, say, 500 miles between two ports is higher than for the other good in every country.

As well as these similarities among countries of the costs of trade for particular goods, there are of course many differences. The costs of trade vary among countries with, for example, their geographical locations, the efficiency of their ports, the quality of their customs administrations, and the restrictiveness of their trade policies. Many of these country-specific variations raise or lower the costs of trading most goods. Many of them also alter the relative costs of trading different goods – an inefficient port, for

[2] Exceptions are Hillberry (2002), Koren (2004) and sundry analyses of specific tariffs (mainly in the industrial organisation literature, but also in Anderson and Neary (2005)). Melitz (2003) includes a fixed cost of trade for each firm, in addition to iceberg variable costs.

example, raises the relative trade costs of goods with high weight-to-value ratios that cannot economically be air-freighted.

What is rarely seen in practice, though often assumed in theory, is variation among countries in the relative costs of trading pairs of goods that parallels variation in the relative costs of producing them. There are important sources of parallel variation in absolute costs: in a country with higher wages or lower overall efficiency, both the costs of producing a good and the costs of putting it on a ship or selling it in a shop tend to be higher. But there is no general reason to suppose that a country which can produce a good relatively more cheaply, compared to some other good and some other country, is also able to trade it relatively more cheaply. In special cases, that may be so, but usually relative trade costs either do not vary among countries or vary in some way that is independent of variation in relative production costs.

How trade costs damp elasticities

Relative trade costs that vary among countries independently of relative production costs would not fundamentally alter the theory if price elasticities in world markets were strictly infinite. The pattern of non-traded ranges for goods and countries would change, and the models would become more complicated, but the story would remain basically the same. The situation is different if world demand functions already have some inelasticity, because then fixed trade costs will reduce the elasticity that matters most for the influence of trade on the composition of output – which relates variation in the quantities of goods sold to variation in the prices received by producers.[3]

As mentioned, it is widely agreed that differentiation by purchasers among goods by country of origin causes at least some degree of demand inelasticity. This inelasticity refers to the relationship between quantities sold and the prices paid by purchasers. But what affects production is the relationship between quantities sold and producer prices, meaning prices received at the factory or farm gate. Abstracting from indirect taxes and subsidies, the differences between purchaser prices and producer prices are

[3] In this sense, my argument resembles that of Obstfeld and Rogoff, who also combine trade costs with imperfect substitutability in use, and differs from that of Rauch and Trindade, whose model can explain low elasticities of substitution even if substitutability in use is perfect.

trade costs.[4] If trade costs are fixed (or vary independently of producer prices), variation in producer prices must be associated with proportionally smaller variation in purchaser prices and hence in quantities sold. Trade costs, in other words, cause demand to be less elastic for the producer than it is for the purchaser (a proposition with analogies and antecedents in industrial organisation theory).[5]

To see more clearly how fixed trade costs reduce producer price elasticities, consider a simple numerical example. The purchaser price elasticity of demand for a good is -10, so in the absence of trade costs, a country whose unit producer price was $5 would sell three times as much as a country whose unit producer price was $6. Now let the cost of trading this good for both countries be $5 per unit, so that purchaser prices are $10 and $11, narrowing the proportional gap from 20% to 10%. At these prices, the country with the lower producer price sells only twice as much: the elasticity of sales with respect to production costs is halved, from -10 to -5.

The degree to which elasticities are damped in this way clearly depends on the size of the fixed trade costs, relative to producer prices (which in competitive industries are equal to costs of production). In practice, they are big – the numerical example is not an exaggeration. Anderson and van Wincoop (2004) conclude that a representative ratio of trade costs to production costs for developed countries is 170%, of which international trade costs are 74%, and that trade costs in developing countries are even higher. Similarly large numbers emerge from comparisons in the value chain and fair trade literatures between the prices paid by consumers in developed countries and the prices received by producers in developing countries.[6] There is thus likely often to be heavy damping of purchaser price elasticities.

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[4] The term 'purchaser's price' means the same here as in the UN System of National Accounts, except that in the SNA it includes indirect taxes as well as trade costs. The SNA distinguishes 'producer's price' from 'basic price', which excludes more taxes. The term 'producer price' is used here for ease of understanding (dropping the SNA apostrophes on producer's and purchaser's for brevity).

[5] Simple examples, pointed out to me by *bon viveur* Sherman Robinson, being that the price elasticity of demand for a meal out is raised if a baby sitter also has to be hired, and similarly for a London theatre ticket if a train ticket to London also has to be purchased

[6] The costs of internationally traded intermediate inputs, which are much the same for all countries that produce the goods concerned, may have damping effects similar to those of trade costs (specifically, to internal trade costs, because they must be incurred by all suppliers to a market). This depends, though, on how the prices and quantities of goods are measured in production and trade statistics – net or gross of intermediate inputs. For simplicity, it will be assumed in this paper that the basis is always net.

The resulting producer price elasticities depend also on the levels of purchaser price elasticities. As already noted, it is crucial for the present argument that there be some purchaser price inelasticity. This is plausible in almost all circumstances, for two complementary reasons. One is less than perfect substitutability in use: even for basic commodities such as oil and grain, there are differences among supplier countries in the physical attributes of goods and in terms and conditions of supply. The other is limited information, as emphasised by Rauch and Trindade (2003): purchasers are not sure that goods from abroad are going to be what they want. Even so, purchaser price elasticities vary widely among goods – for some there is high substitutability and for some there is excellent information – and hence so do elasticities of sales with respect to variation in producer prices, some of which are still likely to be high.

Outline of the paper

The intuition that big trade costs, independent of producer prices, together with some purchaser price inelasticity, could explain why effective demand elasticities in trading economies are far from infinite, is simple. The details are less simple, largely because the damping mechanism is an awkward mixture of proportional differences and absolute differences, but the purpose of the rest of the paper is to show that it can be modelled with basic algebra in ways that generate sensible and useful results.

Section 2 formalises the damping mechanism for the simplest case of a single good, in one market and in many markets. Section 3 extends this formalisation to many goods, as is required for analysing the commodity composition of trade. This extension involves more approximations, whose accuracy is checked by numerical simulations in section 4. Section 5 looks more closely at purchaser price elasticities, which are also affected by trade costs. Section 6 explores the effects of trade costs on different sorts of producer price elasticities in a trading economy – demand for home sales, for exports and for imports – and on the ratio of exports to output. Section 7 concludes and discusses possible further research, including empirical testing.

To avoid misunderstandings, it is also worth flagging what is not in this paper. It is entirely theoretical. It is oriented to explaining the commodity composition of trade, not its direction. It does not present a complete model of trade: the focus is on the demand side, with little on the supply side. Such parts of the supply side as do appear are those of 'old' trade theory. Returns to scale are constant, firms identical, and industries perfectly competitive. Consumers distinguish among goods by country, but not firm, of origin. 'Fixed' trade costs refer to constancy among countries, not to the fixed costs firms incur in order to enter export markets in Melitz (2003) models.

2. Demand elasticities for a single good

Consider the simplest case of a single market in which sales, q_j, of good j vary with its purchaser price, p_j, according to the demand function

$$q_j = \alpha_j p_j^{\tilde{\varepsilon}_j} \tag{1}$$

where α_j reflects the size of the market and $\tilde{\varepsilon}_j$ is the purchaser price elasticity. Since the purchaser price is by definition the sum of the producer price, c_j, and the unit cost of trade, t_j, the demand function can be rewritten as

$$q_j = \alpha_j \left(c_j + t_j\right)^{\tilde{\varepsilon}_j} \tag{2}$$

from which, holding the trade cost per unit constant, the producer price elasticity of demand, ε_j, can be derived as

$$\varepsilon_j = \frac{\tilde{\varepsilon}_j}{1 + \tau_j} \tag{3}$$

where $\tau_j = t_j / c_j$. The producer price elasticity is smaller than the purchaser price elasticity, to a degree that depends on the ratio of the trade cost to the producer price.

This simple equation (3) is at the heart of the present paper, so it is worth explaining it more fully. Note that the ratio $1/(1 + \tau_j)$ is just the share of the producer price in the purchaser price, $c_j / (c_j + t_j)$, rewritten so as to make the role of the trade/producer price ratio more explicit. This share is the weight of producer price changes in purchaser price changes: thus

$$\hat{p}_j = \frac{c_j}{c_j + t_j}\hat{c}_j + \frac{t_j}{c_j + t_j}\hat{t}_j \qquad (4)$$

where hats denote proportional changes. If the unit trade cost is fixed ($\hat{t}_j = 0$), this reduces to

$$\hat{p}_j = \frac{c_j}{c_j + t_j}\hat{c}_j = \frac{1}{1 + \tau_j}\hat{c}_j \qquad (5)$$

Proportional differences in the purchaser price are therefore a fraction of proportional differences in the producer price, the fraction being the share of the producer price in the purchaser price. The relationship in (3) between the elasticities is a corollary.

Consider now many countries, indexed by superscripts $z = 1, \ldots., Z$, in each of which there are producers of good *j* and markets for good *j* (where there are two superscripts, the first refers to the origin and the second to the destination). Let the representative country be 1, whose producers of good *j* may sell it in their own and other national markets. Their producer price, assumed to be independent of the scale of production and the same for all firms, is c_j^1.

To sell in each market, *z*, firms in country 1 must incur a fixed trade cost per unit sold, t_j^{1z},which is specific to the good (some goods cost more to trade than others) as well as to the countries of origin and destination (some countries have better transport infrastructure than others, some destinations are further away than others). Internal trade costs are incurred even for sales in the home market, so that $t_j^{11} > 0$.

