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[DRAFT: unfinished revision, still with some internal inconsistencies]

Softening comparative advantage: how trade costs damp and distort specialisation

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Abstract

Because most trade costs do not vary in proportion to production costs, the relative prices of goods vary across countries by less than the relative costs of producing them. In consequence, trade costs reduce and distort the effects of variation across countries in relative production costs on the composition of their output and trade. Since trade costs are also often high, these effects are large, causing the pattern of specialisation across countries to be less pronounced and less clear-cut than would be expected simply on the basis of variation in their comparative advantage in terms of relative production costs.

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1. Introduction

That countries specialise according to comparative advantage is a basic principle of economic theory and a basic feature of economic reality. A long-standing puzzle for economists, however, has been that the real world is not nearly so specialised as most theoretical models of trade predict. The solution, it will be argued in this paper, is that the relative costs of trading goods are largely independent of the relative costs of producing them. The effect of trade costs thus resembles that of measurement error in the independent variables of regressions: it attenuates, as well as introducing noise into, the relationship between comparative advantage and specialisation.

The world predicted by theoretical models of comparative advantage is one in which countries are highly specialised, each producing a few goods, exporting large shares 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).

The real world does not look like that. Most countries produce most sorts of traded goods. There is far less inter-sectoral trade than is predicted by the Heckscher-Ohlin-Vanek model (Trefler, 1995). Relative outputs vary smoothly, not discontinuously, with relative costs (as for example in the Balassa, 1963, test of Ricardo). To achieve realistic results, computable general equilibrium (CGE) modellers have to depart from conventional trade theory by introducing import and export functions that lessen the responsiveness of the sectoral structures of countries to world prices.

One suggested explanation for these discrepancies between theory and reality 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 industry and services there are increasing returns at the sectoral level. A second 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 theory and reality.

The third main suggested explanation for limited specialisation is that the varieties of goods produced by different countries are imperfect substitutes for one another. This insight of Armington (1969) underlies the import functions named after him in CGE models, and the same assumption is made in most gravity models (Anderson and van Wincoop, 2004). Rauch and Trindade (2003) argue, too, that even among identical national varieties, elasticities of substitution are reduced by information costs.

That local and foreign varieties are generally imperfect substitutes is widely accepted, and will be an important assumption of this paper. 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. There is less agreement, however, about the degree of imperfection. In particular, the substitution elasticities that CGE models need to achieve realistic results (often less than 4)[1] seem well below those estimated econometrically. Anderson and van Wincoop (2004: 715-6) conclude from a review of the literature that these elasticities 'are likely to be in the range of five to ten', and Broda and Weinstein (2006: 568) estimate a mean of 12.6 at the 10-digit level.

It will be shown in the present paper, though, that trade costs can have the same effect as lower elasticities of substitution among varieties, namely to reduce elasticities of demand. It will also be shown, in simulations with reasonably realistic data, that the proportionate reduction of elasticities caused by trade costs is large (roughly halving them) and could thus explain the gap between the elasticities needed by CGE models and those suggested by econometric estimates. Entwined with this 'damping' effect of trade costs is a 'distortion' effect – dispersion of elasticities among countries with the same comparative advantage (as measured by relative production costs).

What generates both effects is that the relative (variable) trade costs of different goods are not strictly proportional to relative production costs, as is usually assumed, but are largely independent of relative production costs. The relative prices of goods (the sum of production costs and trade costs) thus vary across countries by proportionally

[1] 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.

less than their relative costs of production, which reduces variation across countries in relative sales of the goods. The degree of reduction, however, depends on the precise configuration of trade costs and production costs for individual goods in each country, which can differ among countries with the same relative production costs.

The reduction of elasticities can be illustrated 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 price elasticity of demand to be 10, so that in the absence of trade costs, a country whose unit production cost was $5 would sell six times as much as a country whose unit production cost was $6. Let the cost of trading this good for both countries be $5 per unit, so that prices are $10 and $11, narrowing the proportional price gap from 20% to 10%. The country with the lower production cost then sells less than three times as much: the elasticity of sales with respect to production cost is 5 rather than 10.

Non-proportional trade costs 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'. 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 contribution of the present paper is to argue that this idea is of far more general relevance. Non-proportional trade costs affect the pattern of trade across goods, not only across different qualities of given goods. This has been pointed out by Hilberry (2002) and Matsuyama (2007), and shown empirically for particular sorts of goods by Nunn (2007) and Levchenko (2007) and for many goods by Greenaway et al (2009). The 'distortion' point of the present paper is thus not particularly novel, though it has yet to be widely understood. What is new, to the best of this author's knowledge, is the 'damping' point: that non-proportional trade costs attenuate the relationship across countries between comparative advantage and specialisation.

The objective of the paper is to show how damping (and the associated distortion) works in theory. It uses actual data only indirectly, to calibrate simulations. It does not, however, contain a complete theoretical model: the relative production costs of different countries are taken as given, without explanation of how they are determined or how they might be affected by trade or by trade costs, or of how markets interact within countries or countries interact in the world economy. This is partly for lack of space, but mainly because the analysis of damping in this paper could be fitted into many different models of trade, with different detailed implications (some of which for Heckscher-Ohlin models are worked out in Wood, 2009).

Section 2 discusses the non-proportionality of trade costs in general terms. Section 3 formalises the analytics of damping for one good, and section 4 extends its analysis to the damping of comparative advantage with two or more goods. Section 5 simulates a world of many countries. Section 6 distinguishes between exports and home market sales. Section 7 concludes with a discussion of some possible implications for theory, empirical research and policy.

1a (to become 2). Non-proportional trade costs

The main purpose of this section is to outline the empirical grounds for believing that most trade costs are non-proportional. It also explains how this paper relates to other recent work on trade costs.

But first, some definitions. The trade costs of a good will be called 'proportional' if adding them to production costs leaves its price in any country as a ratio of its price in any other country the same as the cross-country ratio of production costs. A good that was cheaper to produce in one country than another would thus need to be also and to the same degree cheaper to export from that country.[2] If the trade costs of two goods were both proportional, and even if one had higher trade costs than the other, then the

[2] With iceberg trade costs, this would be so if the fraction of the good that melted away each mile were the same for all countries and if all countries were the same distance apart (which could be true of no more than three countries).

ratio across any two countries of the relative prices of the goods would be the same as the corresponding ratio of relative production costs.

All other trade costs will be called ‘non-proportional’. But, like the unhappy families in *Anna Karenina*, such trade costs can be non-proportional in many different ways. The clearest case is that of ‘independent’ trade costs, whose relative size for a pair of goods is the same in all countries or varies among countries in ways that are unrelated to their relative production costs. For purposes of analysis, moreover, it is convenient to assume that there are only two sorts of trade costs, strictly independent and strictly proportional, and to treat total trade costs for any good as a weighted combination of these two sorts. On this basis, ‘independent trade costs’ will be used as short-hand for ‘non-proportional trade costs’.

