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ABSTRACT

This paper argues that the theoretical foundations for the gravity equation are general, while the empirical performance of the gravity equation is specific to the type of goods examined. Most existing theory for the gravity equation depends on the assumption of differentiated goods. We show that the gravity equation can also be derived from a 'reciprocal dumping' model of trade in homogeneous goods. The different theories have different testable implications. Theoretically, the gravity equation should have a lower domestic income elasticity for exports of homogeneous goods than of differentiated goods, because of a 'home market' effect which depends on barriers to entry. We quantify the home market effect empirically using cross-sectional gravity equations, and find that domestic income export elasticities are indeed substantially higher for differentiated goods than for homogeneous goods.

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1. Introduction

It is well-known that international trade flows can be well described by a "gravity equation" in which bilateral trade flows are a log-linear function of the incomes of and distance between trading partners. Indeed, the gravity equation is one of the greater success stories in empirical economics. However, the theoretical foundations for this finding are less clearly understood. The gravity equation is not implied by a plausible many-country Heckscher-Ohlin model (which has nothing to say about bilateral trade flows).[1] An equation of this type does arise, however, from a model in which countries are fully specialized in differentiated goods.[2] While specialization might characterize manufacturing goods, it is presumably not a feature of homogeneous primary goods. Despite this theoretical presumption, the gravity equation seems to work empirically for both OECD countries and developing countries (Hummels and Levinsohn, 1995). Since developing countries tend to sell more homogeneous goods, it seems puzzling that the gravity equation works well for these countries. Thus, it is hard to reconcile the special nature of the theory behind this equation with its empirical performance.

In this paper, we argue that conventional wisdom should be reversed: the theory behind the gravity equation is general, but its empirical performance depends on the particular sample. On the theoretical side, we show how a gravity equation can arise even with *homogeneous* goods produced by all countries. We model the market structure in the homogeneous good as Cournot-Nash competition, and use the "reciprocal dumping" model of trade described by Brander

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[1] Deardorff (1998) derives a gravity equation in a model with homogeneous goods and a complete absence of trade frictions, so that countries are indifferent between consuming domestic and foreign goods. We view this result as being of greater theoretical interest than of empirical relevance.

[2] This specialization can arise due to an Armington structure of demand (Anderson, 1979, Bergstrand, 1985, Deardorff, 1998), economies of scale (Helpman, 1987, Bergstrand, 1989), technological differences across countries (Davis, 1995, Eaton and Kortum, 1997), or factor endowment differences (Deardorff, 1998). Indeed, in his comment on Deardorff (1998), Grossman (1998, p. 29) states "Specialization – and not new trade theory or old trade theory – generates the force of gravity." Most recently, Evenett and Keller (1998) have argued that a gravity

(1981), Brander and Krugman (1983) and Venables (1985). A two-country version of this model is developed in section 2, and used to solve for trade flows using a simple graphical technique.

We use our model to derive the gravity equation in section 3. We find that the implications of the homogeneous goods model are similar to those obtained from a differentiated-products, monopolistic competition model. One important common feature is the "home market effect" (Krugman, 1980): larger countries tend to be *exporters* of a product, *ceteris paribus*, since the larger market attracts firms to locate there. Krugman established this result for a model with a monopolistically competitive sector producing differentiated-products, subject to transportation costs in trade.[3] We show that the home market effect – an elastic supply of exports with respect to domestic income – also characterizes a *homogeneous-product* sector with free entry. Since both differentiated and homogeneous goods models have a home market effect, it might seem that they do not have distinct empirical implications. But if homogeneous goods have greater barriers to entry (due to resource-dependency, for example), then the home market effect is *reversed*. These theoretical results will be important for interpreting our empirical findings which we turn to in section 4.

Our theoretical results indicate that the home market effect should be larger for differentiated goods with free entry than for homogeneous goods with restricted entry. We test this hypothesis in our empirical work. We regress bilateral *exports* (from one country to each of its trading partners) on domestic- and partner-country GDP (and other controls). We are interested in the elasticity of exports with respect to domestic GDP, since our theory indicates that the size of this elasticity depends on the type of good. We expect to see higher elasticities

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equation can arise with incomplete specialization if there are just two countries, and Keller (1998) extends this result to many countries when indeterminate trade flows are resolved by a "minimal factor content" rule.

[3] Transportation costs in this sector must be greater than those found for exporting a numeraire good; otherwise Davis (1998) shows that the home market effect vanishes. We return to this point below.

for manufacturing goods with few entry barriers, and smaller elasticities for homogeneous goods with more entry barriers (e.g., because they are resource-based). Using Rauch's (1999) classification, we divide our sample into three; homogeneous goods, differentiated goods, and an in-between category. We then estimate gravity equations over aggregate bilateral exports in each of these three groups. As we move from homogeneous to differentiated goods, we indeed find that the elasticity of exports with respect to own GDP *rises* significantly. This finding is empirically robust and significant both economically and statistically. It is also consistent with the theoretical hypothesis that the home market effect is more prevalent for differentiated goods where entry is easy, than for homogeneous goods with restricted entry. Further conclusions are given in section 5.

1. Modeling Bilateral Trade in Homogeneous Goods with 'Reciprocal Dumping'

We consider a two-country model where each country has two industries, and labor is the only factor. The first industry uses one unit of labor to produce each unit of output. There are no transport costs for international trade in this good. Provided that it is produced in both countries, the wage is equalized across countries and is set at unity. The second industry produces a homogeneous good under Cournot-Nash competition, where markets are segmented across countries, (i.e., have different prices). Let x_{ij} denote the amount produced of this good in country i and sold in country j, i,j=1,2. There is free entry of firms; N_i denotes the equilibrium number of firms located in country i.

With equalized wages, the marginal cost of producing in the Cournot-Nash industry is also equalized across countries, and is denoted by c. The fixed costs of production are F. A firm located in country i and selling to country j faces "iceberg" transport costs, so that if one unit of the good is shipped, only $1/\tau_{ij} < 1$ units arrive. This means that the marginal cost of exporting is $c\tau_{ij}$. We ignore domestic transport costs so that $\tau_{ii}=1$, $i=1,2$. A firm in country i chooses its local sales (x_{ii}) and its export sales (x_{ij}) to solve:

$$\max_{x_{ij}} \sum_{j=1}^{2} (p_i - c\tau_{ij}) x_{ij} - F, \tag{1}$$

where the inverse demand curve is given by the function $p_i(N_i x_{ii} + N_j x_{ji}, L_i)$.

The first-order conditions for (1) can be written as,

$$p_j \left(1 - \frac{\theta_{ij}}{\eta_j} \right) = c\tau_{ij}, \tag{2}$$

where $\theta_{ij} \equiv x_{ij} / (N_i x_{ij} + N_j x_{ji})$ denotes the market share of a typical firm from country i in market j, and η_j is the elasticity of demand in that market. Notice that from (2) we have,

$$\theta_{ij} = \eta_i \left(1 - \frac{c\tau_{ij}}{p_j} \right) < \theta_{jj}, \tag{3}$$

so that the share of an exporting firm must be less than the share of the local firm in that market, because there are no local transportation costs ($\tau_{ii}=1$, $i=1,2$).