In each market, there is a demand function of the form (2), and country 1 firms sell up to the point at which the purchaser price covers the producer price plus trade cost, so that their total sales of good *j* across all markets are thus

$$q_j^1 = \sum_{z=1}^{z=Z} q_j^{1z} = \sum_{z=1}^{z=Z} \alpha_j^{1z} \left(c_j^1 + t_j^{1z}\right)^{\tilde{\varepsilon}_j^{1z}} \quad (6)$$

where α_j^z reflects the size of the market for *j* in country *z*, and $\tilde{\varepsilon}_j^{1z}$ is the purchaser price elasticity of demand for country 1 firms in that market.[7] The elasticity of total sales with respect to country 1 producer prices is

$$\varepsilon_j^1 = \sum_{z=1}^{z=Z} \frac{q_j^{1z}}{q_j^1} \frac{\tilde{\varepsilon}_j^{1z}}{\left(1+\tau_j^{1z}\right)} \quad (7)$$

where $\tau_j^{1z} = t_j^{1z} / c_j^1$, and is simply an average of the producer price elasticity in each market, weighted by the share of each market, q_j^{1z} / q_j^1, in country 1's total sales.

The elements of equation (7) and its simpler single-market form (3) will be examined more closely later: trade costs will be divided up, distinguishing particularly between internal and international trade; and the way in which elasticities vary among markets, particularly between home sales and exports, will be explored. But it is worth bearing in mind the limitations of these equations. Given the purchaser price elasticity, the producer price elasticity varies among countries with the level of trade costs, t_j, which are the numerator of τ_j and the focus of this paper. But the producer price elasticity also varies with the level of producer prices, c_j, which are the denominator of τ_j: there is thus not a unique relationship between trade costs and producer price elasticities, as will be discussed further in section 4.

3. Demand elasticities for many goods

To consider the composition of trade, the analysis must be extended to many goods, *j* = 1, …., *n*. Taking 1 as the numeraire, consider any pair of goods, *j* and 1. The relative sales of these goods by any country in any market (temporarily omitting the

[7] In practice, sales in many markets will be zero: the equation implies that some sales are made even where the trade cost is very high, but in reality there are fixed elements of trade costs which deter firms from entering markets in which sales would be small.

origin and destination superscripts to simplify the notation) depend on the country's relative purchaser prices in that market

$$\hat{q}_j - \hat{q}_1 = \tilde{\varepsilon}_{j1}\left(\hat{p}_j - \hat{p}_1\right) \qquad \text{(9: no 8)}$$

where $\tilde{\varepsilon}_{j1}$ depends on substitutability in demand between the two goods and between different national varieties of each good (as will be explained in section 5).

The elasticity of relative sales with respect to relative producer prices is obtained by substituting as in equation (5) for the purchaser price terms in equation (9) to obtain

$$\hat{q}_j - \hat{q}_1 = \tilde{\varepsilon}_{j1}\left\{\frac{\hat{c}_j}{1+\tau_j} - \frac{\hat{c}_1}{1+\tau_1}\right\} \qquad (10)$$

where $\hat{c}_j$ and $\hat{c}_1$ are proportional differences in the producer prices of goods *j* and 1, and τ_j and τ_1 are the ratios of trade cost to producer price for the varieties of these goods supplied by the country concerned to the market concerned. If these trade cost ratios were equal ($\tau_j = \tau_1 = \tau_{j1}$), equation (10) would simplify to

$$\hat{q}_j - \hat{q}_1 = \frac{\tilde{\varepsilon}_{j1}}{1+\tau_{j1}}\left(\hat{c}_j - \hat{c}_1\right) \qquad (11)$$

and the elasticity of the relative sales of this pair of goods with respect to their relative producer prices, just as for a single good above, would be lower than the elasticity of substitution with respect to their relative purchaser prices to a degree determined by the ratio of trade costs to producer prices.

Equation (11) is a convenient simplification, and shows clearly how trade costs can lower producer price elasticities, but it requires $\tau_j = \tau_1$. If these trade cost ratios are unequal, the relative sales of *j* and 1 depend on the two producer price differences individually, not just on their relative size. And as mentioned above, trade cost ratios can vary widely among goods, both because of variation in trade costs arising from characteristics of the goods and because of variation in producer prices.

When trade cost ratios differ, expression (11) can still be used by interpreting τ_{j1} as some average of τ_j and τ_1, but is inaccurate. The nature and extent of the inaccuracy depends on the sign and size of the difference between the trade cost ratios, relative to the signs and sizes of the producer price differences. Differences in relative purchaser prices are linked to producer prices and trade costs by

$$\hat{p}_j - \hat{p}_1 = \frac{\hat{c}_j}{1+\tau_j} - \frac{\hat{c}_1}{1+\tau_1} \qquad (12)$$

If the value of τ is the same in both terms on the rhs, both $\hat{c}$'s are reduced by the same proportion, and the equation simplifies as in (11). If, however, the value of τ differs between the terms on the rhs, then the $\hat{c}$ with the larger τ is reduced by proportionally more. This is so whether the $\hat{c}$'s are positive or negative (a fall in cost is shrunk more by a larger τ, just as is a rise in cost).

Table 1 shows how differences in τ's would affect the size of the difference in relative purchaser prices caused by a given difference in relative producer prices, compared to the purchaser price difference that would arise if the τ's were equal (at some level in between their actual values). The table applies to both rises and falls in the producer price of good *j* relative to good 1, and regardless of whether these are caused by different-sized rises in both *c*'s, by different-sized falls in both *c*'s, or by a rise in one *c* and a fall in the other.

Table 1 Effect of differing trade cost ratios on differences in relative purchaser prices

Relative size of differences in producer price	Direction of difference in trade cost ratios	
	$\tau_j > \tau_1$	$\tau_j < \tau_1$
$\lvert\hat{c}_j\rvert > \lvert\hat{c}_1\rvert$	Reduce	Increase
$\lvert\hat{c}_j\rvert < \lvert\hat{c}_1\rvert$	Increase	Reduce

The pattern is logical. A difference in trade cost ratios reduces the size of a relative purchaser price difference when it is in the same direction as the gap in the absolute sizes of the producer price differences (since this shrinks the bigger of the two producer price differences and enlarges the smaller). Conversely, a difference in trade cost ratios increases a relative purchaser price difference when it is in the opposite direction to the gap in the absolute sizes of the producer price differences (since this enlarges the bigger of the two cost differences and shrinks the smaller).

The inaccuracies in measuring the damping of relative purchaser price differences that result from averaging trade cost ratios have a similar pattern. Where a difference in trade cost ratios reduces a relative purchaser price difference (in either direction), averaging trade cost ratios makes the purchaser price difference seem larger than it actually is, and so understates the degree of damping. Conversely, where a difference in trade cost ratios increases a relative purchaser price difference, averaging trade cost ratios makes the purchaser price difference seem smaller than it actually is, and so overstates the degree of damping.

The degree of understatement or overstatement as a result of averaging is greater, the larger is the difference between the trade cost ratios, compared to the difference in relative producer prices. With averaged trade cost ratios, moreover, the outcome will always seem to be damping (relative purchaser prices varying in the same direction as, but less than relative producer prices), but in the subset of cases where the relative producer price difference arises from unequal differences in the same direction, large differences in trade cost ratios could cause the actual outcome to be not damping but amplification or a difference in the opposite direction (as explained in Appendix A).

4. Cross-country numerical simulations

The argument of this paper, to recapitulate, is that trade costs cause the elasticities of relative demand with respect to variation in relative producer prices, which are what matter for the effects of trade on the sectoral structure of output, to be lower than the corresponding elasticities with respect to relative purchaser prices. This is because the relative unit costs of trade are independent of relative producer prices, differences in which thus usually cause proportionally smaller differences in purchaser prices.

Sections 2 and 3 developed this argument algebraically – its simplest statement being in equation (11) – but also noted the imprecision of the resulting relationship between relative producer prices and relative purchaser prices. Inaccuracy arises if the τ's differ between the two goods, and thus must be averaged. The equations also assume the τ's to be constant with respect to changes in the c's, which is accurate only for small changes in the c's. Moreover, since the τ's vary across countries as a result of variation in both trade costs, t, and producer prices, c (because $\tau = t/c$), imprecision can arise also as a result of averaging across countries.

What matters in practice is not the existence of these inaccuracies, but their size and nature. In particular, is equation (11) a reasonable approximation, or is it seriously misleading or too imprecise to be useful? Numerical simulations can help to answer these questions, by comparing, for one pair of goods, j and 1, proportional differences across hypothetical countries, z, in relative producer prices

$$\ln\left\{\frac{c_j^z}{c_1^z}\right\} \tag{13}$$

with proportional differences in relative purchaser prices, which depend on the sum of producer prices and trade costs.

$$\ln\left\{\frac{p_j^z}{p_1^z}\right\} = \ln\left\{\frac{c_j^z + t_j^z}{c_1^z + t_1^z}\right\} = \ln\left\{\frac{c_j^z + t^z\left(1 + t_j\right)}{c_1^z + t^z\left(1 + t_1\right)}\right\} \tag{14}$$

Trade costs are made up of two elements. One is a country-specific cost of a given absolute size, t^z, that is common to both goods but varies among countries with, say, their locations and the quality of their transport infrastructure. The other is a pair of good-specific trade cost coefficients, t_j and t_1, which are common to all countries. These coefficients make the trade cost for the goods concerned proportionally higher or lower than the average for all goods in a country. Thus, for example, a heavy good would have a high coefficient and a light good a smaller one.

As in reality, the form of equation (14) makes the country-specific and good-specific trade costs partly additive and partly multiplicative. They are partly additive because some country-specific features affect trade costs for all goods similarly (for example, difficulty of contract enforcement). They are partly multiplicative because the impact on trade costs of many good-specific features depends also on features of the country: for example, transport cost depends both on the portability of the good concerned and on the location of the country concerned.[8]

The producer price for each country and each good is a random number between 1 and 10, drawn from a uniform distribution. The range of possible producer price ratios for the two goods $\left(c_j^z / c_1^z\right)$ is thus from 0.1 to 10, clustered around a median of 1: a hundred-fold variation among countries. Variation among countries in absolute producer prices, and in currency units, is not included because it cancels out in calculating producer price ratios (although on these assumptions the average producer price of the two goods varies quite widely among countries – its variance is roughly half that of the producer price of each of the goods individually).

