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Openness is a matter of degree: how trade costs reduce demand elasticities

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The relative costs of trading different goods vary much less than the relative costs of producing them. The costs of trade are also often high. In consequence, as this paper shows theoretically and with simulations, demand elasticities in open economies are much lower than substitution elasticities between different national varieties of goods. Output structures in open economies thus respond to variation of relative production costs in qualitatively the same way as in closed economies, in sharp contrast to what standard trade theory predicts, but the degree of responsiveness tends to be higher in countries with lower trade costs.

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1. Introduction

This paper argues for treating openness to trade as a matter of degree, determined by the level of trade costs, rather than supposing, as in the standard theory of trade, that there is a qualitative difference between closed and open economies in the way in which the composition of output is affected by relative production costs. The paper shows how trade costs turn this dichotomy into a continuum by lowering (to varying degrees) elasticities of demand, which the standard theory assumes to be infinite in all economies that trade.

In closed economies, the relative outputs of different goods vary inversely with their relative costs of production, according to demand-side elasticities of substitution. In open economies, in which unlimited amounts of goods can be sold or bought at given world prices, standard trade theory predicts an entirely different pattern of behaviour. If a country's cost of production for a good is above the world price, it produces none of it and relies on imports. If its cost of production for a good is at or below the world price, it produces as much as resources permit, supplying all of its home demand and exporting any surplus.

The world predicted by the standard theory is thus one in which countries are highly specialised, each producing a few goods, exporting high proportions of their output, and importing most of what they consume. It is also a world in which small changes in a country's relative production costs or trade costs, or in world prices, can cause huge changes in the sectoral structure of its output, or, depending on the assumptions, not alter it at all (Deardorff, 2006).

In important respects, the real world does not conform to these predictions. The composition of output in individual countries is not nearly so specialised or sensitive to cost variation as the theory implies. For example, Balassa's (1963) test of Ricardo showed relative outputs to vary smoothly, not discontinuously, with relative costs. There is far less inter-sectoral trade than is predicted by the Heckscher-Ohlin-Vanek model (Trefler, 1995), and factor prices do not behave in the ways implied by the Heckscher-Ohlin-Samuelson model (Wood, 2007). To achieve sensible results, CGE modellers need to assume that elasticities of demand are low.

Many explanations for these familiar discrepancies between the standard theory and the evidence have been suggested. Perhaps the oldest is that some factors are specific to sectors, so that returns to scale diminish. Outside primary sectors, however, factor specificity is implausible in the long run, and in manufacturing and services returns to scale at the sectoral level seem usually to be increasing. A more recent explanation is data aggregation (Davis and Weinstein, 2001; Schott, 2003): countries are actually more specialised than it seems from comparison of their sectoral structures, because the same statistical sectors contain different goods. This is surely correct, though it probably bridges only part of the gap between the standard theory and reality.

Another category of explanations abandons infinite demand elasticity. For example, Rauch and Trindade (2003) have argued that elasticities of substitution are lowered by information costs, even though goods may be perfect substitutes. Following Krugman (1979), many models have assumed that consumers distinguish between the products of different firms. Empirical work on trade also often assumes, following Armington

(1969), that local and foreign varieties of the same goods are imperfect substitutes. This assumption is made in most CGE models, and in some gravity models (Anderson and van Wincoop, 2004). Trefler (1995) notes it as one reason for 'missing trade'.

Trade theorists, however, have for nearly four decades been unwilling to incorporate the Armington assumption into their standard models (e.g. Deardorff, 2006: slides 29-31). The reason seems to be a concern about magnitudes. Theorists accept that local and foreign varieties are rarely perfect substitutes, but the substitution elasticities used in many empirical models of trade (often less than 4) are far lower than is suggested by casual observation and some econometric estimates from highly disaggregated data (up to 10), which imply a sufficient degree of substitutability to make the assumption of infinite elasticity a reasonable simplification for theoretical work.[2]

The explanation proposed in the present paper of the qualitative similarity of sectoral output responses to variation in relative production costs in open economies and in closed economies is trade costs. This idea is not new: it goes back beyond Samuelson (1953: 6), and is frequently mentioned (for example, Leamer, 1995: 19; Trefler, 1995: 1042; Krugman and Obstfeld, 2006: 43). But it has not found its way into mainstream theory, apparently for lack of any general and accepted analysis of exactly how trade costs might have this particular effect.

There is a mass of excellent work, empirical and theoretical, on how trade costs have other sorts of effects. Gravity models use trade costs to explain the aggregate volume and directions of trade of countries (surveyed by Anderson and van Wincoop, 2004). Many studies analyse the effects of trade costs on the spatial distribution of economic activity (surveyed by Henderson *et al*., 2001). Following Melitz (2003), much work has been done on how trade costs affect the exporting behaviour of individual firms (surveyed by Bernard *et al*., 2007). A rapidly growing literature on the unbundling and off-shoring of production activities, to which falling trade costs have contributed, is surveyed by Baldwin (2006). Obstfeld and Rogoff (2000) argue that trade costs explain the main empirical puzzles of international macroeconomics.

However, the way in which trade costs are modelled in this literature does not explain why in reality the sectoral structure of output is less specialised across countries, and more gradually and smoothly responsive to variation in relative production costs, than standard trade theory predicts. The variable cost of trading a good is usually taken to be a set proportion of its price or production cost, like an ad valorem tariff. 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. Other countries remain in the 'produce nothing' or the 'produce as much as resources permit' ranges of standard theory.

This 'iceberg' assumption about trade costs can be applied to enhance and extend the predictions of the standard theory. It can explain why some goods are non-traded in all countries, why particular countries specialise in particular goods, and how trade affects welfare (for example, Markusen and Venables, 2007). But it does not alter the

[2] Of the elasticities in the 42 material-goods sectors in the current version of the GTAP model, 31 are below 4 (Dimaranan et al., 2007: table 20.2). Harrison et al. (1997), in their modelling analysis of the Uruguay Round, take 4 as their base elasticity. By contrast, Anderson and van Wincoop (2004: 715-6) conclude from their review of econometric estimates that the elasticity of substitution between national varieties of the same good is 'likely to be in the range of five to ten'.

prediction that, except for goods whose trade costs put them in the 'non-traded' range for some or all countries, there will be an unrealistically high degree of specialisation and sensitivity to variations in production costs, trade costs and world prices.[3]

Nor is this prediction altered by adding fixed trade costs, as in Melitz (2003), helpful though this is in explaining which firms export to which markets. Deardorff (2006) points out that the predictions of the standard theory could in principle be brought into line with reality by assuming unit costs of trade to rise with the quantity sold. Aldaz-Carroll (2003) makes a similar argument. Deardorff also notes, however, that this assumption seems highly unrealistic (and it is the opposite of that of Melitz).

The argument of the present paper is that this gap between theory and reality can be bridged by recognising that the relative (variable) trade costs of different goods, rather than varying in strict proportion to relative production costs, are largely independent of relative production costs. As a result, the relative prices of goods, which depend on the sum of production costs and trade costs, vary – across countries and over time – by proportionally less than their relative costs of production, which in turn reduces variation in their relative sales.

Non-proportional trade costs, too, are not a new idea. They have been suggested as a cause of incomplete exchange rate pass-through, and their effects studied in industrial organisation theory. Recently, moreover, this idea has been applied to international trade by Hummels and Skiba (2004), who formalise and test the conjecture of Alchian and Allen (1964) about 'shipping the good apples out'.[4] The conjecture was that, since the cost of transport is the same for all qualities of a good, while the cost of production rises with quality, the relative price of the better-quality varieties will be lower at the point of sale than at the point of production. Hummels and Skiba confirm this conjecture, using data on trade in varying qualities of the same goods.

The present paper argues that this idea is of far more general relevance. It applies to all aspects of the composition of trade and output – across goods and sectors, not only across different qualities of given goods. Adding non-proportional trade costs to the standard theory can bring it into line with reality by damping elasticities of relative demand for different goods, without needing to assume unrealistically low degrees of substitutability in consumption among national varieties (though this substitutability needs to be finite, as explained below). It also allows the responsiveness of relative outputs to relative production costs to vary among countries (as well as among goods and markets) with levels of trade costs, which makes openness a matter of degree.

The usual assumption of proportionality implies that the relative costs of trading any pair of goods vary from country to country and over time in parallel with the relative costs of producing them. A good that is relatively cheaper to produce in a country is assumed to be also and to the same degree relatively cheaper to export from or import into that country. A fall in the relative production cost of a good in a country is also assumed to be associated with an equi-proportional fall in its relative trade cost.

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[3] However, Neary (1985) shows that the responsiveness of factor prices to factor supplies may depend on the number of non-traded goods.

[4] A related contribution is Hillberry (2002), who uses non-proportional trade costs to explain the effect of borders on the commodity composition of trade. Koren (2004) uses non-proportional trade costs to explain deviations from the law of one price.

This common assumption seems appropriate for some trade costs, such as ad valorem tariffs and insurance premia, but less appropriate for most other trade costs. Fees and commissions, for example, should in principle vary in absolute terms from good to good, depending on the amounts and types of work involved, even though in practice they are often simplified to percentages. Similarly, retail mark-ups, though also often simplified to rules of thumb, should vary absolutely among goods with the amounts of labour and floor space needed to sell them. The effects of the many technical barriers to trade that now exist are also unlikely to be proportional to production costs.[5]

Physical features of goods also make relative transport costs similar across space and time: a good that is heavy, bulky or fragile tends to be costlier to transport than a good which is lighter, more compact or more solid, for reasons that are largely independent of its relative costs of production in the country or time period concerned. Relative production costs may have some effect on relative transport costs. Interest charges on goods in transit are higher for more expensive items, which may induce the choice (or construction) of faster and costlier modes of transport. Likewise, as Hummels and Skiba (2004) point out, ocean liner cartels with monopoly power may charge higher freight rates for higher-priced goods. But the relationship between relative production costs and relative transport costs is surely not strictly proportional.

Recent econometric studies of detailed trade flows yield results inconsistent with the standard assumption of proportionality. Hummels and Skiba (2004), using data on the imports of six countries from all other countries, estimate the elasticity of freight costs with respect to f.o.b prices (controlling for distance and quantity shipped) to be about 0.6, well below the implied iceberg value of unity. Their IV estimate of this elasticity falls to 0.1 using more finely disaggregated data for US imports alone. Baldwin and Harrigan (2007) and Bernard *et al*. (2007) find that the unit value of US exports rises with distance shipped, which is consistent with the conclusion of Hummels and Skiba that transport costs are largely 'per unit' rather than 'ad valorem' – *x* dollars per mile, rather than *x* percent of the value of the good per mile.

Trade costs vary among countries not only with their locations and thus distances, but also with other things such as the quality of their ports, which affect both the absolute costs of trading most goods and the relative costs of trading different goods. A bad port, for example, raises the relative cost of trading goods with high weight-to-value ratios that cannot affordably be sent by air. But cross-country variations of this sort in the relative costs of trading goods do not parallel variations in the relative costs of producing them. The absolute levels of trade costs and production costs may vary in parallel: in a country with higher wages or lower overall efficiency, both the costs of making a good and the costs of putting it on a ship or selling it in a shop tend to be higher. Relative trade costs, however, either vary little among countries or vary in ways that have little or no causal connection with relative production costs.

The share of trade costs that is proportional to production costs cannot be accurately assessed from currently available data. It surely differs among goods, countries and markets, but seems likely usually to be small: on the basis of the discussion above, the proportional share is assumed in this paper to average about 20%. Total trade costs

[5] I owe this point to Richard Baldwin.

are large: Anderson and van Wincoop (2004) estimate the average ratio of trade costs to production costs to be 170% for developed countries and even higher in developing countries. So if 80% of total trade costs are independent of production costs, their damping effect on elasticities is likely to be big.

In analysing how non-proportional trade costs damp demand elasticities, it is vital to distinguish between purchaser prices (those paid by the customer) and producer prices (those received at the factory or farm gate). The differences between purchaser prices and producer prices are, by accounting definition, trade costs (together, in statistical practice, with indirect taxes and subsidies).[6] Producer prices, which include profits, may differ from production costs, though they are usually assumed to be equal. This paper from here on uses the words 'producer price' rather than 'production cost', but as a reminder of the connection, the producer price is denoted by the letter c.