By definition, the market shares must satisfy:

$$\begin{aligned} N_1\theta_{11} + N_2\theta_{21} &= 1, \\ N_1\theta_{12} + N_2\theta_{22} &= 1. \end{aligned} \tag{4}$$

This simple system allows us to solve for the number of firms in each country as,

$$N_1 = \frac{1}{|\theta|}(\theta_{22} - \theta_{21}),$$

$$N_2 = \frac{1}{|\theta|}(\theta_{11} - \theta_{12}), \tag{5}$$

where $|\theta| \equiv \theta_{11}\theta_{22} - \theta_{12}\theta_{21} > 0$, using (3), and integer constraints are ignored.

Surprisingly, the first-order conditions do not guarantee that N_1 and N_2 in (5) are non-negative. To ensure this we impose an additional condition onto the system, one that makes economic sense. In particular, suppose that that the elasticities of demand are equal, $\eta_i = \eta_j$. Then substituting (3) into (5) we obtain:

$$N_1 = \frac{\eta_i}{|\theta|}\left(\frac{c\tau_{21}}{p_1} - \frac{c}{p_2}\right) \geq 0 \quad \text{iff} \quad p_1/\tau_{21} \leq p_2,$$

and,

$$N_2 = \frac{\eta_i}{|\theta|}\left(\frac{c\tau_{12}}{p_2} - \frac{c}{p_1}\right) \geq 0 \quad \text{iff} \quad p_2/\tau_{12} \leq p_1.$$

Thus, we have obtained the following result:

<u>Proposition 1</u>

When the elasticities of demand are equal, then N_1 and $N_2 \geq 0$ if and only if,

$$p_i/\tau_{ji} \leq p_j, \quad i, j = 1,2. \tag{6}$$

The conditions in (6) are simply *arbitrage conditions,* needed to ensure that goods exported from country i to j cannot be profitably re-exported back to i. That is, the price received from re-exporting, p_i/τ_{ji}, should not exceed the purchase price in country j, p_j. When this condition holds as an *equality*, the number of firms located in the country with the higher price is zero: import competition eliminates the local firms. To understand this result, note that when $p_1/\tau_{21}=p_2$, the price in country 1 is sufficiently high to offset fully the barrier created by transporting from country 2. We can think of p_1/τ_{21} as the F.O.B. ("free on board") price received for country 2 exports, the price net of transportation charges. When this equals the home price p_2, a firm in country 2 will have the *same market share* in its export and home markets, as can be seen from (3). From (4), the only way for the market shares to add up to unity is for all the firms to be located in country 2; intuitively, the firms in country 1 have been eliminated through import competition.

To close the model, we need to solve for the equilibrium prices from the zero-profit conditions $\sum_j (p_j - c\tau_{ij})x_{ij} = F$. Using (2), these can be re-written as

$$\sum_{j=1}^{2} \left(\frac{\alpha p_j L_j}{\eta_j} \right) \theta_{ij}^2 = F, \tag{7}$$

where α denotes the share of the Cournot-Nash good in the total consumer's budget (which depends on the relative price of that good). The first-order conditions (2) are four equations that determine the market shares, given prices; the zero-profit conditions (7) are two equations that determine the price in each country, given the market shares. Solving these simultaneously, the number of firms in each country is then determined by (5). In Appendix 1, we discuss some properties of this model under the assumption of Cobb-Douglas preferences, so that α is constant and $\eta_j = 1$, j=1,2. We also assume that transportation costs between the two countries are identical, denoted by $\tau_{12}=\tau_{21}=\tau$.

In the remainder of this section we summarize the properties of the model using Figure 1. This graph shows allocations of labor between the two countries on the horizontal axis, keeping the world labor supply (L_1+L_2) fixed.

In general, there is an inverse relationship between country size and the price of the Cournot-Nash good. Larger countries have more firms, and greater competition leads to lower prices. This inverse relation between country size and prices is illustrated by the lines P_1 and P_2 in the top panel of Figure 1. For allocations of labor between the countries in the interval (L_A,L_B), both countries will be *producing* the Cournot-Nash good. This does not guarantee that they will both be *exporting* the good, since transportation costs might make exports unprofitable for one or both countries. Nevertheless, we will illustrate the case where exports occur whenever production does, while noting below the conditions to ensure this.

As country 1 grows within the interval (L_A,L_B), its price falls while the price in country 2 rises, until point B is reached. At this point the F.O.B. price received from exporting to country 2, net of transportation charges, is just equal to the home price in country 1 ($p_2/\tau = p_1$), and no firms in country 2 produces the Cournot-Nash good. Firms in country 1 are indifferent between selling at home or abroad, earning the same profits per unit in each location. For this reason, further growth of country 1 has *no impact* on the equilibrium prices, which are fixed at $\overline{P}$ in country 2 and $\overline{P}/\tau$ in country 1. Conversely, when country 1 is small ($L_1 \leq L_A$) it has no firms producing the Cournot-Nash good, and its prices are fixed at $\overline{P}$, while those in country 2 are $\overline{P}/\tau$. Summarizing, the equilibrium prices in country 1 are shown by the bold line segment $\overline{P}A(\overline{P}/\tau)$, while those in country 2 are shown by $(\overline{P}/\tau)B\overline{P}$.

Exports $X_{ij} \equiv N_i x_{ij}$ from country i to country j are shown in the lower panel of Figure 1. Within the interval (L_A, L_B) both countries are producing the Cournot-Nash good, and they will also both be exporting provided that the F.O.B. price received (which is net of transport costs) exceeds marginal cost. This will be true in Figure 1 provided that $\overline{P}/\tau > c$, as we shall assume.[4] When $L_1 = L_A$ then exports of the Cournot-Nash are zero because production is also zero, but as country 1 grows then exports also rise, as illustrated by the curve X_{12}. When $L_1 = L_B$, country 2 ceases production of the Cournot-Nash good. Further re-allocations of labor towards country 1 *reduce* its exports, because demand falls in country 2.[5] Thus, the general shape of exports from country 1 are as illustrated by X_{12}, increasing from L_A and then decreasing after L_B. The corresponding export curve X_{21} from country 2 is also illustrated.

Reciprocal dumping occurs in the interval (L_A, L_B) in the sense that the F.O.B. price for exports p_j/τ, is *below* the price p_i for both countries. As is clear from Figure 1, the reciprocal dumping interval depends on transport costs: as $\tau \to 1$, the two export curves move apart and the interval (L_A, L_B) shrinks to the point $L_1 = L_2 = 1/2$. Thus, to observe a significant range of reciprocal dumping transport costs cannot be too small. On the other hand, recall that Figure 1 is drawn under the assumption that that $\overline{P}/\tau > c$, which requires that transport costs are not too large.[6] Thus, the range of reciprocal dumping is greatest when transport costs are at some intermediate level.

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[4] If this condition is not met, then as a country grows, it will first begin producing and then at a larger size begin exporting. In terms of Figure 1, production by both countries will occur in the interval (L_A, L_B), but exports by both will occur in a smaller interval $(L_A', L_B') \subset (L_A, L_B)$.

[5] Exports can be written as $X_{12} = N_1 \theta_{12} (\alpha L_2 / p_2)$. For $L_1 > L_B$, prices are fixed in country 2 and so is the market share θ_{12}. So X_{12} declines *linearly* with L_2.