The country-specific trade cost for each country, t^z, is a random number between 3 and 10, again drawn from a uniform distribution, which implies a threefold range of variation between countries with the lowest and the highest trade costs (Anderson and van Wincoop, 2004: 747, suggest 'a factor of two or more'). Different simulations use different values of the good-specific coefficients, but in the first to be discussed, $t_j = t_1 = 1$. At the medians of the distributions of c (5.5) and t^z (6.5), the value of τ for each good is thus about 2.4 (Anderson and van Wincoop, 2004, suggest an average of 1.7 for developed countries and higher values for developing countries).

Figure 1 plots the relationship between relative purchaser prices and relative producer prices for 200 'countries', which is roughly how many there are in the world and also

[8] The nature of the interaction between country-specific and good-specific trade costs varies among countries and goods, depending on the cause of the good-specific difference – e.g. weight-related or language-related? A single interaction between the two sorts of trade costs is a simplification.

a large enough number to make variation among different samples small (repeating the simulations with different random c's and t^z's hardly alters the results). The figure also shows an OLS regression line, whose equation is

$$\ln\left(p_j^z / p_1^z\right) = 0.001 + 0.258 \ln\left(c_j^z / c_1^z\right) \qquad R^2 = 0.911$$

The relationship between relative purchaser prices and relative producer prices in the figure is essentially log-linear (a cubic regression fits only fractionally better). In other words, the degree of damping is similar at all levels of relative prices. This is important because it would make the producer price elasticity equiproportionally less than the purchaser price elasticity over its whole range. In particular, if the purchaser price elasticity were constant, the producer price elasticity also would be constant.

The slope of the regression line, which measures the average degree of damping, is more or less what would be expected from the trade cost ratios. The mean value of $1/(1 + \tau)$, averaged first across the two goods and then across all countries, is 0.29, which is close to, though somewhat greater than, the slope coefficient of 0.26.[9] In other words, the proportional variation of relative purchaser prices across countries is less than one third as large as the proportional variation in relative producer prices.

As expected, the relationship across countries between variation in relative purchaser prices and in relative producer prices is not exact. However, it fits tightly, with an R^2 above 0.9, which is high by the standards of cross-country regressions. The scatter is particularly tight in the middle of the producer price ratio range, near the origin.[10] This is because of the assumption that $t_j = t_1$, which makes trade costs the same for both goods in each country: thus if c_j^z / c_1^z is close to unity, so must be p_j^z / p_1^z. Where the producer price ratios differ widely from unity, in either direction, the scatter is looser. This is because each c_j^z / c_1^z can be generated by many different

[9] This mean value is greater than that implied by the ratio of the medians mentioned earlier because the distribution of τ (the ratio of two uniformly distributed random variables) is asymmetric. Appendix B shows how the slope can be interpreted in terms of the bias caused by omitting trade costs.
[10] The concentration of observations in the middle of the distribution thus contributes to the high R^2.

pairs of c_j^z and c_1^z: given the absolute trade costs for the two goods, the value of p_j^z / p_1^z depends on whether both c_j^z and c_1^z are absolutely high or absolutely low.[11]

Table 2 reports results with alternative values of t_j and t_1. The first three experiments raise and lower both t's in parallel, at values ranging from 0.4 to 1.8. The last four experiments involve differences between t_j and t_1 of varying sizes (roughly two-fold, four-fold and nine-fold) in both directions. The middle three columns report the slope coefficient, the mean value of $1/(1 + \tau)$ for all countries and both goods, and the ratio of the slope to this predicted value. The last two columns show the R^2's of the linear regression and of a cubic regression (as a test for linearity).

In all cases, the relationship between relative purchaser prices and relative producer prices remains roughly log-linear. Differences between t_j and t_1 widen the margin of superiority of fit of the cubic regression over the linear one, but never to a degree that challenges the linear regression as an excellent approximation to the true form of the relationship.[12] The slopes of the regressions vary in parallel with the predictions from average trade cost ratios. In all cases, the slope, which measures the actual damping of variation of relative purchaser prices across countries compared to variation in their relative producer prices, is smaller than the predicted value – implying more than the predicted degree of damping. But the predictions are fairly close (in all cases about 10% more than the estimated slope).

Parallel increases in t_j and t_1 (which are equivalent to across-the-board increases in t^z for all countries) somewhat reduce the closeness of fit of the linear regression, which is further reduced by the introduction of differences between t_j and t_1. But even when one of these t's is nine times the other, which, in conjunction with variation in c_j^z / c_1^z,

[11] The direction of this effect depends on whether the producer price ratio is above or below unity. In the left-hand half of figure 1, the points above the line are those with lower absolute producer prices and the points below the line are those with higher absolute producer prices. In the right-hand half of the figure, this relationship is reversed. Variation in trade costs, t^z, among countries also contributes to the scatter around the line. In particular, if t^z did not vary among countries, the scatter would be tight at both ends of the producer price ratio distribution, as well as in the middle, because extreme values of the producer price ratio can be generated by only a few pairs of values of c_j and c_1. As will be seen, this happens in figure 3, which controls for variation in trade costs among countries.

[12] If the distribution of c's is widened to include values between 0 and 1, which greatly widens the range of possible producer price ratios, the relationship flattens at the top and bottom, resembling a logistic curve. Hints of this logistic shape can be seen in almost all the cubic regressions.

results in a near-fifty-fold variation in τ_j^z / τ_1^z (Anderson and van Wincoop, 2004: 747, mention 'factors of as much as ten or more'), R^2 remains over 0.8.

Figure 2 shows the scatter and regression line for the case of $t_j = 1.6$ and $t_1 = 0.4$. The slope is similar to that of figure 1 (in which $t_j = t_1 = 1$), but the inequality between the t's means that the intercept is no longer at the origin.[13] As in figure 1, the scatter is tightest where the producer price ratio equals the trade cost ratio (1.86 = (1 + 1.6)/(1 + 0.4), or in logs 0.62). The scatter is much looser for producer price ratios below this point than above it: this is because, if the trade costs of two goods differ in the opposite direction to their producer prices, the effect of variation in their absolute producer prices on their relative purchaser price is increased (and vice versa).

These results relate to the average degree of damping of demand elasticities by trade costs across all countries. It may also be wondered, however, whether it is possible to capture with reasonable accuracy variation in the degree of damping among countries caused by variation in their own trade costs. The answer to this question matters a lot for the central argument of the present paper, which is that a country's openness is a matter of degree, measured by the elasticity of demand for its products and dependent on the level of its trade costs.

This issue is explored by running regressions similar to those discussed above, except that each country's log producer price ratio is adjusted by its average trade cost ratio, which makes the independent variable

$$0.5\left(\frac{1}{1+\tau_j^z} + \frac{1}{1+\tau_1^z}\right)\ln\left\{\frac{c_j^z}{c_1^z}\right\} \tag{15}$$

where $\tau_j^z = t^z\left(1+t_j\right)/c_j^z$ and similarly for τ_1^z. Looked at another way, the adjustment factor is the unweighted mean of the shares of the producer prices in the purchaser prices of the two goods for the country concerned. The lower is this share, as a result

[13] The predicted intercept is $\ln((5.5 + 6.5(1 + t_j))/(5.5 + 6.5(1 + t_1)))$, 5.5 being the median of each of the c's and 6.5 the median of t^z. The actual intercepts conform closely with this prediction.

of higher trade costs, the lower is the effect on relative purchaser prices of changes in relative producer prices (and so the lower is the producer price elasticity of demand).

This adjustment to producer prices tends to correct for variation in trade costs among countries. The question is how accurately it does so or, in other words, how well this simple (and potentially practical) adjustment to the producer price ratio allows it to approximate the true behaviour of the purchaser price ratio, given (from 14) by

$$\ln\left\{\frac{c_j^z + t^z\left(1+t_j\right)}{c_1^z + t^z\left(1+t_1\right)}\right\} \qquad (16)$$

The results in table 3, for the same cases as in table 2, suggest that it is an excellent approximation. In particular, the slope coefficient is close to (though a bit lower than) its ‘ideal’ value of unity in all cases. The adjustment of the cost ratio also raises the R^2 of the regressions by between 5 and 10 percentage points, compared to those in table 2 (which were already high). The intercepts are essentially unchanged, and the regressions are all, as in table 2, close to log-linear.

Figure 3 shows the scatter and regression line from table 3 for the same case as figure 2, namely $t_j = 1.6$ and $t_1 = 0.4$. The change of horizontal scales disguises the steeper slope in figure 3 than in figure 2, but the closer fit is apparent from the tighter scatter at below-average values of the producer price ratio. The scatter of points in figure 3 is less heteroskedastic than in figure 2 also because there is no longer a tight bunching around the regression line in a particular part of its range, as in figures 1 and 2.

To summarise, the simulations suggest that equations of the form (11), which describe in a simplified way how trade costs damp the effect of variation in relative producer prices on relative purchaser prices, are good approximations, despite their inherent imprecision. They generate predictions about the damping of demand elasticities that are correct in direction and close in size. The relationships are conveniently log-linear and fit well by the standards of cross-country regressions. Variation among countries in the degree of damping is well explained by variation in their trade costs.