The demand decisions of customers depend on purchaser prices, in a way described by the elasticity of demand with respect to purchaser prices. The production decisions of firms and farms, however, depend on producer prices. If trade costs varied in strict proportion to producer prices, so too would purchaser prices, and the elasticity of demand with respect to producer prices would be the same as that with respect to purchaser prices. If trade costs vary less than producer prices, however, purchaser prices vary proportionally less than producer prices. Sales therefore respond less to a given percentage difference in producer prices than to the same percentage difference in purchaser prices.

This damping mechanism will be explained more precisely in algebraic terms below. But it may be helpful to illustrate it here with a numerical example for a single good whose trade costs are independent of production costs in the simplest sense of being a fixed sum of money. Suppose the purchaser price elasticity of demand to be 10, so that in the absence of trade costs, a country whose unit producer price was $5 would sell six times as much as a country whose unit producer price was $6. 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%. The country with the lower producer price then sells less than three times as much: the elasticity of sales with respect to producer prices is halved, from 10 to 5.

Trade costs could not damp a purchaser price demand elasticity that was infinite. But it is plausible in almost all circumstances to suppose that that purchasers regard the goods produced by one country as imperfect substitutes for goods produced by other countries, for two complementary reasons.[7] One is less than perfect substitutability in use, as emphasised by Armington (1969): even for 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, though these are small and hence elasticities are high. The other reason is limited information, as emphasised by Rauch and Trindade

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[6] The term 'purchaser price' means the same in this paper as in the UN System of National Accounts, except that in the SNA it includes indirect taxes as well as trade costs. The SNA makes a distinction between 'producer price' and 'basic price', which excludes more taxes, but the term 'producer price' is used here to make the meaning clearer. The SNA apostrophes on both terms are dropped for brevity.

[7] If purchaser price elasticities were infinite, relative trade costs that were independent of relative production costs would affect the non-traded ranges for particular goods and particular countries, and would make models more complicated, but would not fundamentally alter the standard theory.

(2003): purchasers are less sure that goods from foreign suppliers will be what they want. In addition, purchaser price demand elasticities in a country's home market are themselves reduced by trade costs, as will be explained later.

The next two sections analyse the damping effects of non-proportional trade costs on producer-price demand elasticities, in section 2 for changes over time and in section 3 for differences across countries. Section 4 investigates the effects of trade costs on purchaser price elasticities, which are significant for home sales. Section 5 uses the algebra of earlier sections to show, for changes over time, how trade costs of various kinds affect producer-price elasticities of demand for exports, home sales and output. Section 6 simulates a world of 200 countries to explore the same issues in the context of cross-country differences in relative producer prices. Section 7 concludes.

2. Damping of price ratio elasticities: changes in a single country

This section shows algebraically how non-proportional trade costs damp the elasticity of demand in the context of changes over time in a single country. The next section will extend the analysis to differences across countries.

Consider a country selling in the world market a pair of goods, j and 1 (with 1 as the numeraire and j as an example from all goods j = 1, …., n). Its relative sales of the two goods depend on the relative purchaser prices it charges, p_j and p_1, according to a demand function

$$\frac{q_j}{q_1} = \alpha_{j1}\left(\frac{p_j}{p_1}\right)^{-\tilde{\varepsilon}_{j1}} \tag{2.1}$$

where $\tilde{\varepsilon}_{j1}$ is the elasticity of substitution in demand with respect to relative purchaser prices, or for short the purchaser price elasticity (whose determinants are analysed in section 4). The parameter α_{j1} depends on consumer preferences, the prices charged by other countries for these goods, and the prices of other goods, all of which are assumed to be constant. Since each purchaser price, p_j, is the sum of the producer price, c_j, and the unit cost of trade, t_j, the demand function can be expanded to

$$\frac{q_j}{q_1} = \alpha_{j1}\left(\frac{c_j + t_j}{c_1 + t_1}\right)^{-\tilde{\varepsilon}_{j1}} \tag{2.2}$$

By defining the relative producer price as $c = c_j/c_1$ and the relative trade cost as $t = t_j/t_1$, and making the relative trade cost a function of the relative producer price, $t = T(c)$, the demand function can be rewritten as

$$\frac{q_j}{q_1} = \alpha_{j1}\left(\frac{c + \tau_1 T(c)}{1 + \tau_1}\right)^{-\tilde{\varepsilon}_{j1}} \tag{2.3}$$

where $\tau_1 = t_1/c_1$, from which the elasticity of substitution in demand with respect to relative producer prices, or for short the producer price elasticity, can be derived as

$$\varepsilon_{j1} = \tilde{\varepsilon}_{j1}\left(\frac{1+\tau_1 T_c(c)}{1+\tau_1 T(c)/c}\right) \tag{2.4}$$

where $T_c(c)$ is the derivative of $T(c)$ with respect to c. Equation (2.4) specifies how this country's relative sales of goods j and 1 would respond to a change over time in its relative producer prices of the two goods. It can be rewritten more concisely as

$$\varepsilon_{j1} = \tilde{\varepsilon}_{j1}\delta_{j1} \tag{2.5}$$

where δ_{j1}, the bracketed term in (2.4), is the elasticity of relative purchaser prices with respect to relative producer prices, or for short the price ratio elasticity. The value of this elasticity is what determines the degree of damping, and is the focus of the rest of this and the next section, in which $\tilde{\varepsilon}_{j1}$ is assumed to be exogenous and constant.

The standard assumption of proportional trade costs can be captured by giving the function $T(c)$ a particular form, namely Tc, so that $T_c(c) = T$. This would be the case if, for example, the only trade costs faced by this country were ad valorem tariffs in its partner countries. The result is a price ratio elasticity of unity and thus no damping

$$\delta_{j1} = \frac{1+\tau_1 T}{1+\tau_1 Tc/c} = 1 \tag{2.6}$$

The case of trade costs that are strictly independent of producer prices (for example, consisting only of transport costs determined by the relative weight of the two goods) can be captured by giving the function $T(c)$ another particular form, namely T, so that $T_c(c) = 0$. The price ratio elasticity is then

$$\delta_{j1} = \frac{1}{1+\tau_j} \tag{2.7}$$

It depends simply on the ratio, τ_j, of the trade cost to the producer price of good j. The higher is τ_j, the lower is δ_{j1} and hence the greater is the degree of damping.

Equation (2.7) contains the trade cost ratio only of good j because the calculus used to obtain equation (2.4) implicitly holds constant the producer price of the numeraire good 1 (if the ratios c and t were inverted, τ_1 would appear instead). Its form is due to the fact that $1/(1 + \tau_j)$ is the share of the producer price in the purchaser price, $c_j/(c_j + t_j)$, rewritten to make the trade/producer price ratio explicit. This share determines, in familiar fashion, how big a proportional change in the purchaser price is caused by a given proportional change in the producer price: for example, if c_j were half of p_j, a 10% rise in c_j would cause a 5% rise in p_j.

Between the cases in equations (2.6) and (2.7) there is damping to some lesser degree, depending on how much relative trade costs change with relative production costs and on the magnitude of trade costs relative to producer prices. The function $T(c)$ can be written as a geometric weighted average of the two forms considered above

$$T(c) = (Tc)^a T^{1-a} = Tc^a \tag{2.8}$$

where $a \in (0,1)$ is the weight of proportional trade costs in total trade costs.[8] This makes the price ratio elasticity

$$\delta_{j1} = \frac{1 + a\tau_j c^a}{1 + \tau_j c^a} \tag{2.9}$$

which reduces to equations (2.6) and (2.7) respectively with proportional trade costs (a = 1) and strictly independent trade costs (a = 0). Its value is less than unity if a is less than unity, and gets closer to $1/(1 + \tau_j)$, the closer a is to zero. The degree of damping depends also on the ratio of good j's trade cost to its producer price: with $a <$ 1, larger values of τ_j make δ_{j1} smaller.

These relationships refer to small changes, but can be extended to larger changes by working in logs. A good approximation to the change in relative purchaser prices is

$$\Delta \ln\left(\frac{p_j}{p_1}\right) \approx \frac{1}{1+\bar{\tau}_{j1}} \Delta \ln\left(\frac{c_j}{c_1}\right) + \frac{\bar{\tau}_{j1}}{1+\bar{\tau}_{j1}} \Delta \ln\left(\frac{t_j}{t_1}\right) \tag{2.10}$$

where $\bar{\tau}_{j1}$ is the geometric mean of $\tau_j = t_j/c_j$ and $\tau_1 = t_1/c_1$. The change in the relative purchaser price is thus an average of the changes in the relative producer price and relative trade costs, weighted by, respectively, the average shares of the producer price and trade costs in the purchaser price, $1/(1+\bar{\tau}_{j1})$ and $\bar{\tau}_{j1}/(1+\bar{\tau}_{j1})$.

If the relative trade costs of the two goods in the country concerned were strictly independent of its relative producer prices, so that $\Delta \ln (t_j/t_1)$ was zero, the price ratio elasticity,

$$\delta_{j1} = \frac{\Delta \ln(p_j/p_1)}{\Delta \ln(c_j/c_1)} \tag{2.11}$$

would be approximately

$$\delta_{j1} \approx \frac{1}{1+\bar{\tau}_{j1}} \tag{2.12}$$

which is similar to equation (2.7). If the relative trade costs of the two goods vary with their relative producer prices, the price ratio elasticity is approximated by

$$\delta_{j1} \approx \frac{1 + a\bar{\tau}_{j1}}{1+\bar{\tau}_{j1}} \tag{2.13}$$

[8] Hummels and Skiba (2004: 1390) specify a similar function for freight rates.

where

$$a = \frac{\Delta \ln\left(t_j / t_1\right)}{\Delta \ln\left(c_j / c_1\right)} \tag{2.14}$$

which is similar to equation (2.9). If a is zero (because relative trade costs are fixed and hence $\Delta \ln (t_j / t_1)$ is zero), equation (2.13) reduces to equation (2.12); if a is unity (because relative trade costs vary in proportion to relative producer prices), δ_{j1} is also unity, as in equation (2.6); and if a is between zero and unity, it lessens the degree of damping by making the price ratio elasticity larger than in equation (2.12).

Equation (2.13) shows that the degree of damping depends both on the average ratio of trade costs to producer prices, $\bar{\tau}_{j1}$, and on the share of proportional trade costs in total trade costs, a. Many different combinations of $\bar{\tau}_{j1}$ and a can generate the same value of δ_{j1}. Moreover, differentiating equation (2.13)

$$\frac{\partial \delta_{j1}}{\partial a} = \frac{\bar{\tau}_{j1}}{1 + \bar{\tau}_{j1}} \tag{2.15}$$

shows that increasing a raises the price ratio elasticity by more, the higher is $\bar{\tau}_{j1}$. Not only can the damping effect of a higher trade cost ratio be offset by more of the trade costs being proportional, but the offset is greater, the higher is the trade cost ratio.

3. Damping of price ratio elasticities: differences among countries

This section shows how non-proportional trade costs lower the price ratio elasticity in the context of differences across countries at a moment of time. The analysis is more complex than in the previous section, which involved only one pair of prices (those of goods j and 1 in one country), because it must involve also the prices – both producer prices and purchaser prices – of these goods in the rest of the world. In other words, it needs to address comparative advantage. More precisely, the issue for this section is how trade costs affect the mapping of a country's comparative advantage in producer-price space into its comparative advantage in purchaser-price space.

