Using The Gravity Equation To Differentiate

Among Alternative Theories Of Trade

Robert C. Feenstra
Department of Economics
Univ. of California, Davis
and National Bureau
of Economic Research

Professor James R. Markusen
Department of Economics
Univ. of Colorado, Boulder
and National Bureau
of Economic Research

Andrew K. Rose
Haas School of Business
Univ. of California, Berkeley
and National Bureau
of Economic Research

September 25, 2000

Abstract

The simple gravity equation explains a great deal about the data on bilateral trade flows, and is consistent with several theoretical models of trade. We argue that alternative theories nevertheless predict subtle differences in key parameter values, depending on whether goods or homogeneous or differentiated, and whether or not there are barriers to entry. Our empirical work for differentiated goods delivers results consistent with the theoretical predictions of the monopolistic-competition model, or a reciprocal-dumping model with free entry. Homogeneous goods are described by a model with national (Armington) product differentiation or by a reciprocal-dumping model with barriers to entry.

JEL Classification Number: F10, F12

Keywords: homogeneous; empirical; theoretical; simulation; Cournot-Nash; reciprocal dumping.

Corresponding Author: Robert C. Feenstra, Department of Economics, University of California, Davis, CA 95616, Tel: (530) 752-7022, Fax: (530) 752-9382; rcfeenstra@ucdavis.edu

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). An equation of this type does arise, however, from a model in which countries are fully specialized in differentiated goods.[1] 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 are presumed 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 *general* empirical success.

In this paper, we argue that a wider range of theories than previously recognized are consistent with a gravity-type equation. Nevertheless, alternative theories (or more precisely, alternative conditions of entry) predict subtle differences in key parameter values that should emerge in an estimated gravity equation, which can therefore be used to distinguish the theories. We first consider models of product differentiation (and therefore, complete specialization). After describing the benchmark case of zero transport costs in section 2, we consider two models with transports costs in section 3: monopolistic competition, and national (Armington) product differentiation. The first of these predicts a larger export elasticity with respect to the exporter's income than with respect to the importer's income, a result that is closely related to the "home-market effect" (Krugman, 1980). This relationship is reversed in a model with an Armington structure.

In section 4, we turn to models with homogeneous products. We note that two-way or "intra-industry" trade indeed be generated by a model with homogeneous goods if there is imperfect competition and segmented markets. The combination of these two assumptions is often referred to as the "reciprocal dumping" model of trade following Brander (1981), Brander and Krugman (1983), and Venables (1985). Since the amount of trade depends on country size, it can be expected that some version of a gravity equation applies.[2] This model has different predictions with and without free entry of firms, however. Our theoretical results indicate that the own-income elasticity of exports is larger than the importer-income elasticity in a model with reciprocal dumping and free entry, but that the "reverse" result holds when entry is restricted.

Having developed a set of theoretical predictions, in section 5, we turn to an empirical investigation. We regress bilateral exports (from one country to each of its trading partners) on domestic- and partner-country GDP and other controls. Using Rauch's (1999) classification, we divide our sample into three groups: 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 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 consistent with the theoretical hypothesis that the "differentiated" goods fit the predictions of a monopolistic-competition model with free entry. The results for the "homogeneous" goods fit the predictions of a reciprocal dumping model with restricted entry. Additional conclusions and comparison with recent literature are given in section 6.

2. Zero Transport Costs

It will be useful to begin with a brief review of the gravity equation in the case of zero transport costs and complete specialization (Helpman, 1987). Suppose that countries specialize in different products, and let y_{ik} denote the value of country i production of good k. Also let I_i denote the total value of production (equal to income) in country i=1,…,N, and I_w denote world income. With identical and homothetic tastes, each country i will demand a share (I_i/I_w) of any good produced, so exports of good k from country i to j are $y_{ik}(I_j/I_w)$. Summing this over all goods k, total exports from country i to j will be $X_{ij}=I_iI_j/(I_w)$. Thus, exports are determined by the log-linear equation:

$$\log(X_{ij}) = -\log(I_w) + \log(I_i) + \log(I_j)\,. \tag{1}$$

The term $-\log(I_w)$ is treated as a constant running (8) over a cross-section of countries, in which case we expect to find coefficients of unity on both the own and partner–country GDP. This result will be modified with *positive* transport costs, as included in all models considered below.

3. Product Differentiation

In this section, we explore the implications of two versions of models with product differentiation and positive trade costs. The first version is a familiar large-group monopolistic-competition model, with firm-level product differentiation. The second is an Armington formulation, with perfect competition, constant returns to scale, and national-level product differentiation.

