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WHAT CAN WE LEARN FROM BILATERAL TRADE?
GRAVITY AND BEYOND

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Abstract: Much empirical international trade research requires a careful analysis of bilateral trade patterns. In this paper we examine a commonly used technique called the gravity equation. Though the use of the gravity equation on aggregate data is well-grounded in monopolistic competition trade theory, we show that central predictions necessary for its derivation can be rejected with simple tests on disaggregated data. We also show why the aggregate equation fits data well, and demonstrate when it is useful for testing theory, estimating correlates of trade volumes, and norming bilateral trade flows.

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I. Introduction

Why do national borders and geographic distance still pose such impressive barriers to international transactions? What are the welfare effects of customs unions? Does currency volatility reduce the gains from trade? What economic models best describe trade patterns? These, and related questions, have recently been at the forefront of empirical research in international trade. Each requires the careful analysis of bilateral trade patterns, yet we lack a standard set of tools for such a task.

Neoclassical trade theory contains rich predictions regarding the factor content of trade, but has little to say about the volume of trade, and is virtually mute with respect to trade's bilateral distribution. This silence has not, however, prevented empiricists from studying bilateral trade flows using a model commonly referred to as the gravity equation. Though originally considered an ad hoc specification, and frequently dismissed for that reason, subsequent developments in trade theory have provided a compelling justification for its use. Specifically, the inclusion of monopolistic competition into the canon of trade models provides a sound framework for linking empirical work on bilateral trade to theory.

Nevertheless, the gravity model of international trade remains an enigma. Many economists remain skeptical about its use despite a number of long-standing papers exploring its theoretical foundations. Meanwhile, gravity estimates abound in the empirical


2 See Savage and Deutsch (1960), Tinbergen (1962) and Poyhonen (1963) for early examples.
trade literature, with literally scores of studies employing gravity models over the last three
decades, and even greater use of late. 3 We are, however, left with a quandary: is it faith
in these models or skepticism about them that is misplaced?

Our purpose here is not to expand an already voluminous literature on the deter­
minants of bilateral trade volumes. Rather, we intend to look more deeply at the empirical
relationship captured by gravity models in order to understand two things. One, why does
the gravity model fit the data so well? Two, what can we learn about trade by examining
bilateral trade flows? In particular, we focus our analysis around the three common uses of
gravity models to learn what bilateral trade flows tell us about partial correlates of trade,
“norming” trade flows, and testing trade theories.

To answer this, we provide two exercises that examine the robustness of gravity
models and their use. In the first, we look beyond the predictions of specific economic
models to investigate the general properties of bilateral matrices. Once we understand
the patterns that must result from a bilateral matrix, we will be better equipped to un­
derstand what econometric estimates of these patterns means. In the second, we turn to
disaggregated data to demonstrate the strengths and shortcomings of the aggregate gravity
equation and to show what we can learn from bilateral trade. Sectoral data allows us to
explore why trade is missing relative to a simple bilateral trade baseline, when aggregate
data can be used to norm trade flows, and how we can separate several margins that ulti­
mately affect trade volume. We conclude that the gravity equation has proved a useful if
crude technique for sorting out bilateral trade patterns, but that the time for more careful
techniques is at hand.

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3 All of the empirical work cited in the introductory paragraph employs some form of gravity estimate.
II. The Gravity Model: theoretical foundations

The simple form of the gravity model relates aggregate bilateral imports to the size of trading partners and the distance between them

\[ M_{ij} = \frac{Y_i Y_j}{D_{ij}} \]  

where \( M_{ij} \) is \( i \)'s total imports from \( j \), \( Y_i \) and \( Y_j \) are the countries' GDPs, and \( D_{ij} \) is the distance from \( i \) to \( j \). A typical estimate\(^4\) is given by

\[
\ln M_{ij} = 0.87 \ln Y_i + 1.05 \ln Y_j - 1.32 \ln D_{ij} \\
\text{obs} = 7402 \quad R^2 = 0.66
\]

Early empirical work employing gravity equations predates careful theoretical motivation. Instead of a model, we are offered intuition: bilateral trade volume is a function of each country's overall potential to trade, and the bilateral costs that resist trade and allocate it over partners. Thus, large countries have more production to trade, and pairs separated by distance or high tariff walls will see little of that potential. This same intuition is present in all the subsequent models used to explicitly derive the gravity equation. The contribution in the careful work is to show why bilateral flows depend on trade potential and resistance, and to provide precise predictions about the trade volume of specific pairs.

The theoretical justification for trade potential is easiest to convey in a model first developed by Anderson (1979). The production of goods is completely specialized so that every country is the sole supplier of the goods that it produces. Preferences are identical across countries and there is no trade resistance in the form of tariff barriers or transport costs. With identical preferences each country \( i \) will consume an amount of every good \( k \) equal to \( i \)'s share in world income,

\[ C^k_i = s_i Y^k, \]

\(^4\) This sample represents all bilateral country pairings with positive trade observations in 1992 from the Statistics Canada World Trade Database.
where $s_i = Y_i / Y_{world}$, and $Y^k$ is world production of $k$. With complete specialization, world output of $k$ is produced entirely in country $j$, $Y^k = Y^k_j$. Were many exporters to produce $k$, the model would exhibit a bilateral indeterminacy—while $i$’s multilateral imports of $k$ would be known, the distribution of those imports over multiple partners would not. This indeterminacy is a hallmark of neoclassical trade models with homogeneous goods. Here, in contrast, the consumption vector directly pins down the pattern of bilateral imports as

$$M_{ij}^k = s_i Y^k = s_i Y^k_j.$$  

Country $i$ will demand a similar fraction of all the goods produced in country $j$. Summing over all sectors we arrive at the simple gravity model:

$$M_{ij} = \frac{Y_i Y_j}{Y_w}.$$  

(3)

Here, trade potential consists of all of national product. A simple variant is to allow fractions $b_i$ and $b_j$ of consumption and production to be non-traded. Bilateral imports are then

$$M_{ij} = \frac{b_i b_j Y_i Y_j}{\sum_l b_l Y_l}.$$  

(4)

Trade potential is now given by the size of the traded goods sectors. Determining the appropriate trade potential between two partners is then key to providing a no-resistance or frictionless baseline for trade.

To understand the role of trade resistance requires more structure. Most empirical work on bilateral trade patterns employs some variant on the monopolistic competition model to motivate estimates. This model is very familiar in the literature, so details of the derivation are left to the appendix. Consumers purchase varieties of a single differentiated good according to Dixit-Stiglitz preferences, and transport costs, $t$, are of iceberg form.\(^5\)

Alternatively, think of these costs as ad-valorem tariffs. Deriving country $i$’s demand for a single variety at location $j$, and adding over all varieties from $j$ gives the

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\(^5\) Many studies appeal to the $t_{ij}$ term as a kind of catch-all for any variable that affects trade costs: distance, common borders and language, exchange rate variability, customs unions, and so on. This is not strictly appropriate unless the trade cost is of iceberg form. Fixed costs like market adaptation can result in markedly different predictions about the pattern of trade and welfare gains from it. See Romer (1994).
(landed) volume of bilateral imports

\[ M_{ij} = Y_i Y_j p_j^{-\sigma} (t_{ij})^{1-\sigma} \frac{1}{P_i}, \]  

where \( P_i \) is a CES price index over all varieties

\[ P_i = \sum_l Y_l p_l^{-\sigma} (t_{il})^{1-\sigma}. \]

Setting relative prices equal to one, and allowing \( t_{ij} = 1 \) (no trade costs), we arrive back at the frictionless model (3). Again, trade potential is given by national products and trade resistance takes the form of relative prices, inclusive of trade costs. When c.i.f. prices are high for \( j \)'s varieties relative to the index, \( i \) buys less of \( j \)'s goods.