The prices and trade costs of goods j and 1 are assumed to be measured in a common currency (for example, dollars per quantity unit). The relative purchaser price of the two goods in the country concerned, compared to the rest of the world (an average of other countries, denoted by a * superscript), is defined as

$$\frac{p_j}{p_j^*} \bigg/ \frac{p_1}{p_1^*} \tag{3.1}$$

and similarly for the relative producer price (replacing p's by c's). The cross-section price ratio elasticity (distinguished from the time-series elasticity by a tilde) is thus by definition

$$\tilde{\delta}_{j1} = \frac{\ln\left(p_j / p_j^*\right) - \ln\left(p_1 / p_1^*\right)}{\ln\left(c_j / c_j^*\right) - \ln\left(c_1 / c_1^*\right)} \tag{3.2}$$

Each p term in (3.2) can be rewritten as $(c + t)$ and the equation rearranged as

$$\tilde{\delta}_{j1} = 1 + \frac{\ln\left((1+\tau_j)/(1+\tau_j^*)\right) - \ln\left((1+\tau_1)/(1+\tau_1^*)\right)}{\ln\left(c_j / c_j^*\right) - \ln\left(c_1 / c_1^*\right)} \tag{3.3}$$

where each of the τ terms is the ratio of the relevant t to the corresponding c.

The value of $\tilde{\delta}_{j1}$ is determined by all the τ terms and c terms in a complicated way that depends partly on the relative trade costs of the two goods. In brief, trade costs usually damp comparative advantage: the divergence of a country's relative purchaser prices from world average relative purchaser prices is in most cases smaller than the divergence of its relative producer prices from world average relative producer prices. The degree of damping, as with the time-series elasticity, tends to be greater, the higher are ratios of trade costs to producer prices, and to be smaller, the larger is the share of proportional trade costs in total trade costs. Across countries, however, some combinations of τ's and c's yield not damping, but in some cases amplification and in other cases reversal of the direction of the difference in the relative price.

Readers who are content with this summary could now skip to section 4. Those who would like to know more about when and how these outcomes arise should read on.

The overall price ratio elasticity, $\tilde{\delta}_{j1}$, can be analysed as a weighted sum of the price ratio elasticities for the two goods individually. The elasticity for good 1 is defined as

$$\tilde{\delta}_1 = \frac{\ln\left(p_1 / p_1^*\right)}{\ln\left(c_1 / c_1^*\right)} \tag{3.4}$$

and compares the proportional difference between the purchaser price of this good in the country concerned and in the rest of the world to the corresponding difference in its producer price. Damping ($0 < \tilde{\delta}_1 < 1$) means that the purchaser price difference is smaller than the producer price difference or, more precisely, that p_1 / p_1^* is closer to unity than (and on the same side of unity as) c_1 / c_1^*.

If the trade cost for good 1 in the country concerned were equal to its average trade cost in the rest of the world ($t_1 = t_1^*$), this one-good cross-section price ratio elasticity would be approximately

$$\tilde{\delta}_1 \approx \frac{1}{1+\bar{\tau}_1} \tag{3.5}$$

where $\bar{\tau}_1$ is the geometric mean of $\tau_1 = t_1 / c_1$ and $\tau_1^* = t_1^* / c_1^*$, and is similar in form to the time-series elasticity in equation (2.12). If the trade cost for good 1 in the country concerned differs from the average trade cost of this good in the rest of the world (because all trade costs are unusually high or low in this country, or because features of the country and the good interact to make trade costs unusually high or low for this particular good), the – more general – approximation is

$$\tilde{\delta}_1 \approx \frac{1 + b_1 \bar{\tau}_1}{1 + \bar{\tau}_1} \tag{3.6}$$

where

$$b_1 = \frac{\ln\left(t_1 / t_1^*\right)}{\ln\left(c_1 / c_1^*\right)} \tag{3.7}$$

Equation (3.6) resembles the time-series equation (2.13). What b_1 captures, however, is not the same as a in equation (2.13), which was the share of proportional trade costs in total trade costs (and will reappear shortly). Instead, it is the relationship between the divergence of trade costs between the country concerned and the rest of the world and the corresponding divergence of producer prices. Unlike a, b_1 may lie outside the range of zero to unity, and hence so may the good 1 price ratio elasticity.

If t_1 and c_1 diverge from the world average in the same direction (the trade cost and the producer price of good 1 both being higher or lower in this country than elsewhere), b_1 is positive, which makes the elasticity greater than with equal trade costs (as in equation 3.5) and hence lessens the degree of damping. If the divergences of t_1 and c_1 from the world average were not only in the same direction but also of the same proportional size, b_1 would be unity, as would be the price ratio elasticity – hence no damping, as in any model with proportional trade costs. And if t_1 diverged from the world average by proportionally more than c_1, b_1 would be greater than unity, as would $\tilde{\delta}_1$, implying amplification – the country's purchaser price diverging from the world average price by proportionally more than its producer price.

If t_1 and c_1 diverge from the world average in opposite directions (the trade cost being higher in the country concerned than elsewhere, but the producer price being lower, or vice versa), b_1 is negative, which makes the elasticity smaller than with equal trade costs (as in equation 3.5) and hence tends to increase the degree of damping. And if the divergence in opposite directions of t_1 and c_1 were big enough, relative to $\bar{\tau}_1$ (more specifically, if $b_1 \bar{\tau}_1 \leq -1$), the price ratio elasticity would be zero, meaning that the purchaser price equalled the world average, despite the difference in the producer price, or negative. A negative elasticity would mean that trade costs were causing the purchaser price of a good in a country to be above the world average, even though its producer price was below the world average, or vice versa.

The price ratio elasticity for good j is of the same general form as for good 1,

$$\tilde{\delta}_j \approx \frac{1 + b_j \bar{\tau}_j}{1 + \bar{\tau}_j} \tag{3.8}$$

and, like $\tilde{\delta}_1$, it can lie outside the range of zero to unity. But it is not independent of $\tilde{\delta}_1$, because the trade costs of the two goods are linked by

$$\frac{t_j}{t_1} = \overline{\pi}_{j1}\left(\frac{c_j}{c_1}\right)^a \tag{3.9}$$

which is substantively identical to equation (2.8) but with the ratios spelled out and T relabelled as $\overline{\pi}_{j1}$ for later use. It can be shown that

$$\overline{\tau}_j = \overline{\pi}_{j1}\overline{\tau}_1^a\left(\frac{t_1}{c_j}\frac{t_1^*}{c_j^*}\right)^{0.5(1-a)} \tag{3.10}$$

implying, unsurprisingly, that $\overline{\tau}_j$ is linked to $\overline{\tau}_1$ by $\overline{\pi}_{j1}$. It depends also on a pair of hybrid trade cost ratios and on a. If $a = 0$,

$$\overline{\tau}_j = \overline{\pi}_{j1}\left(\frac{t_1}{c_j}\frac{t_1^*}{c_j^*}\right)^{0.5} \tag{3.11}$$

in which the absolute trade costs of good j are simply those of good 1 multiplied by $\overline{\pi}_{j1}$, and if $a = 1$,

$$\overline{\tau}_j = \overline{\pi}_{j1}\overline{\tau}_1 \tag{3.12}$$

where by contrast the trade cost *ratio* for good 1 is multiplied by $\overline{\pi}_{j1}$. It can also be established that

$$b_j = a + (b_1 - a)C \tag{3.13}$$

which shows that b_j is linked to b_1 and depends also on a and a trade cost ratio, C, to be discussed shortly. The sign of b_j need not be the same as that of b_1, and if a is small, so that $b_j \approx b_1 C$, the signs are likely to be opposite, since C is often negative. If both a and b_1 are zero, $b_j = 0$, and

$$\tilde{\delta}_j \approx \frac{1}{1 + \overline{\pi}_{j1}\sqrt{(t_1/c_j)(t_1^*/c_j^*)}} \tag{3.14}$$

which is similar to equation (3.5). If both a and b_1 are unity, $b_j = \tilde{\delta}_j = \tilde{\delta}_1 = 1$, and so relative purchaser prices are equal to relative producer prices, with no damping.

Given the price ratio elasticities for the two individual goods, the divergence between relative purchaser prices in the country concerned and in the rest of the world is by definition linked to the corresponding divergence of relative producer prices by

$$\ln\left(\frac{p_j}{p_j^*}\right) - \ln\left(\frac{p_1}{p_1^*}\right) = \ln\left(\frac{c_j}{c_j^*}\right)\tilde{\delta}_j - \ln\left(\frac{c_1}{c_1^*}\right)\tilde{\delta}_1 \qquad (3.15)$$

from which the overall price ratio elasticity can be derived, by substitution into (3.2) and rearranging, as

$$\tilde{\delta}_{j1} = \frac{1}{1-C}\tilde{\delta}_j + \frac{1}{1-1/C}\tilde{\delta}_1 \qquad (3.16)$$

where

$$C = \frac{\ln\left(c_1/c_1^*\right)}{\ln\left(c_j/c_j^*\right)} \qquad (3.17)$$

which is a weighted sum of the elasticities for each of the goods individually. To understand the weights, think of *C* as the percentage difference between this country and the world average in the producer price of good 1, divided by the corresponding difference for good *j*. Since each of these percentage differences could be either positive or negative, *C* (and its inverse) could also be either positive (if the differences were in the same direction) or negative (if the differences were in opposite directions). Its size depends on the absolute difference between the percentages for the two goods, regardless of their signs: the further apart are the percentage differences, the further does this ratio diverge from unity (as does its inverse, in the opposite direction).

If the producer price differences are in opposite directions (for example, good *j* costs more in the country concerned than on average elsewhere, but good 1 costs less), the weights are between zero and one, as well as summing to one. The overall price ratio elasticity is thus the weighted arithmetic mean of the price ratio elasticities for each of the goods separately. If these opposite differences were of exactly the same size, each weight would be half, and it would be a simple average. In other cases, the overall price ratio elasticity is closer to that of the good for which the proportional difference between the producer price in this country and elsewhere is (absolutely) larger, which is intuitive – the good that is more different has more effect on the average.

If the producer price differences are in the same direction (both goods costing less or more in this country than on average elsewhere, which is possible since these are just two out of many goods[9]), the weights still sum to one, but are no longer individually between zero and one. They are of opposite sign, and at least one must be absolutely greater than one. The overall price ratio elasticity may still lie between the price ratio elasticities for the two goods individually, but it can also lie outside this range. As before, it is the price ratio elasticity of the good for which the producer price difference between this country and the world average is bigger that has the larger influence on the overall elasticity. If the overall elasticity lies outside the range of the

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[9] In a model with only two goods, and with balanced trade and a floating exchange rate, this case could not exist in equilibrium – the producer prices of the goods would need to differ from the world average in opposite directions. But if there are many goods, the producer prices of any two, for example shirts and shoes, could in a particular country both be below or above their world average producer prices.

two individual elasticities, this likewise occurs in the direction of the elasticity of the good for which the producer price difference is larger.

The equations which determine $\tilde{\delta}_j$ and $\tilde{\delta}_1$ individually can be substituted into the weighted average equation (3.16) to give a complete (but approximate) explanation of the cross-section price ratio elasticity $\tilde{\delta}_{j1}$. The resulting expression can be simplified by focusing on the special case in which $\bar{\tau}_j = \bar{\pi}_{j1}\bar{\tau}_1$ (for which a sufficient condition is $c_1 c_1^* = c_j c_j^*$), which makes it

$$\tilde{\delta}_{j1} \approx \frac{1}{1-C}\frac{1+\bar{\pi}_{j1}\bar{\tau}_1\left[a+(b_1-a)C\right]}{1+\bar{\pi}_{j1}\bar{\tau}_1}+\frac{1}{1-1/C}\frac{1+b_1\bar{\tau}_1}{1+\bar{\tau}_1} \tag{3.18}$$

In the case of a country with average trade costs, where $b_1 = 0$, the expression can be further simplified and rearranged as

$$\tilde{\delta}_{j1} \approx \frac{1}{1-C}\frac{1}{1+\bar{\pi}_{j1}\bar{\tau}_1}+\frac{1}{1-1/C}\frac{1}{1+\bar{\tau}_1}+\frac{1+a\bar{\pi}_{j1}\bar{\tau}_1}{1+\bar{\pi}_{j1}\bar{\tau}_1} \tag{3.19}$$

If C is negative, as is often the case, so that both weights are positive, equation (3.19) confirms that higher trade cost ratios increase damping (higher $\bar{\tau}_1$ and $\bar{\pi}_{j1}$ lower all three terms) and that a larger share of proportional trade costs in total trade costs, a, reduces damping (by making the third term bigger).[10] Moreover, the relative producer prices of the country concerned, c_j / c_1, play no direct or simple role in (3.19), which conveys, importantly, that $\tilde{\delta}_{j1}$ is an (approximately) constant elasticity.

