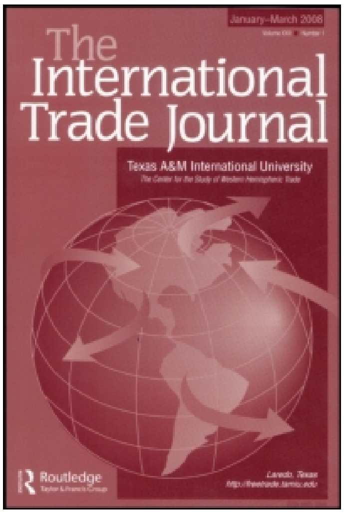

The International Trade Journal
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713772442

A SENSITIVITY ANALYSIS OF THE GRAVITY MODEL

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Online Publication Date: 16 February 2005

To cite this Article Yamarik, Steven and Ghosh, Sucharita(2005)'A SENSITIVITY ANALYSIS OF THE GRAVITY MODEL',The International Trade Journal,19:1,83 — 126

To link to this Article: DOI: 10.1080/08853900590905784

URL: http://dx.doi.org/10.1080/08853900590905784

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Steven Yamarik
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In this article, we examine the robustness of variables used in the gravity model literature. We use a variant of Leamer's extreme-bounds analysis, which tracks the sign and significance level of the variable of interest to changes in the conditioning set of variables. Of the 47 variables investigated, we find 20 measuring level of development, trade policy, linguistic and colonial ties, geographic factors, relative population density, common currency, and membership in the Central American Common Market (CACM), Caribbean Community (Caricom), Mercado Común del Sur (Mercosur), Australia-New Zealand Closer Economic Relations Trade Agreement (ANZCERTA), and Asian Pacific Economic Cooperation (APEC) are robustly linked to trade. As a result, this study provides researchers with a suitable starting point in which to examine new potential determinants of international trade.

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I. INTRODUCTION

During the past 40 years, the volume of international trade has increased markedly across the world. In 1960, the worldwide ratio of exports plus imports of goods and services to GDP stood

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THE INTERNATIONAL TRADE JOURNAL, Volume XIX, No. 1, Spring 2005
ISSN: 0885-3908 print/1521-0545 online. DOI: 10.1080/08853900590905784

at 24 percent. By 2002, this ratio has doubled to 47 percent. Similarly, for low income countries, the ratio has risen from 19 to 46 percent during the same time period (World Development Indicators, 2004).

The rise in the flow of trade has led to an increase in the number of studies investigating the sources of trade. The gravity model has long been the workhorse model used to explain bilateral trade.[1] Based upon Newton's Law of Gravitation, the gravity model predicts that the volume of trade between two economies should increase with their size (proxied by real GDP) and decrease with transactions cost (measured as bilateral distance).

Even though the gravity model initially suffered from a weak theoretical foundation, it has recently become extremely popular in the empirical trade literature. The reasons for its popularity are four-fold. First, modern theories of trade based on differentiated products provide an improved theoretical foundation for the gravity equation. Second, the gravity model has proved quite successful in estimating bilateral trade flows. Third, there has been an increased interest in empirically testing the trade effects of regional trading arrangements. Fourth, there has been a new interest among economists in the subject of geography and trade (c.f. Frankel, 1997).

At the core, the gravity model predicts that bilateral trade should increase with GDP and decrease with distance. There are theoretical reasons to include additional variables. For instance, Frankel (1997) described three types of transaction costs faced by the firm: shipping, time elapsed in transporting and cultural unfamiliarity. Geographical factors such as land area, common

[1]Exceptions include Balassa (1974) who estimated income elasticities of demand for imports and Resnick and Truman (1973) and Winters (1984, 1985) who estimated systems of import demand equations.

border, and being landlocked affect the first two costs, while linguistic and historical ties such as common language and former colonial ties impact the third cost. Furthermore, Heckscher-Ohlin predict that countries with different factor endowments will trade *more* with each other, while Linder (1961) hypothesized that nations of similar development level will have similar preferences and thus will trade *less* with countries possessing different factor endowments.

For the most part, researchers have extended the gravity model beyond the core in an *ad hoc* fashion. For instance, early work by Bergstrand (1985), Thursby and Thursby (1987), and De Grauwe (1988) included adjacency and regional trading arrangement dummies and measures of relative prices and exchange rate volatility. Despite the significance of relative prices and exchange rate volatility, later studies by Frankel and Wei do not include such measures, but instead consider new variables like common language, colonial ties and real GDP per capita along with adjacency and membership in trading blocs. More recent work by Rose (2000) and Frankel and Rose (2002) included exchange rate volatility in the form of currency unions along with thirty other potential independent variables.

Given the numerous gravity model specifications, each with a partial listing of variables that are significantly correlated with bilateral trade, researchers are uncertain as to the confidence they should place in the results of any one study. The choice of which variables to include and which to omit is of utmost importance since misspecification either lowers the precision of the estimates, or worse, biases the estimates.[2] Gravity empirics in the international trade literature would thus

[2]Greene (2003), chapter 8 showed that the inclusion of an irrelevant variable leaves the estimator unbiased but lowers the precision, while the omission of a relevant variable biases the estimates.

benefit greatly from robustness checking, which is the objective of this article.

In this study, we examine the robustness of variables used in the gravity model literature. We use a variant of Leamer's (1983, 1985) extreme-bounds analysis, which tracks the sign and significance level of the variable of interest to changes in the conditioning set of variables. By following a systematic approach to testing the fragility of coefficient estimates, extreme-bounds analysis allows us to identify which independent variables are robustly linked to bilateral trade and which are not.[3]

We find that of the 47 variables investigated only 20 variables are robustly linked to trade. These variables are the level of development, trade policy, linguistic and colonial ties, geographic factors, relative population density, common currency, and membership in the Central American Common Market (CACM), Caribbean Community (Caricom), Mercado Común del Sur (Mercosur), Australia-New Zealand Closer Economic Relations Trade Agreement (ANZCERTA), and Asian Pacific Economic Cooperation (APEC). As a result, this study provides researchers with a suitable starting point in which to examine new potential determinants of international trade flows.