Data on trade costs are scarce (Anderson and van Wincoop, 2004: 692), but probably sufficient for an informed guess about the degree of non-proportionality. A few trade costs are clearly proportional, such as ad valorem tariffs and insurance premia, but the majority of trade costs seem likely to be non-proportional. 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 simplified into percentages. Similarly, retail mark-ups, though also often simplified to rules of thumb, should vary 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.[3]

Physical features of goods make relative transport costs similar in different countries: 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 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

[3] [Cite supporting evidence from Chen and Novy]

higher-priced goods. But relative transport costs seem most unlikely to vary in strict proportion to relative production costs.

Econometric studies of detailed trade flows yield results that are inconsistent with the common 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 fits 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 degree of responsiveness of the relative trade costs of goods to variation across countries in their relative production costs surely differs among goods, countries and markets, but seems likely on average to be fairly low. A summary measure, with total trade costs represented simply as a weighted combination of strictly independent and strictly proportional, is the average weight or share of proportional trade costs. The base case share assumed in the simulations in section 5 is 20%. Total trade costs 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. Thus if independent trade costs are the equivalent of 80% of total trade costs, their damping effect on elasticities is likely to be big.

How does the present paper relate to the large amount of other recent work on trade costs? Following Melitz (2003), there have been many studies of the effects of fixed trade costs on the export behaviour of firms (surveyed by Bernard *et al.*, 2007). But although fixed trade costs have proved very helpful in explaining which firms export to which markets, they cannot explain why countries are less specialised than would be expected from standard theory – since fixed trade costs generate increasing returns, they should if anything tend to amplify specialisation. As Deardorff (2006) explains, what would bring the predictions of the standard theory into line with reality would be to assume that the unit costs of trade rise with the quantity sold (Aldaz-Carroll, 2003, makes a similar argument), but that would be the opposite of Melitz.

Another active area of recent work on trade costs has been gravity models (Anderson and van Wincoop, 2004). Gravity models have tended to focus on how trade costs influence the aggregate amount and direction of trade of countries, with less emphasis on sectoral structure (among the exceptions is Chen and Novy, 2008). However, non-proportionality could in principle be introduced into gravity models to give trade costs a role in explaining the product mix of trade, as well as its level and directions. Non-proportionality could also be brought into the analysis of unbundling and off-shoring of production activities (Baldwin, 2006), to which falling trade costs have contributed and which is closely connected with comparative advantage.

2. Simple analytics of damping

In analysing how trade costs affect demand elasticities, it is necessary to distinguish between purchaser prices (those paid by the customer), denoted by p, and producer prices (those received at the factory gate or farm gate), denoted by c. The differences between purchaser prices and producer prices are, by definition, trade costs (together, in statistical practice, with indirect taxes and subsidies).[4] Producer prices are equal to

[4] 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

production costs if excess profits are zero, as is usually assumed in theoretical models, but they can diverge, so this paper from here on uses the words ‘producer price’ rather than ‘production cost’, but with the label *c* as a reminder of the connection.

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, and the elasticity of demand with respect to producer prices is thus lower than with respect to purchaser prices. In other words, non-proportional trade costs ‘damp’ the producer-price elasticity.

To show more formally how damping works and to develop some basic relationships that will be deployed later to analyse comparative advantage, it is convenient to start with the case of a single good, whose sales, *q*, depend on its purchaser price according to a demand function

$$q = \alpha p^{-\tilde{\varepsilon}} \tag{2.1}$$

where α is a parameter and $\tilde{\varepsilon}$ is the purchaser-price elasticity of demand. Since the purchaser price, *p*, is the sum of the producer price, *c*, and the unit cost of trade, *t*, the demand function can be expanded to

$$q = \alpha (c + t)^{-\tilde{\varepsilon}} \tag{2.2}$$

The elasticity of demand with respect to the producer price, labelled ε (with no tilde) can by definition be written in the form

$$\varepsilon = \tilde{\varepsilon} \delta \tag{2.3}$$

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.

where δ is the elasticity of p with respect to c , which is multiplied by $\tilde{\varepsilon}$, the elasticity of q with respect to p (which must be assumed to be finite: trade costs could not damp a purchaser-price elasticity that was infinite). If δ is less than unity (and greater than zero), the producer-price elasticity is damped. To show what determines the value of δ, let t be a function $t(c)$ of c and differentiate

$$p = c + t(c) \tag{2.4}$$

with respect to c to obtain, after some rearrangement,

$$\delta = \frac{1 + a\tau}{1 + \tau} \tag{2.5}$$

where τ is the trade cost ratio, t/c, and a is the elasticity of t with respect to c. The degree of damping thus increases (δ becomes smaller) as the ratio of trade costs to the producer price rises, but it depends also on the elasticity a (whose role is analysed in a similar way by Hummels and Skiba, 2004: 1390-1).

If trade costs varied in strict proportion to producer prices, as for example with an ad valorem tariff, a would be unity, and so also would be δ, with no damping (whatever the value of τ). If, by contrast, unit trade costs were strictly independent of producer prices, for example consisting only of transport costs determined by the weight of the good, a would be zero, and δ would be determined simply by the trade cost ratio as

$$\delta = \frac{1}{1 + \tau} \tag{2.6}$$

The higher the ratio of (independent) trade costs to the producer price, the greater the degree of damping. The form of (2.6) arises from the fact that $1/(1 + \tau)$ is just another way of writing the share of the producer price in the purchaser price, $c/(c + t)$. This share determines how big a proportional change in the purchaser price is caused by a given proportional change in the producer price: for example, if c were half of p, a

10% rise in c would cause a 5% rise in p. However, δ in (2.6) is clearly not a constant elasticity: given t, as c rises, τ falls and hence so does the degree of damping.

In reality, trade costs are a mixture of things which vary to some degree with producer prices and things which are completely independent of producer prices, so that a is usually between zero and unity, and δ correspondingly lies between the value implied by (2.6) and unity. This mixture can conveniently be approximated by assuming that there are only two sorts of trade costs, strictly independent, denoted by $\tilde{t}$, and strictly proportional, $\ddot{t} = \ddot{\tau} c$, so that the elasticity can be written as

$$\delta = \frac{1}{1 + \tilde{\tau}} \qquad (2.7)$$

where

$$\tilde{\tau} = \frac{\tilde{t}}{\tilde{c}} = \frac{\tilde{t}}{c(1 + \ddot{\tau})} \qquad (2.8)$$

In effect, proportional trade costs have been shifted out of t and into c (while keeping $p = c + t = \tilde{c} + \tilde{t}$). So if $\ddot{\tau} > 0$, $\tilde{\tau} < \tau$ and the value of (2.7) is greater than of (2.6), implying less damping than with only independent trade costs.

