In Defense of the Gravity Model with Pooled Cross-Section and Time-Series Observations: A Reply to Jozef M. van Brabant

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IN DEFENSE OF THE GRAVITY MODEL WITH POOLED CROSS-SECTION AND TIME-SERIES OBSERVATIONS: A REPLY TO JOZEF M. VAN BRABANT

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The objectives of my original article (8) might be divided into those concerning the proper approach for determining the first year in which integration effects occurred within CMEA, measuring these customs union effects and presenting substantive results based on the gravity model. Jozef M. van Brabant, in his comment (2), concludes that I have "chosen to bypass economic theory and reliable historical material—to focus mainly on empiricism"—resulting in "a very ambiguous product" (2: p. 92). Van Brabant's criticism of my article, if it were correct, would impugn both the methodology used and the interpretation of my empirical results. Van Brabant, however, is not correct. His comments, in general, are based upon a fundamental misunderstanding of the trade flow model and the econometric methodology used in the article. Van Brabant's only substantive comments raise the following questions:

1. Why pool cross-section and time-series observations?

2. Why pool trade flow observations from CMEA and non-CMEA member countries?

3. Is the equation fully specified?

The intent of this reply is, therefore, to focus on these three questions in the hope that our clarification will correct those aspects with which van Brabant has difficulty.
Van Brabant's explanation of the gravity model as well as his comments concerning pooling of cross-section and time-series observations are clearly incorrect. The gravity equation as specified in our original paper (8: p. 40) is a general equilibrium reduced form equation:

\[
\log X_{ij} = g_0 + g_1 \log Y_j + g_2 \log Y_i \\
+ g_3 \log N_j + g_4 \log N_i \\
+ g_5 \log D_{ij} + g_6 \log P_{ij} \\
+ \log e_{ij}
\]

Where \(X_{ij}\) is the dollar trade flow from country \(i\) to country \(j\), \(Y_i\) and \(Y_j\) are GNP's in \(i\) and \(j\), \(N_i\) and \(N_j\) are population in \(i\) and \(j\), and \(D_{ij}\) is the distance between commercial centers of \(i\) and \(j\) and \(P_{ij}\) is a dummy variable reflecting membership in CMEA, such that the preference relationship works bilaterally; \(X_{ij} = f(P_{ij}, P_{ji})\). Log \(e_{ij}\) is a log normally distributed error term with \(E(\log e_{ij}) = 0\). Furthermore, because of the reduced form nature of the equation, the inclusion of any policy instruments, as suggested by van Brabant (2: p. 82) has no theoretical justification. \(P_{ij}\) in equation (1) is neither a policy instrument as van Brabant erroneously assumes nor are its estimated coefficients interpreted to imply the existence of integration.

To measure the effects of the CMEA on the trade flows of its member countries would require the use of a gravity trade flow model which does not directly incorporate prices for the specific reasons outlined by van Brabant (2: p. 85). However, van Brabant is wrong stating that "It is inadmissible to pool time-series and cross-section data" (2: p. 84). The exclusion of the price variable in this general equilibrium setting implies that the market clearing quantity \(X_{ij}\) depends on demand and supply factors but not on the price variable. Linnemann (6), therefore used data averaged over a three year period to reflect this general equilibrium nature of the model. However Junz and Rhomberg (4: p. 452) have found that data over a longer time period should be used to eliminate the influence of short run
price changes. Leamer (5, p. 370-371) also suggests the use of cross-section and time-series data because trade patterns may not be fully adjusted to current explanatory variables found in a cross-section equation. Furthermore, the cross section equation above is static, thus paying no attention to the development of trade over time (12: p. 263). Therefore, because we are interested in capturing structural shifts which might develop as a result of integration, the pooling technique is appropriate. Moreover, because we are unaware, a priori, of the first year of integration, pooling associated with the Quandt test (8: p. 43) is a superior procedure than the use of dummy variables as suggested by van Brabant (2: p. 82). Van Brabant's estimated coefficients for Intra-CMEA trade (2: Table 1) are made with the assumption of instant adjustment, which, as noted above, is clearly unjustifiable.

Although van Brabant intends to present the "theoretical considerations underlying... the trade flow model" (2: p. 79) his discussion of the model along with his estimates (2: Table 1) confuse the reader by ignoring a major problem associated with the gravity equation. The gravity equation as specified both here and by van Brabant has a simultaneous equation bias. This bias is due to the fact that some of the explanatory variables appearing in the equation are not truly exogenous but are jointly determined with the dependent variable. In equation 1 income may not be exogenous since we may have a two way causation

\[ X_{ij} = f(Y) \text{ and } Y = f(X_{ij}) \]

Applying ordinary least squares on the gravity equation will therefore result in a bias of unknown sign. Consequently, van Brabant's estimates of the gravity equation are biased resulting in an incorrect conclusion (2, p. 86).