5. A closer look at purchaser price elasticities

With origin and destination superscripts restored, equation (11) becomes

$$\hat{q}_j^{1z} - \hat{q}_1^{1z} = \frac{\tilde{\varepsilon}_{j1}^{1z}}{1+\tau_{j1}^{1z}}\left(\hat{c}_j^1 - \hat{c}_1^1\right) \tag{17}$$

which shows how the relative sales of goods *j* and 1 by country 1 in market *z* depend on its relative producer prices and on its trade costs for these goods in this market. The previous section examined one of the ingredients of this equation: the relationship between relative purchaser prices and relative producer prices, which is damped by trade costs. This section examines its other ingredient: the purchaser price elasticity, which governs the relationship between relative purchaser prices and relative sales, and is also (as will be shown) affected by trade costs.

The purchaser price elasticity, which refers to one country's relative sales of these two goods, must depend on substitutability in demand both between the two goods and between different national varieties of each good. More precisely (from Appendix C),

$$\tilde{\varepsilon}_{j1}^{1z} = \beta_{j1} + s_{j1}^{1z}\left(\gamma_{j1} - \beta_{j1}\right) \tag{18}$$

where γ_{j1} is the elasticity of substitution between the goods, s_{j1}^{1z} is country 1's average share of market *z* for these goods, and β_{j1} is an average of the elasticities for goods *j* and 1 that relate a country's market share to the price of its own variety relative to the average price of all varieties.

Equation (18) resembles the familiar derived demand formula, and its interpretation is clearer if it is rewritten as

$$\tilde{\varepsilon}_{j1}^{1z} = \left(1 - s_{j1}^{1z}\right)\beta_{j1} + s_{j1}^{1z}\gamma_{j1} \tag{19}$$

The purchaser price elasticity is thus a weighted average of the elasticity reflecting substitution among national varieties, to which it is close with a small market share, and the elasticity of substitution between the goods, to which it is close with a large market share. Since β_{j1} is usually larger (in absolute size) than γ_{j1}, a bigger country 1 share of market z tends to reduce the purchaser price elasticity, which is lower also if national varieties are poor substitutes for each other or the goods are poor substitutes for each other. With a small market share and high substitutability among varieties, the purchaser price elasticity would approach infinity, as in standard trade models.

Equation (18) is illuminating and useful, but an approximation (as is shown by all the 'averages' in its description above). The β's and γ's are assumed to be the same for all countries of origin and destination (and so have no superscripts). In addition, the β's and s's are averaged across the two goods: this makes the equation inaccurate because, unless $\beta_j = \beta_1$ and $s_j = s_1$, changes in relative sales depend on changes in p_j and p_1 individually, and not just on changes in p_j / p_1. Neither equality is plausible: substitutability among national varieties varies among goods (lower for cars than for wheat); and a country's market share may vary widely from good to good.

The seriousness of the inaccuracy depends on the size of the differences in the β's and s's, compared (in proportional terms) to the size of the differences in relative prices. With small differences in relative prices, even small differences between β's and s's can make equation (18) highly inaccurate – possibly mispredicting even the direction of the difference in relative sales caused by a difference in relative prices, as well as its magnitude. But if the differences in relative prices are large – for example across highly dissimilar countries – compared to the differences between the β's and s's, the simplified expression is a reasonable approximation.

A simple (though again approximate) equation to explain the average market share is

$$s_{j1}^{1z} = \mu^{1}\left(\frac{p_{j1}^{1z}}{\bar{p}_{j1}^{z}}\right)^{\beta_{j1}} \qquad (20)$$

Country 1's share thus depends on its average purchaser price for goods *j* and 1 in market *z*, p_{j1}^{1z}, relative to the overall average price for these two goods in this market, $\overline{p}_{j1}^{z}$, and on the elasticity β_{j1}. The share depends also on country 1's economic size: μ^1 is its share of total potential supply capacity (larger countries have potentially more optimal-scale plants) and is what its share would be if its average price were equal to the overall average. It is clearer for most purposes to rewrite (20) as

$$s_{j1}^{1z} = \mu^1 \left(\frac{p_{j1}^{1}}{p_{j1}^{*}} \right)^{\left(1-s_{j1}^{1z}\right)\beta_{j1}} \tag{21}$$

in which the price ratio is that between country 1's prices and the average prices of foreign suppliers, denoted by the usual * superscript (though this makes the elasticity itself dependent on the share).[14] This equation can be expanded as

$$s_{j1}^{1z} = \mu^1 \left(\frac{c_{j1}^{1}\left(1+\tau_{j1}^{1z}\right)}{c_{j1}^{*}\left(1+\tau_{j1}^{*z}\right)} \right)^{\left(1-s_{j1}^{1z}\right)\beta_{j1}} \tag{22}$$

to show separately the effects on purchaser prices of producer prices and trade costs: c_{j1}^{1} is country 1's average producer price for goods *j* and 1, and c_{j1}^{*} is the average producer price for these goods in other countries. The ratio c_{j1}^{1}/c_{j1}^{*} depends on the pair of goods and the identity of country 1: it measures the absolute advantage of country 1 in these two goods together, and differs from the relative ratios, c_j^1/c_1^1 and c_j^*/c_1^*, which measure the comparative advantage of country 1 in good *j* relative to good 1, and of which the first appears in the final term of equation (17).[15]

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[14] Equation (21) is derived from equation (20) by assuming the overall average price to be a share-weighted geometric average of country 1 and foreign-supplier prices. An alternative would have been to make the elasticity in (20) dependent on the market share, and the elasticity in (21) independent of it, but this would have made most of the algebra more complicated. These elasticities are related to, but differ from, the elasticity of substitution among national varieties, which determines the *ratio* of country 1-firm to foreign-firm sales, rather than the country 1-firm *share* of the market (discussed further in Appendix D). Anderson and van Wincoop (2004: 707-8) link this share to the elasticity of substitution by using a CES purchaser price index, but that approach would make other aspects of the algebra in this paper more complicated.

[15] The second relative ratio does not appear in this equation because it is assumed that rest-of-the-world relative producer prices are constant – i.e. roughly the same for all individual countries.

Combined with equations (18) and (22), equation (17) thus becomes

$$\hat{q}_j^{1z} - \hat{q}_1^{1z} = \frac{1}{1+\tau_{j1}^{1z}} \left\{ \beta_{j1} + \left(\gamma_{j1} - \beta_{j1}\right)\mu^1 \left(\frac{c_{j1}^1 \left(1+\tau_{j1}^{1z}\right)}{c_{j1}^* \left(1+\tau_{j1}^{*z}\right)} \right)^{\left(1-s_{j1}^{1z}\right)\beta_{j1}} \right\} \left(\hat{c}_j^1 - \hat{c}_1^1\right) \qquad (23)$$

in which country 1's own trade cost ratio, τ_j^{1z}, appears twice, with opposed effects: as before, it makes the producer price elasticity lower than the purchaser price elasticity (the first term); but it can now be seen also to raise the purchaser price elasticity by lowering country 1's share of market *z*. The trade costs of other countries, too, affect country 1's share of market *z* and hence appear in this expanded expression.

6. Home sales, exports and imports

Equation (23) is a general relationship, which describes the dependence of country 1's sales in any market, *z*, on its producer prices and on trade costs. Home and export markets, however, are affected by trade costs in different ways. The purpose of this section is to explore these differences by developing more specialised relationships for the producer price elasticity of demand in a country's home market and in its export markets, as well as for output as a whole and for imports.

To develop equation (23) into specialised equations for home sales and exports, trade costs need to be divided into their internal or domestic (*D*) and international or foreign (*F*) components

$$t_j^{1z} = t_j^{Dz} + t_j^{1Fz} \qquad (24)$$

where t_j^{Dz} is the cost to any supplier of selling one unit of good *j* in market *z* (internal transport, wholesale and retail margins), and t_j^{1Fz} is the additional cost for a supplier from a country $1 \neq z$ (international transport, insurance, legal and language expenses). To simplify the algebra, when using the ratios of these trade costs to producer prices, it will be assumed that τ_j^{Dz} is equal for all suppliers in market *z*, which is inaccurate because the producer price denominator varies, although the trade cost numerator is the same. It will also be assumed that the internal and international trade cost ratios, which should strictly just be added together, can be combined in the form

$$\left(1+\tau_j^{1z}\right)=\left(1+\tau_j^{Dz}\right)\left(1+\tau_j^{1Fz}\right) \tag{25}$$

The relative *home sales* equation, in which the destination superscripts are 1's rather than *z*'s, is thus

$$\hat{q}_j^{11}-\hat{q}_1^{11}=\frac{1}{1+\tau_{j1}^{D1}}\left\{\beta_{j1}+\left(\gamma_{j1}-\beta_{j1}\right)\mu^1\left(\frac{c_{j1}^1}{c_{j1}^*\left(1+\tau_{j1}^{*F1}\right)}\right)^{\left(1-s_{j1}^{11}\right)\beta_{j1}}\right\}\left(\hat{c}_j^1-\hat{c}_1^1\right) \tag{26}$$

The foreign trade costs of home suppliers, τ_j^{1F1}, are by definition zero and so do not appear in the market share term, from which τ_j^{D1} also vanishes by cancellation, since it is assumed to be equal for home and foreign suppliers. However, the elasticity of country 1's relative home sales with respect to its relative producer prices is reduced by internal trade costs. This elasticity is reduced also by the international trade costs of foreign suppliers: the higher the barriers to entry of other countries into its home market, the higher is country 1's market share, and hence the lower is the elasticity of its relative sales with respect to its relative purchaser and producer prices.

If the international trade costs of both goods were prohibitively high, causing them to be non-traded, the average market share of home producers would be unity, and the elasticity in (26) would reduce to $\gamma_{j1}/\left(1+\tau_{j1}^{D1}\right)$. If, by contrast, the international trade costs of both goods were close to zero (and c_{j1}^1/c_{j1}^* close to unity, as in an 'average' country), foreign suppliers would have most of the home market, and the elasticity would approach $\beta_{j1}/\left(1+\tau_{j1}^{D1}\right)$. If one of the goods were non-traded and the other had low trade costs, equation (26) would in principle still apply, but the averaging of very different trade cost ratios would make it more than usually imprecise.