[6] If this assumption is violated, then exports will occur in a smaller interval than where production occurs, as discussed in note 2. For τ suitably large, it is entirely possible that reciprocal dumping never occurs, in the sense

Despite the fact that the countries produce homogeneous goods, the reciprocal dumping model leads to a well-defined trade pattern. This pattern results not from comparative advantage, but from the desire of imperfectly competitive firms to enter each others' markets. Figure 1 suggests that trade will be highest when countries similar in size. This is the most important implication of the "gravity" equation, and in the next section we relate the reciprocal dumping model to that equation.

3. The Home Market Effect and the Gravity Equation

One feature of the export flows in Figure 1 deserves special mention. As drawn, exports X_{12} from country 1 to 2 reach a maximum when country 1 is *somewhat larger* than country 2. This is a deliberate feature of the diagram which illustrates the *home market effect:* as country 1 becomes larger, the number of firms located there grows more rapidly than output, and country 1 becomes a *net exporter* of the good, despite the increase in domestic demand. To confirm this result, we consider a re-allocation of labor between the countries, keeping the world labor supply fixed. The following result is proved in Appendix 1:

Proposition 2

Assume Cobb-Douglas preferences and equal transport costs, so that $\tau_{12}=\tau_{21}=\tau$. Then evaluated at $L_1=L_2$, a slight re-allocation of labor from country 2 to country 1 increases country 1 exports (X_{12}), and reduces country 2 exports (X_{21}).

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that the countries are never exporting simultaneously. Instead, exports from each country will occur over some interval when that country is bigger than the other, and these intervals are disjoint.

Proposition 2 implies that *net exports* of the Cournot-Nash good from country 1 to 2 grow as country 1 grows, given global GDP.[7]

Of course, the home market effect does not rely exclusively on the reciprocal dumping model we have developed. The home market effect also shows up in a monopolistic competition model (Krugman, 1980). Davis (1998) shows that this result relies on the assumption that the monopolistically competitive sector has transport costs, while the numeraire sector does not. Davis argues that the home market effect vanishes when transport costs are present in the numeraire sector. Since our model uses a corresponding assumption, we check for Davis' result by simulating our model.[8] We consider shifting the world resources between the countries in such a way that *relative factor endowments* (specific factor/labor) in the two countries stay identical, while their *absolute sizes* change.

Figure 2 graphs exports from country 1 to 2 for three different cases. Case A portrays (10%) transport costs in only the Cournot-Nash sector; case "B" adds 5% transport costs in the numeraire sector; we discuss case C below. In case A, exports from country 1 to 2 are maximized when country 1 is larger, but in case B exports are maximized when the countries are the same size. Thus, the home market effect vanishes when transport costs are introduced into the numeraire sector, even though these are only half as large as those in the Cournot-Nash

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[7] This result is stronger than obtained by Venables (1985, Proposition 6), who argued that the larger country would have a smaller import share, but did not make a prediction about the net trade balance. Venables did not assume Cobb-Douglas preferences, as we have done, which are needed to prove Proposition 2.

[8] The simulation model that we use is nearly the same as that of the last section, except that it introduces decreasing returns to the numeraire sector using a specific factor. This introduces some concavity that makes it easier to compute the equilibria, and also means that *both* countries will produce and export the homogeneous good. Thus, for all equilibria we investigate there is a zero-profit equilibria with both countries producing the homogeous good; the competitive effect illustrated in Figure 1, where small countries do not produce the homogeneous good, does not occur. This is because smaller countries are producing even less of the homogeneous good (due to the home market effect), leading to lower demand for the factor used in that good, and a lower factor price. Thus, small countries still produce the homogeneous good due to lower costs; this effect was ruled out in Figure 1 due to factor price equalization across countries.

sector. (Essentially the same results to case B are obtained when the transportation costs in the numeraire good are increased further.[9]) This confirms the result of Davis (1998).

As transport costs in the numeraire sector rise (moving from case A to case B), fewer firms move across countries. This effect can be enhanced by simply assuming that the number of firms in each country is *fixed.* Because firms cannot relocate between countries in response to market size, one might expect the zero-entry case to eliminate, or even reverse, the home market effect (as suggested in Markusen, 1981). To solve for this case, we normalize the number at one, and continue to assume that the elasticity of demand is one (the Cobb-Douglas case) for simplicity, and transport costs (τ) are the same between the countries.

The first-order conditions that determine equilibrium in the Cournot-Nash sector are:

$$p_i(1-\theta_{ii}) = c \qquad p_i(1-\theta_{ji}) = c\tau_{ji} \tag{8}$$

$$p_j(1-\theta_{jj}) = c \qquad p_j(1-\theta_{ij}) = c\tau_{ij}. \tag{9}$$

We divide the two equations for sales in market i by one another, and do the same for market j, noting that $(1 - \theta_{ii}) = \theta_{ji}$, and $(1 - \theta_{jj}) = \theta_{ij}$. This allows us to write (8)-(9) as:

$$\frac{(1-\theta ji)}{(1-\theta_{ii})} = \frac{(1-\theta ji)}{\theta_{ji}} = \tau = \frac{(1-\theta ij)}{\theta_{jj}} = \frac{(1-\theta ij)}{(1-\theta_{jj})} \tag{10}$$

This condition requires that the relative shares of the two firms are the same in both export markets, $\theta_{ij}=\theta_{ji}$. Suppose that country i is smaller, so that total demand for the Cournot-Nash good

[9] The symmetry of X_{12} exports around the midpoint in case B indicates that trade is nearly balanced in the Cournot-Nash good. Thus, there is very little trade occurring in the numeraire good, and further increases in the

is less. Then for $\theta_{ij}=\theta_{ji}$ to hold with only a single firm in each country, it must be that $x_{ij} > x_{ji}$. This means that country i, the small country, is the net exporter of the good. Beginning with the countries identical and neither country being a net exporter, a small transfer of income (factor endowment) from i to j leads country i become the net exporter. Thus we reverse the home-market effect of Figures 1 and 2, implying suggesting that a country's exports of the good will be more sensitive to its partner's income than to its own income.

We quantify this in case C of Figure 2, which portrays a no-entry Cournot-Nash model. Case C maintains (10%) transport costs only in the Cournot-Nash sector but restricts the number of firms in each country (to two). In this case, exports are maximized when country 1 is *smaller* than country 2, the reverse of the home market effect. These findings have important implications for the gravity equation, which we turn to next.[10,11]

We use the simulated data of Figure 2 to estimate a log-linear gravity equation:[12]

$$\log(X_{12}) = c + \beta_1\log(Y_1) + \beta_2\log(Y_2). \tag{11}$$

Consider re-allocating resources between the countries, subject to the (cross-sectional) restriction $Y_1+Y_2\equiv\overline{Y}$. The change in exports from (11) is $d\log X_{12}/dY_1=(\beta_1/Y_1)-[\beta_2/(\overline{Y}-Y_1)]$, so that

transportation costs for this good have minimal effect.

[10] Note that the contrasting results of cases A, B, and C does not depend on particular parameter values of the simulation model. Also, these results continue to hold when a third country (representing the "rest of the world) is added, as discussed in Appendix 2.