In order to minimize this bias, we pooled cross-section and time series data as follows:

\[
\log X_{12} = g_0 + g_1 \log Y_1 + g_2 \log Y_2 + g_3 \log N_1 + g_4 \log N_2 + g_5 \log D_{12} + g_6 \log P_{12} + \log e_{12} \\
\log X_{13} = g_0 + g_1 \log Y_1 + g_2 \log Y_3 + g_3 \log N_1 + g_4 \log N_3 + g_5 \log D_{13} + g_6 \log P_{13} + \log e_{13} \\
\vdots \\
\vdots \\
\vdots 
\]

...
\[
\log X_{ij}^t = \log g_0 + g_1 \log Y_i^t + g_2 \log Y_j^t + g_3 \log N_i^t + g_4 \log N_j^t + g_5 \log D_{ij}^t + g_6 \log P_{ij}^t + \log e_{ij}^t
\]

\[\vdots\]

\[
\log X_{ij}^t = \log g_0 + g_1 \log Y_i^t + g_2 \log Y_j^t + g_3 \log N_i^t + g_4 \log N_j^t + g_5 \log D_{ij}^t + g_6 \log P_{ij}^t + \log e_{ij}^T
\]

\[
\vdots\]

\[
\log X_{ij}^t = \log g_0 + g_1 \log Y_i^t + g_2 \log Y_j^t + g_3 \log N_i^t + g_4 \log N_j^t + g_5 \log D_{ij}^t + g_6 \log P_{ij}^t + \log e_{ij}^T
\]

where

\(X_{ij}^t\) = trade flow from country \(i\) to \(j\) in period \(t\).

\(Y_i^t\) & \(Y_j^t\) = GNP for \(i\) and \(j\) in period \(t\).

\(N_i^t\) & \(N_j^t\) = population for \(i\) and \(j\) in period \(t\).

\(D_{ij}^t\) = distance between \(i\) and \(j\).

\(P_{ij}^t\) = dummy variable for membership in the CMEA group.

\(e_{ij}^t\) = disturbance term at time \(t\) of the \(ij\) trade flow.

\(i \neq j; \ t = 1, \ldots, T; \ i = 1, \ldots, I; \ j = 1, \ldots, J.\)

This does not imply that pooling cross-section and time-series data is free from all problems. As I noted in the original article (8: p. 44) the added difficulty arising from this technique is that the disturbance term is likely to consist of time series related disturbances, cross-section disturbances, and a combination of both. Thus, in order to deal with disaggregated trade flows and to take into account the existence of these disturbances, we choose an estimating procedure developed by Zellner (14). A variation of Generalized Least Squares\(^5\), Zellner estimation achieves an improvement in efficiency by taking into account the fact that cross-section error correlations may not be zero.\(^4\) Consequently, the procedure used in the original article, takes into account the major weaknesses of the gravity equation, resulting in estimates with minimum bias.
Van Brabant's second observation concerning the pooling of CMEA and non-CMEA country trade flows further demonstrates his misunderstanding. While it is true that a major weakness in the gravity model is its assumption that the countries in the sample are relatively homogeneous units (10: p. 81), this assumption is partly relaxed in our article. The structural differences between CMEA and non-CMEA member countries which may depend to a large extent upon differences in production patterns is accounted for by splitting the total group of observations into two groups by the use of the dummy variable $P_{ij}$. Van Brabant's suggested procedure of considering cross-section equations for the CMEA group as a specific unit would presuppose that the exchange of goods and services between these countries takes place in a vacuum, independent of both other external trade and the international markets that the CMEA countries can draw upon. Accepting van Brabant's suggestion would, in effect, make the question of CMEA integration effects mute.

While the CMEA cannot be considered a classic Vinerian customs union, some of its traditional effects on income and production can be attributed to it. The expansion of the CMEA market resulting from the creation of CMEA may help to produce a reduction in production costs through an increase in specialization. Long run specialization agreements, by making the CMEA economies more complementary, may further reduce the dangers of trade diversion. Evaluating CMEA trade flows in a vacuum, as suggested by van Brabant (2: p. 86), would invalidate any analysis of trade creation, trade diversion (9) or gross trade creation as carried out in the original paper.