Equation (2.7) has the form of (2.6) rather than of (2.5) because the elasticity of $\tilde{t}$ with respect to $\tilde{c}$ is zero by construction. It is valid for all mixtures of independent and proportional trade costs, including the extremes of wholly independent trade costs ($\ddot{\tau} = 0$, which would make 2.7 the same as 2.6) and wholly proportional trade costs ($\tilde{t} = 0$, which would make $\tilde{\tau} = 0$ and $\delta = 1$). Damping is increased by a higher total trade cost ratio, $\tau = (\tilde{t} + \ddot{\tau} c)/c$, with a given mixture of independent and proportional trade costs, but is reduced by a higher share of proportional in total trade costs.

3. Damping of comparative advantage

The purpose of this section is to analyse the effects of non-proportional trade costs on comparative advantage. It assumes, importantly, that the varieties of a good produced by different countries are imperfect substitutes, so that comparative advantage can be observed in relative price differences even when countries are trading. The focus will be entirely on cross-country differences at a single point in time, though the equations could in principle also be used to analyse changes over time in a single country.[5]

Consider a single country producing its own varieties of two goods, j and 1 (with 1 as the numeraire and j as an example from all other goods, 2, …., n) for sale in a single world market of which it has only small shares for both goods. The relative sales (and outputs) of its varieties depend on the relative purchaser prices it charges for them, p_j and p_1, relative to average world purchaser prices, distinguished by stars, according to a demand function

$$\ln\frac{q_j}{q_1} = \ln\alpha_{j1} - \beta_{j1}\ln\frac{p_j/p_j^*}{p_1/p_1^*} \qquad (3.1)$$

in which the purchaser-price elasticity, β_{j1}, is an average across goods j and 1 of the elasticities of substitution of buyers among national varieties (as will be shown later, this average is a weighted harmonic mean). The parameter α_{j1} depends on consumer preferences and the prices of other goods.

The question is how the country's relative sales depend on its comparative advantage, conventionally defined in terms of its relative production costs. Assuming production costs to be reflected in producer prices, equation (3.1) can be rewritten as

$$\ln\frac{q_j}{q_1} = \ln\alpha_{j1} - \varepsilon_{j1}\ln\frac{c_j/c_j^*}{c_1/c_1^*} \qquad (3.2)$$

[5] For this purpose, the starred values of variables can be interpreted as 'before' and the unstarred values as 'after'. The equations can thus describe the effects on a country's relative purchaser prices and sales of autonomous changes in producer prices and trade costs (including changes in trade policies).

where the c's are treated as exogenous, since this is a demand function (though in a full model, they would usually depend on the q's) and

$$\varepsilon_{j1} = \beta_{j1}\delta_{j1} \tag{3.3}$$

is the elasticity of relative purchaser prices with respect to relative producer prices, or for short the price-ratio elasticity, which is by definition

$$\begin{aligned}
\delta_{j1} &= \frac{\ln(p_j / p_j^*) - \ln(p_1 / p_1^*)}{\ln\left(c_j / c_j^*\right) - \ln\left(c_1 / c_1^*\right)} \\
&= 1 + \left[\ln \frac{c_j}{c_j^*} \frac{c_1^*}{c_1}\right]^{-1} \ln \frac{1+\tau_j}{1+\tau_j^*} \frac{1+\tau_1^*}{1+\tau_1} \\
&= 1 + \left[\ln \frac{c_j}{c_j^*} \frac{c_1^*}{c_1}\right]^{-1} \ln \frac{1+\breve{t}_j c_j^{a_j - 1}}{1+\breve{t}_j^* c^{a_j^* - 1}} \frac{1+\breve{t}_1^* c^{a_1^* - 1}}{1+\breve{t}_1 c_1^{a_1 - 1}}
\end{aligned} \tag{3.4}$$

If $0 < \delta_{j1} < 1$, the country's comparative advantage is damped, to a degree depending on how far δ_{j1} is below unity. Its sales of good j relative to good 1 diverge from world average relative sales (given by α_{j1}) in the direction that would be expected from its relative producer prices, but not by as much as would be expected simply on the basis of the purchaser-price elasticity (β_{j1}).

Equation (3.4) is not easy to analyse. A more illuminating approach is to treat δ_{j1} as an average of the four $1/(1+\tau)$ terms, albeit a complicated average. It first combines the home and world average trade cost ratios for each good, and then combines them again across the goods. At the first stage, it can be rewritten as a weighted sum of the price-ratio elasticities for the two goods individually

$$\delta_{j1} = \frac{1}{1-C}\delta_j + \frac{1}{1-1/C}\delta_1 \tag{3.6}$$

where

$$\delta_j = 1 + \left(\ln \frac{c_j}{c_j^*} \right)^{-1} \ln \frac{1+\tau_j}{1+\tau_j^*} \tag{3.7}$$

with δ_1 similarly defined for good 1, and

$$C = \frac{\ln\left(c_1 / c_1^*\right)}{\ln\left(c_j / c_j^*\right)} \tag{3.8}$$

The weights in (3.6) sum to unity. C is simply the proportional difference between the home country and the world average producer prices of good 1, divided by the proportional difference for good j.[6] If these differences are in opposite directions (for example, good j costs more at home than abroad, but good 1 costs less), the weights are between zero and one, so that δ_{j1} is the weighted arithmetic mean of δ_j and δ_1, and closer to that of the good for which the producer price difference is larger. If the producer price differences are in the same direction (both goods costing less or more at home than abroad, which is possible since these are two out of many goods), the weights must be of opposite sign, and at least one must be absolutely greater than unity, so that δ_{j1} could lie outside the range of δ_j and δ_1, and could thus (though it need not) exceed unity or be less than zero even if both δ_j and δ_1 were within this range.[7]

The price-ratio elasticity for each good can be closely approximated by a more tractable expression, which for good j is

$$\delta_j \approx \frac{1 + \left(a_j + b_j\right)\overline{\tau}_j}{1 + \overline{\tau}_j} \tag{3.9}$$

where

[6] Since each of these differences could be either positive or negative, C (and its inverse) could also be either positive (if they were in the same direction) or negative (if they were in opposite directions). Its size depends on the absolute difference in the differences for the two goods, regardless of their signs.

[7] The good for which the producer price difference between the home country and the world average is bigger again has the larger influence on the overall elasticity. If the overall elasticity lies outside the range of the two individual elasticities, this likewise occurs in the direction of the elasticity of the good for which the producer price difference is larger.

$$\bar{\tau}_j = \sqrt{\tau_j \tau_j^*} \qquad (3.10)$$

and [writing $t_j = \breve{t}_j c_j^{a_j}$, as needs to be added to section 2]

$$b_j = \frac{\ln\left(\breve{t}_j / \breve{t}_j^*\right)}{\ln\left(c_j / c_j^*\right)} \qquad (3.11)$$

[These next paras need some revision of notation and text to match the equations]
The basic ingredient of δ_j is $\bar{\tau}_j$, the geometric mean of the home and world τ_j's. However, the influence of $\bar{\tau}_j$ on δ_j is modified by b_j in equation (3.9), which has the same form as equation (2.5), but an expanded economic meaning. In both equations, the elasticity *a* shows how proportional trade costs cause *t* to vary with *c*. In (3.9), b_j additionally shows the relationship between the autonomous cross-country difference in trade costs and the cross-country difference in the producer price of good *j*. If this country had world average trade costs for good *j*, b_j would be zero, and equation (3.9) would be of the same form as equation (2.5). If its trade cost for good *j* is above or below the world average, there is a range of possibilities.