The models both have two goods, two factors, and two countries. The goods are x and y, where x is the sector of interest and y is a "numeraire" sector with constant returns to scale and perfect competition. The countries are denoted by i and j, where country i will be the larger country throughout. The countries might have multiple factors of production, but we will assume that factor price equalization holds, despite the fact that there are transportation costs in the x sector.[3] Countries also have the same technologies, and therefore, the same costs. Many of the key results are available elsewhere, so what we will do here is provide results in a manner that we hope permits easy comparison and develops intuition. References are provided to more complete proofs.

Consider first the standard monopolistic-competition model. Let subscripts denote countries, and x_{ij} will denote x *produced* in country i and *consumed* in country j. Utility for the representative consumer in country i is given by:

$$U_i = y_i^{1-\alpha} \left[\sum_{i=1}^{n_i} x_{ii}^{\gamma} + \sum_{i=1}^{n_j} x_{ji}^{\gamma} \right]^{\alpha/\gamma}, \qquad \sigma = \frac{1}{1-\gamma}$$

where n_i and n_j are the numbers of varieties of x produced in i and j, respectively, α is the income share spent on the differentiated good, and σ is the elasticity of substitution between varieties.

Let us propose a candidate, symmetric equilibrium in which each country produces a number of varieties in proportion to its size. Following the usual assumptions of the large-group monopolistic-competition model, each good that is produced is produced in the same amount in either country. With constant elasticity of demand, prices p_i are a fixed markup over marginal costs, and are the same in each country. Letting I denote a country's income, measured in terms of y, the proposed equilibrium is thus characterized by the following:

$$\textit{proposed equilibrium:} \qquad n_i / I_i = n_j / I_j, \quad x_{ii} + x_{ij} = x_{jj} + x_{ji}, \quad p_i = p_j \ . \tag{2}$$

Let t > 1 denote a transport cost factor (1 plus an ad valorem transport cost rate). Then demands for x varieties in the two countries are given as follows:

$$x_{ii} = \frac{I_i / \alpha}{p^{\sigma} s_i}, \quad x_{ji} = \frac{I_i / \alpha}{(p\,t)^{\sigma} s_i}, \quad x_{jj} = \frac{I_j / \alpha}{p^{\sigma} s_j}, \quad x_{ij} = \frac{I_j / \alpha}{(p\,t)^{\sigma} s_j}, \tag{3}$$

where $s_i = [\, n_i p^{1-\sigma} + n_j (p\,t)^{1-\sigma}]$. Note that we have,

$$\frac{s_j}{s_i} = \frac{n_i t^{1-\sigma} + n_j}{n_i + n_j t^{1-\sigma}} = \frac{n_j}{n_i}\left[\frac{1 + (n_i / n_j)\, t^{1-\sigma}}{1 + (n_j / n_i)\, t^{1-\sigma}}\right] > \frac{n_j}{n_i}, \tag{4}$$

if $n_i > n_j$ (i.e., country i is larger). The demand functions in (3) can be re-written as:

$$x_{ii} - x_{ji} = \frac{(1 - t^{-\sigma})\, I_i / \alpha}{p^{\sigma} s_i} \tag{5}$$

$$\frac{x_{ii} - x_{ji}}{x_{jj} - x_{ij}} = \frac{I_i / s_i}{I_j / s_j} > \frac{I_i / n_i}{I_j / n_j} = 1 \quad \Rightarrow \quad x_{ii} + x_{ij} > x_{jj} + x_{ji}, \tag{6}$$

where the last equality is due to our proposed equilibrium (2). Equation (6) implies that the demand for each variety produced in the larger country i is *greater than* the demand for each variety produced in the small country j. But each variety is produced (supplied) in the same quantity in each country in the proposed equilibrium, so we arrive at a contradiction. Thus, (2) is not an equilibrium because demand for each large country good exceeds its supply.

As suggested by the high demand for goods produced in the large country, the actual equilibrium must involve *more entry* of firms and greater product variety in the large country, so that $n_i/I_i > n_j/I_j$ in equilibrium (Markusen and Venables, 1996). It follows that $n_iI_j > n_jI_i$, and since $s_i > s_j$ with $n_i > n_j$ and equal prices in the two countries, we readily obtain $n_ix_{ij} > n_jx_{ji}$ using the demand equations in (3). Thus, we have established that country i exports of the differentiated good (n_ix_{ij}) *exceed* imports (n_jx_{ji}), so that net exports of the differentiated good are positive for the larger country. This is termed the "home market effect" (Krugman, 1980), and reflects the disproportionately high entry of firms into the larger country: this supply effect *more than* offsets the higher demand in the larger country, so that net exports are positive.[4]

To develop a testable hypothesis in terms of the gravity equation, let β_i and β_j denote the elasticities of country i's exports of x with respect to own and foreign income, respectively. Beginning with equal incomes and balanced trade in x, a small transfer of income from country j to country i leads country i to become a net exporter, so that $\beta_i > \beta_j$.[5] That is, country i's net exports of x are more sensitive to its own income than to its partner income. We can think of β_i and β_j as coefficients in an equation that extends (1):

$$\log(X_{ij}) = -\log(I_w) + \beta_i \log(I_i) + \beta_j \log(I_j)\,, \qquad (1')$$

where $X_{ij} \equiv n_ix_{ij}$ denotes country i's exports. While there is no guarantee that the monopolistic-competition model we have described above corresponds *exactly* to the log-linear form in (1'), the *qualitative* features of the equilibrium are well described by the coefficients β_i and β_j.[6] The monopolistic-competition model corresponds to $\beta_i > \beta_j$, as reported in Table 1, where we will summarize our theoretical results.