In practice, $\tilde{\delta}_{j1}$ is affected also by the divergence of each country's trade costs from world average trade costs ($b_1 \neq 0$), which can go in either direction, and sometimes by C being positive (and so one of the weights being negative), as well as by $\bar{\tau}_j \neq \bar{\pi}_{j1}\bar{\tau}_1$. The outcome is often still damping ($0 < \tilde{\delta}_{j1} < 1$). But it can also be amplification ($\tilde{\delta}_{j1} > 1$), meaning that trade costs cause relative purchaser prices to differ from the world average by more than relative producer prices, or reversal ($\tilde{\delta}_{j1} < 0$), meaning that the difference in relative purchaser prices between this country and the rest of the world is in the opposite direction to the difference in relative producer prices.[11]

Section 6 will use simulations to compare the frequency of these different outcomes. It will also shed more light on how the cross-section price ratio elasticity discussed in this section relates to the time-series price ratio elasticity in the previous section. The two are generally different, as can be seen by comparing equations (2.13) and (3.19),

[10] Since equation (3.19) is an approximation, it fails to convey that setting $a = 1$ would make the cross-country price ratio elasticity unity, implying instead that the elasticity would be greater than unity.

[11] An overall price ratio elasticity outside the damping range could arise because one or both individual-good elasticities were outside this range, but this is neither a necessary nor a sufficient condition.

and in individual countries they can differ widely from one another. But, as will be seen in the simulations, the average cross-section price ratio elasticity of all countries is often close to the average time-series elasticity.

4. Reduction of purchaser price elasticities

In section 2, in the equation $\varepsilon_{j1} = \tilde{\varepsilon}_{j1}\delta_{j1}$, the elasticity of relative demand with respect to relative producer prices for any two goods, *j* and 1, was split into two multiplicative components: the purchaser price elasticity, $\tilde{\varepsilon}_{j1}$, and the (purchaser to producer) price ratio elasticity, δ_{j1}. Sections 2 and 3 were entirely about the effects of trade costs on δ_{j1}. This section analyses $\tilde{\varepsilon}_{j1}$, and shows how it, too, is affected by trade costs.

The purchaser price elasticity, $\tilde{\varepsilon}_{j1}$, refers to the effect of the relative prices charged by a particular country on its sales of two goods in a market in which, if there is trade, it is competing with other countries that supply these goods. This elasticity depends both on substitutability between the two goods, which can vary widely, depending on their nature, and on substitutability between different national varieties of each good, which again can vary among goods but is likely to be far greater.

The relative impact of these two sorts of substitutability depends on the country's shares of the market concerned for these two goods: if its shares are small, then $\tilde{\varepsilon}_{j1}$ is determined almost entirely by the degree of substitutability among varieties; but with more substantial shares, $\tilde{\varepsilon}_{j1}$ depends also on the degree of substitutability between the goods (because then the prices charged by the country in question for these two goods have a significant effect on the average prices of the two goods). Market shares are affected by trade costs, and can be large, particularly in a country's home market, thus lowering $\tilde{\varepsilon}_{j1}$ – the limiting case being that of a closed economy in which $\tilde{\varepsilon}_{j1}$ depends entirely on the degree of substitutability between the two goods.

Countries of origin (or supplier countries) are from here on indexed by a superscript *z* (= 1, …, *Z*), and markets (or countries of destination) by a second superscript, *ž* (= 1, …, *Ž*). Assuming purchaser demand to be described by a two-level CES utility function (the lower level being choice among national varieties and the upper level choice between the goods), and adapting Sato's (1967: 217) equation for a production function, the relationship between the purchaser price elasticity for a country, *z*, in a market, *ž* (denoted by $\tilde{\varepsilon}_{j1}^{z\check{z}}$) and the two sorts of substitutability is

$$\tilde{\varepsilon}_{j1}^{z\check{z}} = \frac{\dfrac{1}{s_j^{z\check{z}} s_j^{\check{z}}} + \dfrac{1}{s_1^{z\check{z}} s_1^{\check{z}}}}{\dfrac{1}{\beta_j}\left(\dfrac{1}{s_j^{z\check{z}} s_j^{\check{z}}} - \dfrac{1}{s_j^{\check{z}}}\right) + \dfrac{1}{\beta_1}\left(\dfrac{1}{s_1^{z\check{z}} s_1^{\check{z}}} - \dfrac{1}{s_1^{\check{z}}}\right) + \dfrac{1}{\gamma_{j1}}\left(\dfrac{1}{s_j^{\check{z}}} + \dfrac{1}{s_1^{\check{z}}}\right)} \tag{4.1}$$

where β_j and β_1 are the elasticities of substitution among national varieties of goods *j* and 1, γ_{j1} is the elasticity of substitution between goods *j* and 1, $s_j^{\check{z}}$ and $s_1^{\check{z}}$ are the shares of goods *j* and 1 in total expenditure in market *ž* (which reflect the preferences of purchasers and the prices of other goods), and $s_j^{z\check{z}}$ and $s_1^{z\check{z}}$ are country *z*'s shares of the sales of goods *j* and 1 in market *ž*. The overall elasticity $\tilde{\varepsilon}_{j1}^{z\check{z}}$ is thus a weighted harmonic mean of β_j, β_1 and γ_{j1}, where the weights are these shares.

The higher are country *z*'s shares of market *ž* ($s_j^{z\check{z}}$ and $s_1^{z\check{z}}$), the less weight do the βs have on the overall elasticity, relative to γ_{j1}. If $s_j^{z\check{z}}$ and $s_1^{z\check{z}}$ were both unity, equation (4.1) would reduce to γ_{j1}, and if they approached zero and (for simplicity) the two βs were equal, it would approach the common value of β (because the first two terms in the denominator containing the βs would be huge, relative to the third term containing γ_{j1}). The outcome depends also on country *z*'s relative market shares ($s_j^{z\check{z}} / s_1^{z\check{z}}$) and on the relative shares of the two goods in total expenditure ($s_j^{\check{z}} / s_1^{\check{z}}$).

To analyse how trade costs affect country *z*'s share of market *ž* for each good, it is convenient to start with the corresponding ratio (of the sales of country *z* to the sales of other countries), which is assumed to be determined for good *j* by

$$r_j^{z\check{z}} \equiv \frac{p_j^{z\check{z}} q_j^{z\check{z}}}{p_j^{*\check{z}} q_j^{*\check{z}}} = \mu^z \left(\frac{p_j^{z\check{z}}}{p_j^{*\check{z}}} \right)^{1-\beta_j} \tag{4.2}$$

whose middle term defines the ratio more precisely. This ratio depends on country *z*'s purchaser price for good *j* in market *ž*, $p_j^{z\check{z}}$, relative to the average purchaser price of other varieties of good *j* in this market, $p_j^{*\check{z}}$. The impact of this relative price on the relative sales of country *z* depends on β_j, and so is likely to be large.[12]

The sales ratio depends also on country *z*'s economic size relative to the rest of the world, μ^z (its relative potential number of optimal-scale plants or of varieties). Thus if country *z*'s price in market *ž* were equal to the average price charged by other suppliers, its sales ratio would be the same as its economic size ratio, which for the average country is small (about 0.005, since the world contains about 200 countries). To show the effect of trade costs on the sales ratio, the purchaser price ratio in (4.2) can be expanded (as in earlier sections) to yield

$$r_j^{z\check{z}} = \mu^z \left(\frac{c_j^z + t_j^{z\check{z}}}{c_j^* + t_j^{*\check{z}}} \right)^{1-\beta_j} \tag{4.3}$$

What matters, evidently, is how the trade costs to country *z* of supplying this market, $t_j^{z\check{z}}$, compare with the average trade costs of other suppliers, $t_j^{*\check{z}}$. The sales ratio depends also on relative producer prices but, given these, country *z*'s sales ratio will be higher in a market where it has a trade cost advantage over its competitors, of which the most common example is its home market. The same applies to its market share, which is a (decreasingly positive) transformation of its sales ratio

[12] Equation (4.2) resembles, *inter alia*, equation (2) of Anderson and van Wincoop (2004), but it allows for differences in country size (as in their later equation 5).

$$s_j^{z\check{z}} = \frac{1}{1 + 1/r_j^{z\check{z}}} \qquad (4.4)$$

Equation (4.3) and its counterpart for good 1 can be substituted into equation (4.4), which in turn can be substituted into equation (4.1) to show how trade costs affect the purchaser price elasticity, $\tilde{\varepsilon}_{j1}^{z\check{z}}$. However, the resulting expression is indigestible and the best way to understand its practical significance is through numerical simulations, of which a selection is presented in table 1.

Table 1 Simulated response of purchaser price elasticity to a country's trade cost advantage

Country z's trade cost advantage: $t^{z\check{z}}/t^{*\check{z}}$ (assumed the same for both goods)	1.50	1.00	0.75	0.50	0.25
	Purchaser price elasticity: $\tilde{\varepsilon}_{j1}$				
Base case (specification in notes)	10.0	9.9	9.6	8.3	4.8
Higher absolute trade costs: $\tau^{*\check{z}}_1$ raised to 2.0	10.0	9.9	9.3	6.3	3.2
Lower absolute trade costs: $\tau^{*\check{z}}_1$ lowered to 0.5	10.0	9.9	9.8	9.5	8.3
Goods have same trade costs (compensated): $\pi_{j1} = 1.0$; $\tau^{*\check{z}}_1 = 1.5$	10.0	9.9	9.7	8.9	6.2
Relative trade costs of goods reversed: π_{j1} from 2.0 to 0.5	10.0	10.0	9.9	9.8	9.6
Relative producer price difference increased: $c^z_j/c^*_j = 1.8$, $c^z_1/c^*_1 = 0.3$	10.0	10.0	9.9	9.6	8.1
Relative producer price difference reduced: $c^z_j/c^*_j = 1.1$, $c^z_1/c^*_1 = 0.9$	10.0	9.9	9.5	8.0	4.7
Relative producer price difference reversed: $c^z_j/c^*_j = 0.7$, $c^z_1/c^*_1 = 1.3$	10.0	9.9	9.8	9.5	8.3
Larger country: μ^z raised from 0.005 to 0.02	10.0	9.7	8.7	6.0	3.5
Smaller country: μ^z lowered from 0.005 to 0.001	10.0	10.0	9.9	9.6	7.4

Notes: 'compensated' means that $\tau^{*\check{z}}_1$ was adjusted to keep constant the average trade costs of the two goods. All other experiments alter only the variable mentioned. Values in the base case are:

$\tau^{*\check{z}}_1 (\equiv t^{*\check{z}}_1/c^*_1)$	=	1.0
$\pi_{j1} (\equiv t_j/t_1)$	=	2.0
c^z_j/c^*_j	=	1.3
c^*_j	=	5.5
c^z_1/c^*_1	=	0.7
c^*_1	=	5.5
$\beta_j = \beta_1$	=	10.0
γ_{j1}	=	3.0
$s^{\check{z}}_j = s^{\check{z}}_1$	=	0.1
μ^z	=	0.005

Each column refers to a particular degree of trade cost advantage of country *z* over other suppliers, with $t_j^{z\check{z}} / t_j^{*\check{z}}$ ranging from 1.5 (country *z* at a disadvantage) through 1.0 (country *z* with average trade costs) to 0.25 (country *z*'s trade costs a quarter of those of other suppliers). Each row shows how the purchaser price elasticity changes as the trade cost advantage rises, given the values of the other variables in equations (4.1) and (4.3). The assumptions of the base case in the first row are specified in the notes and varied in later rows. The first eight rows refer to a country of average size ($\mu^{\check{z}}$ = 0.005) and the last two rows to larger (0.02) and smaller (0.001) countries.