[This para refers to the case of strictly independent trade costs, where $a_j = 0$]
If the trade cost of good *j* in this country differs from the world average in the same direction as its producer price, $b_j > 0$, which raises δ_j in (3.9) and reduces damping. If the divergence in trade costs were equal to that in producer prices, both b_j and (3.9) would be unity. A bigger divergence in this direction would push (3.9) above unity – the purchaser prices of good *j* at home and abroad differing by proportionally more than their producer prices. If trade costs diverge in the opposite direction to producer prices, $b_j < 0$, lowering δ_j and increasing damping, and a big enough divergence in this direction would make (3.9) negative, too – the purchaser price of good *j* being lower at home than abroad, though its producer price is higher, or vice versa.

There is the same range of possibilities for the price-ratio elasticity of good 1. But δ_1 and δ_j are not independent of one another, because $\breve{t}_j / \breve{t}_j^*$ and $\breve{t}_1 / \breve{t}_1^*$ are likely to be related to one another. For example, a country whose location causes its trade costs for good j to exceed the world average will usually also have above-average trade costs for good 1, though not necessarily to the same degree, since trade-cost-related characteristics of goods and countries interact – greater distance, for instance, would raise the trade cost of good j by more than that of good 1 if good j were heavier.

Regardless of how $\breve{t}_j/\breve{t}_j^*$ and $\breve{t}_1/\breve{t}_1^*$ are related, neither δ_j nor δ_1 need be between zero and unity, which is another reason why δ_{j1} might lie outside the damping range. However, it is neither a necessary nor a sufficient reason: even if both δ_j and δ_1 were between zero and unity, opposite-signed weights, as explained above, could pull their weighted sum outside this range; and suitable weights could bring δ_{j1} into the zero-unity range even if δ_j and/or δ_1 were outside this range. The conditions under which damping of comparative advantage occurs for an individual country are thus subtle.

What is far clearer is the average degree of damping for all countries together. [More text to be added to explain the following equations.]

Substituting (3.9) and its counterpart for good 1 into (3.6) yields

$$\delta_{j1} = \frac{1}{1-C}\frac{1+(a_j+b_j)\bar{\tau}_j}{1+\bar{\tau}_j} + \frac{1}{1-1/C}\frac{1+(a_1+b_1)\bar{\tau}_1}{1+\bar{\tau}_1}$$

which for a country with world average autonomous trade costs (both b's = 0) reduces to

$$\bar{\delta}_{j1} = \frac{1}{1-C}\frac{1+a_j\bar{\tau}_j}{1+\bar{\tau}_j} + \frac{1}{1-1/C}\frac{1+a_1\bar{\tau}_1}{1+\bar{\tau}_1}$$

which from (2.5) and (2.7) can be rewritten as

$$\bar{\delta}_{j1} = \frac{1}{1-C}\frac{1}{1+\tilde{\bar{\tau}}_j} + \frac{1}{1-1/C}\frac{1}{1+\tilde{\bar{\tau}}_1}$$

which, averaging C's of all countries, yields

$$\bar{\delta}_{j1} = \frac{0.5}{1+\bar{\tilde{\tau}}_j} + \frac{0.5}{1+\bar{\tilde{\tau}}_1}$$

[Paragraph to be added on what difference it makes to have more than two goods.]

4. Illustrative simulations

The previous section started from a demand equation (3.1) that determines a small country's relative sales in the world market of its varieties of two goods as a function of its relative purchaser prices, which depend in turn on its producer prices and trade costs. The section showed algebraically how non-proportional trade costs can damp and introduce noise into the response of relative sales to variation in producer-price comparative advantage.

This section approaches the same issue from a different direction, by simulating the demand function across many small countries. The simulations confirm some of the points already made algebraically (in effect for two countries), but are a more realistic context in which to study comparative advantage. They provide further information on the extent of damping and noise, and hence on the likely pattern of specialisation in a world in which trade costs are largely independent of producer prices, compared to one in which trade costs are proportional to producer prices.

The method is cross-country plots of relative sales against relative producer prices. More precisely, the log of the relative sales of goods j and 1 by each country z (= 1, .., Z), calculated as

$$\ln q_{j1}^{z} = \ln \frac{q_j^z}{q_1^z} = -\beta_{j1} \ln \frac{c_j^z + t_j^z}{c_1^z + t_1^z} \bigg/ \frac{c_j^* + t_j^*}{c_1^* + t_1^*} \qquad (4.1)$$

will be related to its relative producer price or comparative advantage

$$\ln c_{j1}^{z} = \ln \frac{c_j^z}{c_1^z} \Big/ \frac{c_j^*}{c_1^*} \tag{4.2}$$

where the starred terms are the unweighted means of the corresponding country z variables across all countries. Equation (4.1) involves the purchaser-price elasticity, β_{j1}, which is assumed to be the same for all countries, and is set at 10 (high, since it depends on substitutability among different national varieties). For simplicity, it is also assumed that α_{j1} in the original demand equation (3.1) is unity, which, since both the dependent and the independent variables are defined relative to their means, means an expected intercept of zero.

The data input is as simple as possible (as will be explained later, more elaborate data do not fundamentally alter the results). Producer prices are assumed to vary randomly across 200 hypothetical countries – roughly how many countries there are in the world. Specifically, the producer price for each country and good, c_j^z, is a random number between 1 and 3, drawn from a uniform distribution.

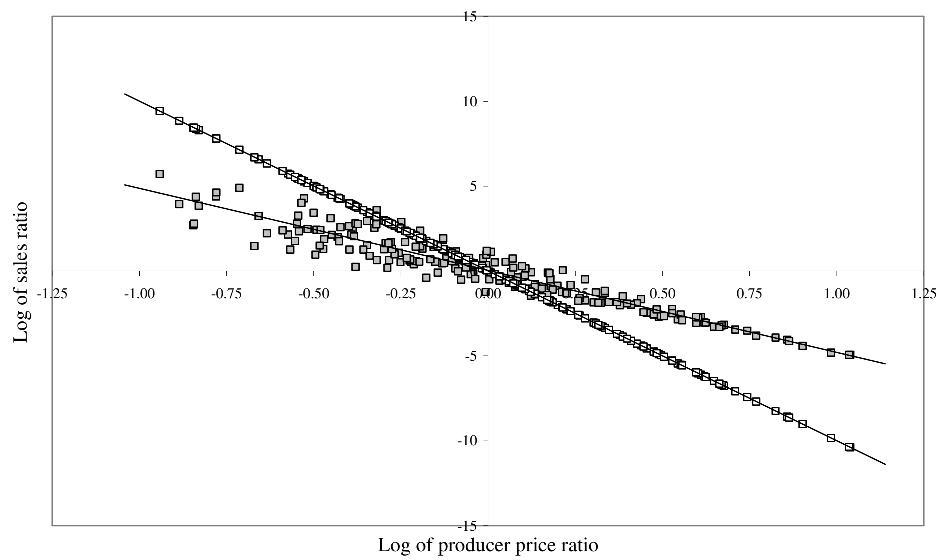
There is thus a nine-fold range of variation among countries in the relative producer price of the two goods, c_j^z / c_1^z, which in logs is more or less symmetrically distributed around a mean close to zero. This range of variation seems realistic, even with the usual assumption of the same technology in all countries, if allowance is made for the influence of economies of scale as well as of differences in factor endowments.