These models make it clear that it is possible to derive the gravity equation from sensible structural models. We know the one-sector monopolistic competition model fits the data, in the sense that estimation yields highly significant coefficients and good explanatory power. The relevant question becomes: does it fit the data uniquely, and if not, do competing theories have different implications for standard empirical exercises that employ the gravity equation?

III. General Properties: Bilateral Matrices

How general is the gravity model? Empirically, the model appears to be extremely general, in the sense that data samples incorporating widely varying countries and time periods fit the model well. Hummels and Levinsohn (1995) point out that a variant of the gravity model fits well even for sets of developing countries that have virtually no intra-industry trade with each other. This has troubling implications for explanations that rely on monopolistic competition theory. In that model, the existence of differentiated goods results in both intra-industry trade and the gravity equation. One explanation may be that complete specialization characterizes production; while gravity predictions result, there will be no intra-industry trade because every industry is found in only one location.6

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6 However, the two models may provide a distinction without a difference. Both rely on complete specialization
Another explanation is provided by Deardorff (1997) who shows that the frictionless
gravity equation can be derived from a standard neoclassical trade model with homoge­
nous goods and incomplete specialization. The model relies on the bilateral indeterminacy
that results when there are multiple buyers and sellers of a commodity at the same price.
In such situations, the actual trading pattern might look like a gravity equation if exporters
sell to, and importers buy from, a world pool of a commodity. With random draws from
a world pool, the chance of a given bilateral pair matching will be a function of the size
of their draws (i.e., their economic size). If trade is generated probabilistically by way of
a large number of very small draws, the equilibrium will converge to equation (3).7

Deardorff’s model widens the set of models consistent with the gravity equation,
but because of the very strong structure, it does not widen the set much. Nevertheless,
this theory points us in an interesting direction. One can interpret Deardorff’s model as
being an exact statement of the bilateral trade of every pair. Alternatively, one can think
of it as a statement of patterns that should hold, on average, when considering all pairs.
The difference is not merely semantic. In the former case, we retain testable implications
of theory, as well as a useful norm against which to benchmark trade. In the latter case,
we may lose any ability to select models, and a bilateral norm becomes meaningless.

To make this clear, we provide several propositions about the general properties
of bilateral matrices. Consider a matrix of all world production and consumption flows,
aggregated over sectors, for all n countries in the world. Assume balanced trade so that each
country’s consumption (row total) and production (column total) are equal in each period.
Include in this matrix consumption of home goods, \( C_i \), where this value is defined as
\[ (Y_i - \sum_{j \neq i} M_{ij}) \] 8 Note that any bilateral allocation must satisfy \( 2n \) adding up constraints,

\[ \sum_{j \neq i} M_{ij} \]

7 A similar argument is provided by Savage and Deutsch (1960), and Leamer and Stern (1970). However, these
descriptions do not follow from careful models, and therefore do not make obvious the extremely strong structure
that Deardorff requires for his results.

8 Later, we generalize by excluding home goods. Also, we ignore intermediate inputs so that the sum of goods
flows equals domestic value added, not domestic gross output. This will not substantively affect any of the
one for each row and column, given by $\sum_j M_{ij} = Y_i$, $\sum_i M_{ij} = Y_j$. That is, when adding country $i$'s purchases over all sources, you must get back the total value of purchases, and similarly for country $j$'s sales.

There are many ways that consumption and production flows could be allocated in this matrix, and some models predict that each pair should be allocated according to the gravity equation. We ask, is it possible to reject (3) in favor of some more likely model?

**Proposition 1:** The simple gravity model $M_{ij} = \frac{Y_i Y_j}{Y_w}$ satisfies the adding up constraints.

Checking the constraints, we find that

$$\sum_i M_{ij} = \sum_i \frac{Y_i Y_j}{Y_w} = \frac{Y_j}{Y_w} \sum_i Y_i = Y_j,$$

and similarly for all columns. Note that there is no error term here. In the monopolistic competition and complete specialization models the production structure pins down each matrix element precisely. Similarly, with complete indifference about trading partners and a random draw allocation the law of large numbers guarantees that the bilateral pattern will converge on this equation exactly.

**Proposition 2:** The gravity model does not uniquely meet the adding up constraints.

Suppose bilateral trade is described by a more general model

$$M_{ij} = \frac{1}{Y_w} Y_i^{\beta_1} Y_j^{\beta_2} X_{ij}^{\gamma} e_{ij}$$

where $e_{ij}$ is a log-normal error term, uncorrelated with the regressors, $\beta_1 \neq 1$, and/or $\beta_2 \neq 1$, and possibly $\beta_i = \beta_j = 0$. We do not know what specific structural model would generate this allocation, but we suppose that one exists. This model is a feasible allocation if the matrix elements add up to the row and column totals, or

$$\sum_i M_{ij} = \frac{1}{Y_w} \sum_i Y_i^{\beta_1} Y_j^{\beta_2} X_{ij}^{\gamma} e_{ij} = Y_j,$$

following conclusions unless there are extremely large differences across countries in value-added to gross output ratios.
and similarly for each row and column. For the $\beta_1 = \beta_2 = 0, \gamma = 1$ case, this amounts to a restriction on the regressor matrix that $[1]X = [1]X' = Y$ where $Y$ is a vector of country sizes and $[1]$ is a vector of ones.\(^9\)

There are an infinite number of $X$ vectors that satisfy the adding up constraints for any values of $\beta_1$, $\beta_2$ and $\gamma$ chosen.\(^{10}\) In short, it is not inevitable that we will find coefficients of one, nor even that these size variables will matter in the regression. Thus, if we specify an alternative model including some variables $X$ that add up in the right way, it will be possible to generate a test with some power relative to the hypothesis that $\beta_1 = \beta_2 = 1$. Whether there exist any economically meaningful variables with this particular property is another matter.

**Proposition 3:** If the bilateral allocation is given by

$$M_{ij} = Y_i^0Y_j^0X_{ij}e_{ij} = X_{ij}e_{ij}$$

estimating a simple gravity model on this data will result in positive income coefficients.

If we estimate the true model, the income coefficients will be zero. If we instead estimate the simple gravity model given by equation (3), omitting the $X$ vector we will find positive coefficients due to omitted variables bias. This bias results in estimated coefficients for each of the income variables given by

$$\hat{\beta} = \beta + \gamma\hat{\beta}_{xy} = \frac{\text{cov}(x,y)}{\text{var}(y)}$$

where $\hat{\beta}_{xy}$ is from the auxiliary regression of $X_{ij}$ on $Y_i$. Using our assumptions that $\beta = 0$ and $\gamma = 1$, $\hat{\beta} = \frac{\text{cov}(X,Y)}{\text{var}(Y)}$. Given that $X_{ij} = M_{ij}$ by assumption, can $Y_i$ and $X_{ij}$ be uncorrelated? If so, then $Y_j$ and $M_{ij}$ must be uncorrelated. Writing out the covariance formula

$$\text{cov}(M_{ij}, Y_i) = \frac{1}{n^2} \sum_i \sum_j (M_{ij} - \bar{M}_{ij})(Y_i - \bar{Y}_i)$$

\(^9\) That is, for each row the adding up constraint is given by $x_{i1} + x_{i2} + \ldots + x_{in} = Y_i$ and similarly for the column constraints, $x_{1i} + x_{2i} + \ldots + x_{ni} = Y_i$.