The effects are asymmetrical: being at a trade cost disadvantage is little different from having average trade costs. Moreover, for an average-sized country, it requires a big advantage (trade costs half those of other suppliers, or less) to reduce $\tilde{\varepsilon}_{j1}^{z\check{z}}$ much below the elasticity of substitution among national varieties (which in these simulations is 10 for both goods). Even then, the reduction varies widely, depending on the absolute level of the trade costs of other suppliers, the producer prices of the two countries and the two goods, and the relative trade costs of the two goods. At a trade cost advantage of 0.5, the value of $\tilde{\varepsilon}_{j1}^{z\check{z}}$ in table 3 ranges from 6.3 to 9.8, around the base case value of 8.3. However, for a country of four times average size, with the other assumptions of the base case, a trade cost advantage of 0.5 reduces $\tilde{\varepsilon}_{j1}^{z\check{z}}$ to 6.0, and one of 0.25 would bring it close to the elasticity of substitution between the two goods (set at 3).

This section has shown that trade costs can lower producer price demand elasticities by reducing purchaser price elasticities, as well as by damping price ratio elasticities. For most countries in most markets, since it is unusual to have a trade cost advantage over other suppliers, this effect is trivial, but it can be substantial in a country's home market. Even in home markets, the effect is on average modest – a reduction of the order of 20%. However, the home market effect also varies widely among countries and goods, depending on country size and combination of producer prices and trade costs, ranging from near zero to more than a halving of the elasticity.

5. Demand elasticities for exports, home sales and output

Sections 2 and 3 analysed the effects of trade costs on the price ratio elasticity, δ_{j1}, and section 4 their effects on the purchaser price elasticity, $\tilde{\varepsilon}_{j1}$, in both cases focusing on a single market. This and the following section have two purposes: to combine the analyses of δ_{j1} and $\tilde{\varepsilon}_{j1}$ into a unified account of the effects of trade costs on the producer price elasticity, ε_{j1}, in the contexts both of changes over time in the relative producer prices of one country and of differences in relative producer prices across countries; and to distinguish more clearly between elasticities in different markets.

For both these purposes, it is necessary to split the trade costs of any supplier country *z* to any market *ž* into their internal or domestic (*D*) and international or external (*F*) components. Thus for any good *j*

$$t_j^{z\check{z}} = t_j^{D\check{z}} + t_j^{Fz\check{z}} \tag{5.1}$$

where $t_j^{D\check{z}}$ is the cost to any supplier of selling one unit of good *j* in market *ž* (internal transport, wholesale and retail margins), and so has no *z* origin superscript, while $t_j^{Fz\check{z}}$ is the additional trade cost for a supplier from a country $z \neq \check{z}$ (international transport, insurance, legal and language expenses, and so on, plus tariffs and the cost of any other policy discrimination against foreign suppliers).

These two sorts of trade cost are in some ways related – bad infrastructure, say, might increase both of them – but in other ways they vary independently among countries (for example, a remote country with high international transport costs might have an unusually efficient retail sector, or vice versa).[13] The two sorts of trade costs also have different effects on different suppliers. For country *z*'s home market, denoted also by *z*, the trade costs of home and foreign suppliers for good *j* are, respectively,

$$t_j^{zz} = t_j^{Dz} \tag{5.2}$$

$$t_j^{*z} = t_j^{Dz} + t_j^{F*z} \tag{5.3}$$

which is why, as analysed in section 4, countries have a trade cost advantage in their home markets. By contrast, in country *z*'s export markets, denoted collectively with a *, its trade costs and those of other suppliers are, respectively,

$$t_j^{z*} = t_j^{D*} + t_j^{Fz*} \tag{5.4}$$

$$t_j^{**} = t_j^{D*} + t_j^{F**} \tag{5.5}$$

again with common internal costs, but country *z* usually having higher-than-average external (and thus total) trade costs, because the average of other suppliers in export markets includes the countries concerned, who have no international trade costs.[14]

The effects of trade costs on the producer price elasticity of any country *z* in any market *ž* can be fully specified by combining the relevant pair of trade cost equations (5.2) to (5.5) with, in the equation $\varepsilon_{j1}^{z\check{z}} = \tilde{\varepsilon}_{j1}^{z\check{z}} \delta_{j1}^{z\check{z}}$, equations (4.1), (4.3) and (4.4), which determine $\tilde{\varepsilon}_{j1}^{z\check{z}}$, and an equation to determine $\delta_{j1}^{z\check{z}}$ from either section 2 (for changes over time) or section 3 (for differences across countries). The resulting expressions, however, are too complex to be worth presenting or analysing directly. Instead, they will be approached below in two ways: in the rest of this section with some simplified algebra that explains their meaning in the context of changes over time in a single country; and in the next section with numerical simulations that explain their meaning in the context of differences across countries.

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[13] Variation across countries in the absolute level of internal trade costs depends on variation in (a) the efficiency of the internal trade system and (b) the level of wages, which pull in opposite directions. On average across countries, these two determinants are inversely correlated (countries with low efficiency tend also to have low wages), which reduces cross-country variation of internal trade costs. But this correlation is far from perfect, which is why absolute internal trade costs vary among countries.

[14] In a two-country world, the relationship between trade costs in a country's home and export markets would be simpler and more symmetrical, since t_j^{F**} would be zero.

For most countries and goods, the key determinants of the elasticity of relative export demand with respect to changes in relative producer prices can be summarised as

$$\varepsilon_{j1}^{z*} = \frac{\beta_{j1}}{1+\bar{\tau}_{j1}^{D*}+\bar{\tau}_{j1}^{Fz*}} \tag{5.6}$$

where β_{j1}, an average across the two goods of the elasticities of substitution among national varieties, is the purchaser price elasticity, since for most countries and goods, export market shares are too small to reduce it appreciably below this level. The trade cost ratios in the denominator are likewise averaged across the two goods, as well as across country *z*'s export markets: $\bar{\tau}_{j1}^{D*}$ is average internal trade costs in these markets, and $\bar{\tau}_{j1}^{Fz*}$ is *z*'s average international trade costs in supplying these markets, in both cases divided by its own producer prices.

Equation (5.6) conveys that the effects of trade costs on producer price elasticities in a country's export markets occur almost entirely through the damping of the price ratio elasticity, δ_{j1}, to a degree that depends on the country's own international trade costs and on internal trade costs in its export markets. The degree of damping depends also (inversely) on the share of proportional trade costs in total trade costs: to simplify the algebra, *a*, is omitted, so that $\bar{\tau}_{j1}^{D*}$ and $\bar{\tau}_{j1}^{Fz*}$ should mentally be adjusted downward, to make the export elasticity higher than it appears in equation (5.6).

For a country's home market, the trade-cost determinants of the elasticity of demand with respect to changes in its relative producer prices can be summarised as

$$\varepsilon_{j1}^{zz} = \frac{\tilde{\varepsilon}\left(t_{j1}^{Dz}/t_{j1}^{F*z}\right)}{1+\bar{\tau}_{j1}^{Dz}} \qquad \tilde{\varepsilon}'(\ )>0 \tag{5.7}$$

where, again, the *j*1 subscripts denote averages across the two goods. The numerator conveys that the purchaser price elasticity is decreasing in the international trade costs of foreign suppliers to country *z*'s home market: the more protected are its markets for these goods, the larger are country *z*'s market shares and so the lower is the elasticity. However, the numerator is increasing in internal trade costs, because, from equations (5.2) and (5.3), the trade cost advantage ratio is

$$t_{j1}^{zz}/t_{j1}^{*z} = t_{j1}^{Dz}/\left(t_{j1}^{Dz}+t_{j1}^{F*z}\right) = \left(1+t_{j1}^{Dz}/t_{j1}^{F*z}\right)^{-1} \tag{5.8}$$

so that higher internal trade costs reduce the advantage conferred on home suppliers by foreign-supplier international trade costs, which tends to raise the elasticity.[15] The denominator of equation (5.7) shows the damping of the price ratio elasticity by trade costs (again requiring a mental adjustment to allow for the omission of *a*), which in a country's home market involves only internal trade costs. Equation (5.7) shows that the net effect of internal trade costs on the producer price elasticity is ambiguous, they

[15] Anderson and van Wincoop (2004: 708-9), in a different sort of model, reach a different conclusion, which is that internal trade costs do not affect trade flows.

reduce the price ratio elasticity, but lessen the lowering effect of international trade costs on the purchaser price elasticity.

Comparison of equations (5.6) and (5.7) also shows that the producer price elasticity could be either higher or lower for exports than for home sales. For most countries and goods, the purchaser price elasticity is likely to be lower in the home market than in export markets, where market shares are smaller. Pulling the other way, however, the price ratio elasticity is likely to be less damped in the home market than in export markets, since exports incur international as well as internal trade costs.[16]

In practice, data aggregation may tend to make producer price elasticities for exports appear higher than for home sales. Statistics on exports and home sales, even for one 'good', are mixtures of items with different trade costs. For instance, if the 'good' is manufactures, low-trade-cost items such as shoes 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 suppliers have larger shares of, and so face lower purchaser (and producer) price elasticities in, markets for manufactures that are sold mainly at home, while the damping of price ratio elasticities in export markets is lessened by the lower trade costs of the sorts of manufactures that are exported.

For some purposes, including the analysis of employment and wages and of economic development, what matters is the sectoral structure not of a country's sales in its home or its export markets, but of its total output – the sum of its sales in all markets. The elasticity of a country's total relative sales of the two goods with respect to changes in its relative producer prices can be written approximately as a weighted arithmetic average of the elasticities in its export and home markets

$$\varepsilon_{j1}^{z} = x_{j1}^{z}\varepsilon_{j1}^{z*} + \left(1 - x_{j1}^{z}\right)\varepsilon_{j1}^{zz} \qquad (5.9)$$

where x_{j1}^{z} is country *z*'s share of exports in output, averaged across the two goods.[17] The output elasticity is thus affected by trade costs both through their influence on its constituent elasticities, ε_{j1}^{z*} and ε_{j1}^{zz}, and through their influence on the export share.

To analyse the effects of trade costs on the export share, it is convenient to start with the corresponding ratio for any good *j*, which is by definition approximately

$$r_{j}^{*z} = \frac{1}{\mu^{z}}\frac{s_{j}^{z*}}{s_{j}^{zz}} \qquad (5.10)$$

where $1/\mu^{z}$ is the economic size of the rest of the world divided by the economic size of country *z*, and hence roughly that of its potential export market relative to its home market, while s_{j}^{z*} and s_{j}^{zz} are, respectively, country *z*'s shares of its export and home markets. Using the equations in section 4 that determine these two shares, equation

[16] Though the opposite is possible: for example, if country *z* had bad internal transport and its producers were on the coast, it might cost them less to supply export markets than their home market.

[17] The export elasticity in turn could be written as a share-weighted average of the elasticities in all of country *z*'s individual export markets.

(5.10) and its counterpart for good 1 can be developed into a complicated expression that shows how trade costs affect the export share.[18]

The key features of this expression are that a country's export share tends to be low if high international trade costs disadvantage foreign suppliers in its home market and if it faces high international trade costs in supplying export markets, relative to those of other suppliers. The size of these effects depends on the level of internal trade costs in the markets concerned, as mentioned earlier. The export share is also strongly and inversely dependent on the country's economic size – potential export markets are just smaller, relative to home markets, for larger countries.[19]

The effects of a country's trade costs on its export share are thus straightforward: they lower it. Their effects on the output elasticity through this route, however, depend on whether and by how much the producer price elasticity is greater in the export market than in the home market. If ε_{j1}^{z*} is lower than ε_{j1}^{zz}, the effect of trade costs through the export share is to raise the output elasticity. If ε_{j1}^{z*} is higher than ε_{j1}^{zz}, the effect is to reduce the output elasticity. And if the difference between ε_{j1}^{z*} and ε_{j1}^{zz} is small, one way or the other, the output elasticity is little affected by the export share.