The rest of the article is organized as follows. Section II derives the gravity model equation, while Section III explains the methodology of the sensitivity analysis. Section IV describes

[3]Traditional econometric theory's approach to the specification problem typically begins with an initial specification that is more general than expected. Using criteria such as coefficient signs, t-statistics, R-squares, and Durbin-Watson statistics, the researcher removes variables to find the true specification. This is called "testing down." Alternatively, under the traditional approach, the researcher can begin with an initial specification that is more specific than expected and then add variables that are deemed significant. This is called "testing up." However, traditional econometric theory provides very little guidance on which specification to begin with and no systematic way to either "test down" or "test up" to find the true model.

the data and econometric issues. Section V presents the results and interpretations. Section VI proposes a preferred gravity model specification based on the sensitivity analysis. Section VII concludes.

II. THE GRAVITY MODEL

In its earliest form, Tinbergen (1962) and Pöyhönen (1963) posited the following gravity model equation:

$$(1) \qquad trade_{ij} = A\frac{(GDP_i GDP_j)^{b_1}}{(distance_{ij})^{b_2}}$$

where $trade_{ij}$ is the value of bilateral trade between country i and j, GDP_i and GDP_j are country i and j's respective national incomes, $distance_{ij}$ is a measure of the bilateral distance between the two countries and A is a constant of proportionality.

While the core gravity model has been used empirically since the studies of Tinbergen (1962) and Pöyhönen (1963), the theoretical justification behind the core gravity model has evolved gradually. Trade theorists have found that the core model is consistent with models of imperfect competition and Heckscher-Ohlin. Anderson (1979), Helpman and Krugman (1985), and Bergstrand (1985, 1989, 1990) obtained the core Eq. (1) from various trade models with increasing returns and monopolistically competitive markets. More recently, Deardorff (1998) derived the gravity model equation from two extreme cases of the Heckscher-Ohlin model—the first case based upon frictionless trade between nations and the second case premised upon different countries producing different goods. Deardorff (1998) and Feenstra, Markusen, and Rose (2001) provided recent contributions and references of the theoretical work behind the gravity model.

To get the estimable form of the gravity equation, we take the natural logarithm of the gravity model equation (1) and add an error term to get

$$\text{(2)} \qquad \log(trade_{ij}) = A + b_1 \log(GDP_i GDP_j) + b_2 \log(distance_{ij}) + \varepsilon_{ij}$$

where A, b_1 and b_2 are coefficients to be estimated. As trade increases with size and decreases with distance, b_1 is predicted to be positive and b_2 negative. The error term, ε_{ij}, captures any other chance events or shocks that may affect bilateral trade between the two nations. Equation (2) provides the core set of variables that are included for estimation purposes.

Researchers, however, have added other variables to the core model to control for differences in geographic factors, historical ties, exchange rate risk and trade policy. For example, Frankel (1997) talked of real GDP and distance constituting a “basic” gravity model, while the two core factors plus common border, common language, per capita GDP and membership in regional trading arrangements making up a “full” gravity model. Similarly, Rose (2000) spoke of an “augmented” gravity model, which consists of Frankel’s variables plus colonial ties, exchange rate volatility, and common currency. However, the extensions to the core gravity model have been decided more upon the interests of the researcher and less from a systematic specification search. Nevertheless, for the purposes of this article, we define the “extended” gravity model as

$$\text{(3)} \qquad \log(trade_{ij}) = A + b_1 \log(GDP_i GDP_j) + b_2 \log(distance_{ij}) + b_3 X_{ij} + \varepsilon_{ij}$$

where X_{ij} is a vector of other variables that help explain bilateral trade between the two countries. It is the intention of this paper to find which of these other variables are robustly linked to bilateral trade.

III. A SENSITIVITY ANALYSIS OF THE GRAVITY MODEL

We follow the methodology of Levine and Renelt (1992) to conduct a sensitivity analysis of the gravity model. We begin with an equation of the general form:

$$(4) \qquad T = \beta_0 + \beta_1 I + \beta_M M + \beta_z Z + \beta_T TIME + \mu$$

where T is the logarithm of bilateral trade, I is a set of core variables included in the regression, M is the variable of interest, Z is a subset of variables chosen from a pool of variables identified as potentially important explanatory variables in past studies, $TIME$ is a set of time dummies and μ is a random disturbance term.[4]

Drawing upon past studies of the gravity model, we identify 50 variables for estimation of Equation (4). First, we use the sum of exports and imports for T. Second, we include the product of real GDP and bilateral distance in the set of core variables, I. Third, each of the 47 variables drawn from past studies is entered one-by-one as the M variable. Lastly, a subset of the remaining 46 variables is then used for the Z variables.

The set of Z variables are grouped into eight general categories: level of development, relative development, trade policy, linguistic and historical ties, geographic factors, exchange rate risk, relative factor endowments, and regional trading arrange-

[4]Torstensson (1996), Crain and Lee (1999), and Hussain and Brookins (2001) used the methodology of Levine and Renelt (1992) to identify robust variables of intra-industry trade, regional growth and national saving, respectively.

ments.[5] Appendix A describes the variables in each category. For the first three categories (level of development, relative development, and trade policy), we use one variable from each category.[6] This gives us three Z variables: Z_1, Z_2 and Z_3. For the remaining five categories (linguistic and historical ties, geographic factors, exchange rate risk, relative factor endowments, and regional trading arrangements), we include all the variables as a group. This gives us five vectors: Z_4 (with 3 variables), Z_5 (with 5 variables), Z_6 (with 4 variables), Z_7 (with 3 variables), and Z_8 (with 24 variables). In total, we have three Z variables—Z_1, Z_2 and Z_3—and five Z vectors—Z_4, Z_5, Z_6, Z_7, and Z_8.