Next, consider an Armington-type model, where $n_1 = n_2 = 1$, as analyzed by Head and Ries (1999). With prices the same across countries and only one variety produced in each, the variable s will have the same value in each country. Then it is immediate from the demand equation in (3) that $I_i > I_j$ implies $x_{ij} < x_{ji}$. This means that the large country's exports (x_{ij}) are less than its imports (x_{ji}). Thus, the home-market effect of the monopolistic-competition model is *reversed*, with a country's net exports of x being more sensitive to its partner's income than to its own income. In terms of the income elasticities and the gravity equation (1'), this case is described by $\beta_i < \beta j$ in Table 1. We collect our results together as:

Result 1 (differentiated products)

(a) In the monopolistic-competition model, a country's net exports of x are more sensitive to own income than to partner's income.

(b) In the Armington model (perfect competition, national product differentiation), a country's net exports of x are more sensitive to partner's income than to own income.

The intuition behind these results runs follows. In the monopolistic-competition model, *aggregate* x *production* plays little role; the focus is on the *individual* variety which is produced in the same amount regardless of country of production. But country size plays a role in *demand*. If prices of an i and a j variety are the same, total demand will be higher for the variety produced in the large country, because most of the total demand will be at the low no-transport-cost price in the domestic market. This implies a more-than-proportionate entry of firms to restore zero profits. This is the origin of the "home market effect".

In the Armington formulation, by contrast, *aggregate* production and consumption are what matters. If the price of country i's variety is the same as the price of country j's variety (they produce x in proportion to size), each country will demand the domestic variety and the foreign variety in the same ratio. But this cannot be consistent with total production being in proportion to income in each country, since there would be an excess demand for the small-country's good. With the two x goods being symmetric but imperfect substitutes, the small country must be the net exporter of x.

4. Oligopoly with Homogeneous Goods and Segmented Markets

In the previous section, we derived a testable hypothesis distinguishing the free-entry monopolistic competition model from the no-entry Armington case. Both of these rely on product differentiation, which is usually assumed when deriving the gravity equation. We think it is important to also consider homogeneous products, given the results of Hummels and Levinsohn. Accordingly, in this section we explore the implications of two versions of models with homogeneous goods, oligopoly, and segmented markets. Collectively, these assumptions are sometimes referred to as the "reciprocal dumping" model of international trade. In both versions, firms are Cournot competitors. In the first version, there is free entry and exit of firms (Brander and Krugman, 1983, sect. 3; Venables, 1985; Markusen and Venables, 1988), while in the second version there is one firm in each country (Brander, 1981; Brander and Krugman, 1983, sect. 2).

The underlying general-equilibrium model is the same as that in the previous section, with $\gamma = 1$; that is, the x goods are perfect substitutes. Cournot equilibrium is given by the equality between marginal-revenue and marginal-cost, where θ_{ij} is the markup of a firm *located* in market i and *selling* in market j, and c_i is the marginal cost of production in country j in terms of good y:

$$p_i (1 - \theta_{ii}) = c_i, \qquad p_i (1 - \theta_{ji}) = c_j t. \tag{7}$$

Similar equations apply to market j. With x homogeneous, demand for x in each market is given as follows:

$$n_i x_{ii} + n_j x_{ji} = \frac{I_i / \alpha}{p_i}, \qquad n_j x_{jj} + n_i x_{ij} = \frac{I_j / \alpha}{p_j}, \tag{8}$$

where x_{ij} is the sales of a firm *located* in market i and *selling* in market j. The Cournot markup formula is well known: it is a firm's market share, divided by the price elasticity of demand. With Cobb-Douglas demand, this price elasticity is unity, so the markup is just the firm's market share:

$$\theta_{ii} = \frac{x_{ii}}{n_i x_{ii} + n_j x_{ji}}, \qquad \theta_{ji} = \frac{x_{ji}}{n_i x_{ii} + n_j x_{ji}}, \tag{9}$$

with similar equations for market j. It is worth stressing that there is *two-way* trade (or "reciprocal dumping") in the x product, which does not come as a consequence of product differentiation, but instead occurs as firms in each country attempt to increase their profits by also selling in the other market.[7]

