Volume Title: The Regionalization of the World Economy

Volume Author/Editor: Jeffrey A. Frankel, editor

Volume Publisher: University of Chicago Press

Volume ISBN: 0-226-25995-1

Volume URL: http://www.nber.org/books/fran98-1

Publication Date: January 1998

Chapter Title: Determinants of Bilateral Trade: Does Gravity Work in a Neoclassic World?

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Chapter URL: http://www.nber.org/chapters/c7818

Chapter pages in book: (p. 7 - 32)

## Comment Jeffrey H. Bergstrand

For over thirty years, international trade economists have evaluated empirically the economic determinants of bilateral international trade flows using the "gravity equation." As Alan Deardorff notes, Jan Tinbergen (1962) provided one of the first sets of estimates of a gravity equation applied to international trade flows. He estimated a version very similar to this paper's equation (1), but allowing the right-hand-side variables' coefficients to vary from unity. Over the years, numerous trade economists have used gravity equations to explain statistically international trade flows with various ulterior economic motives, including but not nearly limited to the papers referenced in Deardorff's study.

### Theoretical Foundations

Those thirty years have also witnessed a frustrating fascination of trade economists with the gravity equation. The fascination stems from the consistently strong empirical explanatory power of the model, with $R^2$ values ranging from 65 to 95 percent depending upon the sample, which has been a persuasive motivation for its usage. For many years, the frustration has stemmed from a so-called absence of formal theoretical foundations. Yet as Deardorff notes in section 1.2, there are several formal theoretical foundations for the gravity equation in international trade. Anderson (1979), Helpman and Krugman (1985), and Bergstrand (1985, 1989, 1990) motivate the multiplicative gravity equation assuming either products differentiated (somewhat arbitrarily) by origin or monopolistically competitive markets with (well-defined) product differentiation. Baldwin (1994, 82) aptly summarizes the state of theoretical foundations for the gravity model: "The gravity model used to have a poor reputation among reputable economists. Starting with Wang and Winters (1991), it has come back into fashion. One problem that lowered its respectability was its oft-asserted lack of theoretical foundations. In contrast to popular belief, it does have such foundations."

Despite these theoretical foundations, part of the frustration of trade economists with the gravity equation has been a lack of willingness to motivate the gravity equation in the context of *classical* theories, especially the Heckscher-Ohlin framework.[1] Deardorff's paper addresses this concern carefully and adeptly.

### Frictionless Models

Before focusing upon classical issues though, Deardorff first challenges the reader to think of international trade unconventionally. Whereas classical mod-

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1. As Deardorff notes, an exception is Bergstrand (1989), which imbeds monopolistically competitive product-differentiated markets in a two-sector economy with differing relative factor intensities between the two industries.

els typically consider export supplies as residual production after satisfaction of domestic demands, and conversely import demands as residual consumption beyond domestic production, Deardorff's first set of models—frictionless models—asks the reader to think of consumers and producers as being basically indifferent between domestic and foreign consumption and production, respectively. The essence of Deardorff's frictionless models can be reflected in the following simple framework. Suppose a country produced and consumed one homogeneous good under conditions of perfect competition. If the country's production and consumption were split into two equal economic "nations" (A and B), the representative consumer in A would be just as likely to consume A's output as B's output, and the representative producer in A would be just as likely to sell its output in the domestic market as in the foreign market.

The thrust of Deardorff's first frictionless model can be captured in three assumptions. (1) In each country, income ($Y_i$) equals production ($PX_i$) and consumption ($PC_i$), implying

(1) $$Y_i \equiv PX_i \equiv PC_i \equiv \sum_j^N PX_{ij}$$

and

(2) $$Y_j \equiv PX_j \equiv PC_j \equiv \sum_i^N PX_{ij},$$

where $PX_{ij}$ is the flow of trade from $i$ to $j$ for all $i, j = 1, \ldots, N$ (including $i$ to itself). (2) Tastes are identical across countries and homothetic, implying

(3) $$PX_{ij} = \gamma_i Y_j.$$

(3) The probability of country $i$ exporting to country $j$ is determined by the law of large numbers, implying

(4) $$\gamma_i = X_i / \sum_j^N X_j = Y_i / \sum_j^N Y_j = Y_i / Y^W,$$

where $Y^W$ is world GDP ($\sum_j^N Y_j$) and is constant across country pairs. Substituting equation (4) into equation (3) yields a simple frictionless gravity equation:

(5) $$PX_{ij} = Y_i Y_j / Y^W.$$

This suggests that the gravity model can be derived under few assumptions and international trade can be generated without natural or acquired comparative advantages. Although one might consider little trade likely to be generated in this simple context, it is useful to see that the usual sources of international trade between nations—relative factor endowment differences or product diversity combined with increasing returns—are unnecessary for, but can be incorporated easily into, this simple trade framework.