[11] It is relatively easy to show the same result hold is we switch to a competitive model with national-level (Armington) product differentiation in X. Let p_{ij} denote the price of country i's good in country j. Equations (8)-(9) become: $p_{ii}=c$, $p_{ji}=c\tau$, $p_{ij}=c\tau$ and $p_{jj}=c$. Divide the two equations for prices in country i by one another, and similarly for country j. Then we have: $p_{ji}/p_{ii} = \tau = p_{ij}/p_{jj}$. Under fairly general demand assumptions (identical preferences between countries and the x_i, x_j "nest" in the utility function is weakly separable from y), this must again imply that each good has the same relative market share in each country. But with country i smaller, country i must be a net exporter of x: $x_{ij} > x_{ji}$. Using the same argument as above, we reverse the home-market effect and expect that a country's exports of X are more sensitive to its partner's income than to its own income.

[12] This equations differs from the standard gravity equation in two ways. First, the regressand is the log of exports, not total trade. Second, controls for distance, adjacency and the like are omitted, since they are not included in our simulations.

exports are maximized when $Y_1/Y_2=\beta_1/\beta_2$. Thus we expect $\beta_1 > \beta_2$ to characterize case A, where exports are maximized when country 1 is *larger*. Conversely, we expect case C, where exports are maximized when country 1 is *smaller*, to be described by $\beta_1 < \beta_2$.

These expectations are confirmed when we use the simulated data from Figure 2 to estimate the log-linear equation (11), as reported in Table 1. The dependent variable is the log of exports from country 1 to country 2, and the dependent variables are the log of GDP in each country. These regressions shown the expected pattern or coefficients, with $\beta_1 > \beta_2$ for case A, $\beta_1 \approx \beta_2$ for case B, and $\beta_1 < \beta_2$ for case C. The home market effect appears as an elasticity of domestic income which exceeds the elasticity of partner income, so that it can be measured through a gravity equation. The home market effect is: a) present with free entry and high transport costs in the Cournot-Nash sector (case A); b) absent with transport costs in the numeraire good (case B); and c) reversed when entry is restricted (case C). In the next section, we search for results of this type with actual rather than simulated data.

4. Estimation Results

Our theoretical results have shown that with free entry, a home market effect is apparent in the form of a coefficient restriction in a gravity equation; the domestic-income elasticity exceeds the partner-income elasticity. As entry becomes more restricted, this effect should be reversed. We now test this hypothesis by estimating separate gravity equations for differentiated goods and homogeneous goods. The former are manufactured goods likely to have low barriers to entry and a home market effect. In contrast, the latter are likely to be resource-based and to have large entry barriers.

Rauch (1999) has classified products at the 5-digit SITC level according to whether they are: (a) traded in an organized exchange, and therefore treated as "homogeneous"; (b) not traded in an organized exchange, but having some quoted "reference price," such as in industry publications; (c) not having any quoted prices, and therefore treated as "differentiated." We use Rauch's classification, which he aggregates to the 4-digit SITC bilateral trade data from the Statistics Canada World Trade Database (WTDB), described in Feenstra, Lipsey and Bowen (1997). Our WTDB data are designated homogeneous, reference priced, or differentiated, according to the share of disaggregate commodities falling into these three categories.[13]

Using (both of) Rauch's classification scheme, we summed the bilateral exports of each country into the categories of homogeneous, reference priced, and differentiated goods. Thus, for each country pair within the WTDB, there are three bilateral trade flows. For example, in 1990 Canada exported $62.4 billion of differentiated goods to the U.S., $20.4 billion of reference prices goods, and $18.0 billion of homogeneous goods. Conversely, the U.S. sent to Canada $67.6 billion of differentiated goods, $13.1 billion of reference prices goods, and $4.6 billion of homogeneous goods. Thus, trade was roughly balanced between the two countries, but Canada exported a higher percentage of homogeneous goods than did the U.S. This confirms our intuition that Canada, as a country with a relatively high endowment of resources, is likely to export products which are disproportionately homogeneous.[14] The log of these export values between each pair of countries forms the dependent variable in our gravity equation.

The gravity equation that we estimate is an extension of (11), augmented for a number of auxiliary variables relevant for bilateral trade flows:

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[13] This leads to some ambiguities; accordingly, Rauch has developed two classification schemes: a "conservative" classification scheme which minimized the number of homogeneous or reference priced commodities when ambiguities existed; and a "liberal" classification scheme that maximized these numbers. We are left with a set of about 650 distinct classified products. The "liberal" classification is our default scheme.

[14] In the "conservative" classification for 1990, Canada exported $63.4 billion of differentiated goods to the U.S., $23.8 billion of reference prices goods, and $13.8 billion of homogeneous goods, while the U.S. sent to Canada $69.5 billion of differentiated goods, $12.5 billion of reference prices goods, and $3.2 billion of homogeneous goods.

$$\ln(X_{ij}) = \beta_0 + \beta_1\ln(Y_i) + \beta_2\ln(Y_j) - \beta_3\ln D_{ij} + \beta_4 Cont_{ij} + \beta_5 Lang_{ij} + \beta_6 FTA_{ij} + \beta_7 Rem_{ij} + \varepsilon_{ij} \quad (12)$$

where the variables are defined as:

- X_{ij} denotes the value of exports from country i to country j,
- Y_i is the real GDP of country i,
- D_{ij} is the distance between i and j,
- $Cont_{ij}$ is a binary variable for geographic contiguity of i and j,
- $Lang_{ij}$ is a binary variable for common language of i and j,
- FTA_{ij} is a binary variable for a free trade agreement common to i and j,
- Rem_{ij} denotes the remoteness of j, given i, equal to GDP-weighted negative of distance, and
- ε_{ij} represents the myriad other influences on bilateral exports, assumed to be orthogonal.

Our real GDP measures are drawn from the Penn World Table 5.6 ; we use Great Circle distance between capital cities. All countries for which the control variables are available are included in the sample, a sample of somewhat over 110 countries (though the exact number depends on the year because of missing GDP data). We have data for five different cross-sections: 1970, 1975, 1980, 1985 and 1990. Our default estimation results are estimated with OLS, and are tabulated in Table 2.

The top panel of Table 2 – Case A – uses exports of *differentiated* goods. The coefficient on own-GDP is somewhat greater than one, while the estimate on partner-GDP is around 0.65. Both of these are tightly estimated, and the hypothesis that the coefficients are equal is rejected at any reasonable significance level. Case B deals with intermediate *reference priced* exports. For those goods, the coefficient on own-GDP is below unity (at around 0.9), while the coefficient on partner-GDP remains at about 0.65. These coefficients are again quite different, both economically and statistically. Case C deals with *homogeneous goods.* These have drastically different GDP coefficients, estimated at about 0.5 for own-GDP and 0.8 for partner-GDP.

Thus, the domestic-income coefficient *rises* as we move from homogeneous to differentiated goods.[15] This is consistent with a more pronounced home market effect for differentiated goods; manufacturing can move between countries more easily than production of resource-based homogeneous goods. (In our simulation model we captured this idea by simply treating the number of firms in each country as fixed.) Our empirical results twin with our simulated case C, in that we obtained an estimated coefficient on own-GDP smaller than obtained on partner-GDP, reversing the home market effect.