The relative *export sales* equation, in which for simplicity all export markets are taken to be a single market and the destination superscript z is replaced by X (referring to the total of all destinations $z \neq 1$), is

$$\hat{q}_j^{1X} - \hat{q}_1^{1X} = \frac{1}{\left(1+\tau_{j1}^{DX}\right)\left(1+\tau_{j1}^{1FX}\right)} \left\{ \beta_{j1} + \left(\gamma_{j1} - \beta_{j1}\right)\mu^1 \left(\frac{c_{j1}^1\left(1+\tau_{j1}^{1FX}\right)}{c_{j1}^*\left(1+\tau_{j1}^{*FX}\right)} \right)^{\left(1-s_{j1}^{1X}\right)\beta_{j1}} \right\} \left(\hat{c}_j^1 - \hat{c}_1^1\right) \quad (27)$$

The elasticity of country 1's relative export sales with respect to its relative producer prices is unambiguously reduced by internal trade costs in export markets (which damp producer price differences) and by the international trade costs of foreign countries (which raise country 1's share of export markets, reducing its purchaser price elasticity).[16] The effect of country 1's own international trade costs, however, is in principle ambiguous: a higher τ_{j1}^{1FX} tends to raise the export market purchaser price elasticity (by reducing market share), but also to push the producer price elasticity further below the purchaser price elasticity.

Because the typical country is small (μ^1 is low) and because, in an average country, $c_{j1}^1\left(1+\tau_{j1}^{1FX}\right) / c_{j1}^*\left(1+\tau_{j1}^{*FX}\right) \approx 1$, it is usually reasonable to assume that country 1's share of export markets is negligibly small, which simplifies (27) to

$$\hat{q}_j^{1X} - \hat{q}_1^{1X} = \frac{\beta_{j1}}{\left(1+\tau_{j1}^{DX}\right)\left(1+\tau_{j1}^{1FX}\right)} \left(\hat{c}_j^1 - \hat{c}_1^1\right) \quad (28)$$

in which the purchaser price elasticity reflects only substitutability among varieties, but the producer price elasticity is reduced by internal trade costs in export markets. It is reduced also by country 1's own international trade costs, whose effects are no longer ambiguous: the more costly it is for suppliers in country 1 to sell in foreign markets, because of their country's location, infrastructure or policies, the less are its relative exports of goods j and 1 affected by its relative producer prices.

[16] In a two-country world, τ_{j1}^{*FX} would be zero, since the export market would be the home market of foreign suppliers, in which they would not incur international trade costs.

In principle, the producer price elasticity for exports could be either higher or lower than for home sales. The export market trade cost ratio $\left(1+\tau_{j1}^{DX}\right)\left(1+\tau_{j1}^{1FX}\right)$ is usually higher than in the home market $\left(1+\tau_{j1}^{D1}\right)$ because of the extra costs of international trade, which tends to make the export elasticity lower.[17] Pulling the other way, however, the additional trade costs incurred by foreign suppliers are likely to cause the home market share to exceed the export market share, making the purchaser price elasticity higher in the export market (more dependent on the elasticity of substitution among national varieties of a good) than in the home market (closer to the elasticity of substitution among goods).

In practice, two weaknesses of the available data also tend to make producer price elasticities for exports appear higher than for home sales. One weakness is that data on exports and home sales are aggregates of many items, between which trade costs systematically differ. For instance, if the 'good' is manufacturing, low-trade-cost items such as garments are over-represented in the export aggregate, while high-trade-cost items such as cement are over-represented in home sales. As a result, local firms tend to have larger shares of, and so face lower purchaser (and hence producer) price elasticities in, markets for manufactures that are sold mainly at home, while the higher purchaser price elasticities in export markets (where shares are lower) are less heavily damped by trade costs, which are on average lower for the sorts of manufactures that are exported than for those that are sold at home.

The other weakness is that the data are usually measured in value rather than volume, and that the relative purchaser prices of goods sold in home markets may vary across countries in ways which offset variation in relative volumes (where outputs are lower, prices are higher). This could cause estimated elasticities in home sales regressions to be lower than in export regressions, where, although the dependent variable is also in value terms, the relative purchaser prices of goods vary less among countries than for home sales, so that variation in value is a better measure of variation in volume.

[17] Though the opposite is possible, for example, if producers were on the coast of a large country with bad internal transport facilities

It is worth considering also the producer price elasticity of a country's relative outputs in total, including both home sales and export sales. Changes in relative outputs are a weighted average of changes in home sales and exports

$$\left(\hat{q}_j^1 - \hat{q}_1^1\right) = x_{j1}^1\left(\hat{q}_j^{1X} - \hat{q}_1^{1X}\right) + \left(1 - x_{j1}^1\right)\left(\hat{q}_j^{11} - \hat{q}_1^{11}\right) \qquad (29)$$

where x_{j1} is the average ratio of exports to output for goods j and 1, and hence

$$\left(\hat{q}_j^1 - \hat{q}_1^1\right) = \left[x_{j1}^1 \varepsilon_{j1}^{1X} + \left(1 - x_{j1}^1\right)\varepsilon_{j1}^{11}\right]\left(\hat{c}_j^1 - \hat{c}_1^1\right) \qquad (30)$$

where ε_{j1}^{11} and ε_{j1}^{1X} are the producer price elasticities implied by equations (26) and (27) respectively. Whether a higher average export/output ratio increases or decreases the producer price elasticity of relative outputs depends on whether the producer price elasticity of exports is higher or lower than the producer price elasticity of home sales. If, as argued above, measured producer price elasticities are usually higher for exports than for home sales, then countries with higher export/output ratios will have higher elasticities of relative total outputs with respect to relative producer prices.

Producer price elasticities of relative outputs tend to be lower in countries with higher trade costs. The main reason is that higher trade costs reduce elasticities in both home markets (ε_{j1}^{11}) and export markets (ε_{j1}^{1X}) – though in rather different ways, especially for international trade costs, which act on home sales by reducing the purchaser price elasticity and on export sales by pushing the producer price elasticity further below the purchaser price elasticity. Higher trade costs, especially international trade costs, further reduce the producer price elasticity of demand for relative outputs by lowering the average export/output ratio (x_{j1}^1), thus decreasing the weight of (what is usually) the higher of the two individual elasticities.[18]

[18] Equation (30) can be expanded by substituting from equations (26), (28) and (31) and differentiated with respect to trade costs, but the resulting expression is extremely messy.

The influence of trade costs on the average export/output ratio (which is often used in itself as a measure of openness and as an indirect measure of the height of trade costs) is summarised in

$$x_{j1}^{1} = \left[1 + \tilde{\mu}^{1} \left(\frac{\left(1 + \tau_{j1}^{*FX}\right)}{\left(1 + \tau_{j1}^{*F1}\right)\left(1 + \tau_{j1}^{1FX}\right)} \right)^{\left(1 - s_{j1}^{1}\right)\beta_{j1}} \right]^{-1} \tag{31}$$

The key element of this equation is the big term in the square bracket, which refers to the ratio of home sales to exports and is converted by the [1 + *term*]$^{-1}$ operation into a ratio of exports to output (or total sales). The home sales/exports ratio is by definition the product of the two other ratios that are combined in this term. One is the ratio of country 1's average home market share to its average export market share (dividing the share term in equation 26 by the share term in equation 27).[19] The other ratio is the size of the home market for these two goods relative to that of all export markets, which depends on the economic size of country 1: this is denoted by $\tilde{\mu}^{1}$ because it is likely to be similar to μ^{1}, country 1's share of world supply potential, but adding a tilde as a reminder that it is a share of world demand rather than of world supply.[20]

Equation (31) shows that export/output ratios tend to be lower in bigger countries, as in reality, but are affected also by three aspects of international trade costs (internal trade costs have cancelled out). Country 1's ratio of exports to output is increased by: higher international trade costs for foreigners in export markets and lower country 1 international trade costs in export markets (both of which raise country 1's export market share); and by lower costs of foreign entry into country 1's market (which reduce country 1's home market share).

These three aspects of international trade costs are likely in some ways to be related to one another. For example, high transport costs, caused by remote location or poor infrastructure, increase both τ_{j1}^{*F1} (the cost to foreign firms of supplying the country 1

[19] To simplify the equation, the market share in the exponent of the price ratio is taken to be an average of those in the home and export markets.
[20] The supply-side μ^{1} terms in equations (26) and (27)cancel out in the derivation of (31).

market) and τ_{j1}^{1FX} (the cost to country 1 firms of supplying foreign markets).[21] Over time, too, all three aspects of costs may change in parallel, for example as improved global transport systems lower everyone's trade costs. In other respects, though, the three aspects are independent: for instance, high tariffs in country 1 could increase τ_{j1}^{*F1} without affecting τ_{j1}^{1FX}; and the trade costs of country 1 exporters, τ_{j1}^{1FX}, could be either higher or lower than the average for other exporters, τ_{j1}^{*FX}.

Since purchasers distinguish among different national varieties of goods, imports are not (as in standard models) simply negative exports, but need a separate explanation. Relative imports are related to country 1's relative producer prices by the following equation (derived, with a health warning, in Appendix D)

$$\hat{q}_j^{M1} - \hat{q}_1^{M1} = (\gamma_{j1} - \beta_{j1})\left[\mu^1\left(\frac{c_{j1}^1}{c_{j1}^*(1+\tau_{j1}^{*F1})}\right)^{(1-s_{j1}^{11})\beta_{j1}}\right]\frac{\hat{c}_j^1 - \hat{c}_1^1}{1+\tau_{j1}^{D1}} \qquad (32)$$

where M refers to the total of all origins $z \neq 1$. The elasticity is positive (because β is absolutely larger than γ, and both are negative): intuitively, higher relative producer prices cause higher relative imports, though their effects are damped by internal trade costs. Its size depends on the difference between the purchaser price elasticities of demand for the good as a whole and for its local variety, $\gamma_{j1} - \beta_{j1}$ (imports being the difference between total sales in a country and the sales of local producers). A higher β_{j1} raises the import elasticity, because a higher price for the local variety then causes a bigger shift to foreign suppliers. A higher γ_{j1} lowers the elasticity because a higher price for the local variety then causes more of a reduction in total sales of the good.