6. Simulation of cross-country demand elasticities

The previous section analysed the effects of trade costs on the elasticities of demand for exports, home sales and total output in the context of changes of relative producer prices in a single country. This section undertakes the corresponding analysis in the context of differences in producer prices across countries. The main modification is to the price ratio elasticity, whose determination is described by the algebra of section 3 rather than of section 2. This algebra shows that there can be wide variation among countries in the degree of damping, as well as outcomes other than damping, but does not reveal the pattern or frequency of these outcomes, nor show what a world of many countries might look like. These gaps can be filled by numerical simulations.

The simulations will measure the effects on the relative sales of a pair of goods, *j* and 1, of random differences in relative producer prices across 200 hypothetical countries – which is roughly how many there are in the world. The producer price for each country and each good, c_j^z, assumed to be measured in a common currency, is a random number between 1 and 10, drawn from a uniform distribution. There is thus a one hundred-fold range of variation among countries in the relative producer prices of the two goods, c_j^z/c_1^z, from 0.1 to 10, so that $\ln\left(c_j^z/c_1^z\right)$ varies from -2.3 to 2.3 around an average close to zero.

Trade costs are assumed to be in some respects the same for all countries and in other respects to vary among countries. Two parameters are common to all countries: the ratio of world average international trade costs to world average producer prices for

[18] The link between trade costs and the export share is analysed and used also in Novy (2006).
[19] Country size (acting through potential supply capacity rather than market size) also affects both the market shares in equation (5.10), but in ways that cancel out – larger countries have larger shares of both their home and their export markets

good 1, $\bar{\tau}_1^F = \bar{t}_1^F / \bar{c}_1$; and the average ratio of internal to international trade costs $\bar{\pi}_{DF}$ (the same for both goods).[20] All countries also have the same substitution elasticities, β_j, β_1, γ_{j1}, and the same shares of each good in total expenditure, $s_j^{\bar{z}}$ and $s_1^{\bar{z}}$. The ratio of good j trade costs to good 1 trade costs, assumed to be the same for internal and international costs, varies among countries according to

$$\pi_{j1}^z = \bar{\pi}_{j1}\left(\frac{c_j^z}{c_1^z}\right)^a \qquad (6.1)$$

(substantively the same as equations 2.8 and 3.9) where $\bar{\pi}_{j1}$ and a are parameters, the former being the world average (median) ratio of good j to good 1 trade costs and the latter being the share of proportional trade costs in total trade costs (assumed to be the same for all countries).

Three aspects of trade costs vary randomly (and independently) among countries, in each case uniformly distributed (in logs) around unity between one-half and two:[21] the international trade costs of their exports relative to world average international trade costs, π_F^z; their anti-trade 'bias', π_B^z (the ratio of the international trade costs faced by their importers to the international trade costs faced by their exporters);[22] and the ratio of their internal trade costs to world average internal trade costs, π_D^z. Independently of their trade costs, countries also vary in size, with the distribution being what it is in the real world: most countries are small (60 have shares of less than one-hundredth of one percent of world GDP), and a few are large.[23]

The trade costs of each country depend on both world average parameters and its own relative trade costs. For good j, the trade costs faced by country z's exporters are

$$t_j^{z*} = \bar{\tau}_1^F \bar{c}_1 \pi_{j1}^z \left(\pi_F^z + \bar{\pi}_{DF}\right) \qquad (6.2)$$

of which part varies with country z's relative trade costs and part is the same for all countries. The trade costs of country z's competitors in export markets, which do not depend on country z's own relative trade costs, are

$$t_j^{**} = \bar{\tau}_1^F \bar{c}_1 \bar{\pi}_{j1} \left(\bar{m}_j + \bar{\pi}_{DF}\right) \qquad (6.3)$$

---

[20] All these averages are unweighted arithmetic means of the values for all countries.

[21] Anderson and van Wincoop (2004: 747) suggest that trade costs vary among countries by 'a factor of two or more'.

[22] Or, to use the terminology of Anderson and van Wincoop (2004), the ratio of 'inward resistance' to 'outward resistance'. The average ratio is set at unity, on the grounds that world average anti-trade bias is already included in the world average level of international trade costs (which include policy barriers as well as natural barriers to trade). But for individual countries, there can be and is asymmetry (in the sense of Bergstrand *et al*., 2007).

[23] The size distribution is based on data for GDP at PPP in 2005 from World Development Indicators: for about 30 countries, mainly tiny, these data are unavailable, so to get the number in the simulations up to 200, 22 hypothetical countries were given the same GDP as the average for the smallest 22 for which data are available.

of which part is the common average internal trade cost and part is related to the world average international trade costs of good *j* by $\overline{m}_j$, which is the world average share of imports in the supply of good *j* (determined endogenously in the simulations). The international trade costs of non-*z* suppliers to export markets are thus an import-share-weighted average of (for other foreign suppliers) world average international trade costs and (for home suppliers) zero. In country *z*'s home market, its suppliers of good *j* face trade costs (only internal) of

$$t_j^{zz} = \overline{\tau}_1^F \overline{c}_1 \pi_{j1}^z \overline{\pi}_{DF} \pi_D^z \qquad (6.4)$$

which vary among countries with their ratios of good *j* to good 1 trade costs and with their relative internal trade costs, while importers face trade costs of

$$t_j^{*z} = \overline{\tau}_1^F \overline{c}_1 \overline{\pi}_{j1} \left(\pi_F^z \pi_B^z + \overline{\pi}_{DF} \pi_D^z \right) \qquad (6.5)$$

which vary among countries of destination with their relative international trade costs, relative bias and relative internal trade costs. For good 1, trade costs are the same as in (6.2) to (6.5), but without the π_{j1} terms (and with $\overline{m}_1$ rather than $\overline{m}_j$).[24]

The purchaser price of each good for each country in its export and home markets is calculated by adding the relevant trade cost (from equation 6.2 or 6.4) to its randomly determined producer price. The purchaser prices of its competitors in each market are likewise determined by adding the relevant trade cost (from equation 6.3 or 6.5) to the world average producer price for the good concerned. The purchaser price elasticities in each country's export and home markets are determined by the algebra of section 4. Given these elasticities, each country's relative exports and home sales are determined by its relative purchaser prices and those of its competitors. Its relative output is derived by adding its exports to its home sales.

6.1 Elasticity of relative demand for exports

It is convenient to begin by analysing the results for exports alone. In the next sub-section, these are compared with results for home sales and for total output. Figure 1 plots the simulated relationship across the 200 'countries' between relative exports and relative producer prices (both logged), and shows also an OLS regression line. In this simulation, $\overline{\tau}_1^F = 1$ and $\overline{\pi}_{j1} = 2$, so that average international trade costs (across both goods and all countries) are 150% of average producer prices, and $\overline{\pi}_{DF} = 0.5$, making the sum of internal and international trade costs 225% of producer prices (a world average broadly consistent with the Anderson and van Wincoop, 2004, estimate of 170% for developed countries and higher trade costs in developing countries). The share of proportional trade costs in total trade costs, *a*, is assumed on the basis of the evidence discussed in section 1 to be 0.2.

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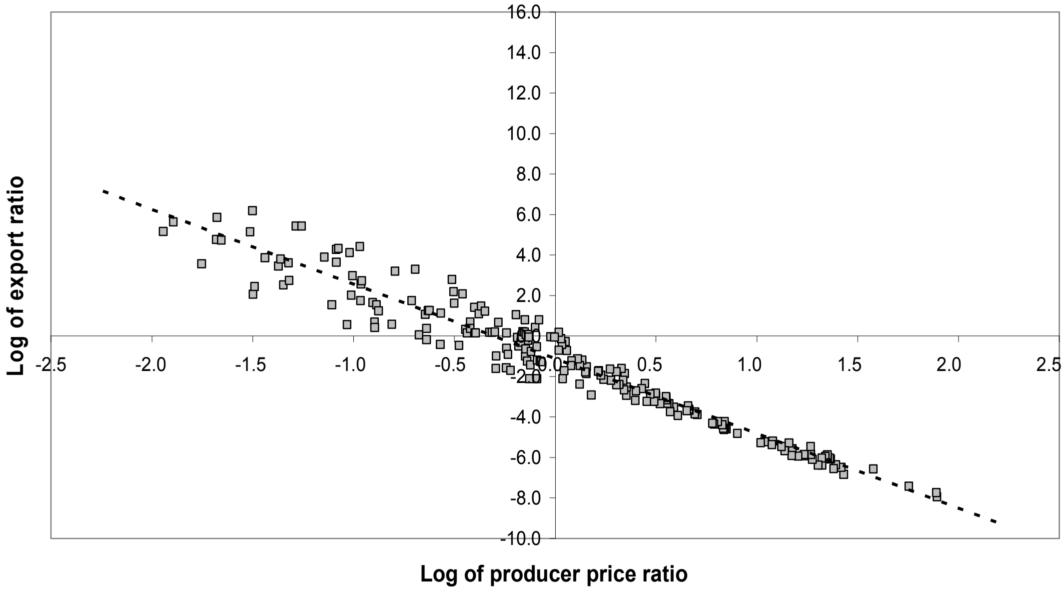
[24] For the sake of simplicity, this specification of trade costs does not allow for interaction between the characteristics of countries and of goods. For example, transport cost depends both on the portability of the good and on the location of the country. The nature of the interaction also varies, depending on the cause of the good-specific difference – e.g. weight-related or language-related.

Figure 1 Effect of relative producer prices on relative exports



The cross-section producer price elasticity of demand for each country is the slope of a ray from the origin to its point (but with the sign reversed). The slopes vary widely among countries, almost entirely because of variation in their price ratio elasticities – all their purchaser price elasticities are close to the elasticity of substitution among varieties, which is set at 10 throughout these simulations.[25] As expected from section 3, moreover, not all of the cross-section elasticities are in the damping range of zero to unity: 15 percent are negative (in the North-East and South-West quadrants), and 8 percent are amplified (greater than the elasticity of substitution among varieties).[26]

The overall cross-country pattern, however, is orderly (since most of the non-damping cases are close to the origin). Exports of good *j*, relative to good 1, tend to decline across countries as their relative producer prices of good *j* rise. This relationship is virtually log-linear (a cubic regression fits only fractionally better), implying that the average elasticity is roughly constant. The relationship is also close ($R^2 = 0.94$).

The elasticity implied by the slope of the regression line (3.7) is only about a third of the elasticity of substitution among varieties, meaning that it is heavily damped by trade costs. The slope is close to the arithmetic mean of the individual country cross-section elasticities (3.6, excluding eight countries near the origin with wild values).[27] The slope is also fairly close to (about 15 percent below) the average of the individual country time-series elasticities. However, the correlation across countries between the

[25] In only 5 percent of countries is the purchaser price elasticity less than 9.90.

[26] In figure 1, all the countries with negative elasticities are in the South-West quadrant, with relative producer prices below the world average but relative producer prices above the world average because trade costs for good *j* are higher than for good 1.

[27] The countries excluded are those for which the log of the relative producer price is within 0.05 of zero (which include ones with elasticities of 174 and -575): with them included, the mean is 2.6.

cross-section and the time-series elasticities is low, even excluding the countries with wild cross-section values.[28] It is low partly because all the time-series elasticities are in the damping range, between zero and unity, while the cross-section elasticities can (and in nearly a quarter of the countries do) lie outside this range.

The scatter of cross-section elasticities around the regression line exists partly because of variation in country-specific trade costs, but a more important source of variation is that each country's τ's, crucial determinants of its price ratio elasticity, vary inversely with the absolute level of its producer prices. Any particular c_j^z / c_1^z can be generated by many different pairs of c_j^z and c_1^z: given the trade costs of the two goods, the price ratio elasticity is greater (damped less) if c_j^z and c_1^z are both high, which reduces the τ's, and smaller (damped more) if they are both low.[29]

The scatter is tightest where c_j^z / c_1^z is around 2 (or in logs 0.7) and thus close to the average trade cost ratio, $\bar{\pi}_{j1}$, because there all countries have similar purchaser price ratios and hence similar relative exports, regardless of whether the absolute levels of c_j^z and c_1^z are high or low. Where c_j^z / c_1^z diverges more from $\bar{\pi}_{j1}$, the scatter is looser. It is loosest on the left of the figure, where the high relative trade cost of good *j* in combination with its low relative producer price amplifies the effects on relative purchaser prices and hence on relative exports of differences in the absolute levels of c_j^z and c_1^z. On the right, the relative trade cost and relative producer price of good *j* are both high, which lessens the effect on relative purchaser prices and hence relative exports of differences among countries in the levels of c_j^z and c_1^z.