\(^{10}\) It is a simple matter to verify this numerically. This relationship will work for any $X$ vector that is correlated with the $Y$ vector and is related to trade potential; e.g., capital stock.
\[
= \frac{1}{n^2} \sum_i (Y_i - \bar{Y}_i) \sum_j (M_{ij} - \bar{M}_{ij})
\]

where \( \sum_j M_{ij} = Y_i \) and \( \sum_j \bar{M}_{ij} = \bar{Y}_i \)

\[
= \frac{1}{n^2} \sum_i (Y_i - \bar{Y}_i)(Y_i - \bar{Y}_i)
\]

\[
= \frac{1}{n} \text{var}(Y_i)
\]

we find that \( \text{cov}(M_{ij}, Y_i) > 0 \) and the estimated income coefficients will be positive. Since \((Y_i Y_j)\) and \(X_{ij}\) must be correlated, the income variables will always appear to matter when estimating a simple gravity model naively, even when the coefficients in the true model are zero. We know that a model given by equation (3) satisfies the adding-up constraints, only another model with a similar distribution could also satisfy these constraints.

Proposition 4: Any bilateral allocation can be described by a "noisy" gravity equation if the other determinants of that allocation are uncorrelated with country size.

First note that a "noisy" gravity model, \[ M_{ij} \equiv \frac{Y_i Y_j U_{ij}}{Y_w}, \]

with \(U_{ij}\) uncorrelated with the regressors, satisfies the adding up constraints. That is,

\[ \sum_i M_{ij} = \sum_i \frac{Y_i Y_j}{Y_w} U_{ij} = \frac{Y_j}{Y_w} \sum_i Y_i U_{ij} = Y_j \]

if and only if \(Y_i\) and \(U_{ij}\) are uncorrelated in every row and column. This seemingly strong constraint, that the error must be uncorrelated with the included variables over the entire sample and over \(2n\) subsets of that sample, will always be met.\(^{11}\) Similarly, we can expand the error by writing \(U_{ij} = X_{ij} e_{ij}\). Here, \(U_{ij}\) can be explained by observed economic phenomenon, \(X_{ij}\), and a log-normal error term, \(e_{ij}\), both uncorrelated with

\(^{11}\) To see this, note that \(\sum_i Y_i U_{ij} = Y_w\) for every row, and consider the uncorrelated case as a baseline. If \(Y_i\) and \(U_{ij}\) are positively correlated for a single row, it will increase the left hand side of this expression. But since the right hand side is equal for all \(2n\) constraints, this can only be true if \(Y_i\) and \(U_{ij}\) are positively correlated for all rows. This contradicts the initial assumption about \(U_{ij}\).
country size. This also meets the adding up constraints.\footnote{Writing out the constraints and using the zero correlation property, this model adds up as long as $\sum_i X_{ij} = 1$. This constraint is easily met even if a particular variable (e.g., distance or tariffs) in the $X$ vector has different values for a particular row if we include row and column specific scaling.} This tells us that any variable can be incorporated into the “noisy” framework, so long as it is uncorrelated with country size.

The claim in Proposition 4 is considerably stronger than this. To demonstrate, suppose that an $X$ vector – including perhaps endowments, technology, trade barriers, and the like – explains the entire bilateral allocation but that it is uncorrelated with country size. Can this allocation, $M_{ij} = X_{ij}e_{ij}$, satisfy the adding up constraints, $\sum_i M_{ij} = Y_j$ for all rows and columns? No. The allocation meets the constraints if and only if $\sum_i X_{ij} = Y_j$ for all $i, j$. This contradicts the assumption that $X_{ij}$ is uncorrelated with country size.

Compare this “noisy” version to the simple gravity model from Proposition 1. Both models yield identical predictions for the coefficients on the country size variables but the potential for error in the “noisy” version allows for two interesting differences. The first difference is understanding the source of that error. For example, the probability model requires that all buyers and sellers be exactly indifferent about their trading partners. It is thus fundamentally incompatible with trade resistance and will not hold in the presence of transport costs or tariffs. Proposition 4 says that we need none of the strong structure in the monopolistic competition or probability models – any variable can be included in the model and still satisfy the constraints, as long as it is uncorrelated with country size.

The second difference is that the “noisy” model tells us something about the potential size of the error, or, equivalently, the amount of variation that variables other than country size can explain.\footnote{In contrast, the probability model has no noise, and should fit the data perfectly. To verify this, we generate a matrix by assigning $Y_w$ “transactions” such that each matrix element $i, j$ has probability $\frac{Y_{ij}}{Y_w}$ of drawing a particular dollar of trade. We then regress (log) bilateral trade volumes on (log) country sizes. Repeated simulations demonstrate that as the number of transactions grows large, coefficients on the size variables and the regression $R^2$ converge on one.} Divide the regressor matrix into the size variables, $\frac{Y_i}{Y_w}$ and “noise” $U_{ij}$ or equivalently, $X_{ij}e_{ij}$. What percentage of the total variation in bilateral trade volumes can each explain? Interestingly, this depends on the variance in country size.
size – as var($Y_i$) rises, the fraction of variation explained by “noise” falls. This results from the fact that bilateral import volumes are positively correlated with GNP. Increasing the variability in GNP results in an increased variability in import volumes without altering the variability of the “noise”. This implies that as the variability in $Y_i$ increases, the regression $R^2$ will increase. That is, the total sum of squares increases while the error sum of squares remains fixed; this implies that the regression sum of squares will account for a larger fraction of the total.

To demonstrate this, we simulate trade flow data in a matrix with heterogeneous country size. First, we generate elements in a matrix using draws from a uniform distribution. Each matrix element is equal in expected value, but has random variability. Every row and column total is then equal in expected value, and therefore will not initially add up to imposed country size constraints. We multiply each element in row $i$ by $\frac{Y_i}{Y_m}$ so that the row constraints are met. Since column constraints are not yet satisfied, we then search for the minimum number of reallocations necessary in order to meet all adding up constraints.\footnote{That is, the algorithm searches for elements $i, j$ where the existing row $i$, column $j$ totals exceed the constraints and moves some of the value to elements $k, l$ where the existing row $l$, column $k$ totals are short of the constraints.} Once the constraints are met, we regress (log) bilateral trade volumes on (log) country sizes in the manner of a simple gravity model. We repeat the simulation, using the same allocation algorithm and holding total matrix size constant, while varying size heterogeneity.