Trade costs, too, are assumed to vary randomly among countries. In each country, the independent trade cost of good 1, $\tilde{t}_1^{\,z}$, is again a random number between 1 and 3 from a uniform distribution. The independent trade cost of good j is fixed in each country as a ratio, $\tilde{t}$, initially set at 2, of $\tilde{t}_1^{\,z}$. There are also proportional trade costs, which are set initially at 20% of total trade costs for each good at world average producer prices and vary randomly across countries in parallel with independent trade costs.

On these initial assumptions, the world average ratio of total trade costs to producer prices (across both goods and all countries) is approximately 2, which is consistent with Anderson and van Wincoop's (2004) estimate of 170% for developed countries and higher levels for developing countries. Trade costs also vary among countries to a degree broadly consistent with Anderson and van Wincoop's suggestion of 'a factor of two or more' (2004: 747). The 20% proportional trade cost share is a conjecture, based on the sorts of evidence reviewed in section 2. All these assumptions are varied in a subsequent series of experiments.

Figure 1 plots the simulated relationship across the 200 'countries' between relative sales and relative producer prices (with both ratios logged): each country is a small grey square, and the line fitted through these squares is an OLS regression. The other, steeper line in the figure (with unshaded squares), shows what the relationship would be if trade costs were proportional to producer prices . What the figure depicts is the outcome for one random draw of producer prices and trade costs, but all such draws yield similar results, as will be documented later.

Figure 1 Effect of relative producer prices on relative sales



Whether or not trade costs are proportional, the sales of good *j*, relative to those of good 1, obviously tend to be lower in countries whose producer price of good *j* is higher, relative to that of good 1. But as the figure shows, non-proportional trade costs alter the outcome in two ways: they make the relationship flatter (less variation across countries of relative sales with relative producer prices) and they make it fuzzier – the country points are not all on a single line.

[More text to be added to explain the following] The regression line in the figure is not estimating: it is simply describing. But the simple algebra of a one-variable OLS regression helps to understand what is going on. Defining

$$c = \ln \frac{c_j^z}{c_1^z} \Big/ \frac{c_j^*}{c_1^*} \text{ and } p = \ln \frac{p_j^z}{p_1^z} \Big/ \frac{p_j^*}{p_1^*}$$

the slope of the regression line is

$$\bar{\varepsilon}_{j1} = \beta_{j1}\bar{\delta}_{j1} = \beta_{j1}\frac{\text{cov}(p,c)}{\text{var}(c)}$$

and its closeness of fit (ie 1 – its dispersion), its R^2, is

$$R^2 = \frac{\text{cov}(p,c)^2}{\text{var}(p)\,\text{var}(c)}$$

If trade costs were proportional, var(p) = var(c) = covar(p,c), bearing in mind that these are logged ratios, so both slope and R^2 are unity (no damping and no distortion). What non-proportional trade costs do, as is intuitively obvious, is to reduce covar(p,c) below var(c), causing both slope and R^2 to be below unity. But not in parallel, mainly because what happens to the R^2 depends also on how var(p) is affected. Varies with precise assns made about input data (to be illustrated with experiments).

Digging a little deeper, we can establish links with the algebra of the previous section. Expanding the slope algebra

$$\frac{\text{cov}(p,c)}{\text{var}(c)} = \frac{\frac{1}{Z}\sum\left(p^z - p^*\right)\left(c^z - c^*\right)}{\frac{1}{Z}\sum\left(c^z - c^*\right)^2}$$

which is losely related to the price-ratio elasticity expression for a single country

$$\delta_{j1}^{z} = \frac{p^z - p*}{c^z - c*} = \frac{\left(p^z - p*\right)\left(c^z - c*\right)}{\left(c^z - c*\right)^2}$$

bearing in mind that each country's δ_{j1}^{z} in the figure is the slope (divided by -10) of a ray to its point from the origin. The average of all the country slopes is

$$\bar{\delta}_{j1} = \tfrac{1}{Z}\sum \frac{p^z - p*}{c^z - c*} = \tfrac{1}{Z}\sum \frac{\left(p^z - p*\right)\left(c^z - c*\right)}{\left(c^z - c*\right)^2}$$

which has some strong similarities with the expression for the slope of the regression, though these are different sorts of averages and yield different numbers, depending on the details of the distributions of the variables.

The algebra cannot tell us much more about the determinants of the R^2, because this depends on the details of the distributions of the four tau terms. This is where the simulations are particularly useful.

[Following discussion of details of the figure to be revised, including the numbers.]

As mentioned. each country's δ_{j1}^{z} in the figure is the slope (divided by -10) of a ray to its point from the origin. More than four-fifths of the δ_{j1}^{z}'s are between zero and one, damping producer-price comparative advantage. However, x percent of them are negative (reversing comparative advantage), while y percent of them are above unity (amplifying comparative advantage), in both cases mostly for countries with c_j^z / c_1^z's close to the world mean.[8]

[8] The countries with negative δ_{j1}^{z}'s are those with points in the North-East or South-West quadrants. The countries with δ_{j1}^{z}'s above unity are those whose points lie above the proportional-trade-cost line in the North-West quadrant or below it in the South-East quadrant. Non-damping elasticities are more frequent for countries with c_j^z / c_1^z close to the world mean mainly because C (equation 3.xx) is more

The slope or implied average value of δ^z_{j1} is under 0.5, which means a high degree of damping. The relative sales of goods *j* and 1 are varying across countries by on average less than one-half as much as they would if trade costs were proportional to producer prices.

The regression line is virtually (log) linear: a cubic form fits only fractionally better (R^2 is increased by x.xx). The value of δ^z_{j1} thus does not vary systematically and substantially across countries with their c^z_j / c^z_1's [discuss results of differentation of the δ_{j1} equation in section 3]. In other words, and conveniently for economic analysis, the cross-country price-ratio elasticity is roughly constant: non-proportional trade costs tend to damp producer-price comparative advantage to a similar degree over a wide range of relative producer prices.