In the sensitivity analysis, we first run a "base" regression for each M variable, which entails estimating Eq. (4) after imposing the constraint $\beta_Z = 0$. We then regress T on I, M, $TIME$ and all linear combinations of the Z variables taken two at a time. This gives us 21 regressions for each of the 47 M variables.[7]

[5]Previous authors have included infrastructure and foreign direct investment in the gravity model. For example, Bougheas, Demetriades, and Morgenroth (1999) included the stock of highways in their analysis of bilateral trade among 10 European countries, while Eaton and Tamura (1994) incorporated inward and outward foreign direct investment in the gravity model of American and Japanese trade. However, data limitations prevent us from collecting stock measures of infrastructure and foreign direct investment for most countries in our sample.

[6]For each of these categories, we use the variable that has complete data and thus maximizes the number of observations in the sensitivity analysis. Specifically, we use the log product of real GDP per capita for level of development, the absolute difference in the log of real GDP per capita for relative development and the sum of the Sachs-Warner index of openness to trade.

[7]The Z-variable combinations selected here exclude the other variables in the same category as the variable of interest. For example, if we use the natural log of the product of real GDP as the M variable for level of development, the other development variables—the sum of value added in manufacturing and the sum of manufactures exports—will not be included as a Z variable since each is measuring the same economic factor and thus are highly correlated. Moreover, for each of the five vectors Z_4, Z_5 Z_6, Z_7, and Z_8, there can be no other variable in the same category since they are all included. Hence, the variable in each category has all possible combinations of two Z-variables in the other seven categories. This gives us 21 regressions for each M variable.

The results from the 21 regressions for each M variable allow us to identify the highest and lowest values for the coefficient for M (given as β_M), thereby defining the upper and lower bounds of β_M. The highest value of β_M plus two standard deviations is the extreme upper bound, while the lowest value of β_M minus two standard deviations is the extreme lower bound. If β_M remains significant and of the same sign at each of the extreme bounds, the partial correlation between Y and M variable is labeled "robust." If β_M does not remain significant or if it changes signs at one of the extreme bounds, the partial correlation is labeled "fragile."

IV. DATA AND ECONOMETRIC ISSUES

The data set consists of six annual observations for 186 developing and developed countries. The sample is from Frankel and Rose (2002). The annual observations are for 1970, 1975, 1980, 1985, 1990, and 1995 and are representative of international trade. Appendix B lists the countries in our sample.

The data set contains 50 total variables divided into ten categories: dependent variable, core factors, level of development, relative development, trade policy, linguistic and historical ties, geographic factors, exchange rate risk, relative factor endowments, and regional trading arrangements. The dependent variable is the natural log of real bilateral trade (exports plus imports). The core factors are the natural log of the product of bilateral real GDP and the natural log of bilateral distance.[8] The remaining 47 variables are the variables of interest M. To minimize the problems of sample selectivity, we use 14,522 observations which

[8]Bilateral distance is measured as the great-circle distance—i.e. "as the crow flies"—between the two capital cities of the trading partners. There are alternative measures of distance, but Frankel (1997) showed that the coefficient estimate on b_2 is not sensitive to the use of these alternatives.

have complete data in all but seven variables.[9] The measurement and source of each variable are described in Appendix A, while the descriptive statistics of the data set are presented in Table I.

To make optimal use of the available data, the estimation strategy must account for the cross-sectional and time-series information in the data. One strategy is to treat all the observations as equal and estimate a pooled model using least squares. This strategy requires that the coefficients are constant across time. An alternative approach is to allow for country-pair heterogeneity in the regression. Cheng and Wall (2002) showed that heterogeneity can be incorporating either through bilateral country-specific effects or individual country-specific effects. However, the inclusion of country-specific effects will ignore potentially useful information contained in cross-sectional variation. As a result, many time-invariant variables—like distance, common border, common language and membership in regional trading arrangements—would have to be dropped to prevent perfect multicollinearity.[10] Since the objective of this article is to test the robustness of commonly-used variables, including those that are time-invariant, we choose the first estimation strategy.

However, we still need to check for stability of the coefficients across time. To do so, we run a modified Chow test on the core gravity Eq. (2).[11] The observed F-statistic for constant coefficients through time is 1256.66, which is distributed as $F(15, 14502)$; while the observed F-statistic for constant slope coefficients through time is 2.32, which is distributed as $F(10, 14508)$. The test results reject the poolability of all coefficients, but fail to reject the

[9]The seven variables that have incomplete data are the (i) sum of value added in manufacturing, (ii) sum of manufactures exports, (iii) absolute difference of value added in manufacturing, (iv) absolute difference of manufactures exports, (v) sum of the mean tariff rates, (vi) sum of the black market premium, and (vii) absolute log difference in the capital to labor ratio.

[10]See Mátyás (1997), Egger (2000), and Cheng and Wall (2002).

[11]See Baltagi (1995), chapter 4 for details on the modified Chow test.