Since the allocation model is identical in each case, our prediction is that the size coefficients will be one in every regression, but that the fit of the regression will rise with size heterogeneity. Both predictions are strongly borne out. Every regression yields size coefficients insignificantly different from one. Figure 1 reports the $R^2$ as a function of heterogeneity, and shows that the fit rises from .02 to .88 as countries become more dissimilar. That is, the “noisy” gravity equation is revealed in the data, but it explains a range from almost none to almost all of the variation in bilateral trade. For comparison, note that regressions on actual data reported in the introduction have an $R^2 = .66$. In the
simulated data, samples with the same standard deviation of size dispersion generate an $R^2 = .675$. In short, the gravity equation explains almost precisely the same amount of variation in simulated data as in real data.

The propositions of this section demonstrate the extreme generality of the gravity equation when applied to a full bilateral matrix.\textsuperscript{15} Though the literature contains several models that generate the gravity equation, we have dramatically generalized the set of models consistent with it. Monopolistic competition, complete specialization, and probability models all require very strong structure to generate the gravity equation precisely. In contrast, proposition 4 shows that almost any model may be consistent with a "noisy" gravity equation. Thus, stories that involve perfect or imperfect competition, relative endowments or technology, and trade barriers of any sort will all generate trade patterns consistent with the gravity equation so long as these variables are not strongly correlated with country size. The ubiquity of the gravity equation stems not so much from the fact that many models are able to predict it, but rather that the structure of bilateral matrices force it to hold.

III.1 Measuring "International Trade"

With some exceptions, gravity equations are estimated on international trade data, omitting home consumption. In this section, we extend our remarks on model generality to this case, and also provide insights into correlates of trade volumes. First, recognize that any bilateral allocation of flows will be governed by the above propositions, after an appropriate re-scaling of the new row and column totals. As before, the product of the new row and column totals need not describe the true allocation model, but the allocation will necessarily be related to these variables.\textsuperscript{16}

\textsuperscript{15} It is natural to ask whether subsets of the matrix behave similarly. A small country, choosing first, could easily import more from small than from large countries without violating the aggregate adding up constraints. Despite some effort to devise tests that utilize this fact, we are not hopeful that studying portions of the matrix will yield useful information. If equilibrium trade relationships are solved simultaneously small countries cannot choose first, and will then be bound, on average, by the constraints.

\textsuperscript{16} See Propositions 2 and 3.
If we omit home consumption from the data, the resulting trade matrix has row and column totals $M_i, EX_j$, and sums over all values $M_w$. A perfectly general representation of these totals is

$$M_i = Y_i \cdot \sum_k (\gamma_i^k - \lambda^k) \quad (8)$$

The volume of imports depends on the total output of the country, and the difference between what it produces, $\gamma_i^k$ and the average of world production, $\lambda^k$, in each sector. This is only an accounting identity and does not tell us that multilateral imports and size will be related in equilibrium. Size may directly affect the allocation of production (for reasons related to market scale), or because the cross-country distribution of tastes, technology or endowments happens to be correlated with size. Trade will be a positive function of size except in special cases where

$$\sum_k (\gamma_i^k - \lambda^k) = \frac{1}{Y_i^\delta}, \quad \text{for } \delta \geq 1.$$

Propositions 4 then explain why the simple gravity model fits bilateral trade data. Any allocation whose other determinants are not strongly correlated with total imports and exports must involve these variables adding up. Similarly, Propositions 2 and 3 tell us that there may be a true model of the bilateral allocation $M_{i,j} = X_{i,j}e_{i,j}$ that does not involve total imports or exports, but that regressing bilateral trade volumes on $M_i$ and $EX_j$ will yield positive coefficients. In short, bilateral trade will be well represented by a gravity model because multilateral trade increases with size and the bilateral allocation depends on the multilateral totals.

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17 Define sectoral output shares as $\gamma_i^k$, so that output of a good $k$ in country $i$ is given by $Y_i^k = \gamma_i^k Y_i$ and $\sum_k \gamma_i^k = 1$. Without loss of generality, assume identical and homothetic preferences in each country, so that each country will consume a fraction $s_i = \frac{Y_i}{Y_{world}}$ of every consumption good, or its share in world income, $C_i^k = s_i \gamma_i^k$. An accounting identity gives the volume of imports as production less consumption, or

$$M_i^k = \gamma_i^k Y_i - s_i \gamma_i^k$$

Defining $\lambda^k$ as the share of good $k$ in world consumption, $\lambda^k = \frac{\gamma_i^k}{\sum_k \gamma_i^k}$ and summing over all imported goods, we arrive at equation INSERT HERE.

18 As an example, in a Heckscher-Ohlin world, allow a small country to expand by increasing all factor endowments equi-proportionally. Production and consumption shares remain unchanged so the elasticity of trade with respect to country size is one. If countries vary with respect to both size and factor endowments, the share of trade in output depends on both.
Next we examine the implications of our results for correlates of bilateral trade volumes. First, what does the coefficient on country size this tell us? Suppose that the trade share of output is a decreasing function of country size (larger countries are less trade-dependent) so that \( M_i = Y_i^\beta \) where \( \beta < 1 \). Here, country size is a perfect measure of total imports so, if Proposition 4 holds, we will estimate a bilateral trade coefficient \( \beta < 1 \). The coefficient interpretation seems straightforward – the trade share of income is a diminishing function of income. However, an alternative interpretation of this same coefficient is that trade shares are uncorrelated with \( Y_i \), but our estimates are subject to attenuation bias.

To see this, suppose that bilateral trade is proportional to \( M_i \) and \( EX_j \) as suggested by Proposition 4, but that we estimate this relationship using the simple gravity model. Here, \( Y_i \) and \( Y_j \) become proxy variables for total imports and exports. This errors in measurement problem results in an estimated coefficient for the proxy variable of

\[
\hat{\beta} = \frac{\beta}{1 + \sigma_u^2 / Q^*}
\]

\( \beta \) is the coefficient on the multilateral imports variable, \( (\beta = 1 \) in the random allocation model), \( Q^* \) is the variance of (log) multilateral imports, \( \sigma_u^2 \) is the variance in the (log) fraction of total output that is traded. Suppose that the variance in multilateral imports is large relative to the variance in the fraction of output that is traded. Then, our estimates for the proxy variable (country size) will closely approximate the estimates for the true variable (total trade). The more heterogeneous is the sample with respect to the fraction of output that is traded, the greater is this attenuation bias.\(^{19}\) So, even if the true elasticity of trade with respect to output is one, the estimated \( \hat{\beta} < 1 \). Worse yet, Proposition 2 and 3 tell us that the true model of bilateral allocation may not involve country size at all so that its significance in the regression is an (unpredictable) function of omitted variables bias.

\(^{19}\) This is one explanation for the Evenett and Keller (1997) result that the income coefficients fall systematically as factor dissimilarity rises.
Consider other variables that plausibly affect the trade share of output such as per capita income, or the aggregate level of protection. These variables may affect bilateral trade only to the extent that they affect the multilateral totals. That is, rich and open countries trade a lot with specific bilateral partners, but only because they trade a lot with everyone. Propositions 2-4 tell us that these variables will be significant in a bilateral regression in much the same manner that country size is. Of course, these variables may affect the bilateral allocation as well, and their estimated coefficients reflect both roles. Using a gravity regression then gives us the ability to say that bilateral trade volumes are correlated with certain variables and little else. Unless we know the true model of trade, we cannot know what estimated coefficients mean.