Table 2 reports the results of simulations with alternative values of the common trade cost parameters, the base case being the figure 1 results in the top row. The first two experiments double and halve $\bar{\tau}_1^F$. The next two vary the share of proportional costs in total trade costs from 0.2 to zero and 0.5. The other four vary the relative trade costs of the two goods, in both directions, with $\bar{\pi}_{j1}$ ranging between 0.25 and 4, but adjusting $\bar{\tau}_1^F$ to hold average trade costs constant. The first two columns report the intercept and slope coefficients of each regression, and the next two the R^2s of the linear regression and a cubic alternative (as a test for linearity). The last four columns show the average cross-section and time-series elasticities, and the percentages of cross-section elasticities that are outside the damping range.[30]

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[28] Excluding the same eight countries as in the previous footnote, in a regression of the time-series elasticities on the cross-section elasticities, the slope coefficient is 0.04 and the R^2 is 0.07.

[29] 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 with lower absolute producer prices and thus greater damping are below the line, and the points with higher absolute producer prices and thus less damping are above the line. In the right-hand half of the figure, this relationship is reversed.

[30] Tests of the statistical significance of the coefficients are not reported because the difference of the slope from zero is not economically interesting and the differences of the slopes from the elasticity of substitution among varieties are in all cases so large as not to require any test.

Table 2 Effects of trade costs on regressions of relative exports on relative producer prices

	Coefficients		R^2		Average elasticities		Non-damping cross-section elasticities	
	Intercept	*Slope*	*Linear form*	*Cubic form*	*Cross section*	*Time series*	*% < 0*	*% > β*
Base case (specification in notes)	-1.13	-3.69	0.94	0.94	3.61	4.36	15	8
Changes in average international trade costs								
τ_1^F bar raised from 1.0 to 2.0	-1.23	-2.74	0.95	0.95	2.70	3.42	23	8
τ_1^F bar reduced from 1.0 to 0.5	-0.77	-4.92	0.95	0.95	4.83	5.56	10	7
Changes in share of proportional trade costs								
a reduced from 0.2 to zero	-1.09	-2.66	0.87	0.87	2.60	2.96	21	7
a raised from 0.2 to 0.5	-1.29	-5.24	0.97	0.98	5.14	6.46	12	13
Changes in relative trade costs (compensated)								
π_{j1}bar raised from 2.0 to 4.0	-2.09	-4.15	0.86	0.87	3.64	4.63	23	15
π_{j1}bar reduced from 2.0 to 1.0	-0.02	-3.48	0.97	0.98	3.79	4.27	2	1
π_{j1}bar reversed from 2.0 to 0.5	1.15	-3.53	0.93	0.94	4.24	4.36	11	8
π_{j1}bar reduced from 2.0 to 0.25	2.18	-3.83	0.83	0.86	4.97	4.63	20	16

Notes: export ratios and producer price ratios are logged. Linear and cubic regressions are fitted by OLS. 'Average elasticities' are arithmetic means: cross-section averages exclude 8 countries with relative producer prices close to the world average. 'Compensated' means that τ_1^F bar was adjusted to keep world average trade costs constant. In all experiments, $\beta_j = \beta_1 = 10$, $\gamma_{j1} = 3$, and $s^{\check{z}}_j = s^{\check{z}}_1 = 0.1$. Trade cost parameters in the base case are

τ_1^F bar = 1.0
π_{j1}bar = 2.0
π_{DF} bar = 0.5
a = 0.2

In all these experiments, the cross-country relationship between relative exports and relative producer prices remains roughly log-linear: the cubic regression always fits slightly better, but the linear one is an excellent approximation. Its closeness of fit declines as the share of proportional in total trade costs falls, and as the difference in trade costs between the goods widens, but R^2 is never below 0.83. Higher average trade costs, a lower share of proportional trade costs, and wider differences in trade costs between the goods also increase the percentages of countries with cross-section elasticities outside the damping range.

The slopes of the regressions vary more or less in parallel with the average values of the cross-section and the time-series elasticities of individual countries. The average time-series elasticity is consistently higher than that implied by the slope, while the average cross-section elasticity is sometimes higher and sometimes lower.[31] Higher average trade costs and lower shares of proportional in total trade costs clearly reduce average elasticities. The average elasticities are affected rather less by changes in the relative trade costs of the goods: the reason is that damping is caused by *invariance* of relative trade costs with respect to variation in relative producer prices, a property that is largely independent of the average direction or size of relative trade costs.

The sign and size of the intercept depend mainly on the relative trade costs of the two goods. In the base case of figure 1, the intercept is negative: the higher trade cost of

[31] The cross-section average is more affected by a few extreme values in some of the simulations. That the time-series elasticity is always above the slope may be a result of the mild non-linearity of the cross-section relationship. The way in which trade costs damp the price ratio elasticity causes the cubic regression to flatten at each end.

good *j* than of good 1 ($\overline{\pi}_{j1}$ = 2) causes countries to be more disadvantaged in export markets, relative to their competitors (who include home suppliers), for good *j* than for good 1, and so on average to export less of it. Widening the difference in relative trade costs makes the intercept more negative, while reversing the direction of the difference in relative trade costs makes it positive. The intercept depends also on the relative expenditure shares of the goods, $s_j^{\bar{z}}$ and $s_1^{\bar{z}}$, which are assumed to be equal in all the experiments: making these shares unequal alters the intercept in the expected direction, but has little effect on either the slope or the fit of the regression.

6.2 Export, home sales and output elasticities

In this sub-section, the cross-country simulations of the effects of trade costs on the producer price elasticity of demand for exports, analysed in the previous sub-section, are extended to cover also home sales and output. The main difference is the effect of trade costs on the purchaser price elasticity, which is negligible for exports but can be substantial for home sales (and hence also for a country's total output).

Figure 2 is based on the same principles and the same assumptions about trade costs and other variables as figure 1, but includes the results for home sales and output, as well as for exports. The three sets of points show relative exports, home sales and output for each country, and the three lines are linear OLS regressions through these points, whose coefficients are reported in the first row of table 3. (The second and third rows show the means and standard deviations of the coefficients from ten other runs of the same case, with the same assumptions but different random distributions of $c_j^z, c_1^z, \pi_F^z, \pi_B^z$ and π_D^z, demonstrating that the results are always similar.)

Figure 2 Effects of relative producer prices on sales in different markets

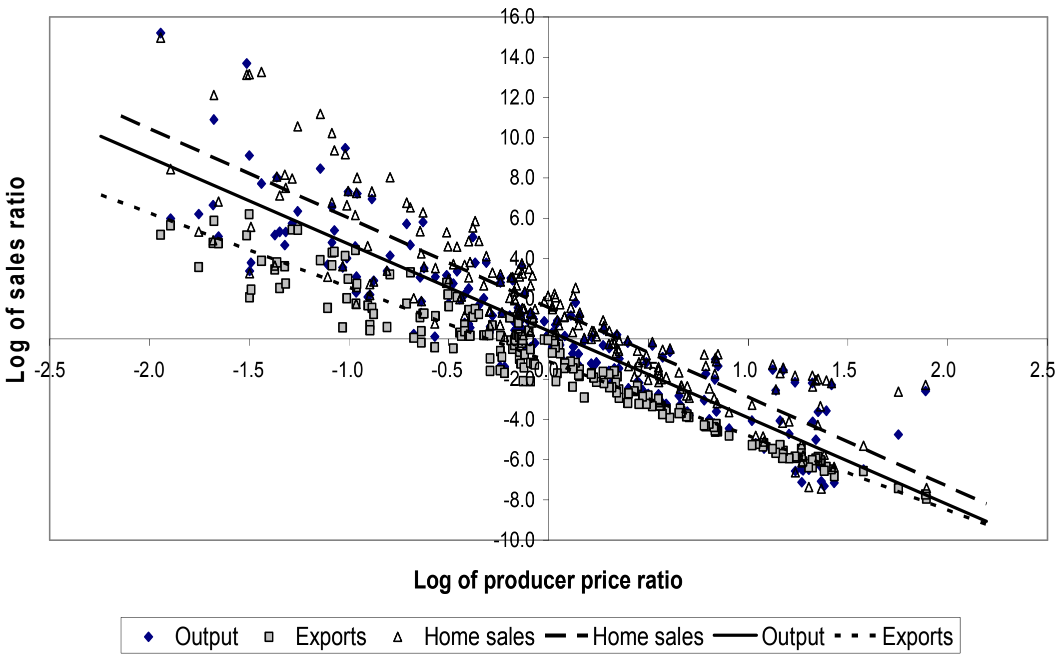

Table 3 Regressions of relative exports, home sales and output on relative producer prices

	Relative exports			Relative home sales			Relative output			Exports/
	Intercept	Slope	R^2	Intercept	Slope	R^2	Intercept	Slope	R^2	output
Base case (specification in notes)	-1.13	-3.69	0.94	1.55	-4.44	0.81	0.39	-4.31	0.83	0.61
Mean values of ten random variations	-1.12	-3.66	0.94	1.48	-4.55	0.86	0.31	-4.40	0.87	0.63
Standard deviations of these variants	0.22	0.07	0.01	0.17	0.12	0.02	0.19	0.13	0.01	0.02
Changes in average international trade costs										
τ_1^F bar raised from 1.0 to 2.0	-1.23	-2.74	0.95	1.09	-2.91	0.75	0.34	-2.78	0.79	0.43
τ_1^F bar reduced from 1.0 to 0.5	-0.77	-4.92	0.95	1.69	-6.07	0.89	0.33	-6.00	0.92	0.79
Changes in share of proportional trade costs										
a reduced from 0.2 to zero	-1.09	-2.66	0.87	1.43	-3.92	0.78	0.29	-3.49	0.79	0.61
a raised from 0.2 to 0.5	-1.29	-5.24	0.97	1.70	-5.24	0.85	0.55	-5.60	0.86	0.61
Changes in relative trade costs (compensated)										
π_{j1}bar reduced from 2.0 to 1.0	-0.02	-3.48	0.97	0.11	-4.06	0.84	0.11	-3.94	0.90	0.60
π_{j1}bar reversed from 2.0 to 0.5	1.15	-3.53	0.93	-1.28	-4.17	0.81	-0.09	-4.10	0.85	0.61
π_{DF} bar lowered from 0.5 to 0.2	-2.29	-4.00	0.94	2.06	-4.87	0.79	0.92	-4.84	0.81	0.39
π_{DF} bar raised from 0.5 to 1.0	-0.47	-3.40	0.94	1.15	-4.09	0.84	0.21	-3.85	0.88	0.79
Other experiments ('real data' problems)										
Trade costs of *H* goods twice *X* goods	-1.24	-3.69	0.94	1.09	-2.91	0.75	0.27	-3.34	0.80	0.49
Relative values instead of volumes	-1.08	-3.32	0.94	1.29	-3.87	0.78	0.13	-3.73	0.80	0.61
Omitting the 100 smallest countries	-1.15	-3.64	0.93	1.42	-3.50	0.74	0.68	-4.05	0.79	0.46

Notes: 'Exports/output' refers to the average of both goods and all countries. 'Compensated' means that τ_1^F bar was adjusted to keep world average trade costs constant: all other experiments alter only the specified parameter. In all the experiments, $\beta_j = \beta_1 = 10$, $\gamma_{j1} = 3$, and $s_{\dot{z}j} = s_{\dot{z}1} = 0.1$. Trade cost parameters in the base case are:

τ_1^F bar = 1.0
π_{j1}bar = 2.0
π_{DF} bar = 0.5
a = 0.2

None of the regression lines (in any of the simulations) deviates appreciably from log-linearity. The best fitting one is for exports ($R^2 = 0.94$). The home sales regression fits less well ($R^2 = 0.81$), because, in addition to variation among countries caused by differences in their cross-section price ratio elasticities (which determine the fit of the export regression), there is variation in purchaser price elasticities, because countries' home market shares vary. The fit of the output regression is closer to the R^2 for home sales than to that for exports, because of the imperfect correlation (R = 0.93) between export and home sales ratios. Exports are on average 61 percent of output.