As before, we propose a symmetric equilibrium with each country having equal prices for x in the two countries, and equal marginal costs:

$$\textit{proposed equilibrium:} \quad p_i = p_j\,, \quad c_i = c_j\;. \tag{10}$$

These assumptions, combined with (9), imply symmetry in markups. Symmetry in markups in turn imply that sales in each country are proportional to country size.

$$p_i = p_j \;\Rightarrow\; \theta_{ii} = \theta_{jj} \;\Rightarrow\; \frac{x_{ii}}{n_i\, x_{ii} + n_j\, x_{ji}} = \frac{x_{jj}}{n_j\, x_{jj} + n_i\, x_{ij}} \;\Rightarrow\; \frac{x_{ii}}{I_i} = \frac{x_{jj}}{I_j}\,, \tag{11}$$

$$p_i = p_j \;\Rightarrow\; \theta_{ji} = \theta_{ij} \;\Rightarrow\; \frac{x_{ji}}{n_i\, x_{ii} + n_j\, x_{ji}} = \frac{x_{ij}}{n_j\, x_{jj} + n_i\, x_{ij}} \;\Rightarrow\; \frac{x_{ji}}{I_i} = \frac{x_{ij}}{I_j}\,. \tag{12}$$

Free entry requires that each firm's markup revenues equal fixed costs. Letting F denote fixed costs, these conditions can be written, using (13) and (14), as:

$$p_j\, \theta_{ii}\, x_{ii} + p_j\, \theta_{ij}\, x_{ij} \;=\; p\, \theta_{ii}\, x_{ii} + p\, \theta_{ji}\, x_{ji}\, (I_j / I_i) \;=\; F\,, \tag{13}$$

$$p_j\, \theta_{jj}\, x_{jj} + p_i\, \theta_{ji}\, x_{ji} \;=\; p\, \theta_{ii}\, x_{ii}\, (I_j / I_i) + p\, \theta_{ji}\, x_{ji} \;=\; F\,. \tag{14}$$

However, the proposed equilibrium and (7) imply that $\theta_{ii} > \theta_{ij}$, so with $\theta_{ji} = \theta_{ij}$ it follows from (9) that $x_{ii} > x_{ji}$, and therefore that $\theta_{ii}\, x_{ii} > \theta_{ji}\, x_{ji}$. But then both equations (13) and (14) cannot hold. Given $I_i > I_j$, if there are zero profits for a country j firm (i.e. (14) holds with equality), then there are positive profits for a country i firm. The proposed equilibrium (12) is not valid since there are excess profits for firms located in the larger country.

As expected, the excess profits for firms located in the larger country implies that entry must occur there to obtain equilibrium. That, in turn, drives down the price in that market. Further analysis, found in Venables (1985) and Feenstra, Markusen and Rose (1998), confirms that the equilibrium must involve (a) $p_i < p_j$, (b) firms located in country i more than in proportion to the size differences between countries, and as a consequence of these, (c) exports of the x product from the large country ($n_i x_{ij}$) that *exceed* its imports ($n_j x_{ji}$). Thus, beginning with countries of equal size, a transfer of income from country j to country i leads to higher exports of the x commodity by country i. The result is again described by $\beta_i > \beta_j$ in Table 1, so that the own-income elasticity of demand exceeds the foreign (importer's) income elasticity of demand.

Finally, the case where there is some implicit barrier to entry such that each country has only a single x firm is fairly straightforward. The pricing equations (7) still hold. We divide these by one another, and do the same for market j, noting that $(1 - \theta_{ii}) = \theta_{ji}$, and $(1 - \theta_{jj}) = \theta_{ij}$, to obtain:

$$\frac{(1-\theta_{ji})}{(1-\theta_{ii})} = \frac{(1-\theta_{ji})}{\theta_{ji}} = t = \frac{(1-\theta_{ij})}{\theta_{ij}} = \frac{(1-\theta_{ij})}{(1-\theta_{jj})}. \qquad (15)$$

This condition requires that the relative shares of the two firms are the same in both export markets, $\theta_{ij} = \theta_{ji}$. Assume again that country i is larger, so that total demand for x is greater than in country j. Then for $\theta_{ij} = \theta_{ji}$ with only a single firm in each country, it must be that $x_{ij} < x_{ji}$.

Therefore, the smaller country j has higher exports (x_{ji}) than does the larger country (x_{ij}).

Beginning with the countries identical, a small transfer of income from i to j leads country i to become the net exporter (Markusen, 1981). This once again reverses home-market effect, and implies that a country's exports of the good will be more sensitive to its partner's income than to its own income, as indicated by $\beta_i < \beta_j$ in Table 1. Summarizing, we have:

Result 2 (homogeneous goods with oligopoly and segmented markets)

(a) With free entry and exit, a country's net exports of x are more sensitive to own income than to partner's income.

(b) With a single firm in each country, a country's net exports of x are more sensitive to partner's income than to own income.