IV. What Can we Learn from Bilateral Trade?

The previous section makes clear why the gravity equation fits the data. Here we explore the more interesting question – what does the gravity equation, or indeed any analysis of bilateral trade, tell us about the data? We focus on three common uses of the gravity equation: testing trade theory, norming bilateral trade flows, and examining partial correlates of trade flows. In order to highlight the strengths and shortcomings of the aggregate approach, we employ a multi-sector monopolistic competition model and disaggregated trade data. We show that the basic notions of trade potential and trade resistance translate exactly to the disaggregated case, but that the aggregate analog may badly mismeasure them. More constructively, we show how techniques with disaggregated data can avoid these problems and sort out why variables matter.

In the multi-sector model there are \( k = 1 \ldots K \) sectors, each monopolistically competitive. The sub-utility function for each sector is a CES aggregator over varieties in that sector, and total utility is an aggregation over sectors.

\[
U = f(U_1, U_2, \ldots, U_K)
\]

\[
U_k = \left( \sum_i X_{kl}^\delta \right)^\frac{1}{\delta}
\]
Bilateral imports in sector $k$ depend on sectoral income and output shares. For good $k$, denote $\alpha_i^k$ as $i$'s income share, and $\gamma_j^k$ as $j$'s output share. These shares will depend in complicated ways on the form of the aggregate utility function, the distribution of technology and endowments, relative prices, and trade barriers. Rather than solving for shares endogenously in a specific model, we emphasize the manner in which cross-country variation in shares will affect estimates, and how to control for them in certain cases.\footnote{The reason for this is two-fold. One, all of the points below follow, regardless of how the shares are determined. Two, a complete solution of the model for multiple sectors can be exceptionally complicated. See Bergstrand (1989).}

The volume of imports of a single variety depends on $i$'s expenditure and relative prices, just as in the one sector model.\footnote{See appendix for details. The only difference is that in the one sector model, total expenditure on the good is simply $Y_i$.} The intuition from the one sector model also tells us that a sector expands output by increasing the number of varieties while holding the output of each existing variety fixed.\footnote{The simple relation of varieties to sectoral output is a product of strong symmetry assumptions (identical fixed costs of entry for all varieties). A more general model with varying costs of entry would imply a different relationship. However, we follow the intuition of the one sector result so that we can focus on the problems that result purely from aggregation. A failure of the variety - output relationship is a general critique that applies no matter the number of sectors.} The number of varieties at $j$ and the value of bilateral imports is then a function of $j$'s output of sector $k$. Summing over all varieties at $j$\footnote{The reason for this is two-fold. One, all of the points below follow, regardless of how the shares are determined. Two, a complete solution of the model for multiple sectors can be exceptionally complicated. See Bergstrand (1989).}

\begin{equation}
M_{ij}^k = \alpha_i^k \gamma_j^k Y_i Y_j \frac{(p_i^k)^{-\sigma} (t_{ij}^k)^{1-\sigma}}{P_i},
\end{equation}

where

\begin{equation}
P_i^k = \sum_l \gamma_l^k Y_l (p_i^l)^{-\sigma} (t_{il}^k)^{1-\sigma}.
\end{equation}

As in the one sector model, the role of trade potential and trade resistance is clear. Trade potential depends on the importer's expenditures and exporter's output of the good. Trade resistance is a function of differences in relative landed prices.
IV.1 Testing Trade Theory

For reasons demonstrated in the previous section, using aggregate data to examine the correlation between trade volumes and trade potential (country size) provides no information that can be used to select models. Harrigan (1993) applies a closely related test to sectoral data and finds strong support for complete specialization models. However, the same critique may also apply to disaggregated data. Rather than pursuing an analysis of trade volumes, we begin by examining the presence or absence of trade. The strong CES structure results in a fundamental prediction common to the aggregate and disaggregate versions of the model. Assuming finite transport costs, the one sector model predicts that all country pairs will exhibit positive trade. In the multi-sector model, all country pairs will exhibit trade in every sector where the importer consumes the good, and the exporter produces it. We begin our analysis by checking these basic predictions. This will provide direct evidence on the model while also providing information about partial correlates of trade and bilateral trade norms.

For 1992, we have data on 114 countries and 12,882 country pairs. In Table 1, we list a set of these countries, ranked by their total volume of imports. Column (1) presents the number of partners with which each importer has a zero aggregate trade volume. Summing over all countries, 42.5 percent of the pairs have no trade. Large countries import from virtually all potential exporters, while smaller countries import from a substantially smaller set of partners.

This trade is “missing” relative to the one sector model’s prediction that all pairs will have positive trade. However, if the zero observations all correspond to exporters who are small and very distant from the importers, the model predicts that their trade should be close to zero. To gauge the importance of the zeros, we estimate the one sector model with an augmented gravity equation, pooling over all country pairs in our data.\(^{23}\) Using the estimated coefficients we predict the value of trade for all country pairs, and

\(^{23}\) The included variables and coefficient estimates are presented in column (1) of Table 2.
Table 1

Evidence on Missing Trade: Values and Volumes

<table>
<thead>
<tr>
<th>Country</th>
<th>Aggregate Zeros</th>
<th>Missing Trade</th>
<th>Fraction of Zero Observations³</th>
<th>Observations³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>All Goods</td>
<td>Imported Goods</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0-4</td>
<td>5-9</td>
</tr>
<tr>
<td>USA</td>
<td>0</td>
<td>0</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>Germany</td>
<td>1</td>
<td>0</td>
<td>42</td>
<td>52</td>
</tr>
<tr>
<td>Japan</td>
<td>2</td>
<td>0</td>
<td>48</td>
<td>61</td>
</tr>
<tr>
<td>UK</td>
<td>1</td>
<td>0</td>
<td>42</td>
<td>54</td>
</tr>
<tr>
<td>France</td>
<td>2</td>
<td>0</td>
<td>44</td>
<td>55</td>
</tr>
<tr>
<td>Italy</td>
<td>2</td>
<td>0</td>
<td>45</td>
<td>57</td>
</tr>
<tr>
<td>Canada</td>
<td>11</td>
<td>1</td>
<td>53</td>
<td>69</td>
</tr>
<tr>
<td>China</td>
<td>18</td>
<td>9</td>
<td>62</td>
<td>79</td>
</tr>
<tr>
<td>Korea</td>
<td>11</td>
<td>1</td>
<td>55</td>
<td>70</td>
</tr>
<tr>
<td>Mexico</td>
<td>16</td>
<td>2</td>
<td>61</td>
<td>78</td>
</tr>
<tr>
<td>Sweden</td>
<td>8</td>
<td>1</td>
<td>52</td>
<td>67</td>
</tr>
<tr>
<td>Thailand</td>
<td>12</td>
<td>2</td>
<td>58</td>
<td>76</td>
</tr>
<tr>
<td>Australia</td>
<td>26</td>
<td>13</td>
<td>54</td>
<td>74</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>62</td>
<td>399</td>
<td>57</td>
<td>75</td>
</tr>
<tr>
<td>Brazil</td>
<td>29</td>
<td>25</td>
<td>64</td>
<td>80</td>
</tr>
<tr>
<td>Israel</td>
<td>52</td>
<td>365</td>
<td>60</td>
<td>77</td>
</tr>
<tr>
<td>Argentina</td>
<td>39</td>
<td>49</td>
<td>64</td>
<td>82</td>
</tr>
<tr>
<td>Greece</td>
<td>19</td>
<td>3</td>
<td>57</td>
<td>72</td>
</tr>
<tr>
<td>India</td>
<td>22</td>
<td>10</td>
<td>66</td>
<td>84</td>
</tr>
<tr>
<td>Venezuela</td>
<td>46</td>
<td>22</td>
<td>65</td>
<td>82</td>
</tr>
<tr>
<td>Egypt</td>
<td>35</td>
<td>20</td>
<td>67</td>
<td>85</td>
</tr>
<tr>
<td>New Zealand</td>
<td>33</td>
<td>21</td>
<td>63</td>
<td>82</td>
</tr>
<tr>
<td>Peru</td>
<td>68</td>
<td>108</td>
<td>73</td>
<td>87</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>57</td>
<td>169</td>
<td>89</td>
<td>96</td>
</tr>
<tr>
<td>Uruguay</td>
<td>59</td>
<td>55</td>
<td>76</td>
<td>91</td>
</tr>
<tr>
<td>Honduras</td>
<td>62</td>
<td>35</td>
<td>84</td>
<td>93</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>48</td>
<td>49</td>
<td>82</td>
<td>96</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>74</td>
<td>494</td>
<td>83</td>
<td>95</td>
</tr>
<tr>
<td>Sudan</td>
<td>78</td>
<td>1161</td>
<td>85</td>
<td>95</td>
</tr>
<tr>
<td>Nicaragua</td>
<td>67</td>
<td>52</td>
<td>86</td>
<td>94</td>
</tr>
<tr>
<td>Nepal</td>
<td>85</td>
<td>627</td>
<td>89</td>
<td>97</td>
</tr>
<tr>
<td>Uganda</td>
<td>79</td>
<td>1450</td>
<td>88</td>
<td>97</td>
</tr>
</tbody>
</table>