We have performed extensive sensitivity analysis, and find that our results are robust. For instance, we have used a more conservative goods-classification scheme, but found little change to the income elasticities.[16] We also repeated the estimation using Tobit estimation to account for the country-pairs with zero exports between them. The Tobit estimation changes the GDP elasticities not at all, regardless of whether the censoring is done at a zero exports, or allowing the censoring level to be estimated.[17]

Do the differing effects we have found between different types of *goods* really describe differences between *countries*? Hummels and Levinsohn (1995) found that the conventional gravity equation performed well on both OECD and non-OECD countries, so that our results may be the result of country-specific characteristics, not differences between types of goods. To check, we re-ran the gravity equation over two different groups of countries: a) exports within the OECD, and b) exports between OPEC and non-OPEC countries. The former sample represents countries between which firms can move relatively freely; the latter trade where the

[15] It is also interesting that the sum of the domestic and foreign income elasticities is economically and statistically higher for differentiated goods than for homogeneous goods.
[16] The reference good elasticities are closer for own-GDP and partner-GDP, while the homogeneous good elasticities are somewhat smaller for both home and partner countries.
[17] We do not perform sensitivity analysis by replacing exports with bilateral trade on the left-hand side of equation (10). Doing so would completely obscure the results we have obtained, because it would then impossible to distinguish own-GDP and partner-GDP, and these coefficients would need to be treated as equal.

exports of one country are heavily resource-dependent, so that entry is limited. Our results can be found in Table 3, which repeats the estimation for differentiated (case A) and homogeneous (case C) goods, using the a) OECD and b) OPEC-non-OPEC samples. For brevity we only report the results in Table 3 for 1970, 1980 and 1990 and exclude reference-priced goods.

There are two key results in Table 3: 1) no large differences between the different samples of *countries*; and 2) important differences between different types of *goods*. The OECD countries have a higher coefficient on own-GDP than either the OPEC or full sample for either type of good in 1970, but this difference in reversed by 1990. There remains, however, a very consistent difference between the differentiated goods (case A) and homogeneous goods (case C), using either of the samples. In particular, the differentiated goods show strong evidence of a home market effect in either sample, whereas the homogeneous goods have a reversed home market effect. These results reinforce our finding that the differing estimates of the gravity equation pertain to types of *goods*, rather than being features of *countries* with differing factor endowments.

5. Conclusions

In this paper, we have developed a reciprocal dumping model to motivate two-way trade in homogeneous products. Firms desire to export products whenever the marginal revenue abroad exceeds their marginal cost, inclusive of transportation charges. For the first unit exported by a firm, marginal revenue equals price, and so exporting occurs whenever the price abroad exceeds their marginal cost. The resulting trade patterns display a "home market" effect when there are transportation charges in the Cournot-Nash good. This is because firms will want to locate in the larger market to avoid transportation costs, as pointed out by Krugman (1980) in the context of a monopolistic competition model. That is, exports of a country are maximized when it is somewhat larger than its partner. However, when transportation charges are added for the numeraire good, the home market effect disappears. This arises because the transport costs in the homogeneous good effectively limits the mobility of firms; again, this result twins with one in a monopolistic competition model (in this case Davis, 1998). If the mobility of firms between countries is reduced further, the home market effect is reversed, and exports of a country will be maximized when it is somewhat smaller than its partner.

We examine whether the home market effect depends on the type of good by estimating gravity equations for bilateral export trade between country-pairs. We exploit Rauch's (1999) division of 5-digit SITC products into homogeneous, differentiated, or an in-between category. We sum the country-pair trade within these types of goods, and estimate separate gravity equations for different types of goods. As predicted, the home market effect shows up consistently for differentiated goods in the form of a domestic-income elasticity which exceeds the partner-income elasticity. This effect is much less pronounced for the in-between category, and reversed for homogeneous goods. This supports the hypothesis that firms are more mobile across countries for production of differentiated goods: a result that is statistically robust and economically interesting.

Our results can be usefully compared to other recent literature. Davis and Weinstein (1998) have found evidence of a home market effect in disaggregate trade between OECD countries, and rely on a gravity-type equation for demand. Our results are complementary, since we have found a home market effect for aggregate bilateral imports among a broader sample of countries. Davis and Weinstein argue that the home-market effect is supportive of an increasing-returns model, and we agree: the home-market effect in either the monopolistic competition or the free-entry Cournot-Nash model depends on fixed costs and increasing returns. But if barriers to entry are stronger for the homogeneous goods Cournot-Nash model, then the home-market effect no longer appears. Thus, increasing returns is a necessary but not a sufficient condition for the home-market effect.

Our results are also broadly consistent with Evenett and Keller (1998). They argue that the gravity equation can be used to distinguish different theoretical models (such as increasing returns versus a conventional Hecksher-Ohlin model), and rely on the Grubel-Lloyd measure of intra-industry trade to separate their samples. In contrast, we have used Rauch's (1999) measure of homogeneous versus differentiated goods to separate our samples. Despite the differences in methodology with these papers, the overall results are supportive of a world where increasing returns leads to a home market effect in differentiated goods, whereas in homogeneous goods a gravity equation still applies, but without the home market effect due to barriers to entry.

To conclude: this paper began with a puzzle. Existing plausible theoretical justifications for the gravity equation rely on product specialization. But much trade is in homogeneous goods. If specialization allows us to understand the success of the gravity model only in manufacturing goods, why does the gravity equation work so well? Our answer is twofold: the theoretical foundations for the gravity equation are actually quite general, but the empirical performance quite specific. Gravity equation can be derived for both differentiated and homogeneous goods, and we show how to do the latter in this paper. But the different theories lead to measurably different home market effects, and we have shown that these are important in the data.

Appendix 1: Proof of Proposition 2

We assume Cobb-Douglas preferences, and that the transportation costs between each country are equal, $\tau_{12}=\tau_{21}=\tau$. For small changes in L_1, the total derivatives of the zero-profit equations (7) are:

$$2\theta_{11}L_1\left(\frac{c}{p_1^2}\right)dp_1 + 2\theta_{12}L_2\left(\frac{c\tau}{p_2^2}\right) = -\theta_{11}^2 dL_1 \,, \tag{A1}$$

$$2\theta_{12}L_1\left(\frac{c\tau}{p_1^2}\right)dp_1 + 2\theta_{22}L_2\left(\frac{c\tau}{p_2^2}\right) = -\theta_{21}^2 dL_1 \,, \tag{A2}$$

where the shares θ_{ij} are given by (3). Letting $\hat{z} = dz/z$ denotes percentage changes, the change in prices can be solved as,

$$\hat{p}_1 = -\hat{L}_1\left(\frac{p_1}{2c}\right)\left[\frac{\theta_{11}^2\theta_{22} - \theta_{21}^2\theta_{12}\tau}{\theta_{11}\theta_{22} - \theta_{12}\theta_{21}\tau^2}\right], \tag{A3}$$

$$\hat{p}_2 = \hat{L}_1\left(\frac{L_1 p_2}{2L_2 c}\right)\left[\frac{\theta_{11}^2\theta_{21}\tau - \theta_{21}^2\theta_{11}}{\theta_{11}\theta_{22} - \theta_{12}\theta_{21}\tau^2}\right]. \tag{A4}$$

The denominator of these expressions is positive provided that $\theta_{ii} > \theta_{ij}\tau$, $i \neq j$. Using (3), this condition is satisfied provided that,

$$p_i/c < 1 + \tau \,. \tag{A5}$$

Recalling that $\tau \geq 1$, a sufficient condition for (A5) to hold is that prices are not more than twice as large as marginal costs, which can reasonably hold in the zero-profit equilibrium. Under (A5), $\hat{p}_1 < 0$ for $\hat{L}_1 > 0$, which demonstrates that downward sloping relation between prices and the labor endowment shown in Figure 1. Also, $\hat{p}_2 > 0$ for $\hat{L}_1 > 0$.