The intuition behind these results is related to that in the previous section. With free entry and the market sizes differing, zero-profit conditions demand that the larger country's firms export to the smaller market. A symmetric equilibrium with balanced trade implies that either the larger country's firms make positive profits and/or the small country's firms make losses. The price of x must be lower in the large market, and firms must be located disproportionately in the large market as they are in the monopolistic-competition model, leading to higher exports from that country.[8]

With only a single firm in each country, a symmetric solution with no trade would mean that the large country's firm have a larger market share in the small country than the small-country's firm have in the large country. The former would have a lower perceived marginal revenue, and this cannot be an equilibrium. The pricing equations in (7) imply that (at constant marginal cost) each firm must have an equal market share in the other firm's market, implying that the small country is the net exporter.

5. Estimating the Gravity Equation

Table 1 provides a summary of our theoretical predictions for the nature of the home market effect (or lack thereof); these are testable via income coefficients in a gravity equation. In order to test for these differences, we run into the immediate problem that the barriers to entry in an industry are not directly observable. What we *do* have ready access to, is a classification of products according to whether they are *differentiated* or not. 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." Rauch then aggregates this classification to the 4-digit SITC level, matching the bilateral trade data from the Statistics Canada World Trade Database (WTDB), described in Feenstra, Lipsey and Bowen (1997). Thus, the WTDB data are designated homogeneous, reference priced, or differentiated, according to the share of disaggregate commodities falling into these three categories.[9]

We consider a null and two alternative hypotheses relating barrier to entry to product differentiation:

H_0: barriers to entry and product differentiation are uncorrelated across industries;

H_1: industries producing differentiated products tend to have higher barriers to entry;

H_2: industries producing homogeneous products tend to have higher barriers to entry.

Under the null hypothesis H_0, estimating a gravity equation like (1') over different types of goods (homogeneous versus differentiated) should result in own and partner income elasticities (β_i and β_j) that are *not significantly different from each other*. The reason is that, from Table 1, low barriers to entry results in $\beta_i > \beta_j$, whereas high barriers to entry results in $\beta_i < \beta_j$, so that if these two cases occur with roughly equal probability for both homogeneous and differentiated goods, then we would expect to estimate $\beta_i \approx \beta_j$ for either type of good. A rejection of the null implies that entry barriers and product differentiation *are indeed* correlated; dis-aggregating by type of good should lead us to one of the two alternatives.

The first alternative hypothesis (H_1) is motivated by the idea that product differentiation is itself a form of a barrier to entry, so these industries would have higher barriers than for homogeneous goods. If that is the case, then we expect to find $\beta_i < \beta_j$ for differentiated goods, as the barriers to entry lead to a "reverse" home market effect, but $\beta_i > \beta_j$ for homogeneous goods. On the other hand, the second alternative hypothesis (H_2) is motivated that the idea that entry might be *more free* for differentiated goods. By definition, these goods allow for now products to be readily developed and marketed in small scale. In contrast, the homogeneous goods in Rauch's classification tend to be basic industries like steel or resource extraction, which oftentimes have very large fixed costs, acting as a deterrent to entry. Under this second alternative hypothesis, we expect to find $\beta_i > \beta_j$ for differentiated goods, as free entry leads to reverse" home market effect, but $\beta_i < \beta_j$ for homogeneous goods.

In order to implement these tests, we use Rauch's classification scheme to sum 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 six export 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.[10] 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 (1'), augmented for a number of auxiliary variables relevant for bilateral trade flows:

$$\ln(X_{ij}) = \beta_0 + \beta_1\ln(Y_i) + \beta_2\ln(Y_j) - \beta_3\ln D_{ij} + \beta_4 Cont_{ij} + \beta_5 Lang_{ij} + \beta_6 FTA_{ij} + \beta_7 Rem_{ij} + \varepsilon_{ij} \qquad (16)$$

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.[11] This is consistent with a home market effect for differentiated goods and monopolistic competition, found in section 3, and homogeneous goods with "reciprocal dumping" and restricted entry of firms, as in section 4. Our finding that the own-income elasticity exceeds the partner-income elasticity for differentiated but not homogeneous goods, strongly support the second alternative hypothesis (H_2) mentioned above, whereby barriers to entry are strongest in the homogeneous goods.

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.[12] We have 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.[13]

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 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: i) no large differences between the different samples of *countries*; and ii) 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.