Source: Calculations by the author based on data from the NBER World Trade Flows CD.
See Feenstra et al., 1997.

1. The sample of countries is ordered by 1992 import volumes.
2. The elements of this column are calculated as: $MT = \sum_{j \in M_{ij}=0} \widehat{M}_{ij} / \sum_{j \in M_{ij}<>0} \widehat{M}_{ij}$
   Where $\widehat{M}_{ij}$ is from the regression presented in column 1 of Table 2.
3. The fraction of zero observations is calculated separately for each 4 digit SITC industry and then averaged across all industries in the relevant group:
   All industries, SITC 1-digit industries (0-4) and (5-9).
report the missing trade ratio for each importer in column (2). The ratio's numerator sums over predicted values for country pairs with zero reported trade; the denominator sums predicted trade for pairs with positive reported trade.

The first six countries in the table have essentially no missing trade, while the missing trade rises for smaller and poorer countries. Summing the predicted values of missing and non-missing trade over all importers, missing trade amounts to only about 0.3 percent of total trade. In other words, the model predicts that these observations should be close to zero and they are. We next look to sector level data to see if the model's prediction about zero trade is as strongly supported. In columns 3-5 of Table 1, we present numbers based on the following statistic:

\[
MISS_i^k = \frac{\sum_{j \in \{M_{ij}^k = 0\}} EX_j^k}{\sum_{l \in \text{World}} EX_l^k}
\]

We calculate \(MISS_i^k\) separately for each importer and four-digit SITC commodity. This number is the fraction of world exports in a four-digit SITC industry represented by exporters that a given importer does not trade with. A value of zero means that the importer purchases from every exporter in that sector - no trade is missing. A value of 50 percent means the importer does not purchase from countries representing half of world exports in that industry. The simple differentiated goods story with identical preferences predicts that we should observe a value of zero for every country and every industry.

For ease of display, we average \(MISS_i^k\) over all commodities for a given importer and report them in the column (3) of Table 1. Columns (4) and (5) break this number out for SITC categories 0-4 (commodities) and 5-9 (manufactures). There are three basic messages from this table. One, there are a very substantial number of zeros, even for large and well-developed countries. Two, the incidence of missing trade is larger for smaller and poorer countries. Three, far more trade is missing in the 0-4 commodity classification.

---

24 These are, arguably, not the countries the model is designed to explain.

25 We have also calculated averages of \(MISS_i^k\) at the one digit and two-digit SITC level; the incidence of zeros declines significantly with each level of aggregation. However, manufactures are characterized by less missing trade at each level of aggregation.
Why is so much trade missing? Consider three explanations. The simplest is that countries do not demand every variety in the way suggested by CES utility functions. Second, individuals may purchase every variety of consumption good, but a large fraction of imports are intermediate goods. To the extent that final goods production differs across countries, we expect import demands to differ as well. Third, if there are fixed costs of transport, consumers with CES preferences will buy only a subset of available varieties. 26

In columns 6-8 of Table 1, we examine the hypothesis that trade is missing because of cross-country differences in what is imported. We ask: conditional on a country importing a product from any source, does it import from every source? We re-calculate the index omitting 4-digit categories for which the country has no imports from any source. We find three interesting things. First, for most countries the amount of missing trade declines substantially. In other words, much of the missing trade we found earlier was because the country in question did not import the good at all. This is consistent with an intermediate goods trade explanation. Second, the amount of the decrease is greater for large countries – conditional on buying the good from someone, large countries tend to buy from a larger fraction of exporters. This is consistent with a story of fixed costs in transport. Third, the decrease was greater for industries 5-9 than for industries 0-4. This suggests that the "love of variety" intuition of CES utility functions describes manufactured goods to a much greater extent than commodity categories.

The clear message of Table 1 is that a large amount of trade is missing relative to a baseline model of monopolistic competition and identical preferences. This is damaging to the very strong form of the model, but the tenor of the results still accords well with its basic intuition. After allowing for differences in consumption vectors, perhaps due to intermediate goods purchases, we see less missing trade. The variety story looks better in the manufactured sectors than among commodity sectors, and better among rich countries than among poor – precisely as one might think. And, even the missing varieties can be

explained with the simple expedient of fixed costs of transport. These results suggest a rich set of issues to be explored in the cross-country, cross-commodity variation in these zero observations. We leave this to future research while noting that none of these patterns can be informatively addressed using aggregate trade data.

IV.2 Norming Bilateral Trade

With a sound theoretical justification for the gravity equation in hand, researchers have used the model as a benchmark norm of bilateral trade. Equation (3) tells us not only what trade is in the frictionless case, but what trade should be. That is, with a precise description of trade potential in hand, deviations from that norm have direct and quantifiable welfare consequences. We ask, under what circumstances is the aggregate gravity model a precise description of trade potential?