Even so, individual-country price-ratio elasticities vary, which is why the relationship is fuzzy. The OLS regression fits well (R^2 = 0.xx), but far from perfectly. This is partly because trade costs vary randomly among countries, but more basically because each country's trade cost ratios, $\tilde{\tau}^z_j$ and $\tilde{\tau}^z_1$, which influence its price-ratio elasticity, vary inversely with the absolute level of its producer prices. A given c^z_j / c^z_1 can be generated by many different pairs of c^z_j and c^z_1 and, given a country's independent trade costs for the two goods, δ^z_{j1} is greater (less damping) if c^z_j and c^z_1 are both high, which reduces the $\tilde{\tau}$'s, and smaller (more damping) if c^z_j and c^z_1 are both low.[9]

The scatter in figure 1 is tightest where c^z_j / c^z_1 is close to 2 (or in logs 0.7) and thus equal to the relative trade costs of the goods (by assumption, set at 2), because at that point all countries have the same purchaser price ratios (and relative sales), regardless of the absolute levels of their c^z_j and c^z_1. The scatter is loosest on the left side of the

often non-negative (i the producer prices of both goods differ from their world averages in the same direction), which puts the weights in equation (3.xx) outside the zero-one range.

[9] On the left side 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. On the right side of the figure, this relationship is reversed.

figure, where the low relative producer price of good *j*, in combination with its high relative trade cost, amplifies the effects on relative purchaser prices, and so on relative sales, of variation in the absolute levels of c_j^z and c_1^z.[10]

Table 1 [to be added] reports the results of experiments with alternative values of the input data. The first two columns report the actual slope of each regression and the slope predicted by equation (4.x).[11] The next two columns report the R^2s of the linear regression and a cubic alternative (as a test for linearity). The final two columns show the percentages of price-ratio elasticities that are outside the damping range.

The base case, in the top row, corresponds to the figure 1 results. 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 and $\tilde{t}_1^z$, demonstrating that the results are always similar.

The experiments in panels A-C vary trade costs for all countries, with no change in the ranges of variation of c_j^z, c_1^z and $\tilde{t}_1^z$. Those in panel A scale all trade costs up and down by altering the mid-point of the $\tilde{t}_1^z$ range. Those in panel B vary the share of proportional trade costs in total trade costs from 0.2 to zero and 0.4, adjusting the $\tilde{t}_1^z$ midpoint to keep the world average trade cost ratio constant (or 'compensated', for short). Those in panel C vary the relative trade costs of the two goods, in both directions, with $\tilde{t}$ ranging between 0.25 and 4, again compensated.

In all these experiments, the cross-country relationship between relative exports and relative producer prices remains almost 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.xx). Higher average trade costs, a lower share of proportional trade costs, and wider differences in trade

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[10] On the right side, the relative trade cost and relative producer price of good *j* are both high, which lessens the effect on relative purchaser prices of differences in the absolute levels of c_j^z and c_1^z.

[11] Tests of the statistical significance of the coefficients are not reported because this regression, as explained in the text, is not estimating anything, just describing.

costs between the goods also increase the percentages of countries with cross-section elasticities outside the damping range.

The actual slopes of the regressions are always close to those predicted from average world trade costs, though the relationship is not exact. Higher average trade costs and lower shares of proportional in total trade costs clearly reduce average elasticities. The effect of changes in the proportional share is substantial and asymmetrical, with a fall to zero (only independent trade costs) reducing the absolute value of the slope from x.x to y.y, but a doubling of the share to 40% raising it from x.x. to z.z. The slope is less affected 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 experiments in panel D of table 1 alter the threefold range of autonomous cross-country variation of trade costs, again with compensation by adjusting the mid-point of the range to keep the world average trade cost ratio constant. Variation is completely eliminated (apart from that caused by variation in producer prices) for trade costs in total and for proportional trade costs only [and independent trade costs only]. The final experiment in panel D also alters the pattern of the distribution of trade costs across countries from uniform in absolute values to uniform in logs. [In all cases, the main effect is on the fit of the regressions, with variation of independent trade costs being the main influence, and there is relatively little effect on the slope. Note that even with no autonomous c-c variation of trade costs, there is still noise as a result simply of the existence of independent trade costs.]

The experiments in panel E alter the three-fold ranges of variation of producer prices, again with compensation. The ranges are widened, to six-fold and ten-fold, and the pattern of their distribution is altered, from uniform in absolute values to uniform in logs both for c_j and c_1 individually and for c_j / c_1. This does not radically alter the pattern of the results. Simply widening the ranges makes little difference to either the slopes or the fit, but it does somewhat widen the gap in fit between the linear and the cubic regressions.[12] Altering the distribution affects both the fit and the slope but the latter remains well predicted by world average trade costs.

[Summary para on the simulations to be added.]

5. Exports, home sales and production

The analysis of sections 3 and 4 was simplified by assuming that each country sells its varieties of goods in a single world market (including its domestic market) of which it has small shares for all goods. This section distinguishes among different markets, in which outcomes differ mainly because trade costs differ. Some modifications to the analysis are required, but the main conclusions of sections 3 and 4 are unaltered: trade costs damp and distort the cross-country relationship between comparative advantage and the pattern of specialisation of trade and production.

Countries of origin (or supplier countries) are still indexed by a superscript z (= 1, …, Z), but now markets (or countries of destination) are indexed by a second superscript, $\check{z}$ (= 1, …, $\check{Z}$). For example, country z's sales of good j in market $\check{z}$ are $q_j^{z\check{z}}$, and its purchaser price in that market is $p_j^{z\check{z}}$, but its producer price, common to all its markets, is just c_j^z. The superscript * is substituted for either z or $\check{z}$ to refer to the rest of the world as a whole: for example, country z's total exports are q_j^{z*}.

What varies among markets for each supplier country is the producer-price elasticity of demand, whose general form is now

$$\varepsilon_{j1}^{z\check{z}} = \tilde{\varepsilon}_{j1}^{z\check{z}} \delta_{j1}^{z\check{z}} \tag{5.1}$$

where $\tilde{\varepsilon}_{j1}^{z\check{z}}$ is the purchaser-price elasticity, which so far has been just β_{j1}, and $\delta_{j1}^{z\check{z}}$ is the price-ratio elasticity. Both these ingredients of the producer-price elasticity in equation (5.1) have z and $\check{z}$ superscripts, because both of them vary with trade costs.

[12] Elaborate [some flattening of the relationship at both ends (implying heavier damping), which becomes more pronounced if the range of producer price ratios is extended]

The reason for variation of $\delta_{j1}^{z\check{z}}$ with trade costs is clear, and will be discussed in more detail below, but the effect of trade costs on $\tilde{\varepsilon}_{j1}^{z\check{z}}$ requires more explanation.