We also performed one other sensitivity analysis, motivated by the fact that many of the homogeneous goods are resource related. Since natural resources are a specific-factor in their respective industries, it is perhaps not surprising that in increase in overall country GDP has a less-than-proportionate effect on exports of those goods. It seems sensible in this case to control for the presence of natural resources in the economy within the gravity equation. To develop a specification, let us go back to the derivation of the gravity equation in section 2, without any transport costs.[14] There we summed across exports of all goods k in an economy to obtain (1). If instead we sum across a subset of goods denoted by k, representing the resource industries, we obtain $X_{ijk}=\lambda_k I_i I_j /(I_w)$, where X_{ijk} are country i exports to j of all these goods k, and λ_k is the share of these goods in country i GDP. The gravity equation then becomes:

$$\log(X_{ijk}) = -\log(I_w) + \log(I_i) + \log(I_j) + \log(\lambda_k) \quad . \qquad (1'')$$

If the GDP-share of this group of goods k is uncorrelated with GDP, then there is little harm in omitting the share variable. But for natural resources in particular, there is a literature noting that resource-rich countries tend to grow more slowly (Sachs and Warner, 1995; Asea and Lahiri, 1999). If this correlation between resources and the growth of GDP also applies to resources and the level of GDP, then omitting the resource share will bias the own-income elasticity in the gravity equation. Accordingly, we have re-estimated the gravity equation (16), while including the share of "minerals and fuel production" in GDP, for both country i and j, taken from Sachs and Warner (1995).[15] Since this variable is available for fewer countries than are in our dataset, the number of observations is reduced.

The results of re-estimating the gravity equation for selected years are shown in Table 4. It is evident that inclusion of the natural resource share has very little impact on the income elasticities, though the share themselves (especially for the own country) are quite significant and have the expected signs. The own-income elasticity is raised slightly in the gravity equation for homogeneous goods, as one might expect, but even this change is hardly significant. The hypothesis that the own-income elasticity is less than the partner elasticity is still strongly confirmed for the homogeneous goods, indicating a "reverse" home market effect. The conventional home market effect still appears for the differentiated and reference-price goods. Thus, inclusion of the natural resource share has not changed our overall results.

6. Conclusions

In this paper, we have argued that a gravity-type equation can arise from a wide range of models, though they have subtly different implications for the coefficient estimates. Notably, some models imply a "home market" effect, whereby an increase in exporter's income has a more-than-proportionate effect on exports, while other models imply a "reverse" home market effect. 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. 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, consistent with a reciprocal dumping model with barriers to entry.

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.

Head and Ries (1999) focus on models with differentiated goods, and contrast the home-market effect under monopolistic competition with the “reverse” Armington result, as in our Result 1. Empirically, they investigate a panel of U.S. and Canadian manufacturing industries, and are therefore able to distinguish the time-series versus cross-sectional result. They find some support for the home-market effect in the cross-section, but not in the time-series, where the “reverse” Armington result is more apparent. By comparison, we have focused exclusively on cross-sectional results, but have distinguished the types of goods.

Our results are also broadly consistent with Evenett and Keller (1998). Like us, 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 or national product differentiation.

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, but the different theories lead to measurably different home market effects, and we have shown that these are important in the data.

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Table 1: Theoretical Predictions

	Coefficients
Models with free entry:	
Monopolistic Competition:	$\beta_i > \beta_j$
Reciprocal Dumping with Free Entry	$\beta_i > \beta_j$

Models with restricted entry:

Armington National Product Differentiation	$\beta_i < \beta_j$
Reciprocal Dumping with No Entry	$\beta_i < \beta_j$

Note:

This table shows the elasticity of bilateral exports with respect to own income (β_i) and with respect to partner income (β_j), obtained from various models.

Table 2: Regressions using Full Sample,
Dependent Variable – Log of Bilateral Exports

	Own GDP	Partner GDP	Distance	Common: Border	Language	FTA	Remote	R^2	N
				Case A: Exports of Differentiated Goods					
1970	1.11	.62	-1.11	.02	.94	2.20	493	.49	6498
	(.02)	(.02)	(.04)	(.16)	(.08)	(.12)	(81)		
1975	1.15	.65	-1.14	.03	.80	1.89	491	.49	7058
	(.02)	(.02)	(.04)	(.16)	(.09)	(.12)	(80)		
1980	1.06	.65	-1.04	.06	.71	1.53	572	.50	7779
	(.01)	(.01)	(.03)	(.15)	(.07)	(.16)	(68)		
1985	1.02	.64	-1.05	-.12	.70	1.70	442	.48	7858
	(.01)	(.01)	(.03)	(.16)	(.08)	(.15)	(67)		
1990	1.12	.72	-1.10	-.03	.69	1.73	794	.57	6367
	(.02)	(.02)	(.04)	(.16)	(.08)	(.11)	(62)		
				Case B: Exports of Reference Priced Goods					
1970	.94	.69	-1.06	.06	.66	1.73	523	.47	5381
	(.02)	(.02)	(.04)	(.16)	(.16)	(.15)	(66)		
1975	.94	.66	-1.16	.-.02	.56	1.42	537	.47	5713
	(.02)	(.02)	(.04)	(.15)	(.09)	(.13)	(77)		
1980	.88	.68	-1.05	.13	.47	1.08	583	.50	6279
	(.02)	(.01)	(.03)	(.14)	(.08)	(.15)	(61)		
1985	.89	.66	-1.00	.17	.58	1.33	489	.50	6411
	(.02)	(.01)	(.03)	(.14)	(.07)	(.13)	(67)		
1990	.91	.74	-1.15	-.01	.55	1.38	719	.56	5439
	(.02)	(.01)	(.04)	(.15)	(.08)	(.11)	(63)		
				Case C: Exports of Homogeneous Goods					
1970	.44	.85	-.75	-.07	.91	.77	227	.35	5505
	(.02)	(.02)	(.04)	(0.4)	(.10)	(.22)	(67)		
1975	.49	.86	-.77	-.11	.73	.74	116	.34	5805
	(.02)	(.02)	(.04)	(.16)	(.10)	(.21)	(70)		
1980	.54	.82	-.73	.05	.50	1.12	51	.34	6258
	(.02)	(.02)	(.04)	(.16)	(.09)	(.21)	(70)		
1985	.55	.76	-.76	.07	.55	1.17	112	.35	6382
	(.02)	(.02)	(.04)	(.16)	(.09)	(.18)	(70)		
1990	.54	.81	-.89	.26	.61	1.06	384	.40	5095
	(.02)	(.02)	(.04)	(.16)	(.09)	(7.5)	(72)		