Table I
Summary Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum	Sum
Dependent Variables					
$\log(trade_{ij})$	10.08311	3.287377	1.537117	19.39635	146426.9234
Core Factors					
$\log(GDP_i GDP_j)$	37.97506	6.20193	27.12118	58.02229	551473.8213
$\log(distance_{ij})$	8.287728	0.7738138	4.737697	9.421514	120354.386
Level of Development					
$\log(GDPPC_i GDPPC_j)$	16.44795	1.342703	12.12465	19.8297	238857.1299
$(man/GDP_i + man/GDP_j)$	0.372692	0.092027	0.087117	0.740607	3851.027
$(man/exp_i + man/exp_j)$	1.31819	0.185635	0.57	1.72	10645.7
Relative Development					
$\text{abs}(GDPPC_i - GDPPC_j)$	1.233038	0.8638348	0	4.559222	17906.17784
$\text{abs}(man/GDP_i - man/GDP_j)$	0.081746	0.060601	6.79E-06	0.368396	844.6845
$\text{abs}(man/exp_i - man/exp_j)$	0.118559	0.0938	0	0.68	957.4801
Trade Policy					
$OPEN_i + OPEN_j$	1.062044	0.7051855	0	2	15423
$tariff_i + tariff_j$	0.182672	0.122845	0	0.818114	1027.165
Linguistic and Historical Ties					
$COMLANG_{ij}$	0.1428178	0.349899	0	1	2074
$COMCOL_{ij}$	0.058463	0.234625	0	1	849
$COLONY_{ij}$	0.0135656	0.1156828	0	1	197

(*continued*)

Table I
(*Continued*)

Variable	Mean	Standard Deviation	Minimum	Maximum	Sum
Geographical Factors					
$BORDER_{ij}$	0.0293348	0.168749	0	1	426
$remote_i remote_j$	0.0006898	0.0003791	0.0000558	0.0038765	10.0172756
$LANDLOCK_{ij}$	0.1924666	0.4140178	0	2	2795
$ISLAND_{ij}$	0.3694395	0.5472608	0	2	5365
$\log(area_i area_j)$	24.91896	2.797462	12.52212	32.08535	361873.1371
Exchange Rate Risk					
$volatility_{ij}$	4.561679	7.09001	0	77.44818	66244.70244
$CURRENCY_{ij}$	0.0024101	0.0490356	0	1	35
$FLOAT_{ij}$	0.8395538	0.7418803	0	2	12192
$bmprem_i + bmprem_j$	0.935044	3.57977	−0.3157	42.38049	10300.45
Relative Factor Endowments					
$\text{abs}(school_i - school_j)$	1.14792	0.9326815	0	5.715711	16670.09424
$\text{abs}(density_i - density_j)$	1.641681	1.25246	0.0001115	7.900488	23840.49148
$\text{abs}(K/L_i - K/L_j)$	1.721075	1.297511	0.000215	5.885201	19924.89
Regional Trading Arrangements					
EU_{ij}	0.0134968	0.1153929	0	1	196
$EFTA_{ij}$	0.0030987	0.055582	0	1	45
EEA_{ij}	0.0060598	0.077611	0	1	88
$CACM_{ij}$	0.0039251	0.0625295	0	1	57
$Caricom_{ij}$	0.0006197	0.0248879	0	1	9
$NAFTA_{ij}$	0.0002754	0.0165948	0	1	4
$LAIA_{ij}$	0.0226553	0.1488071	0	1	329

$Andean_{ij}$	0.0058532	0.0762845	0	1	85
$Mercosur_{ij}$	0.0004132	0.020323	0	1	6
$ASEAN_{ij}$	0.0027544	0.0524122	0	1	40
$ANZERTA_{ij}$	0.0002066	0.014372	0	1	3
$APEC_{ij}$	0.0110178	0.1043893	0	1	160
EU_i	0.2384658	0.42616	0	1	3463
$EFTA_i$	0.1291833	0.3354143	0	1	1876
EEA_i	0.0613552	0.2399889	0	1	891
$CACM_i$	0.0930313	0.2904862	0	1	1351
$Caricom_i$	0.0436579	0.2043398	0	1	634
$NAFTA_i$	0.0274756	0.1634701	0	1	399
$LAIA_i$	0.2357113	0.4244572	0	1	3423
$Andean_i$	0.128839	0.3350332	0	1	1871
$Mercosur_i$	0.0187302	0.1355752	0	1	272
$ASEAN_i$	0.0943396	0.2923107	0	1	1370
$ANZERTA_i$	0.0315384	0.1747735	0	1	458
$APEC_i$	0.1155488	0.3196941	0	1	1678
Time Dummies					
1970	0.1368269	0.3436763	0	1	1987
1975	0.1514943	0.3585424	0	1	2200
1980	0.1748382	0.3798417	0	1	2539
1985	0.1704311	0.376024	0	1	2475
1990	0.1884727	0.3911026	0	1	2737
1995	0.1779369	0.3824728	0	1	2584

Note: All variables have 14,522 observations except $(man/GDP_i + man/GDP_j)$ and abs$(man/GDP_i - man/GDP_j)$ – 10,333; $(man/exp_i + man/exp_j)$ and abs$(man/exp_i - man/exp_j)$ – 8,076; $tariff_i + tariff_j - 5,623$; $bmprem_i + bmprem_j - 11,016$; and abs$(K/L_i - K/L_j) - 11,577$.

poolability of the slope coefficients at the 1% level.[12] Therefore, we conclude that the majority of structural change occurs through the intercept, and not the slope, coefficients.

We use the pooled least squares model in our estimation. We include fixed time dummies so that the intercept term varies through time. We also compute robust standard errors to allow for arbitrary patterns of heteroscedasticity and serial correlation.[13]

V. RESULTS AND INTERPRETATION

The regression results for the core model (including time dummies) are

$$\begin{aligned} (5) \qquad \log[\text{trade}_{ij}] = &\underset{(52.43)}{-15.204} + \underset{(159.13)}{1.062} \log[GDP_i GDP_j] \\ &- \underset{(68.14)}{1.388} \log[distance_{ij}] \end{aligned}$$

($R^2 = 0.63$; number of observations = 14,522; robust t-statistics in parenthesis). The core variables of the gravity model explain just under two-thirds of the variation in bilateral trade flows. Each variable enters in with its predicted sign and is significant at the 1% level. The coefficients imply an elasticity with respect to real GDP of one and an elasticity with respect to distance of one and a third.