A slight re-allocation of labor between countries will satisfy $dL_1 = -dL_2$, or $\hat{L}_1 = -\hat{L}_2$. Then the total change in prices is computed from (A3)-(A4) as:

$$\hat{p}_1 = -\hat{L}_1\left(\frac{p_1}{2c}\right)\left[\frac{(\theta_{11}^2\theta_{22} - \theta_{12}^2\theta_{22}) + \tau(\theta_{22}^2\theta_{12} - \theta_{21}^2\theta_{12})}{\theta_{11}\theta_{22} - \theta_{12}\theta_{21}\tau^2}\right], \tag{A6}$$

$$\hat{p}_2 = \hat{L}_1\left(\frac{p_2}{2c}\right)\left[\frac{(\theta_{22}^2\theta_{11} - \theta_{21}^2\theta_{11}) + \tau(\theta_{11}^2\theta_{21} - \theta_{12}^2\theta_{21})}{\theta_{11}\theta_{22} - \theta_{12}\theta_{21}\tau^2}\right]. \tag{A7}$$

Condition (A5) again ensures that $\hat{p}_1 < 0$ and $\hat{p}_2 > 0$ for $\hat{L}_1 > 0$. Expressions (A6)-(A7) can be simplified further by noting that $\theta_{11}=\theta_{22}$ and $\theta_{12}=\theta_{21}$ for $L_1=L_2$, as we shall make use of below.

The real exports from country1 to 2 are given by $X_{12}=N_1\theta_{12}(\alpha L_2/p_2)$, so the change in real exports is:

$$\hat{X}_{12} = \hat{N}_1 + \hat{\theta}_{12} - \hat{L}_1 - \hat{p}_2. \tag{A8}$$

From (3), the change in prices (A6)-(A7) will imply a change in market share:

$$\hat{\theta}_{12} = \left(\frac{1}{\theta_{12}}\right)\left(\frac{c\tau}{p_2}\right)\hat{p}_2. \tag{A9}$$

An increase in the price in country 2 will therefore lead to an increase in the market share of an exporter from country 1. Using (A5) it follows that $\hat{\theta}_{12} > \tau\hat{p}_2$, so that $\hat{\theta}_{12} - \hat{p}_2 > (\tau - 1)\hat{p}_2 > 0$ for $\hat{L}_1 > 0$. Thus, the market share increases by more than the price in country 2.

The others change in market share $\hat{\theta}_{ij}$ can be computed from (3), using (A6)-(A7). Then differentiating (4), the endogenous change in the number of firms in each country 1 can be computed as

$$\hat{N}_1 = (1+\tau)\left(\frac{\hat{L}_1}{2}\right)\left[\frac{(\theta_{11}^3 - \theta_{12}^2\theta_{11}) + \tau(\theta_{11}^2\theta_{12} - \theta_{12}^3)}{(\theta_{11}^3 - \theta_{12}^2\theta_{11}\tau^2) - (\theta_{11}^2\theta_{12} - \theta_{12}^3\tau^2)}\right]. \tag{A10}$$

Using $\theta_{11}>\theta_{12}$, it follows that $\hat{N}_1 > (1+\tau)(\hat{L}_1/2) \geq \hat{L}_1$ for $\hat{L}_1 > 0$. Thus, the number of firms exporting from country 1 increases by more than its labor force. Combined with the increase in the market share in country 2 by more than the price, shown just above, this establishes that the change in real exports in (A8) is positive for $\hat{L}_1 > 0$. Similar calculations show that $\hat{X}_{21} < 0$ for $\hat{L}_1 > 0$.

Appendix 2: Additional Simulation Results

In this Appendix we report additional simulation results to those in Table 1, including a wider range of country sizes and also a third country. For simplicity, these simulations used *nine* different country sizes (resource endowments) in each country, rather than 99 as in Table 1. The first three regressions in Table A1 report the gravity equation (11) run over nine observations, where the *sum* of GDP in countries 1 and 2 is held constant. This assumption was also used in Table 1, so the first three regression in Table A1 are analogous to those in Table 1 but with a smaller number of observations; the regression results are similar in the two Tables.

In the second set of regressions in Table A1, we now allow world GDP to vary. With nine distinct sizes for each country, there is a matrix of 81 equilibria, ranging from both countries small, to both countries large, to one small and one large, etc. Running the gravity equation (11) over these 81 equilibria, we obtain the results shown in panel (II). It is evident that the magnitude of the coefficients is reduced substantially from panel (I), often to one-half of their previous size. But the *relative* size of the coefficients is much the same, with $\beta_1 > \beta_2$ for case A, $\beta_1 \approx \beta_2$ for case B, and $\beta_1 < \beta_2$ for case C. Thus, the relative size of the coefficients is still an indicator of the "home market" effect.

We believe that the reason for the reduction in coefficients moving from panel (I) to (II) is that *world* GDP is a missing variable from the regression. The conventional derivation of the gravity equation, as in Helpman (1987), shows that this variable should appear. To see this, suppose that countries specialize in different products, and there are no transport costs between them. Let y_{ij} denote the amount of good i produced in country j, and Y_j denote the value of production (equal to income) in country j=1,…,N, while Y_w denotes world income . With identical and homothetic tastes, each country k will demand a share (Y_k/Y_w) of any good produced, so exports of good i from country j to country k are $y_{ij}(Y_k/Y_w)$. Summing this over all goods i, total exports from country j to k will be $X_{jk}=Y_j Y_k/(Y_w)$. Thus, exports are determined by the log-linear equation:

$$\log(X_{jk}) = -\log(Y_w) + \log(Y_j) + \log(Y_k) \qquad \text{(A11)}$$

The term $-\log(Y_w)$ is treated as a constant when running (A11) over a cross-section of countries. In our two-county simulations, we have tried to approximate a cross-section of countries by keeping world GDP constant (panel I). When world GDP varies (panel II), then the term $-\log(Y_w)$ is an omitted variable. Since it is negatively correlated with the GDP of each country, the omitted variable *pulls down* the coefficients obtained in the gravity equation, as we found moving from panel (I) to panel (II).