The response of relative sales of a country's varieties of two goods to changes in its relative purchaser prices depends in principle not only on the degree of substitutability among different varieties of each good, measured by β_{j1}, but also on the degree of substitutability between the two goods, measured by γ_{j1}. The relative impact of these two sorts of substitutability depends on the country's shares of the market for the two goods: if its shares are small, $\tilde{\varepsilon}_{j1}^{z\check{z}}$ is determined almost entirely by β_{j1}, but with larger shares, $\tilde{\varepsilon}_{j1}^{z\check{z}}$ depends also on γ_{j1}, since the prices charged by the country in question for its varieties then have an appreciable effect on the average prices of the goods. Trade costs can thus influence purchaser-price elasticities by affecting market shares.

More precisely, $\tilde{\varepsilon}_{j1}^{z\check{z}}$ is a weighted harmonic mean of β_j, β_1 and γ_{j1} (which have no $\check{z}$ superscripts, assuming preferences to be identical and homothetic in all markets). If demand can be described by a two-level CES utility function (the lower level being choice among national varieties and the upper level being choice between the goods), adapting Sato's (1967: 217) production function, the relationship is

$$\tilde{\varepsilon}_{j1}^{z\check{z}} = \frac{\dfrac{1}{s_j^{z\check{z}} s_j^{\check{z}}} + \dfrac{1}{s_1^{z\check{z}} s_1^{\check{z}}}}{\dfrac{1}{\beta_j}\left(\dfrac{1}{s_j^{z\check{z}} s_j^{\check{z}}} - \dfrac{1}{s_j^{\check{z}}}\right) + \dfrac{1}{\beta_1}\left(\dfrac{1}{s_1^{z\check{z}} s_1^{\check{z}}} - \dfrac{1}{s_1^{\check{z}}}\right) + \dfrac{1}{\gamma_{j1}}\left(\dfrac{1}{s_j^{\check{z}}} + \dfrac{1}{s_1^{\check{z}}}\right)} \tag{5.2}$$

where $s_j^{\check{z}}$ and $s_1^{\check{z}}$ are the shares of goods j and 1 in total expenditure in market $\check{z}$, and $s_j^{z\check{z}}$ and $s_1^{z\check{z}}$ are country z's shares of the total sales of goods j and 1 in market $\check{z}$. If $s_j^{z\check{z}} \approx s_1^{z\check{z}} \approx 0$, $\tilde{\varepsilon}_{j1}^{z\check{z}}$ is just an average of the two βs, while if $s_j^{z\check{z}} = s_1^{z\check{z}} = 0$, as in a closed economy or for a pair of non-traded goods, $\tilde{\varepsilon}_{j1}^{z\check{z}} = \gamma_{j1}$.

To take the analysis further, trade costs need to be split into their internal or domestic (D) and international or external (F) components. Thus, for any good j,

$$t_j^{z\check{z}} = t_j^{D\check{z}} + t_j^{Fz\check{z}} \tag{5.3}$$

where $t_j^{D\check{z}}$ is the cost to any supplier of selling one unit of good j in market $\check{z}$ (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, plus tariffs and the cost of any other policy discrimination against foreign suppliers). The two sorts of trade costs have different effects on different suppliers. In particular, in country z's home market, denoted also by z, the trade costs of home and foreign suppliers for good j are, respectively,

$$t_j^{zz} = t_j^{Dz} \tag{5.4}$$

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

This trade cost advantage tends to give countries larger shares of their home markets than of their export markets. It thereby also tends to make purchaser-price elasticities lower in home markets than in export markets, in which for most countries and goods market shares are so small that the effects of trade costs on purchaser-price elasticities can be neglected. (A country's market shares depend on other important things, too, of course, including its producer prices and its size.)

Market shares depend on total trade costs – independent plus proportional – whereas what matters for price-ratio elasticities are just independent trade costs. The influence of different trade costs on the producer-price elasticity of demand is summarised in Figure 2. Independent trade costs, both internal and international, in the shaded cells, lower price-ratio elasticities. International trade costs, independent and proportional, in the heavy-bordered cells, affect purchaser-price elasticities through their influence on market shares, lowering elasticities for home suppliers ($\tilde{\varepsilon}_{j1}^{zz}$). Trade costs that are both internal and proportional reduce damping, as explained earlier. They also reduce the proportional trade cost advantage of home suppliers, $t_j^{Dz} \big/ \left(t_j^{Dz} + t_j^{F^*z} \right)$, lowering their market shares and raising their purchaser-price elasticities.

Figure 2 How different sorts of trade costs affect $\varepsilon_{j1}^{z\bar{z}} = \tilde{\varepsilon}_{j1}^{z\bar{z}} \delta_{j1}^{z\bar{z}}$

	Independent	Proportional
International	Lower $\delta_{j1}^{z\bar{z}}$ and $\tilde{\varepsilon}_{j1}^{zz}$	Lower $\tilde{\varepsilon}_{j1}^{zz}$
Internal	Lower $\delta_{j1}^{z\bar{z}}$	Raise $\delta_{j1}^{z\bar{z}}$ and $\tilde{\varepsilon}_{j1}^{zz}$

The combined effects of trade costs through these different channels on the producer-price elasticity of demand, and hence on the translation of comparative advantage into the pattern of specialisation, are quite complicated. They will first be explained for a single country, with simplified algebra, and then the results of simulating a more fully specified model across many countries will be described.

The determinants of the producer-price demand elasticity for country z's total exports can be summarised as

$$\varepsilon_{j1}^{z^*} = \frac{\beta_{j1}}{1 + \tilde{\tau}_{j1}^{Dz^*} + \tilde{\tau}_{j1}^{Fz^*}} \qquad (5.6)$$

where β_{j1}, the purchaser-price elasticity, is as before an average of the two elasticities of substitution among varieties, on the assumption that in most cases 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: $\tilde{\tau}_{j1}^{Dz^*}$ is average internal trade costs in these markets, and $\tilde{\tau}_{j1}^{Fz^*}$ is country z's average international trade costs in supplying these markets, in both cases divided by its own producer prices.

The price-ratio elasticity in (5.6) is the reciprocal of its denominator, and is simplified in two ways. First, by assuming that country z has world average trade costs, making it possible to write the price-ratio elasticity for each good in the form $\delta_j = 1/(1+\tilde{\tau}_j)$, rather than in the more complicated form of equation (3.xx). Second, by writing the equation as if trade cost ratios had been averaged directly across the two goods, rather than averaging δ_j and δ_1 in the more accurate way described by equation (3.yy).

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, to a degree that depends on the country's own international trade costs and on internal trade costs in its export markets (with the $\tilde{\tau}$'s being raised by independent trade costs and lowered by proportional trade costs). The equation could be modified to refer to any individual export market by substituting $\check{z}$ ($\neq z$) for *. The distribution of a country's exports across individual markets depends on the relative sizes and trade costs of the markets, in ways that are analysed in gravity models.