The slopes of the three regressions are similar, with implied producer price elasticities ranging from 3.7 to 4.4, all far lower than the elasticity of substitution among national varieties (which is still 10 for both goods). As expected, the output elasticity (4.3) is between the other two elasticities. The export elasticity is lower than the home sales elasticity: on these assumptions, the heavier damping of the price ratio elasticity in export markets as a result of international trade costs outweighs the higher purchaser price elasticities in export markets than in more protected home markets.

The intercepts of the export and home sales regressions are of opposite sign, because of the difference in trade costs between the goods ($\overline{\pi}_{j1} = 2$). The higher trade cost of good *j* puts countries at a disadvantage in selling it in export markets, especially against competition from home suppliers, so that the export intercept is negative. But it gives them an advantage in selling good *j* in their home market against competition from foreign suppliers, making the home sales intercept positive.[32]

The other rows of table 3 report the results of varying some of the assumptions. In the fourth and fifth rows, world average trade costs are doubled and halved. All three elasticities, as expected, vary inversely with average trade costs, with that for output, for example, being reduced from 4.3 to 2.8 by the doubling and raised to 6.0 by the halving. Higher trade costs cause the home sales and output regressions to fit worse. They also unsurprisingly reduce the world average export share.

The following two rows vary *a* (the share of proportional in total trade costs) between zero and 0.5. As expected, a higher *a* increases all the elasticities, because it reduces damping of the price ratio elasticity. The impact is substantial: even raising *a* from zero to 0.2 increases the output elasticity from 3.5 to 4.3, and with $a = 0.5$ it is 5.6. The impact is largest for the export elasticity, which is determined almost entirely by the price ratio elasticity, and is smallest for the home sales elasticity, which depends also on the purchaser price elasticity.[33] A smaller share of proportional trade costs also makes all the regressions fit worse.

The next two rows of table 3 vary the average relative trade costs of goods *j* and 1, equalising them and reversing the difference between them, while adjusting $\bar{\tau}_1^F$ to keep average trade costs constant. These changes have small effects on the slopes of the three regressions, and alter the intercepts in the expected ways. With equal trade costs, the intercepts of the export and home sales regressions are both close to zero, while reversing the difference in trade costs reverses the signs of both intercepts. A larger difference in trade costs also makes all three regressions fit worse.

The following two rows vary the relative size of internal and international trade costs, reducing $\bar{\pi}_{DF}$ from 0.5 to 0.2 and raising it to 1.0, again adjusting $\bar{\tau}_1^F$ to keep average trade costs constant. Raising the share of internal trade costs reduces all three slopes. The export regression is least affected, because its slope is determined mainly by the price ratio elasticity, which in turn depends mainly on the (unchanged) sum of internal and international trade costs.[34] The slope of the home sales regression alters more, since the underlying price ratio elasticity depends only on internal trade costs.[35].

[32] The intercepts can be predicted quite accurately by inserting the world average trade cost parameters into equations (6.2)-(6.5) and hence deriving the world average relative price of the two goods for each country in each market, relative to that of its competitors. The resulting average price ratio, logged, is then multiplied by the world average purchaser price elasticity for that market (with the sign reversed).

[33] Increasing *a* to unity is not sufficient, in these simulations, to raise all the elasticities to the assumed value of the elasticity of substitution among national varieties (10). In the case of home sales, this is partly because the average purchaser price elasticity is well below 10. For both home sales and exports it is also because the trade costs of home and foreign suppliers co-vary as a result of sharing a common element, namely internal trade costs in the market concerned. If, as well as setting $a = 1$, internal trade costs are suppressed by setting $\bar{\pi}_{DF}$ close to zero, the average price ratio elasticity for both home sales and exports is close to unity and hence the relative sales elasticity for exports is close to 10.

[34] Increasing $\bar{\pi}_{DF}$ makes the intercepts of both the export and the home sales regressions absolutely smaller, because (with constant total trade costs) this lowers international trade costs and thus reduces both the relative disadvantage of selling good *j* in export markets and the relative advantage of selling it in the home market.

[35] Higher internal trade costs also reduce the proportional trade cost advantage of home suppliers over foreign suppliers, as shown in equation (5.7), which reduces average home market shares and hence

The bottom panel of table 3 addresses three limitations of real-world data – showing how statistical estimates of cross-country elasticities might differ from the simulated ones. The first addresses the problem of aggregation discussed earlier by making the trade costs of the goods sold in each country's home market twice as large as those of its exports: this greatly reduces the home sales elasticity, which becomes appreciably lower than the (unchanged) export elasticity. The second experiment replaces relative sales volumes as the dependent variable with relative sales values, which is how data on sectoral exports and outputs are usually measured: this unsurprisingly lowers all the elasticities, but not greatly. The last experiment omits the 100 smallest countries, on which data are often unavailable: this hardly alters the export elasticity, but lowers the home sales elasticity substantially by raising the average home market share.

This sub-section has focused on world average cross-section elasticities, as expressed in the slopes of the regressions. For individual countries, the cross-section elasticities of relative demand for exports, home sales and output vary around these averages, and for some countries are dramatically different (though the greatest variation is close to the origin, so that the regressions fit well). The world average time-series elasticity is close to the world average cross-section elasticity, for home sales and output as well as for exports.[36] But time-series elasticities, too, vary among countries, and the cross-country correlations between time-series and cross-section elasticities, albeit positive, are low, even if countries with wild cross-section values are omitted.[37]

In principle, the cross-section and the time-series elasticities for exports, home sales and output can be calculated for any country by applying the relevant algebra to the relevant data (as for each country in the simulations in this section). In practice, this would often be difficult, since the data are far from complete, particularly on producer prices and trade costs. Nor are there any short-cuts: for example, the share of exports in output is a widely used and available measure of a country's trade costs, but it is a poor predictor of the time-series elasticity and even worse as a predictor of the cross-section elasticity.[38] The export share is closely related to trade costs,[39] but trade costs alone do not determine elasticities: these depend on ratios of trade costs to producer prices (of which the absolute levels also vary across countries).

The practical difficulty of calculating the elasticities for all individual countries is not, however, a major obstacle to the most likely applications of the analysis in this paper. The first application is just to understand the general economic meaning of cross-country regressions between some proxy for the relative producer prices of a pair of

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raises home market purchaser price elasticities, but not by enough to outweigh the stronger damping effect of higher internal trade costs on the price ratio elasticity.

[36] Excluding from the cross-section average eight countries whose relative producer prices are close to the world average, in the table 3 base case the arithmetic means of the cross-section and time-series elasticities, respectively, are for exports 3.6 and 4.4, and for home sales 4.4 and 5.0.

[37] On the same basis as in the previous footnote, the correlation (R) across countries between the cross-section and the time-series elasticity is 0.26 for exports and 0.20 for home sales.

[38] Excluding the same eight countries as in the last two footnotes, the correlation (R) across countries between the cross-section elasticity and the average export share (for goods *j* and 1) is 0.17 for exports and 0.04 for home sales. The corresponding correlation for the time-series elasticity, with all countries included in the calculation, is 0.43 for exports and 0.52 for home sales.

[39] A cross-country regression of the export share on the relative trade cost variables (π_F, π_B, π_D) and the log of country size yields four statistically significant coefficients of the right signs and an R^2 of 0.89.

goods and their relative sales or output. The key insight in this context is that trade costs usually and powerfully reduce the slopes of such regressions.

A second application is to explain why a specific country or group of countries is 'off the cross-country line' at a moment of time – with a sales or output ratio far higher or lower than would be predicted from its relative producer prices. The algebra of the cross-section elasticity in itself sheds light on this sort of discrepancy. It also shows what data would be needed for a full explanation – on trade costs and on absolute producer prices, both for this country and for the world on average – and for one or a few countries there is a fair chance that these data could actually be collected.

A third application is to explain or predict the time path of the structure of sales or output in a specific country or group of countries in response to changes in its relative producer prices. The algebra of the time-series elasticity points in the right direction, both logically and in the assembly of data. Moreover, the task is easier than for the second application, since trade cost and producer price data are needed only for the country concerned, not for the world as a whole.

All models involve simplification, and the present simulations are no exception: they abstract from things that in reality complicate the relationships involved. An example is inequality of rates of profit. The simulations refer to producer prices, which include profits as well as production costs, but in most applications the main interest would be in (and most of the data on) production costs, which are at the core of comparative advantage. Profit rates that are unequal across goods in a country, even if temporarily so, blur the association between relative production costs and relative producer prices. So, for this and many other reasons, one should not expect the relationships in actual data to be anything like so neat as those in the figures and tables in this section.

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, related to trade costs. The basis for this argument is that variation in the relative costs of trading goods is not proportional to variation in the relative costs of producing them. Coupled with less-than-perfect substitutability among varieties of goods from different countries, non-proportional trade costs damp the elasticity of relative sales with respect to variation in relative production costs. In home markets, trade costs further reduce elasticities by raising market shares.

The logic of this argument seems beyond dispute. What is disputable is its empirical importance, which depends on two facts: the general level of trade costs, relative to production costs; and the division of trade costs between those that are proportional to production costs and those that are not. Assuming trade costs to be high (on average, twice production costs) and the share of them that is proportional to production costs to be low (about 20%), the damping effect is big: the simulations in this paper show that producer price elasticities are on average only about two-fifths of the elasticity of substitution among national varieties. So, for example, if Anderson and van Wincoop (2004: 715-6) are right that purchaser price elasticities are between 5 and 10, producer price elasticities would be between 2 and 4. But if trade costs were low, or most of them were proportional, the damping effect would melt away.

On average, trade costs are clearly high. The estimates of Anderson and van Wincoop (2004), which this paper has used, are based partly on debatable inferences from gravity models (Chaney, 2008), but their general level is consistent with much casual evidence from the fair trade and value chain literatures of big international differences between producer prices and purchaser prices. It also seems clear, especially after Hummels and Skiba (2004), Baldwin and Harrigan (2007) and Bernard *et al*. (2007), that trade costs do not vary in strict proportion to production costs. However, further research is needed to test the assumption of this paper that proportional trade costs are a small share of total trade costs. And of course both total trade costs and the share of them that is proportional vary widely among goods, countries and markets.

If the elasticity-reducing effects of trade costs are large, what are the implications for economic analysis? At the level of theory, mainly for Ricardian and Heckscher-Ohlin models, which if modified in this way should behave more realistically, without the need for dubious assumptions about the specificity of factors to sectors or the degree of imperfect substitutability among national varieties. Most of the insights of these 'old' theories are likely to stay the same, though in less strong forms, for example regarding the effects on national factor prices of world product prices and national factor endowments (Wood, 2007). Damping of elasticities by trade costs may also be relevant to models which combine elements of new and old trade theories.

In empirical work, linking demand elasticities to trade costs would alter the technical structure of CGE and other simulation models: the levels of demand elasticities, being calibrated on reality, would stay the same, but their determinants would alter, which might alter the results of policy experiments. Awareness of the relationship between demand elasticities and trade costs could alter the specification and interpretation of econometric studies of the causes and effects of trade. It might assist in developing gravity models that gave trade costs more of a role in explaining the product mix, as well as the level and direction, of trade. For example, differences in trade costs might explain why the degree of international specialisation varies among traded goods, and why there is more specialisation within countries than between them.[40]

The implications of a link between trade costs and demand elasticities for trade policy and its effects also require further thought. The analysis of this paper might shed light on the effects of trade policy reforms that alter not only total trade costs but also the share of them that is proportional (both would be reduced, for example, by a cut in ad valorem tariffs).[41] There might be changes to conclusions about the effects of public policies that affect transport costs and other barriers, as well as to conclusions about a wider range of policies that affect trade and related economic outcomes.

[40] I owe this suggestion to Richard Baldwin.

[41] I am indebted to participants in a seminar in Geneva for pointing this out.

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