The size of this elasticity is affected also by country 1's share of its home market, and thus by the international trade costs of foreign suppliers, τ_{j1}^{*F1}. The higher the barriers to entry into this market, the bigger is country 1 suppliers' share of it, and hence the bigger also are the effects on relative imports of changes in the relative purchaser prices of country 1 suppliers. If their market share were small, so would be the

[21] These two aspects of international trade costs correspond, respectively, with what Anderson and van Wincoop (2004) label 'inward resistance' and 'outward resistance'.

elasticity, since if local suppliers had little of the local market, changes in their relative prices could not have much effect on the relative sales of foreign suppliers. Thus in contrast to the elasticities for exports, home sales and output, the producer price elasticity for imports is raised rather than lowered by higher trade costs.

The absolute size of the producer price elasticity of demand for imports could in principle be either larger or smaller than that for exports (equations 27 and 28). The export purchaser price elasticity, β_{j1}, must exceed the import purchaser price elasticity, which cannot be larger than ($\gamma_{j1} - \beta_{j1}$), but trade costs normally have a stronger damping effect for exports $\left(1+\tau_{j1}^{DX}\right)\left(1+\tau_{j1}^{1FX}\right)$ than for imports $\left(1+\tau_{j1}^{D1}\right)$. The former difference seems likely usually to outweigh the latter, making the producer price elasticity greater for exports then for imports. The difference in elasticities in this direction, moreover, may be widened in practice by aggregation effects.[22]

7. Conclusions

This paper argues that the usual sharp theoretical distinction between open and closed economies – infinite versus finite demand elasticities – is less helpful than recognising that openness is a matter of degree, and that demand elasticities vary among countries as fairly continuous inverse functions of the levels of their trade costs. The basis for this argument is the fact that variation among countries in the relative costs of trading goods is fundamentally independent of variation in the relative costs of producing them. When coupled with less-than-perfect substitutability among goods of different national origins, the independence of trade costs damps the elasticity of relative sales with respect to variation among countries in relative production costs. Because trade costs are often high, moreover, so usually is the degree of damping.

It has been shown in the paper that these relationships can be modelled algebraically, yielding equations that illuminate the effects of trade costs on variation in elasticities

[22] Exports and imports tend to be items with trade costs below those of items sold by local producers on the home market. The market share of home producers is thus lower than it would be if all items had equal trade costs, which (from equation 32) lowers the import elasticity. Similarly, the international trade cost ratio in the denominator of (28) tends to be lower, which raises the export elasticity.

among goods and countries and between export markets and home markets. Some of the algebra is complicated, but for many purposes one can use the simple equation

$$\varepsilon_{j1} = \frac{\tilde{\varepsilon}_{j1}}{1 + \tau_{j1}} \qquad (33)$$

which shows how the producer price elasticity of relative demand rises as trade costs fall. The purchaser price elasticity in the numerator is also affected by trade costs, but the direction of this effect is usually such as to reinforce the more transparent impact of trade costs in the denominator. The algebra involves approximations, so that the relationships between relative producer prices and relative sales are imprecise, but numerical simulations show that the approximations are close enough to make the algebra meaningful and usable for cross-country empirical analysis.[23]

The approach of this paper brings trade costs into the core of trade models, where they belong. It could make 'old' trade theory, both Heckscher-Ohlin and Ricardian, more realistic – not predicting extreme specialisation or high sensitivity to small changes in prices – without loss of rigour or behavioural plausibility (and without a net increase in complexity, since it would reduce the number of cases that need to be considered). Most of the insights of the old theories would remain relevant, though in less strong forms. Wood (2007) makes a start for Heckscher-Ohlin theory, whose properties alter in similar ways as with rising trade costs in Deardorff (2006). The relevance of this paper's treatment of trade costs to newer trade theories may also merit exploration.

A vital question, of course, is whether the argument of this paper is factually correct. It seems already well established (as explained in section 1) that demand elasticities in trading economies are far than infinite. What is not well established is why, and more specifically whether the main reason is trade costs, as argued in this paper. A strategy for empirical testing should include a review of the many econometric estimates of import price elasticities, but these are not the most relevant demand elasticities in the context of this paper, since they are estimated using data on purchaser prices in the country of destination rather than producer prices in the country of origin.

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[23] In principle, the algebra applies also to changes over time, but because changes in relative producer prices are likely to be small and slow, the predictions of the algebra are likely to be much less accurate.

More relevant would be re-analysis of existing estimates of *export* price elasticities, to test for inverse relationships between these elasticities and levels of trade costs, across countries and across goods. In addition, it would be illuminating to examine whether and to what extent the predictions of multi-country empirical models of trade and production (econometric and global CGE) were improved by including the demand-side specification proposed in this paper. Use could be made both of existing models (for example, Trefler, 1995, and perhaps GTAP) and of newly constructed models. The key test would be whether the degree of specialisation in production (relative to what would be predicted from other causes such as factor endowments) was inversely and fairly continuously related to the level of a country's trade costs.

These approaches to testing are hampered by the limited availability of data on trade costs, especially other than those imposed by policy barriers, and especially of a direct kind (rather than, for example, inferred from gravity models, as in Anderson and van Wincoop, 2004). Another challenge is to disentangle trade costs from other causes of less-than-infinite elasticities, including imperfect substitutability in use (Armington, 1969) and lack of information (Rauch and Trindade, 2003). The ideal would be a decomposition, with purchaser price elasticities reduced to finite levels by imperfect substitutability and limited information, and producer price elasticities further reduced by trade costs, but estimation would be tricky, partly because of overlaps between the available proxies for trade costs and for barriers to information flows.

A lot of thought and work would thus be needed to design and implement satisfactory empirical tests of the propositions in this paper. However, there are enough data and enough hopes of clear-cut results, as well as enough potential benefits to subsequent theoretical and empirical analyses of trade, to make the effort seem worthwhile.

Appendix A: Cases where trade costs do not damp elasticities

As noted in section 3, averaging trade cost ratios across goods will always make trade costs seem to damp producer price changes (relative purchaser prices changing in the same direction as, but by less than, relative producer prices). But where the relative producer price difference arises from unequal differences *in the same direction*, large enough differences in trade cost ratios could cause the outcome to be not damping but relative purchaser prices moving in the opposite direction to relative producer prices, or in the same direction but by more (amplification). This appendix explains further.

Where the error from averaging trade cost ratios is in the direction of *understatement* of damping, and the producer prices of both goods differ in the same direction,[24] a big enough difference in trade cost ratios could cause no difference in relative purchaser prices, and an even bigger difference in trade cost ratios could reverse the direction of the effect (e.g. higher relative producer prices, but lower relative purchaser prices). The condition for remaining within the damping range in this direction is

$$\left|\frac{1+\tau_j}{1+\tau_1}-1\right| \le \left|\frac{\hat{c}_j}{\hat{c}_1}-1\right| \qquad \text{(A1)}$$

or, in words, that the ratio of the producer price differences is further from unity than the ratio of the trade cost terms (bearing in mind that in cases of understatement both ratios must diverge from unity in the same direction). At the boundary, where (A1) is an equality, the rhs of (12) becomes zero, and beyond this boundary its sign is the opposite of that of $\hat{c}_j^1 - \hat{c}_1^1$. In such cases, the difference in trade costs eliminates potential gains from trade arising from differences in relative producer prices, much as would equal but high trade cost ratios (by making the purchaser price difference close to zero, though if trade cost ratios were equal, its sign could not be reversed).

Where the error from averaging trade cost ratios is in the direction of *overstatement* of damping, and the producer prices of both goods differ in the same direction,[25] a big enough difference in trade cost ratios could eliminate the damping of producer price differences (an equal proportional difference in relative purchaser prices), and an even bigger difference in trade cost ratios could cause amplification (relative purchaser prices differing by more than, and in the same direction as, relative producer prices). The condition for remaining within the damping range in this direction is

$$\left|\frac{1}{\left(1-\hat{c}_1/\hat{c}_j\right)\left(1+\tau_j\right)}+\frac{1}{\left(1-\hat{c}_j/\hat{c}_1\right)\left(1+\tau_1\right)}\right| \le 1 \qquad \text{(A2)}$$

[24] If one producer price difference is positive and the other negative, given that both $(1 + \tau)$ terms must be positive, it is clear from equation (12) that the relative purchaser price difference cannot be zero (unless both taus are infinite) and that its sign cannot be reversed (since the negative sign on the second term in 12 implies that both its terms are then either positive or negative, so that no amount of scaling up or down of either or both of them can affect the sign of their sum).