Deardorff's model of frictionless trade under homothetic preferences in section 1.3 is not depicted quite so simply, because his ultimate motive in the section is rather to demonstrate that a slightly modified version of gravity equation (5) above is readily consistent with a Heckscher-Ohlin-type world, although one allowing nonhomothetic tastes. In the latter, consider a world with $N$ countries where each country's share of production of commodity $k$ can differ from the world's share (i.e., $p_k x_{ik}/Y_i = \alpha_{ik} \gtreqless \lambda_k = p_k x_k^W/Y^W$) and each country's relative demand for commodity $k$ can differ from the world's relative demand (i.e., $p_k c_{jk}/Y_j = \beta_{jk} \gtreqless \beta_k = p_k c_k^W/Y^W$). Deardorff demonstrates that if the $\alpha_{ik}$ and $\beta_{jk}$ are positively (negatively) correlated, then trade between countries $i$ and $j$ will exceed (fall short of) the simple frictionless gravity equation (5). The suggestion is that high real per capita income countries have high capital-labor ratios and tend to produce relatively capital-intensive goods. With nonhomothetic tastes, if capital-intensive goods are luxuries in consumption, high real per capita income countries will tend to trade more because of their tendency to produce and consume larger proportions of capital-intensive goods.

The main contributions of section 1.3 are to illustrate that the gravity model stands on its own, but also that Heckscher-Ohlin trade with nonhomothetic preferences can be generated within the context of and consistent with the gravity model. That the gravity model can evolve from an essentially Heckscher-Ohlin world (without any role for monopolistically competitive markets as in Bergstrand 1989) is a useful insight. Footnote 3 underscores the relevance of Deardorff's insight showing that—even in the absence of imperfectly competitive markets and increasing returns to scale—equal-sized countries in the Helpman and Krugman (1985) model (for instance, pp. 22–24) will tend to trade more *for given relative factor endowments.*

### Models with Transportation Costs

What makes section 1.3's model interesting and novel is that the gravity model is derived in the *absence* of product differentiation, as in Leamer and Stern (1970). Section 1.4 considers trade in the *presence* of products differentiated by origin. While the first several pages attempt to motivate a rationale for why products are differentiated by origin from a non-factor-price-equalization context, the results in this section parallel earlier contributions to this literature more closely. The main result of section 1.4 is that the bilateral distance between $i$ and $j$ diminishes trade *and* that trade is influenced by the relative distance of importer $j$ from exporter $i$ (relative to other markets of $i$) relative to the average of all demanders' relative distances from $i$.

These notions have been present in one form or another in the earlier literature, similarly utilizing functions of constant elasticity of substitution; compare Anderson (1979) and Bergstrand (1985, 1989). For instance, Anderson showed that the trade flow was related to the bilateral $i$–$j$ distance *and* to a complex "bracketed" term (as in this paper). In Anderson, the bracketed term was the ratio of a weighted average of importer $j$'s distance from all markets to a weighted average of all countries' weighted average distances.

Bergstrand (1989) also used "iceberg" form transport costs as here. His gravity equation (12) can be rewritten to reflect the bilateral distance and the relative distance terms. Normalizing prices to unity and some algebraic manipulation yields trade flows as a function of (among other variables) the bilateral distance term (ignoring the industry superscript $A$ in the original paper), $C_{ij}^{-(\sigma-1)/(\gamma+\sigma)}$, *and* the bilateral distance between $i$ and $j$ relative to the average distance of exporter $i$ to all markets, $\{C_{ij}[\sum_n^N(1/C_{in})^{1+\gamma}]^{1/(1+\gamma)}\}^{-\gamma(\sigma-1)/(\gamma+\sigma)}$.

Deardorff's formulation is different because the relative distance term in his equation (21) isolates the distance of $j$ from $i$ relative to the average distance importer $j$ faces for all suppliers from the average distance of $i$ to all markets relative to all exporting countries. However, equation (21) is equivalent to equation (18), which specifies (after normalizing prices to unity) that the bracketed term reflect the distance between $i$ and $j$ relative to a weighted average of distances of exporter $i$ to all markets, similar to Bergstrand (1989).