[12] The error term in the pooled or restricted model is likely to be heteroscedastic. Watt (1979) showed that the presence of heteroscedasticity will overestimate the significance level of the F statistic.

[13] We treat each panel of data as a separate regression. We then estimate the three panels simultaneously imposing constant slope parameters where the standard errors are estimated using the method of White (1980). As shown in Arellano (1987), the resulting estimator is robust to heteroscedasticity and serial correlation of unknown form.

Table II presents the results of the sensitivity analysis for the 47 variables of interest. For each variable, three regression results are reported: the base model (which includes the two core variables and the variable of interest), the extreme upper bound, and the extreme lower bound. The regression results contain the estimated coefficient, $\hat{\beta}_M$; the robust t-statistic; the R-squared; and the control variables, Z, included in each regression. Lastly, the EBA result—fragile or robust—is shown in the rightmost column. We discuss the results of each category in the order presented in Table II.

Level of Development

In the core gravity model, bilateral trade depends positively upon the size of the two economies measured as the product of real GDP. Frankel (1997), however, cited a multitude of reasons for why trade may also depend positively upon the level of development. For example, exotic foreign varieties of goods may be superior goods in consumption. Moreover, more developed economies have better transportation infrastructure and thus lower transportation costs.

We consider three measures for the level of development. The first, $\log(GDPPC_i GDPPC_j)$, is the log product of real GDP per capita. Used by Frankel (1997) and others, it is the most commonly used measure. We also consider the sum of the value added in manufacturing as a percent of GDP, $(man/GDP_i + man/GDP_j)$, and the sum of manufactures exports as a percent of merchandise exports, $(man/exp_i + man/exp_j)$. In the base model, we find that each measure of the level of development is positive and significant. For the first measure, the point estimates on $\log(GDP_i GDP_j)$ and $\log(GDPPC_i GDPPC_j)$ imply that by holding population constant a one percent increase in real GDP will increase bilateral trade by 1.6 percent. More importantly,

Table II
Results of the Extreme-Bounds Sensitivity Analysis

Variable of Interest		Coefficient	t-Statistic	R^2	Control Variable Categories*	Result
Group I: Level of development						
$\log(GDPPC_i GDPPC_j)$	High:	0.7869	57.01	0.7154	Relative Development and History	
	Base:	0.7340	54.80	0.6975		Robust
	Low:	0.6054	36.21	0.7092	Relative Development and Trade Policy	
$(man/GDP_i + man/GDP_j)$	High:	6.4402	22.76	0.6910	Relative Development and RTAs	
	Base:	5.0714	19.36	0.6370		Robust
	Low:	2.9673	11.47	0.6807	History and Geography	
$(man/exp_i + man/exp_j)$	High:	2.3596	17.31	0.7188	Relative Development and Geography	
	Base:	1.6987	12.11	0.6674		Robust
	Low:	0.9088	6.03	0.7325	Factor Endowments and RTAs	
Group II: Relative Development						
$\text{abs}(GDPPC_i - GDPPC_j)$	High:	0.3464	19.89	0.7124	Level of development and Geography	
	Base:	0.1253	6.80	0.6315		Fragile
	Low:	−0.0491	−2.63	0.6935	History and RTAs	
$\text{abs}(man/GDP_i - man/GDP_j)$	High:	2.6392	8.18	0.7039	Level of development and Geography	
	Base:	0.1213	0.35	0.6226		Fragile
	Low:	−0.1644	−0.48	0.6570	History and Factor Endowments	
$\text{abs}(man/exp_i - man/exp_j)$	High:	0.6199	2.55	0.7221	Exchange Risk and RTAs	
	Base:	−1.0123	−4.47	0.6620		Fragile
	Low:	−1.4983	−6.71	0.6888	History and Factor Endowments	
Group III: Trade Policy						
$OPEN_i + OPEN_j$	High:	1.1667	46.64	0.6910	Relative Development and History	
	Base:	1.1206	44.54	0.6767		Robust
	Low:	0.3396	10.62	0.7256	Level of development and RTAs	
$tariff_i + tariff_j$	High:	−1.0652	−3.80	0.7814	Level of development and RTAs	
	Base:	−6.3455	−31.53	0.7292		Robust
	Low:	−6.8028	−32.93	0.7436	Relative Development and History	
Group IV: Linguistic and Historical Ties						
$COMLANG_{ij}$	High:	0.7635	15.03	0.7141	Geography and RTAs	
	Base:	0.5664	11.83	0.6411		Robust
	Low:	0.4254	8.41	0.7157	Level of development and Exchange Risk	
$COMCOL_{ij}$	High:	1.0160	12.56	0.7154	Level of development and Relative Development	
	Base:	0.3530	4.15	0.6411		Fragile
	Low:	−0.0459	−0.46	0.6781	Geography and Exchange Risk	
$COLONY_{ij}$	High:	2.0106	20.58	0.7157	Level of development and Exchange Risk	
	Base:	1.9470	20.82	0.6411		Robust
	Low:	1.1200	10.45	0.6986	Exchange Risk and RTAs	