Table 3: Regressions using Country Samples, 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	-1.01	-.57	1.48	1.14	743	.76	414
	(.05)	(.06)	(.06)	(.30)	(.23)	(.15)	(124)		
1980	1.11	.75	-1.09	-.61	1.22	.62	810	.76	414
	(.05)	(.05)	(.06)	(.32)	(.18)	(.13)	(110)		
1990	1.07	.81	-1.07	-.34	.89	.18	591	.84	420
	(.04)	(.04)	(.06)	(.19)	(.17)	(.10)	(85)		
Case C: Exports of Homogeneous Goods									
1970	.56	1.03	-.85	-.27	1.63	.42	454	.57	409
	(.07)	(.07)	(.10)	(.39)	(.34)	(1.7)	(149)		
1980	.55	.95	-1.04	-.14	1.10	.22	687	.56	406
	(.07)	(.08)	(.10)	(.28)	(.36)	(.23)	(142)		
1990	.38	1.04	-1.12	-.06	.83	.30	513	.59	411
	(.07)	(.06)	(.09)	(.26)	(.36)	(.16)	(137)		
(II) Sample of OPEC to non-OPEC countries									
Case A: Exports of Differentiated Goods									
1970	1.10	.75	-.85	.39	.85	NA	-812	.37	844
	(.05)	(.05)	(.13)	(.39)	(.22)		(359)		
1980	1.14	.74	-.76	.36	.56	.28	-1568	.32	1089
	(.05)	(06)	(.12)	(.39)	(23)	(.60)	(348)		
1990	1.26	.80	-.94	-.25	.76	.76	-620	.49	681
	(.05)	(.05)	(.14)	(.36)	(.24)	(.24)	(408)		
Case C: Exports of Homogeneous Goods									
1970	.51	.71	-.78	-.17	.20	NA	-749	.20	751
	(.06)	(.06)	(.17)	(.44)	(.29)		(452)		
1980	.56	.96	-.49	-.22	.06	.95	-1211	.20	964
	(.06)	(.08)	(.15)	(.50)	(.31)	(.72)	(401)		
1990	.50	.98	-1.39	-.53	-.04	.60	-437	.30	566
	(07)	(.08)	(.18)	(.50)	(.37)	(.36)	(488)		

Notes:

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

Table 4: Regressions including Natural Resource Share, Dependent Variable – Log of Bilateral Exports

	Own GDP	Partner GDP	Distance	Natural Resources: Own,	Partner	FTA	Remote	R^2	N
	Case A: Exports of Differentiated Goods								
1970	1.12	.64	-1.09	-2.37	-.03	1.96	587	.50	5451
	(.02)	(.02)	(.04)	(.19)	(.17)	(.13)	(78)		
1980	1.11	.69	-1.05	-1.88	.67	1.28	681	.51	6315
	(.02)	(.02)	(.04)	(.16)	(.13)	(.17)	(68)		
1990	1.16	.75	-1.19	-4.29	-1.26	1.41	823	.60	5521
	(.02)	(.02)	(.04)	(.38)	(.30)	(.11)	(72)		
	Case B: Exports of Reference Priced Goods								
1970	.96	.69	-1.03	-1.81	-.34	1.53	605	.47	4509
	(.02)	(.02)	(.04)	(.25)	(.17)	(.17)	(86)		
1980	.95	.71	-1.09	-0.90	.41	.83	752	.51	5141
	(.02)	(.02)	(.04)	(.18)	(.12)	(.16)	(70)		
1990	.96	.77	-1.24	-1.33	-1.28	1.14	813	.57	4759
	(.02)	(.02)	(.04)	(.38)	(.30)	(.11)	(74)		
	Case C: Exports of Homogeneous Goods								
1970	.47	.86	-.80	1.84	-.61	.56	394	.38	4672
	(.02)	(.02)	(.05)	(.21)	(.18)	(.23)	(87)		
1980	.61	.84	-.82	2.76	-.38	1.02	222	.39	5233
	(.02)	(.02)	(.05)	(.24)	(.16)	(.21)	(83)		
1990	.58	.84	-1.00	2.94	-1.67	.93	407	.42	4517
	(.02)	(.02)	(.04)	(.43)	(.43)	(.14)	(82)		