Nevertheless, an interesting common implication of all three studies is that the typical gravity equation specification with just the bilateral distance between $i$ and $j$ omits a potentially important explanatory variable, that is, the transport costs between $i$ and $j$ *relative* to some measure of "overall" transport costs.

It is interesting to note that the paper here, like Anderson's, normalizes all prices to unity to examine the importance of relative distances. However, suppose one considers the "frictionless" case where distances are normalized to unity but prices are not. In Deardorff's paper, equation (18) simplifies to

$$T_{ij}^{f} = \{Y_i Y_j / Y^W\}\ [(p_i/p_j^I)^{1-\sigma} / \sum_h \theta_h (p_i/p_h^I)^{1-\sigma}]. \tag{6}$$

Similarly, in the absence of the normalization of prices, Anderson's gravity equations would have included measures of relative prices. The importance of relative prices for suggesting the presence of product differentiation was emphasized in Bergstrand (1985). Bergstrand's model, under stronger assumptions, can be shown essentially equivalent to equation (6) above. Assuming the elasticities of substitution between imported and domestic products and that among imported goods are identical and the elasticities of substitution in production among export markets and between export and domestic are infinite (i.e., producers are indifferent between domestic and foreign markets and among foreign markets), the bilateral import demand function in Bergstrand can be written as

$$X_{ij}^{D} = a_i(Y_j/P_{ij})(P_{ij}/P_j^I)^{1-\sigma} \tag{7}$$

or

$$PX_{ij}^{D} = a_i Y_j (P_{ij}/P_j^I)^{1-\sigma} \tag{8}$$

The income constraint ensures

(9) $$Y_j = \sum_j^N PX_{ij}^S.$$

In general equilibrium, $PX_{ij}^S = PX_{ij}^D$, so equation (8) can be substituted into (9) to yield

(10) $$Y_i = \sum_j^N a_i Y_j (P_{ij}/P_j^I)^{1-\sigma}$$

or

(11) $$a_i = Y_i / \sum_j^N Y_j (P_{ij}/P_j^I)^{1-\sigma}$$

Substituting equation (11) into (8) yields

(12) $$PX_{ij} = Y_i Y_j [(P_{ij}/P_j^I)^{1-\sigma} / \sum_j^N Y_j (P_{ij}/P_j^I)^{1-\sigma}].$$

Equation (12) is similar to equation (6) above (and equation [18] in Deardorff) and suggests that relative prices, relative distances, relative tariffs, and so forth all matter in explaining departures of international trade flows from the basic gravity equation. Gravity equation practitioners have tended to ignore the importance of relative prices. Yet work by Kravis and Lipsey (1988) and Summers and Heston (1991) suggest that in cross-section prices differ considerably. In chapter 6 in this volume, by Charles Engel and John Rodgers, this view is lent further support. To the extent that measures of product differentiation, or distance of countries' products from their "ideal" variety (in the Hotelling-Lancaster sense), can be measured cross-sectionally, these factors need to be incorporated along with other asymmetries such as relative distance and relative tariffs in explaining departures from the basic frictionless gravity model. For completeness, in the case that goods are perfect substitutes ($\sigma = 1$), equation (12) simplifies to $PX_{ij} = Y_i Y_j / Y^W$, as in Deardorff's paper.

## Conclusions

First, I agree with the paper's conclusion that simple forms of the gravity equation can be derived from standard trade theories. In fact, the author's first simple multiplicative frictionless gravity model can be derived *apart from* standard classical and the "new" trade theories. Second, I would agree more readily with the statement that the gravity equation appears to *be consistent with* a large class of models, rather than the gravity equation appears to "characterize" a large class of models. Third, the paper's conclusion that "its use for empirical tests of any of them is suspect" is correct; however, this statement is also misleading. Practitioners of the gravity equation over three decades have not—with the notable exception of Helpman (1987) and Hummels and Levinsohn (1995)—typically used the gravity equation to "test" trade theories. In most cases, the basic gravity model has been employed to capture statistically the bulk of trade variation to discern the marginal explanatory power of free trade pacts and/or exchange rate variability—additional variables appended to the basic frictionless model, without an aim to test one theory or another. Moreover, these contributions seem compatible with, and do not preclude, enhancements of the simple frictionless model to incorporate correlations between exporter relative factor endowments with importer relative goods demands, or the inclusion of distance and relative distance, as provided in this paper. Clearly, more work appears warranted on discerning further the gravity equation's empirical role in the context of international trade and trade theory, in step with the excellent enhancements and clarifications initiated in this paper.

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