Group V: Geographic Factors						
$BORDER_{ij}$	High:	0.6778	6.42	0.6977	Relative Development and Trade Policy	
	Base:	0.4950	4.57	0.6713		Robust
	Low:	0.2923	2.59	0.6781	History and Exchange Risk	
$1/(remote_i remote_j)$	High:	691.6343	16.68	0.6852	Relative Development and History	
	Base:	679.3926	16.29	0.6713		Robust
	Low:	364.2371	9.37	0.7164	Level of development and History	
$LANDLOCK_{ij}$	High:	−0.1888	−4.38	0.7174	Factor Endowments and RTAs	
	Base:	−0.2321	−6.00	0.6713		Robust
	Low:	−0.5402	−13.54	0.7089	Level of development and Exchange Risk	
$ISLAND_{ij}$	High:	0.1084	3.69	0.7124	Level of development and Relative Development	
	Base:	0.0463	1.44	0.6713		Fragile
	Low:	−0.0861	−2.40	0.6781	History and Exchange Risk	
$\log(area_i area_j)$	High:	−0.0481	−4.97	0.7089	Level of development and Exchange Risk	
	Base:	−0.2514	−34.30	0.6713		Robust
	Low:	−0.2728	−37.18	0.6852	Relative Development and History	
Group VI: Exchange Rate Risk						
$volatility_{ij}$	High:	0.0048	1.94	0.7268	Level of development and RTAs	
	Base:	−0.0165	−6.16	0.6463		Fragile
	Low:	−0.0175	−6.59	0.6562	Relative Development and History	
$CURRENCY_{ij}$	High:	2.3829	7.70	0.7110	Level of development and Relative Development	
	Base:	1.2257	4.58	0.6463		Robust
	Low:	0.8271	2.90	0.6642	History and Factor Endowments	
$FLOAT_{ij}$	High:	0.1126	3.47	0.6922	Relative Development and RTAs	
	Base:	−0.1609	−5.19	0.6463		Fragile
	Low:	−0.2192	−7.06	0.6642	History and Factor Endowments	
$bmprem_i + bmprem_j$	High:	0.0063	1.26	0.7139	Level of development and Trade Policy	
	Base:	−0.0292	−5.21	0.6463		Fragile
	Low:	−0.0305	−5.63	0.6562	Relative Development and History	
Group VII: Relative Factor Endowments						
$\text{abs}(school_i - school_j)$	High:	0.3073	11.16	0.6809	History and Geography	
	Base:	0.1727	6.06	0.6378		Fragile
	Low:	−0.0208	−0.76	0.6914	Relative Development and RTAs	
$\text{abs}(density_i - density_j)$	High:	0.3400	22.84	0.6551	Relative Development and History	
	Base:	0.3764	25.04	0.6378		Robust
	Low:	0.1982	13.28	0.7070	Level of development and Exchange Risk	
$\text{abs}(K/L_i - K/L_j)$	High:	0.0322	1.59	0.7070	Level of development and Exchange Risk	
	Base:	−0.1160	−45.94	0.6378		Fragile
	Low:	−0.5524	−16.36	0.6615	Relative Development and Exchange Risk	

(*continued*)

Table II
(*Continued*)

Variable of Interest		Coefficient	t-Statistic	R^2	Control Variable Categories*	Result
Group VIII: Regional Trading Arrangements						
EU_{ij}	High:	1.8029	24.38	0.7085	History and Factor Endowments	
	Base:	1.5677	20.76	0.6831		Fragile
	Low:	−0.2723	−3.20	0.7282	Level of development and Geography	
$EFTA_{ij}$	High:	2.1630	20.44	0.6935	Relative Development and History	
	Base:	1.9948	19.38	0.6831		Fragile
	Low:	−0.1965	−1.62	0.7282	Level of development and Geography	
EEA_{ij}	High:	1.1029	10.94	0.7016	Relative Development and Trade Policy	
	Base:	0.7629	7.68	0.6831		Fragile
	Low:	−0.1294	−0.70	0.7268	Level of development and Exchange Risk	
$CACM_{ij}$	High:	3.1869	19.73	0.7108	Trade Policy and Exchange Risk	
	Base:	2.7928	23.79	0.6831		Robust
	Low:	1.9345	14.54	0.7141	History and Geography	
$Caricom_{ij}$	High:	4.5999	11.81	0.7002	Relative Development and Factor Endowments	
	Base:	4.9131	12.40	0.6831		Robust
	Low:	1.7736	10.57	0.7268	Level of development and Exchange Risk	
$NAFTA_{ij}$	High:	1.0563	5.08	0.7034	Geography and Exchange Risk	
	Base:	0.6872	3.21	0.6831		Fragile
	Low:	−0.3858	−1.53	0.7352	Level of development and History	
$LAIA_{ij}$	High:	1.0790	9.20	0.7108	Trade Policy and Exchange Risk	
	Base:	0.4197	4.06	0.6831		Fragile
	Low:	−0.2368	−2.25	0.7352	Level of development and History	
$Andean_{ij}$	High:	0.7212	4.24	0.7246	Level of development and Relative Development	
	Base:	0.7005	4.10	0.6831		Fragile
	Low:	−0.1553	−0.89	0.7133	Trade Policy and History	
$Mercosur_{ij}$	High:	2.7841	10.58	0.6935	Relative Development and History	
	Base:	2.6055	14.09	0.6831		Robust
	Low:	1.3947	6.97	0.7016	Relative Development and Trade Policy	
$ASEAN_{ij}$	High:	1.2762	5.85	0.7352	Level of development and History	
	Base:	1.1226	3.44	0.6831		Fragile
	Low:	−0.5042	−1.63	0.7108	Trade Policy and Exchange Risk	
$ANZCERTA_{ij}$	High:	3.2366	9.86	0.7002	Relative Development and Factor Endowments	
	Base:	3.3107	8.47	0.6831		Robust
	Low:	1.1220	4.78	0.7352	Level of development and History	
$APEC_{ij}$	High:	2.1781	15.11	0.7133	Trade Policy and History	
	Base:	2.1627	14.62	0.6831		Robust
	Low:	1.2842	11.54	0.7316	Level of development and Factor Endowments	