With multiple sectors, the answer to this question depends on the aggregation properties of the model. Beginning with equation 9 set all relative prices equal to 1, and let the transport cost, \( t_{ij}^k = 1 \) so that

\[
M_{ij}^k = \frac{\alpha_i^k \gamma_j^k Y_i Y_j}{Y_{ik}^k}. \tag{10}
\]

Aggregating (10) over all sectors \( k \), we have:

\[
M_{ij} = \frac{Y_i Y_j}{Y_w} \sum_k \frac{\alpha_i^k \gamma_j^k Y_w}{Y_{ik}^k}.
\]

While similar to the simple aggregate gravity equation, an accurate measure of trade potential is potentially confounded by differences in consumption and production patterns across countries. In short, a country pair may exhibit less trade than the simple aggregate model predicts because of trade barriers, or because the importer does not consume what the exporter produces.\(^{27}\) Deardorff (1995) shows in the frictionless case that

\(^{27}\) Recalling Proposition 4, if the \( \frac{\alpha_i^k \gamma_j^k Y_w}{Y_{ik}^k} \) term is uncorrelated with incomes it appears in the aggregate as noise. If the term is correlated with incomes, then the income variables will be measured with omitted variables bias.
if consumption and production shares are uncorrelated the multi-sector model aggregates properly. A sufficient condition for this is that either sectoral consumption or production shares are identical across countries. Thus, if we maintain the standard trade assumption that consumption shares are identical across countries, an aggregate gravity regression is a precise description of trade potential. Unfortunately, the analysis of “missing” trade in the previous section strongly rejects this assumption.28

Consider the implications for two prominent uses of gravity equations: McCallum (1995) and Frankel, Stein, and Wei (1995).29 McCallum estimates the effect of the US-Canadian border on trade flows between US states and Canadian provinces. He finds that there is much less trade between a US-Canada pair than between a Canada-Canada pair of similar sizes and distance. In the one sector monopolistic competition model, the only reason to prefer home varieties is that the border raises the relative cost of foreign goods, and consumers substitute away from these varieties. In this context, the surprisingly large size of the border effect has two possible interpretations: either the border is a very costly barrier to trade, or goods are sufficiently close substitutes that even a small barrier sharply reduces trade.

In a multi-sector model, another interpretation is possible. For a variety of reasons – the distribution of endowments and technology, or past barriers to trade – Canadian provinces produce sets of goods that more closely match Canadian consumption than do states in the US. If we examine disaggregated trade patterns while controlling for sectoral consumption and production shares we would find little border effect. However, if we examine aggregate trade patterns using GDP to wrongly proxy for consumption and production shares, we will find a large border effect even if the cost of moving goods across the border is negligible.

Similarly, Frankel, Stein, and Wei use sets of dummies to capture the degree to which internal versus external trade is affected by customs unions. Suppose a customs

28 It is immaterial to the following analysis if the reason for that rejection is non-identical consumption preferences, or trade in intermediate goods.

29 See also Wei (1996) who uses the gravity equation to assess the extent of “home bias” in consumption.
union takes effect, but does not change the pattern of consumption or production. Then, a tariff variable in an aggregate regression will appropriately capture the substitution effects of customs union formation. However, the customs union may also result in a re-arrangement of production that alters the correlation in the $\alpha_i^k$ and $\gamma_j^k$ terms. It will appear that tariffs have an exceptionally strong effect on trade patterns, because they combine a production reallocation and a substitution effect.

This is troubling for three reasons. First, as with McCallum, the aggregate regression may only be capturing correlations in the consumption and production shares. We can not say for certain whether this correlation is a result of the trade agreement, or if it existed prior to the formation of the bloc.\(^{30}\) Second, if the trading bloc does cause a re-allocation of production, the welfare implications are much different than if only a substitution effect occurs.\(^{31}\) Third, a reduction in trade costs need not have the same effect on the production reallocation and substitution margins, resulting in deeply puzzling conclusions about trade patterns.\(^{32}\)

IV.3 Understanding partial correlates of trade

The basic model in Section 2 provides an attractive structure onto which one can append explanations for trade to suit one's taste. Many studies appeal to the $t_{ij}$ term as a kind of catch-all for any variable that affects trade costs: distance, common borders and language, exchange rate variability, customs unions, and so on. Or, more rigorously, one can include factor endowments, per capita income, and population to help determine trade potential in a multi-sector context, and then aggregate up for estimation.\(^{33}\) The exercise

\(^{30}\) This problem can be addressed by estimating that aggregate equation with panel data, as in Bayoumi and Eichengreen, 1995.

\(^{31}\) Our analysis of “missing” trade also indicates the possibility of a third margin with its own unique welfare implications. With fixed costs of transport, trade blocs may affect the number of varieties actually imported.

\(^{32}\) In other work we present evidence that precisely this sort of two-margin problem exists. Direct evidence from freight data indicates that the marginal costs of distance are falling over time, yet estimates of gravity regressions on aggregate data show that distance is becoming more important and not less. The reason is that the production and consumption vectors of neighboring countries are becoming more highly correlated over time. After controlling for sectoral variation in production and consumption, trade regressions reflect the facts on freight: distance matters less over time

\(^{33}\) See Bergstrand (1985, 1989).
here is usually not intended to be a rigorous structural test of a generalized monopolistic competition model, but rather, to provide a framework for partial correlation analysis that is consistent with known properties of gravity models.\textsuperscript{34}

Of course, such studies are subject to precisely the same criticism just levied: aggregate estimates of trade barrier effects will be mismeasured if these barriers are correlated with production and consumption shares. Worse yet, there are several margins on which barriers may operate, and aggregate data cannot be informative on this point. In this section, we use disaggregated trade data to explore two margins – does a country pair trade in a sector, and conditional on positive trade, what is the volume of that trade?

Studying the volume of trade without worrying about the selection of trading partners can create selection bias in our estimates. If the trade/don't trade margin is influenced by the variables that influence the volume of trade, failure to account for selection will bias our estimates. Table 2 provides insights into this bias. Column (1) is an augmented aggregate gravity regression, provided for reference. In the remaining columns, the independent variables remain the same, but the dependent variable is now bilateral imports measured at the 4 digit SITC level.\textsuperscript{35} Column (2) reports results from a standard OLS regression that ignores selection. Per capita incomes are insignificant, but the signs on the other variables match the aggregate data. Note that the estimated coefficients on the income variables are substantially less than one. This is because using GDP badly proxies for consumption and output shares.\textsuperscript{36}

We know that there are a large number of zero observations in the sectoral bilateral trade data. Column (3) estimates a probit where the dependent variable takes on a value of 1 if there is trade between a pair in that sector, and 0 otherwise. Again, all variables are significant and of the same sign as the aggregate regression indicating that these variables all affect the selection margin. To deal with the bias that selection creates we re-estimate

\textsuperscript{34} We thank Jeff Bergstrand for pointing this out to us.
\textsuperscript{35} As there are over 700,000 potential observations, we limit our analysis to a random subset of observations.
\textsuperscript{36} The next specification corrects this by using country by industry dummy variables to control for these shares. We do not use these initially because we want to show how the income variables operate on several margins.
Table 2
Regression Results
(Standard errors in parentheses.)