The producer-price demand elasticity for a country's home market can be summarised (again in a simplified way) as

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

where, again, the $j1$ 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, relative to internal trade costs: the more protected are its markets for these goods, the larger are country z's market shares and so the lower is the elasticity. The denominator of equation (5.7) shows the damping of the price-ratio elasticity by trade costs, which in a country's home market involves only internal trade costs. Internal trade costs thus raise both the numerator and the denominator, though their net effect is usually to lower ε_{j1}^{zz}.[13]

[13] The internal trade cost term in the denominator has an extra z superscript because it is a trade cost ratio (divided by country z's producer prices), while that in the numerator, which includes proportional as well as independent trade costs, is an absolute number.

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.[14]

Also of economic interest is the producer-price demand elasticity for country *z*'s total relative sales of the two goods, in both export and home markets, which influences its overall specialisation in production. This 'output' elasticity can be written simply as a weighted average of its export and home market elasticities

$$\varepsilon_{j1}^{z} = x_{j1}^{z}\varepsilon_{j1}^{z*} + \left(1 - x_{j1}^{z}\right)\varepsilon_{j1}^{zz} \tag{5.8}$$

where x_{j1}^{z} is country *z*'s share of exports in output, averaged across the goods. The output elasticity thus depends on trade costs both through their influence on ε_{j1}^{z*} and ε_{j1}^{zz} and through their influence on the export share.

A country's export shares tend 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. What matters in both these respects are total trade costs, not just independent trade costs. Export shares are also strongly and inversely dependent on a country's economic size – potential export markets are just smaller, relative to home markets, for larger countries. [Add mention of effects of multilateral resistance on allocation of sales between X and H markets?]

The direction and size of the effect of the export share on the output elasticity depends on the difference in producer-price elasticities between the export and home markets. If $\varepsilon_{j1}^{z*} < \varepsilon_{j1}^{zz}$, the downward effect of trade costs on x_{j1}^{z} raises ε_{j1}^{z}, and conversely if

[14] 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.

$\varepsilon_{j1}^{z*} > \varepsilon_{j1}^{zz}$. But if the difference between ε_{j1}^{z*} and ε_{j1}^{zz} is small, in either direction, the output elasticity is little affected by the export share.

Equations (5.6) to (5.8) describe, under simplifying assumptions, the effects of trade costs on producer-price demand elasticities in many markets for a single country. It remains to describe what happens without the simplifying assumptions and with many countries, and in particular how multiple markets affect the damping and distortion of comparative advantage by independent trade costs. Some answers to these questions can be obtained by extending the simulations of section 4. A more elaborate version of the model and a selection of results are available on request in an appendix to this paper and are summarised in the rest of this section.

In the extended model, each country sells in its home market and in a single export market, with the relative size of these two markets being determined by its trade costs. The sales of its varieties of the two goods in each market depend on its purchaser prices, relative to those of other countries, in that market, each purchaser price being the sum of the suppplier's producer price and trade costs specific to that market, both internal and international, of which some are independent and some are proportional. The country's relative sales depend also on its purchaser-price elasticity in the market concerned, which is affected by its market shares and thus by its purchaser prices and by its size (larger countries have larger shares and thus lower elasticities).

In the simulations, as in section 4, the producer prices of each good for each country are generated randomly, as is cross-country variation of independent trade costs. The size distribution of the 200 countries is approximately that of the real world. Again as before, the average level of trade costs, the share of proportional in total trade costs, and the relative trade costs of the two goods are set (and varied) exogenously, as is the share of internal trade costs in total trade costs. The elasticity of substitution between goods (γ_{j1}) is set much lower (3) than among national varieties (which is again 10).

The method, as before, is regressions across countries on relative producer prices of relative sales in each market and of total output (derived by adding exports to home sales). The base case is similar to that of section 4 (a world average total trade cost ratio of about 2, and proportional trade costs on average about 20% of this total). The experiments involve variations of the exogenous data inputs, and particularly of trade costs, similar in nature and size to those set out in table 1 above.

The results are fundamentally similar to those in section 4. In both home and export markets (and for total output), the slope of the relationship between relative sales and relative producer prices is reduced by trade costs, to a degree that depends roughly on the world average ratio of independent trade costs to producer prices plus proportional trade costs. In all cases, the relationship is again close to log-linear. It is also fuzzy – countries are scattered around the line – and the fuzziness increases with the average level of independent trade costs, with bigger differences in independent trade costs between goods, and with wider variation of trade costs across countries.

The main analytical difference from the section 4 model is that trade costs can affect purchaser-price elasticities by raising market shares. For exports, this effect is trivial in these simulations, which combine all the export markets for each country, making a trade cost advantage over other suppliers (including home suppliers) unlikely: in only 5 percent of countries in the base case is the purchaser-price elasticity less than 9.9, as compared to the elasticity of substitution of 10 among varieties. Even in a country's home market, the average effect is not large – the mean purchaser-price elasticity in the base base is 7.6 – but it varies widely among countries (with a standard deviation of 2.7), depending on country size, producer prices and trade costs.

There is no systematic difference between the slopes of the export and home market regressions (the slope for total output being always in between them). The difference varies in direction with the assumptions, but is rarely large. The heavier damping of the price-ratio elasticity in export markets than in home markets because of the extra (international) trade costs is more or less offset by the purchaser-price elasticity being higher in export markets than in more protected home markets. The export slope is more sensitive than the home market slope to variation in the share of proportional in total trade costs (because it is more influenced by the price-ratio elasticity), but is less sensitive to variation in the internal share of total trade costs.[15]

The cross-country relationship between relative sales and relative producer prices is tightest for exports. The home market regression fits less well ($R^2 = 0.81$ in the base case, compared to 0.93 for exports), because, in addition to variation among countries caused by differences in price-ratio elasticities (which determine the fit of the export regression), there is variation in purchaser-price elasticities as a result of variation in home market shares. The fit of the output regression (R^2 = 0.xx in the base case) is worsened by the imperfect correlation between export and home sales ratios and by cross-country variation in the share of output exported. In all cases, however, the fit is good by comparison with most cross-country regressions. The relationship between relative sales and producer-price comparative advantage is fuzzy, but strong.

Even the more elaborate model used for these simulations is a simplification of reality in many ways, including its treatment of relative producer prices as exogenous (as in this paper as a whole). The appendix contains experiments which address some likely effects of using actual statistics rather than made-up data – especially having to work with value aggregates of sales rather than homogeneous volumes. But although the relationships in actual data could never be anything like so neat as in the simulations, the robustness of the general pattern of the simulation results gives reason to suppose that they are conveying something about the real degree of damping and distortion of comparative advantage by independent trade costs.

6. Conclusions [to be added]

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[15] As mentioned in connection with equation (5.7), the net effect of higher internal trade costs is usually to reduce the home market producer-price elasticity, and by more than for the export market elasticity, whose denominator rises by proportionally less for any given increase in internal trade costs.

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Appendix: More elaborate simulations [to be added and made available on request]