Group VIII: Regional Trading Arrangements						
EU_i	High:	1.4191	34.22	0.6922	Relative Development and Exchange Risk	
	Base:	1.4038	37.55	0.6831		Robust
	Low:	0.5870	15.51	0.7256	Level of development and Trade Policy	
$EFTA_i$	High:	1.3110	32.63	0.7085	History and Factor Endowments	
	Base:	1.1171	27.82	0.6831		Fragile
	Low:	0.0828	1.94	0.7256	Level of development and Trade Policy	
EEA_i	High:	0.3817	5.55	0.7133	Trade Policy and History	
	Base:	0.2055	2.91	0.6831		Fragile
	Low:	−0.5106	−2.46	0.7000	Exchange Risk and Factor Endowments	
$CACM_i$	High:	0.0333	0.53	0.7108	Trade Policy and Exchange Risk	
	Base:	−0.1332	−2.37	0.6831		Fragile
	Low:	−0.3758	−6.95	0.7282	Level of development and Geography	
$Caricom_i$	High:	0.2847	2.36	0.6922	Relative Development and Exchange Risk	
	Base:	0.2833	3.39	0.6831		Fragile
	Low:	−0.9301	−10.63	0.7282	Level of development and Geography	
$NAFTA_i$	High:	0.4951	4.50	0.7034	Geography and Exchange Risk	
	Base:	0.1108	1.25	0.6831		Fragile
	Low:	−0.4527	−5.83	0.7352	Level of development and History	
$LAIA_i$	High:	−0.0402	−0.68	0.7108	Trade Policy and Exchange Risk	
	Base:	−0.4539	−8.28	0.6831		Fragile
	Low:	−0.6404	−12.53	0.7316	Level of development and Factor Endowments	
$Andean_i$	High:	0.0372	0.55	0.7064	Relative Development and Geography	
	Base:	−0.0104	−0.15	0.6831		Fragile
	Low:	−0.4008	−5.40	0.7108	Trade Policy and Exchange Risk	
$Mercosur_i$	High:	0.8846	8.29	0.7064	Relative Development and Geography	
	Base:	0.8306	7.36	0.6831		Fragile
	Low:	0.1999	1.74	0.7133	Trade Policy and History	
$ASEAN_i$	High:	0.3523	5.97	0.7246	Level of development and Relative Development	
	Base:	0.2393	3.50	0.6831		Fragile
	Low:	−0.6421	−8.71	0.7108	Trade Policy and Exchange Risk	
$ANZCERTA_i$	High:	0.8956	10.62	0.7064	Relative Development and Geography	
	Base:	0.6915	7.61	0.6831		Fragile
	Low:	−0.3414	−4.25	0.7352	Level of development and History	
$APEC_i$	High:	0.8224	12.03	0.6935	Relative Development and History	
	Base:	0.7905	11.42	0.6831		Robust
	Low:	0.4434	7.16	0.7282	Level of development and Geography	

*The control variable for Level of Development is $\log(GDPPC_i GDPPC_j)$; Relative Development is $\text{abs}(GDPPC_i - GDPPC_j)$, Trade Policy is $OPEN_i + OPEN_j$ and Relative Factor Endowments is $\text{abs}(school_i - school_j)$ and $\text{abs}(density_i - density_j)$. The control variables for Linguistic and Historical Ties (History); Geographical Factors (Geography); Exchange Rate Risk (Exchange Risk) and Regional Trading Arrangements (RTAs) are all variables in that category.

we find that all three variables are robustly linked to bilateral trade. Therefore, the results indicate that more developed economies trade more.

Relative Development

There are two competing theories on the effects of the relative level of development on international trade. Based upon the theory of comparative advantage, the first argues that the more countries differ the more they will trade with each other. The second is the Linder (1961) hypothesis that contends that countries with similar levels of development will have similar preferences. Therefore, the more alike countries are the more trade will occur.[14]

Previous research has found evidence for each hypothesis. Using different measures of development, Thursby and Thursby (1987) and Egger (2000) found that countries with similar industrial structures and per capita GDP trade more with each other. However, Montenegro and Soto (1996) included the absolute difference in per capita GDP and find that countries trade more if their economies differ.

We include three measures of the relative development between two countries. The first, abs$(GDPPC_i - GDPPC_j)$, follows Thursby and Thursby (1987) and is the absolute log difference of real GDP per capita. The second, abs$(man/GDP_i - man/GDP_j)$, is the absolute difference of the value added in manufacturing as a percent of GDP while the third measure,

[14]The Linder hypothesis is often viewed as being supported by the differentiated product framework of Helpman and Krugman (1985). As pointed out by Frankel (1997), however, there is one crucial difference in the empirical predictions of the two hypotheses. The Helpman-Krugman theory predicts that the sum of the logs of $GDPPC_i$ and $GDPPC_j$ will be positively related to trade, while the Linder hypothesis predicts that the absolute difference in $GDPPC_i$ and $GDPPC_j$ will be negatively related to trade.

abs($man/exp_i - man/exp_j$), is the absolute difference of manufactures exports as a percent of merchandise exports. In the base model, we find support for both theories in that the coefficient on abs($GDPPC_i - GDPPC_j$) is positive and the coefficient on abs($man/exp_i - man/exp_j$) is negative. However, all three variables are fragile. Consequently, we find no conclusive evidence of whether trade is driven more by the theory of comparative advantage or by the Linder hypothesis.

Trade Policy

Another barrier to trade is the imposition of tariffs, quotas and other trade restrictions. Linneman and Verbruggen (1991) and Tamirisa (1999) included the mean tariff rate for the importing country and find that higher tariff rates lower exports. Similarly, Coe and Hoffmaister (1999) used the Sachs-Warner index of trade policy for both nations and show that lower trade barriers raises the volume of bilateral trade.