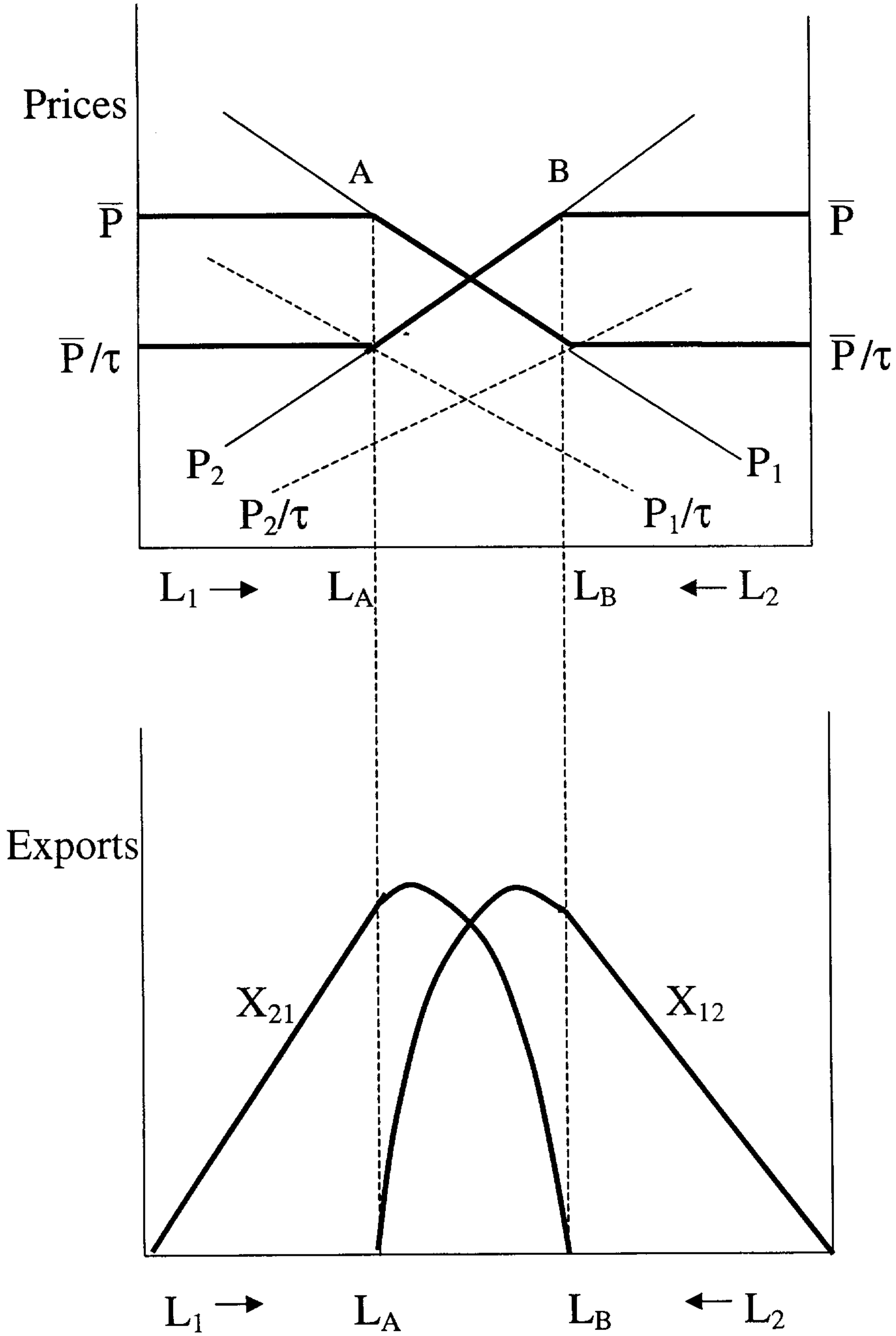
The sensitivity of the gravity equation to the simulation data used is greatly reduced when we introduce a third, large country, as in panels (III) and (IV) of Table A1. We hold the size of the third country fixed, and again consider nine distinct sizes for countries 1 and 2. The gravity equation is run over the nine observations where the sum of GDP in countries 1 and 2 is constant (panel III), and then over all 81 observations for the various countries sizes (panel IV). The results for these two simulations are broadly similar, with the principal exception coming in the coefficient of own-GDP in case C. Furthermore, the results from panel (IV) are quite similar to panel (I), with the same exception just noted. Thus, our results obtained for two countries, and holding world GDP fixed, are quite similar to those obtained with three countries, and either holding world GDP fixed or letting it vary.

Appendix Table A1: Additional Regressions on Simulated Data, Dependent Variable - Log of Bilateral Exports

	Own GDP	Partner GDP	R^2	N
	(I) Two-Country Simulation, Keeping World GDP Fixed:			
Case A	1.24	0.99	0.996	9
Case B	0.91	0.92	0.996	9
Case C	0.64	1.03	0.971	9
	(II) Two-Country Simulation, Letting World GDP Vary:			
Case A	0.66	0.43	0.935	81
Case B	0.51	0.53	0.965	81
Case C	0.30	0.76	0.976	81
	(III) Three-Country Simulation, Keeping World GDP Fixed:			
Case A	1.26	0.99	0.999	9
Case B	1.15	1.02	0.989	9
Case C	0.44	1.16	0.985	9
	(IV) Three-Country Simulation, Letting World GDP Vary:			
Case A	1.25	0.98	0.993	81
Case B	0.99	0.88	0.994	81
Case C	0.18	0.95	0.984	81

Case A: Transport 10% on Cournot-Nash good, 0% on numeraire, free entry
Case B: Transport 10% on Cournot-Nash good, 5% on numeraire, free entry
Case C: Transport 10% on Cournot-Nash good, 0% on numeraire, no entry