[25] If one producer price difference is positive and the other is negative, the absolute size of the relative producer price difference is simply their sum. In equation (12), the $(1 + \tau)$ term for each good makes the purchaser price difference absolutely smaller than the producer price difference, so that the sum of the purchaser price terms cannot be larger in absolute size that the sum of the producer price terms, though it could be the same size if both τ's were zero.

which requires the ratio of the producer price differences, $\hat{c}_j/\hat{c}_1$, to diverge from unity by more than enough to offset the difference (in the opposite direction, in these cases) in the trade cost ratios. At the boundary, where (A2) is an equality, the rhs of equation (12) is $\hat{c}_j - \hat{c}_1$ (as it would be also if $\tau_j = \tau_1 = 0$), and beyond this boundary $\hat{p}_j - \hat{p}_1$ is absolutely larger than $\hat{c}_j - \hat{c}_1$.[26]

Appendix B: Omitted variable bias and the simulation results

The regressions in table 2 can be analysed in terms of an omitted variable. The 'true' relationship between variation in relative purchaser prices, relative producer prices and trade costs, an accounting identity, is

$$\ln\left\{\frac{p_j^z}{p_1^z}\right\} \equiv \ln\left\{\frac{c_j^z + t^z(1+t_j)}{c_1^z + t^z(1+t_1)}\right\} \equiv \ln\left\{\frac{c_j^z}{c_1^z}\right\} + \left[\ln\left\{\frac{c_j^z + t^z(1+t_j)}{c_1^z + t^z(1+t_1)}\right\} - \ln\left\{\frac{c_j^z}{c_1^z}\right\}\right] \qquad \text{(B1)}$$

If this identity were estimated by regression, the 'true' coefficients on each of the two rhs terms would be unity. The final square-bracketed term is in effect an omitted variable in the regression of relative purchaser prices on relative producer prices. By the usual formula for calculating omitted variable bias, the slope of the regression is

$$b_1^S = b_1^L + b_2^L b_{21} \qquad \text{(B2)}$$

where S (short) refers to the regression with the omitted variable and L (long) to that with it included, and b_{21} is the slope coefficient of a regression of the omitted variable on the variable included in the short regression. In this case, (B2) reduces to

$$b_1^S = 1 + b_{21} \qquad \text{(B3)}$$

The slope coefficient in the short regression, b_1^S, is roughly equal to the average share of producer prices in the purchaser prices of the two goods, $1/(1 + \tau)$. The slope coefficient in the auxiliary regression, b_{21}, is roughly equal to minus the average share of trade costs in the purchaser prices of the two goods, $-\tau/(1 + \tau)$. These two shares are complements, and so are the two coefficients in equation (B2). To understand this complementarity in the simplest case of a single good, expand equation (5) from the main text by subtracting $\hat{c}$ from both sides to yield the 'omitted variable'

$$\hat{p} - \hat{c} = \frac{1}{1+\tau}\hat{c} - \hat{c} = \left(\frac{1}{1+\tau} - 1\right)\hat{c} = \left(-\frac{\tau}{1+\tau}\right)\hat{c} \qquad \text{(B4)}$$

whose derivative with respect to $\hat{c}$ is $-\tau/(1 + \tau)$.

[26] The relative purchaser price difference cannot be larger than the larger of the two terms on the rhs of (12): this limit is reached if the other good has an infinite τ and so a zero purchaser price difference.

The regressions in table 2 can also be seen in terms of errors in variables. Trade costs are in effect an error in the measurement of purchaser prices, because the measure of purchaser prices in the regression includes only producer prices, which reduces the slope of the regression below its 'true' value of unity. However, this is not 'classical' measurement error, because the error, which is the square bracketed term in equation (B1), is correlated with the true value of the purchaser price (the middle term in B1), so that the usual simple formula for attenuation bias does not apply.[27]

Appendix C: Derivation of the purchaser price elasticity equation

The relative total sales of goods *j* and 1 in market *z* depend on a demand function

$$\frac{q_j^z}{q_1^z} = \alpha_{j1}^z \left(\frac{\overline{p}_j^z}{\overline{p}_1^z} \right)^{\gamma_{j1}} \tag{C1}$$

where γ_{j1} is the elasticity of substitution between the two goods, the *p* terms with bars are the average purchaser prices of the two goods, and the α term, which shows what relative sales would be if these prices were equal, is a measure of preferences. The relative sales of these two goods by country 1 in market *z* are by definition

$$\frac{q_j^{1z}}{q_1^{1z}} = \frac{q_j^z s_j^{1z}}{q_1^z s_1^{1z}} \tag{C2}$$

where the *s* terms are country 1's shares of market *z* for each of the goods, which are determined (for good *j*, and similarly for good 1) by

$$s_j^{1z} = \mu^1 \left(\frac{p_j^{1z}}{\overline{p}_j^z} \right)^{\beta_j} \tag{C3}$$

in which the elasticity, β_j, relates country 1's share to the price of its own variety, p_j^{1z}, compared to the average price of all varieties of good *j* in that market, $\overline{p}_j^z$. Country 1's market share depends also on its economic size, measured by μ^1, which is its share of total potential supply capacity. Larger countries tend to have larger market shares, because they have a larger potential number of optimal-scale plants in every sector.[28] Substituting (C1), (C3) and its counterpart for good 1 into (C2) yields

$$\frac{q_j^{1z}}{q_1^{1z}} = \alpha_{j1}^z \left(\frac{\overline{p}_j^z}{\overline{p}_1^z} \right)^{\gamma_{j1}} \left(\frac{p_j^{1z}}{\overline{p}_j^z} \right)^{\beta_j} \left(\frac{p_1^{1z}}{\overline{p}_1^z} \right)^{-\beta_1} \tag{C4}$$

from which the μ's have cancelled out, and which can be rearranged as

[27] Mild attenuation bias could, however, be responsible for the slope coefficients in both tables 2 and 3 being somewhat less than their theoretically expected values.
[28] If all countries were of equal economic size, μ^1 would be 1/*Z* (where *Z* is the number of countries).

$$\frac{q_j^{1z}}{q_1^{1z}} = \alpha_{j1}^z \bar{p}_j^{z(\gamma_{j1}-\beta_j)} \bar{p}_1^{z-(\gamma_{j1}-\beta_1)} p_j^{1z\,\beta_j} p_1^{1z-\beta_1} \qquad \text{(C5)}$$

Expressing the average price for good *j* as a share-weighted geometric average of the price of its country 1 variety and the average price of foreign varieties, p_j^{*z},

$$\bar{p}_j^z = p_j^{1z(s_j^{1z})} p_j^{*z(1-s_j^{1z})} \qquad \text{(C6)}$$

and similarly for good 1, equation (C5) can be rewritten as (after rearrangement)

$$\frac{q_j^{1z}}{q_1^{1z}} = \alpha_{j1}^z \frac{p_j^{1z[\beta_j+s_j^{1z}(\gamma_{j1}-\beta_j)]}}{p_1^{1z[\beta_1+s_1^{1z}(\gamma_{j1}-\beta_1)]}} \frac{p_j^{*z(1-s_j^{1z})(\gamma_{j1}-\beta_j)}}{p_1^{*z(1-s_1^{1z})(\gamma_{j1}-\beta_1)}} \qquad \text{(C7)}$$

which shows how country 1's relative sales depends on its own prices for these goods and on the prices of its foreign competitors. Since the focus of the analysis is on how the relative sales of individual countries vary with their relative prices, equation (C7) is rewritten in terms of proportional changes, assuming no changes in preferences (the alpha term) or in average foreign prices (assumed to be more or less the same for all individual countries), and becomes

$$\left(\hat{q}_j^{1z} - \hat{q}_1^{1z}\right) = \left[\beta_j + s_j^{1z}\left(\gamma_{j1} - \beta_j\right)\right]\hat{p}_j^{1z} - \left[\beta_1 + s_1^{1z}\left(\gamma_{j1} - \beta_1\right)\right]\hat{p}_1^{1z} \qquad \text{(C8)}$$

If it were assumed that $\beta_j = \beta_1 = \beta_{j1}$ and $s_j^{1z} = s_1^{1z} = s_{j1}^{1z}$, (C8) would simplify to

$$\hat{q}_j^{1z} - \hat{q}_1^{1z} = \left[\beta_{j1} + s_{j1}^{1z}\left(\gamma_{j1} - \beta_{j1}\right)\right]\left(\hat{p}_j^{1z} - \hat{p}_1^{1z}\right) \qquad \text{(C9)}$$

with a single price elasticity of substitution between country 1 varieties of the two goods in market *z*,

$$\tilde{\varepsilon}_{j1}^{1z} = \beta_{j1} + s_{j1}^{1z}\left(\gamma_{j1} - \beta_{j1}\right) \qquad \text{(C10)}$$

If, as usual in reality, $\beta_j \neq \beta_1$ and $s_j^{1z} \neq s_1^{1z}$, (C10) can be used as an approximation, by interpreting β_{j1} and s_{j1}^{1z} as averages of their values for *j* and 1, though it is inaccurate, as is explained in section 5 of the main text.