Furthermore, accepting van Brabant's suggestions would preclude any objective basis for determining the first year in which integration effects occurred. The procedure used in the paper not only identifies the shift in structure but also allows one to create a confidence interval around the switching point. Van Brabant's reference to this procedure (2: p. 88) is again incorrect.6

The actual procedure to test for the location of this unknown breaking point $t$ involves the use of Quandt's (8) maximum likelihood technique. That is, to find the best estimate of this break $t^*$ we choose the value of $t$ for which $L(t)$ reaches the highest maximum.
\[ L(t) = -T \log \sqrt{2\pi} - t^* \log \hat{\sigma}_1 - (T-t^*) \] (3)

This equation is the logarithm of the maximum likelihood equation for a given value of \( T \), and is a function of \( t \) alone. \( \hat{\sigma}_1 \) and \( \hat{\sigma}_2 \) are the standard errors of the estimates of the left hand and right hand regressions respectively.

Once we determine the best estimate of \( t^* \) we proceed to test the hypothesis that no switch occurred during the period in question. Our alternative hypothesis is that one switch occurred specifically at \( t^* \) given by the maximum maximorum of \( L(t) \). For this purpose we use a likelihood ratio test derived by Quandt (11: pp. 875-876). The likelihood ratio \( \lambda \) is defined as:

\[
\lambda = \frac{\hat{\sigma}_1 \hat{\sigma}_2}{\hat{\sigma}^2}
\]

where \( \hat{\sigma} \) is the standard error of the estimate for a regression taking into account all observations, \( \hat{\sigma}_1 \) and \( \hat{\sigma}_2 \) are the standard errors of the estimates of the left hand and right hand regressions respectively and where \( t^* \) has been chosen so as to minimize \( \lambda \). For large \( T \), \(-2 \log \lambda\) is asymptotically distributed as \( \chi^2 \).

The results of this procedure provide us with a maximum likelihood estimate of the first year of integration and not as van Brabant claims "pure reading into the equation" (2: p. 88).

Van Brabant's final substantive question concerns the proper specification of the gravity equation. If my interpretation of his comment is correct, he suggests the use of additional dummy variables. While other empirical studies using the gravity equation contain more than one dummy variable, the fundamental question remains: are we testing the dummies or are we testing a theoretical hypothesis? It is doubtful whether the dummy variable \( P_{ij} \) will pick up the preference relation. In fact, there is no theoretical basis for the inclusion of policy variables in the gravity equation. Therefore, in our study we do not base our conclusion of positive gross trade creation on the estimated coefficient of \( P_{ij} \). Nor do we base our conclusion simply on "high level decisions" (2: p. 79).
The basic question asked in the original paper was: what are the gross trade creating effects of CMEA integration? A response to this query based on an ex-post, residual measure of integration effects relies on a priori knowledge of the first year of integration. Such a priori knowledge does not exist. An objective indication of this year can be obtained by using Quandt's (11) maximum likelihood technique and likelihood ratio test but not from the estimated coefficient of $P_{ij}$.

The residual GTC effects of CMEA are made on the basis of the hypothesis that the effects on trade of changes in competitive position and trade liberalization among countries in the sample has been small relative to the effects of integration. While this assumption is clearly restrictive, it does not invalidate our conclusion, as van Brabant has stated. In fact, van Brabant's comments, in general, do not nullify the econometric methodology used nor the results obtained in the original paper.
NOTES

1 CMEA as it exists today differs from the classic case of a customs union defined by Viner and Maade (7 and 13). One major difference is that CMEA does not rely on a clearly defined common external tariff. A proxy of such a tariff, however, originates in the annual bilateral negotiations between the CMEA member states. Consequently, it is quite possible to find the existence of trade creation and/or diversion effects of the creation of CMEA as customs union. Empirical measures of TC and TD in CMEA may be found in (9).

2 A number of van Brabant's comments are superfluous in nature and do not merit a response. In addition to uncovering typographical errors van Brabant makes a number of marginal and cryptic comments in notes 5 and 15, resulting from an inadequate understanding of the methodology employed in my article.

3 Van Brabant's suggestion to use GLS further demonstrates his misreading of the original paper.

4 Van Brabant in one of his cryptic notes remarks that R² coefficients for disaggregate equations are not reported. It is not reported because an interpretable R² when using generalized least squares (GLS) estimation does not exist. Zellner's estimation used in the analysis of disaggregate trade flows is simply the application of GLS estimation to a group of "seemingly unrelated equations." Furthermore, as Fisher (3: p. 34) points out "the orthogonality properties of least squares which makes R² easy to interpret in terms of fraction of variance are not preserved" in the above case.

5 In a recent article considering the theoretical explanation for the gravity equation Anderson (1) shows that the homogeneity assumption can be interpreted as one of identical expenditure functions.

6 Van Brabant notes that a detailed explanation was not provided. He is correct. However, while a detailed explanation was removed at the request of the editor, detailed information would have been provided by the author as noted in (9: p. 40).
REFERENCES