Figure 1: Reciprocal Dumping Model



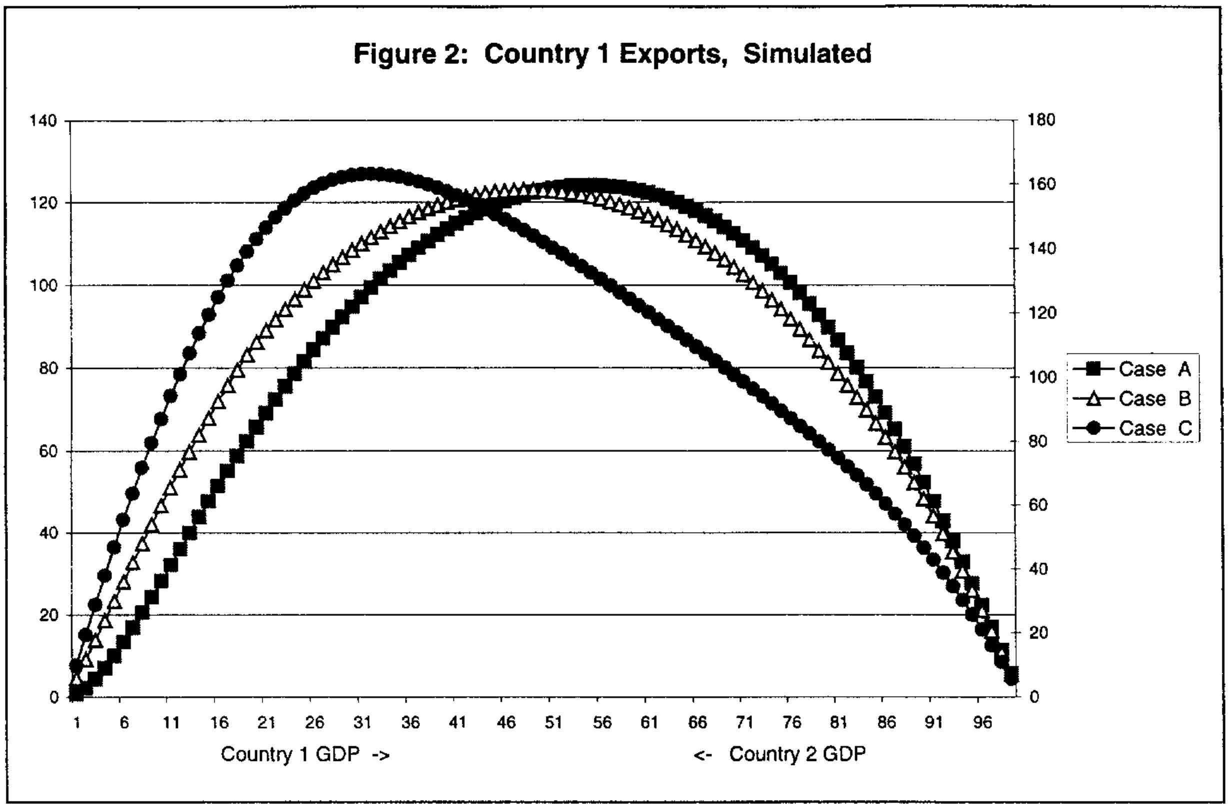


Table 1: Regressions on Simulated Data,
Dependent Variable - Log of Bilateral Exports

	Own GDP	Partner GDP	R^2	N
Case A	1.39	1.07	0.99	99
Case B	0.98	0.96	0.99	99
Case C	0.78	1.07	0.97	99

Case A: Transport 10% on Cournot-Nash good, 0% on numeraire, free entry
Case B: Transport 10% on Cournot-Nash good, 5% on numeraire, free entry
Case C: Transport 10% on Cournot-Nash good, 0% on numeraire, no entry

Table 2: Regressions using World Trade Data,
Dependent Variable – Log of Bilateral Exports

	Own GDP	Partner GDP	Distance	Common: Border	Common: Language	FTA	Remote	R^2	N
Case A: Exports of Differentiated Goods									
1970	1.08	.60	-1.11	.18	.26	2.09	530	.48	6498
	(.02)	(.02)	(.04)	(.16)	(.07)	(.12)	(82)		
1975	1.13	.64	-1.16	.18	.04	1.84	514	.48	7058
	(.02)	(.02)	(.04)	(.16)	(.07)	(.13)	(82)		
1980	1.04	.63	-1.05	.20	.11	1.49	600	.49	7779
	(.01)	(.01)	(.03)	(.15)	(.07)	(.17)	(69)		
1985	1.00	.63	-1.06	.04	.01	1.65	472	.48	7858
	(.01)	(.01)	(.04)	(.16)	(.07)	(.16)	(68)		
1990	1.11	.71	-1.11	.11	.19	1.70	830	.57	6367
	(.02)	(.02)	(.04)	(.16)	(.07)	(.11)	(63)		
Case B: Exports of Reference Priced Goods									
1970	.93	.67	-1.05	.07	.22	1.67	548	.47	5381
	(.02)	(.02)	(.04)	(.16)	(.08)	(.15)	(67)		
1975	.93	.65	-1.17	.10	-.03	1.39	545	.47	5713
	(.02)	(.02)	(.04)	(.15)	(.08)	(.13)	(77)		
1980	.87	.66	-1.05	.23	.11	1.05	597	.50	6279
	(.02)	(.01)	(.03)	(.14)	(.07)	(.15)	(61)		
1985	.88	.65	-1.01	.30	.06	1.30	509	.49	6411
	(.02)	(.01)	(.03)	(.14)	(.07)	(.13)	(67)		
1990	.90	.73	-1.16	.11	.05	1.34	740	.55	5439
	(.02)	(.01)	(.04)	(.16)	(.07)	(.12)	(64)		
Case C: Exports of Homogeneous Goods									
1970	.42	.83	-.76	.12	.13	.66	254	.34	5505
	(.02)	(.02)	(.04)	(.17)	(.08)	(.22)	(69)		
1975	.47	.84	-.79	.04	.01	.70	130	.33	5805
	(.02)	(.02)	(.04)	(.16)	(.09)	(.22)	(72)		
1980	.53	.81	-.74	.19	-.09	1.08	64	.34	6258
	(.02)	(.02)	(.04)	(.15)	(.08)	(.21)	(71)		
1985	.54	.75	-.79	.22	-.12	1.12	133	.35	6382
	(.02)	(.02)	(.04)	(.15)	(.08)	(.18)	(70)		
1990	.53	.80	-.90	.42	-.02	1.01	406	.40	5095
	(.02)	(.02)	(.04)	(.17)	(.09)	(.14)	(74)		

Table 3: Regressions using World Trade Data, Dependent Variable – Log of Bilateral Exports

	Own GDP	Partner GDP	Distance	Common: Border	Common: Language	FTA	Remote	R^2	N
(I) Sample of OECD countries									
Case A: Exports of Differentiated Goods									
1970	1.18	.79	-.94	-.09	.34	1.07	799	.74	414
	(.05)	(.06)	(.07)	(.29)	(.24)	(.15)	(130)		
1980	1.10	.75	-1.02	-.15	.04	.64	834	.74	414
	(.05)	(.05)	(.06)	(.31)	(.24)	(.14)	(115)		
1990	1.07	.81	-1.03	-.07	.26	.18	625	.83	420
	(.04)	(.04)	(.05)	(.19)	(.16)	(.10)	(88)		
Case C: Exports of Homogeneous Goods									
1970	.56	1.03	-.78	.31	.17	.33	517	.54	409
	(.07)	(.07)	(.10)	(.35)	(.30)	(.25)	(157)		
1980	.55	.94	-.97	.38	-.28	.24	692	.54	406
	(.07)	(.08)	(.10)	(.27)	(.30)	(.24)	(150)		
1990	.38	1.03	-1.07	.34	-.28	.31	514	.58	411
	(.07)	(.06)	(.09)	(.24)	(.30)	(.16)	(141)		
(II) Sample of OPEC to non-OPEC countries									
Case A: Exports of Differentiated Goods									
1970	1.07	.72	-.94	.51	.10	a	-620	.36	844
	(.06)	(.05)	(.13)	(.40)	(.20)		(368)		
1980	1.12	.72	-.87	.50	-.19	.10	-1320	.32	1089
	(.05)	(.06)	(.12)	(.40)	(.19)	(.58)	(342)		
1990	1.24	.78	-1.03	-.23	.13	.97	-417	.48	681
	(.05)	(.05)	(.14)	(.40)	(.21)	(.64)	(409)		
Case C: Exports of Homogeneous Goods									
1970	.50	.70	-.80	-.12	-.02	a	-696	.20	751
	(.06)	(.06)	(.17)	(.44)	(.24)		(443)		
1980	.56	.95	-.53	-.15	-.23	.94	-1134	.20	964
	(.06)	(.08)	(.15)	(.50)	(.25)	(.72)	(397)		
1990	.51	.98	-1.43	-.48	-.25	.54	-458	.30	566
	(.07)	(.08)	(.17)	(.49)	(.28)	(.55)	(480)		

Notes:

a. The FTA variable is dropped from sample (II) in 1970 since all exporters were in the same free trade area.

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