Appendix D: Derivation of the import elasticity equation

The objective is to find an equation which relates the relative imports of goods *j* and 1 (which are the relative sales of these two goods by *foreign* firms in the home market) to the relative producer prices of *local* firms. No equation of this type can be both simple and accurate, but a simple approximation can be based on the identity

$$\hat{q}_j^{M1} - \hat{q}_1^{M1} = \left(\hat{m}_j^1 - \hat{m}_1^1\right) + \left(\hat{q}_j^{11} - \hat{q}_1^{11}\right) \qquad \text{(D1)}$$

where the lhs is relative imports into country 1, $m_j^1 = q_j^{M1} / q_j^{11}$ is the ratio of imports to the home sales of local firms, and the final term is the relative home sales of local firms, whose determination was specified in equation (26). To complete the derivation by relating $\left(\hat{m}_j^1 - \hat{m}_1^1\right)$ to $\left(\hat{c}_j^1 - \hat{c}_1^1\right)$, assume that for a single good, j,

$$m_j^1 = \alpha_j^{m1} \left(\frac{p_j^{*1}}{p_j^{11}} \right)^{\tilde{\beta}_j} \qquad \text{(D2)}$$

where α_j^{m1} is what the ratio would be if the purchaser prices of home and foreign suppliers were equal, and $\tilde{\beta}_j$ is the elasticity of substitution among national varieties of good j. For two goods, j and 1, assuming $\tilde{\beta}_j = \tilde{\beta}_1 = \tilde{\beta}_{j1}$,

$$\frac{m_j^1}{m_1^1} = \alpha_{j1}^{m1} \left(\frac{p_j^{*1}}{p_j^{11}} \frac{p_1^{11}}{p_1^{*1}} \right)^{\tilde{\beta}_{j1}} \qquad \text{(D3)}$$

and hence in proportional changes, holding foreign prices and the α term constant,

$$\hat{m}_j^1 - \hat{m}_1^1 = -\tilde{\beta}_{j1}\left(\hat{p}_j^{11} - \hat{p}_1^{11}\right) = -\frac{\tilde{\beta}_{j1}}{1 + \tau_{j1}^{D1}} \left(\hat{c}_j^1 - \hat{c}_1^1\right) \qquad \text{(D4)}$$

which can be substituted into (D1), together with equation (26), to yield, after a bit of rearrangement

$$\hat{q}_j^{M1} - \hat{q}_1^{M1} = \left[-\tilde{\beta}_{j1} + \beta_{j1} + \left(\gamma_{j1} - \beta_{j1}\right)\mu^1 \left(\frac{c_{j1}^1}{c_{j1}^*\left(1 + \tau_{j1}^{*F1}\right)} \right)^{\left(1 - s_{j1}^{11}\right)\beta_{j1}} \right] \frac{\hat{c}_j^1 - \hat{c}_1^1}{1 + \tau_{j1}^{D1}} \qquad \text{(D5)}$$

An obvious simplification is to assume $\tilde{\beta}_{j1} = \beta_{j1}$, which reduces the equation to

$$\hat{q}_j^{M1} - \hat{q}_1^{M1} = \left(\gamma_{j1} - \beta_{j1}\right) \left[\mu^1 \left(\frac{c_{j1}^1}{c_{j1}^*\left(1 + \tau_{j1}^{*F1}\right)} \right)^{\left(1 - s_{j1}^{11}\right)\beta_{j1}} \right] \frac{\hat{c}_j^1 - \hat{c}_1^1}{1 + \tau_{j1}^{D1}} \qquad \text{(D6)}$$

This simplification, however, is inaccurate. For example, in the case of a single good, j, the elasticity of substitution, $\tilde{\beta}_j$, which relates q_j^{11} / q_j^{*1} to p_j^{11} / p_j^{*1}, is different from β_j, which relates country 1's market share, $q_j^{11} / \left(q_j^{11} + q_j^{*1}\right)$, to the purchaser price of local firms relative to the market average, $p_j^{11} / \overline{p}_j^1$. The two elasticities can differ widely when the market share is large.

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Table 2 'Cross-country' regressions of relative purchaser prices on relative producer prices

Good-specific trade cost coefficient Good j	Good 1	*Intercept of regression*	*Degree of damping* Slope coefficient	Average from data	Slope/ average	*Fit and linearity (R^2)* Linear form	Cubic form
0.4	0.4	0.00	0.33	0.36	0.90	0.93	0.93
1.0	1.0	0.00	0.26	0.29	0.89	0.91	0.91
1.8	1.8	0.00	0.20	0.23	0.87	0.90	0.90
1.4	0.6	0.29	0.26	0.30	0.89	0.89	0.89
0.6	1.4	-0.28	0.26	0.30	0.89	0.89	0.89
1.6	0.4	0.43	0.27	0.30	0.89	0.87	0.87
0.4	1.6	-0.43	0.27	0.30	0.89	0.86	0.87
1.8	0.2	0.59	0.28	0.31	0.89	0.84	0.84
0.2	1.8	-0.58	0.28	0.31	0.90	0.83	0.84

Notes: linear and cubic regressions fitted by OLS. 'Average from data' refers to the mean across all 'countries' of the mean for each 'country' of $1/(1 + \tau_j)$ and $1/(1 + \tau_1)$.

Table 3 Effects of controlling for variation in country-specific trade cost ratios

Good-specific trade cost coefficient Good j	Good 1	*Intercept*	*Slope coefficient*	R^2	*Increase in R^2*
0.4	0.4	0.00	0.98	1.00	0.07
1.0	1.0	0.00	0.96	1.00	0.09
1.8	1.8	0.00	0.95	1.00	0.10
1.4	0.6	0.29	0.96	0.97	0.08
0.6	1.4	-0.29	0.96	0.97	0.08
1.6	0.4	0.44	0.96	0.94	0.07
0.4	1.6	-0.44	0.97	0.94	0.07
1.8	0.2	0.60	0.95	0.89	0.05
0.2	1.8	-0.59	0.97	0.89	0.06

Note: table reports results of regressions of $\ln(p_j/p_1)$ on adjusted $\ln(c_j/c_1)$, where the adjustment is multiplication by the mean for each 'country' of $1/(1 + \tau_j)$ and $1/(1 + \tau_1)$. Increase in R^2 is by comparison with the unadjusted regression (in table 2).

Figure 1 Relative purchaser prices and relative producer prices (with $t_j = t_1 = 1$)

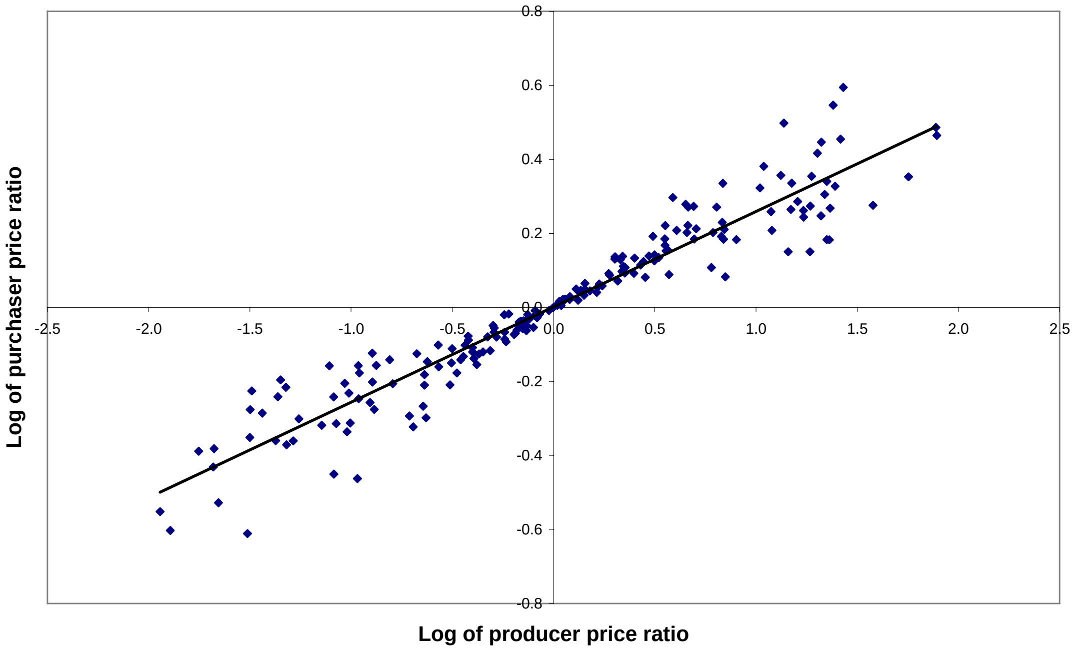

Figure 2 Relative purchaser prices and relative producer prices ($t_j = 1.6$, $t_1 = 0.4$)

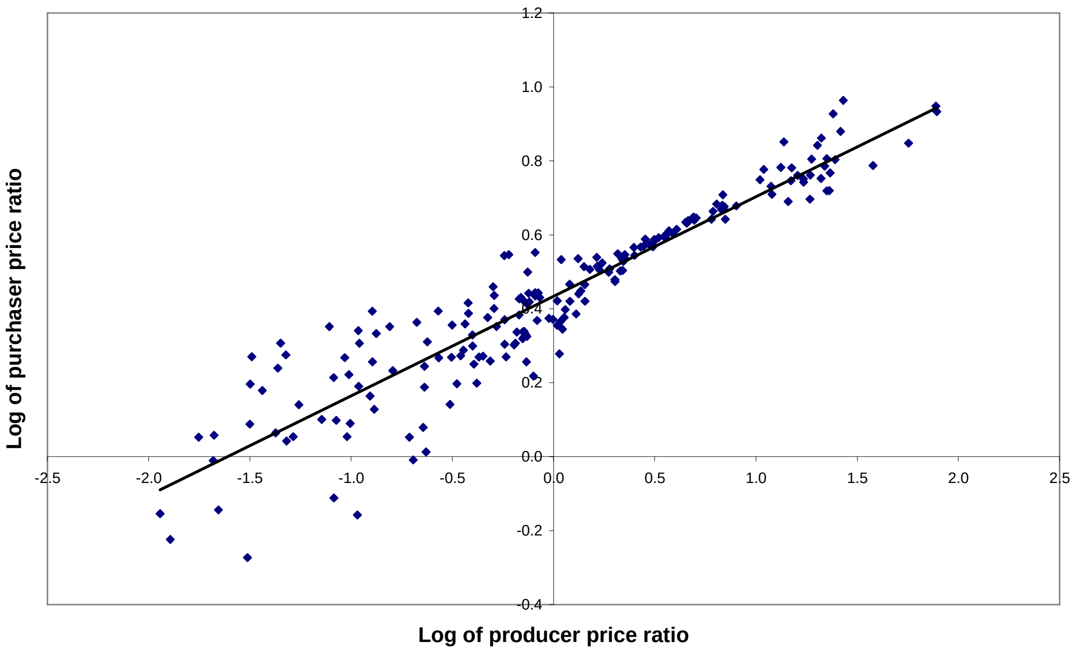

Figure 3 Relative purchaser prices and trade-cost-adjusted relative producer prices