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>OLS (1)</th>
<th>OLS (2)</th>
<th>Probit (3)</th>
<th>Heckit (4)</th>
<th>Beta Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agg. OLS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importer Income</td>
<td>0.836 (0.013)</td>
<td>0.374 (0.008)</td>
<td>0.027 (0.000)</td>
<td>0.732 (0.019)</td>
<td>0.353 (0.172)</td>
</tr>
<tr>
<td>Exporter Income</td>
<td>1.025 (0.013)</td>
<td>0.408 (0.009)</td>
<td>0.048 (0.000)</td>
<td>1.053 (0.031)</td>
<td>0.299 (0.287)</td>
</tr>
<tr>
<td>GDP/Pop - Imp</td>
<td>0.098 (0.017)</td>
<td>-0.011 (0.012)</td>
<td>-0.006 (0.001)</td>
<td>-0.079 (0.016)</td>
<td>-0.008 (0.028)</td>
</tr>
<tr>
<td>GDP/Pop - Exp</td>
<td>0.082 (0.017)</td>
<td>-0.013 (0.012)</td>
<td>-0.007 (0.001)</td>
<td>-0.106 (0.017)</td>
<td>-0.007 (0.031)</td>
</tr>
<tr>
<td>Distance</td>
<td>-1.174 (0.036)</td>
<td>-0.585 (0.018)</td>
<td>-0.062 (0.001)</td>
<td>-1.341 (0.039)</td>
<td>-0.232 (0.121)</td>
</tr>
<tr>
<td>Common Lang.</td>
<td>0.899 (0.071)</td>
<td>0.189 (0.040)</td>
<td>0.066 (0.002)</td>
<td>1.069 (0.064)</td>
<td>0.028 (0.056)</td>
</tr>
<tr>
<td>Common Border</td>
<td>0.437 (0.163)</td>
<td>0.462 (0.061)</td>
<td>0.027 (0.004)</td>
<td>0.425 (0.073)</td>
<td>0.051 (0.011)</td>
</tr>
</tbody>
</table>

R² (Psuedo) 0.671 0.246 0.539 0.261
# of observations 7402 24,301 153,950 24,301

The data used in the regressions are from the NBER World Trade CD and the World Bank CD and Jon Haveman's public international trade resources: http://intrepid.mgmt.purdue.edu/Trade.html.

1 The dependent variable in each regression is related to the bilateral trade of a particular commodity.

The Probit: Y = 1 if there is positive trade. OLS & Heckit: Y = the bilateral value of imports into i from j, \( M_{ij}^k \).

The effect of bilateral trade volumes, while using the Heckman (1979) correction. In column (4), we find that the OLS coefficients are heavily biased by the partner selection mechanism. In fact, when this bias is accounted for, the coefficients return to levels that are startlingly close to those reported on the second page of this paper and in the first column of Table 2.

Clearly both margins matter. To better understand how much they matter, we
present beta coefficients for each regressor in each of the three regressions. A beta coefficient is a measure of the impact of a one standard deviation change in the explanatory variable on the dependent variable.\footnote{This is calculated for the probit by first expressing the coefficients in terms of their marginal impacts on the probability of positive bilateral trade.} Comparing the Beta coefficients between the probit and second stage Heckit regression, we learn that the influence on trade volume is roughly three times larger than on the trade/don't trade decision. Interestingly, there is considerable variation across variables in the importance of the correction. In the case of the income variables, the OLS regressions indicate a more significant influence of importer income while the Heckit suggests that exporter income plays a larger role. More dramatic is the reversal for the border and language variables. Note that while the coefficients on the income and distance variables are similar to those found in the aggregate regression, column 1, the relative magnitudes of the border and language coefficients are reversed in columns 2 and 4. Finally, the Beta coefficients from the OLS regression are comparable in size to the probit Betas; they are thus a dramatic understatement of their true influence on trade volume.

V. Beyond the Gravity Equation

The message for aggregate data is grim. Simple one-sector models provide an elegant rationale for the use of aggregate bilateral trade regressions in testing theory, norming trade flows, and examining the partial correlates of trade volume. Unfortunately, the set of models that generate the gravity prediction should be regarded as exceptionally broad. If large countries trade more than small countries, the gravity model will generally fit the data. Hope for matching theory to data then lies with a disaggregated approach - our sectoral data shows patterns consistent with the rough intuition of monopolistic competition models.

Any exercise in norming trade flows must necessarily rely on a theoretically sound notion of normal trade. Our evidence suggests that such norming on aggregate data is not
sensible. First, the data do not point to any one theory as a likely source of bilateral trade patterns. Even if aggregate bilateral patterns look exactly like the simple gravity equation, deviations from the baseline mean different things in different models. Second, cross-country differences in consumption and production vectors mimic trade barriers relative to an aggregate baseline. Third, included variables operate on trade volumes through several margins, each of which has different welfare implications. This point is also relevant if we employ aggregate gravity equations to do little more than sort out partial correlates of trade. We cannot tell from the aggregate data which margin is relevant, and it may be possible that certain variables work in opposite directions on different margins. Again, sectoral data provides promise on each point.

Gravity models have played a vital role in sorting out crude patterns in trade data, uncovering, among other things, surprisingly large effects from borders and distance. However, in order to truly understand the crucial questions laid out in the introduction, it is time to go beyond the gravity equation to develop more careful, and ultimately more useful, disaggregated techniques.
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This section borrows heavily from Krugman (1980) and Anderson (1979). Utility is given by
\[ U_i = \left( \sum_j X_j^\theta \right)^{\frac{1}{\theta}} \]
where \( \frac{\theta = \sigma - 1}{\sigma} \) and \( \sigma \) is the elasticity of substitution between varieties. Demand for a single variety at location \( j \)
\[ m_{ij} = Y_i \frac{(t_{ij} p_j)^{1-\sigma}}{P_{i}^{1-\sigma}} \]
where the \( P_i \) is an index of prices at country \( i \) given by
\[ P_i = \left( \sum_j (t_{ij} p_j)^{1-\sigma} \right)^{\frac{1}{1-\sigma}}. \]

On the production side, there are four major equations, expressing the production technology, the price of the good as a markup over marginal cost, the quantity of each variety, and the number of varieties.

\[ L_j = a + bX_j \quad \text{(production technology)} \quad (A.1) \]
\[ P_j = \theta^{-1}(bW_j) \quad \text{(markup over marginal cost)} \quad (A.2) \]
\[ X_j = \frac{a \theta}{b(1-\theta)} \quad \text{(quantity of each variety)} \quad (A.3) \]
\[ n_j = \frac{L_j}{a(1-\theta)} \quad \text{(number of varieties)} \quad (A.4) \]

To arrive at the total volume of imports between two countries, note that all varieties in a country will have the same price and face the same vector of bilateral trade costs. This gives us the import demand over all varieties \( n_j \) as
\[ M_{ij} = Y_i n_j \frac{(t_{ij} p_j)^{1-\sigma}}{P_{i}^{1-\sigma}} \quad \text{(demand all varieties)} \quad (A.5) \]
where

\[ P_i^* = (\sum_j n_j (t_{ij} p_j)^{1-\sigma})^{\frac{1}{1-\sigma}}. \]  

(new price index) (A.6)

We can substitute in for the prices and for the number of varieties in each location \( j \) to give

\[ M_{ij} = Y_i \cdot \frac{L_j}{a} (1 - \theta) \frac{[\theta^{-1}(bW_j)]^{1-\sigma}(t_{ij})^{1-\sigma}}{P_i^*}^{1-\sigma} \]

rearrange and note that \( Y_j = W_j L_j \) and we get

\[ M_{ij} = k Y_i Y_j \frac{W_j^{-\sigma}(t_{ij})^{1-\sigma}}{P_i^*}^{1-\sigma} \]

where \( k \) is a constant full of technology and substitution parameters. Alternatively, we could rewrite the price index, and substitute for prices to get equation (5)

\[ M_{ij} = Y_i Y_j \frac{p_j^{-\sigma}(t_{ij})^{1-\sigma}}{\sum_l Y_l p_l^{-\sigma}(t_{il})^{1-\sigma}}. \]
APPENDIX E

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