Notes:
The regressions also included indicator variables for common border and common language, but these coefficients are not reported for brevity.

Lead footnote: Feenstra is Professor of Economics at U.C. Davis, and Director of the International Trade and Investment Program of the NBER. Markusen is Professor of Economics, University of Colorado, Boulder and Research Associate of the NBER. Rose is B.T. Rocca Jr. Professor of International Trade and Economic Analysis and Policy in the Haas School of Business at U.C. Berkeley, Research Associate of the NBER, and Research Fellow of the CEPR. This paper is available at http://www.econ.ucdavis.edu/faculty/fzfeens/ and http://haas.berkeley.edu/~arose, where the data set (in STATA format) is also available. The authors thank Don Davis, David Hummels, Wolfgang Keller, Jacques Melitz, Jim Rauch, David Riker and participants at the UCSC International Economics Conference for helpful suggestions.

[1] 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 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.

[2] In our working paper (Feenstra, Markusen and Rose, 1998) we derive and illustrate the gravity equation for the reciprocal dumping model. In this paper, we focus only on the associated income elasticities.

[3] Factor price equalization obtains, for example, if there is a single factor and both countries are producing the numeraire y good, which is traded without transportation costs. Alternatively,

there might be two factors of production, but equal *relative* endowments across countries. The presence of transport costs in the numeraire good has a substantial impact on the results, as considered in notes 4 and 6.

[4] We note that when the home-market operates, trade will be balanced through the larger country importing the numeraire goods from the smaller country. However, this presumes that there is unimpeded trade in the numeraire good. Davis (1998) has shown that if instead there are transport costs for the numeraire good, at a level greater or equal to those in the differentiated product, then the home-market effect will fail to operate and we will instead obtain a "reverse" result, as in the Armington model, considered next.

[5] In case our assertion that the own-income elasticity exceeds the partner-income elasticity is not clear from the preceding discussion, it can be shown as follows. Let $X_{ij} \equiv n_i x_{ij}$ denote country i exports, and $X_{ji} \equiv n_j x_{ji}$ denote country j exports. With $I_i = I_j$, these are equal. We have argued that an equal *increase* in I_i and *decrease* in I_j leads to $X_{ij} > X_{ji}$. It therefore follows that, $d(X_{ij}-X_{ji})/dI_i - d(X_{ij}-X_{ji})/dI_j > 0$. Now let X_{ij} be represented by (1'), with the analogous equation for X_{ji}. Then we readily calculate that $d(X_{ij}-X_{ji})/dI_i - d(X_{ij}-X_{ji})/dI_j = 2(\beta_i - \beta_j)$, and since this is positive, it follows that $\beta_i > \beta_j$.

[6] We have also considered simulations of the monopolistic competition model, and the reciprocal dumping model described below, and found that a log-linear equation like (1') fits the simulated equilibria from these models remarkably well. Results of this type are included in our working paper, Feenstra, Markusen and Rose (1998).

[7] The existence of two-way trade in the reciprocal dumping model presumes that the countries

are not too different in size, nor that transport costs are too large, in which case the larger country can be the sole exporter of good x (Feenstra, Markusen and Rose, 1998).

[8] As in the monopolistic competition model, the presence of the home market effect depends on our assumption that there are no transport costs in the homogeneous good. We have simulated the reciprocal dumping model with free entry, and allowing for transport costs in the homogeneous good, and find that the home market effect can then be reversed (see our working paper, Feenstra, Markusen and Rose, 1999). This extends the result of Davis (1998), discussed in note 4, to the reciprocal dumping model.

9 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.

[10] 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.

[11] 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.

[12] 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. We also find that the income elasticities are insensitive to controlling for GDP *per capita* of the

countries.

[13] 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.

[14] We thank David Hummels for providing us with this derivation and specification.

[15] According to (1''), we should only include the natural resource share for country i, but country j was also included for completeness. Furthermore, the natural resource share should be entered as a log. This was impossible because the "minerals and fuel production" share is zero for quite a number of countries, that still have positive bilateral exports of Rauch's "homogeneous" good. Accordingly, we entered the shares as levels rather than logs.