We evaluate two measures of trade policy: $OPEN_i + OPEN_j$ and $tariff_i + tariff_j$. The variable $tariff_i + tariff_j$ is the sum of the mean tariff rates of the trading partners. As in Frankel and Rose (2002), we measure the mean tariff rate as the ratio of import duties to imports. Although this ex post tariff rate measure is crude, it does afford the benefit of capturing 5,623 observations. The polychotomous variable $OPEN_i + OPEN_j$ is the sum of the Sachs-Warner index of the two trading partners.[15] In the base regressions, each variable has the correct sign and is significant, indicating that higher trade restrictions decrease

[15] The Sachs-Warner index is a dummy variable that is 1 if (i) average tariff rates are below 40%; (ii) average quota and licensing coverage of imports are less than 40%; (iii) a black market exchange rate premium is less than 20%, and (iv) no extreme export controls such as quotas or state monopolies are present and 0 otherwise. With trade measured as the total volume of trade between countries i and j, the $OPEN_i + OPEN_j$ variable can take on values of (0,1,2) in our data set.

trade. More importantly, though, the sensitivity analysis shows that both variables are robust. Using the formula $exp(x_{ij}) - 1$, the point estimates for the Sachs-Warner index imply that the *unilateral* lowering of trade barriers will increase the flow of trade by 40 to 221 percent.[16]

Linguistic and Historical Ties

Some researchers have included measures of linguistic and historical ties to capture path dependence in trade flows. For example, Frankel and Wei (1995, 1996) and Frankel (1997) found that if two countries share the same language then trade is more likely to occur. A common language is seen to directly lower translation costs and, thereby, transaction costs. Moreover, Brocker and Rohweder (1990) and Frankel, Stein, and Wei (1995) showed that if one country was a former colony of the other then the volume of trade is increased. Eichengreen and Irwin (1998) cited two reasons for the positive relationship between past colonial ties and trade. First, colonial ties enhance both trading partners' understanding of each other's culture and legal system. Second, historical connections that have already resulted in sunk costs, like distribution and service networks, are associated with persistent increases in trade.

We consider three measures of linguistic and historic ties: $COMLANG_{ij}$, $COMCOL_{ij}$, and $COLONY_{ij}$. The variable $COMLANG_{ij}$ is a dummy variable that is unity if both countries share a common language. Likewise, the variable $COMCOL_{ij}$ is a dummy variable that is unity if both countries share a common colonizer and $COLONY_{ij}$ is a dummy variable that is unity if one country was a former colony of the other. All three dummy variables have the correct positive signs in the base regressions.

[16]See Halvorsen and Palmquist (1980) for a derivation of the formula $\exp(x_{ij}) - 1$.

However, the sensitivity analysis identifies $COMLANG_{ij}$ and $COLONY_{ij}$ as robust and $COMCOL_{ij}$ as fragile. The results therefore advocate the inclusion of both $COMLANG_{ij}$ and $COLONY_{ij}$ in the gravity model equation.

Geographic Factors

In the gravity model Eq. (5), the bilateral distance between the capital cities of the two countries is used to measure transportation costs. However, there are several other geographic factors that can affect transportation costs and thus the volume of trade. For instance, the cost of moving goods between two adjacent locations is lower than the cost of moving those goods through a third country. Similarly, the cost of shipping goods across water is lower than over land. Moreover, not all international trade terminates in the capital cities where the bilateral distance is measured. As a result, those countries with larger surface areas should have higher transportation costs *ceteris paribus* than those with smaller surface areas.

Moreover, recent papers by Rose (2000), Feenstra, Markusen and Rose (2001), and Soloaga and Winters (2001) included a remoteness variable to capture the impact of an additional geographic factor on bilateral trade. Remoteness measures how far an exporting country is from all other countries. The intuition behind this variable is that bilateral distance expressed *relative* to the distance of each of the pairs from their *other* partners matters with there being a positive relationship between the remoteness of the exporting country and bilateral trade.

We consider a vector of five variables to measure geographic factors. The first, $BORDER_{ij}$, is a dummy variable that is unity if the two countries share a common land border. The second variable, $1/(remote_i remote_j)$, is the inverse of the product of the average distance of country i from all other trading partners besides the trading partner, country j. The third, $LANDLOCK_{ij}$, is a polychotomous variable that is 0 if both the importing and exporting nations border a navigable sea or ocean, 1 if one nation borders water and the other is landlocked and 2 if both are landlocked. Similarly, the fourth, $ISLAND_{ij}$, is also a polychotomous variable for the number of island countries in the bilateral pair. The fifth variable, $\log(area_i area_j)$, is the log product of the surface areas of both countries.

The signs of all these variables are in agreement with the premise that transportation costs do matter in determining the volume of trade flows between countries. In the base model, we find that a common border, being an island and remoteness are positively related to trade, while greater surface area and being landlocked are negatively related to trade. However, the sensitivity analysis identifies $ISLAND_{ij}$ as fragile and the remaining variables as robust. As such, the results suggest that four measures of geographic factors—$BORDER_{ij}$, $1/(remote_i remote_j)$, $LANDLOCK_{ij}$, and $\log(area_i area_j)$—should be included in the gravity model equation.

Exchange Rate Risk

The variability of real bilateral exchange rates can also affect trade flows. The profit function of a firm depends upon the variability of the real exchange rate. In some instances, the convexity in the profit function will make exports an increasing function of real exchange rate variability. However, if a firm is sufficiently risk-averse, then greater volatility in the real exchange rate will lower the flow of exports. Brada and Méndez (1988) showed that greater exchange rate risk lowers the volume of trade. Frankel and Wei (1993), on the other hand, found mixed evidence on the impact of exchange rate variability on trade. In recent papers, Rose (2000) and Frankel and Rose (2002) found that countries sharing a common currency raises the volume of trade.

We consider four measures of real exchange rate risk. First, as in De Grauwe (1988) and Rose (2000), we include the standard deviation of the first difference in the monthly bilateral real exchange rate during the previous five years, $volatility_{ij}$. Second, we consider a dummy variable, $CURRENCY_{ij}$, which takes a value of one if both countries share a common currency and zero otherwise. Third, we follow Brada and Méndez (1988) and include a dummy variable, $FLOAT_{ij}$, which records whether a country follows a flexible exchange rate regime or a fixed regime. Fourth, as in Larue and Muntunga (1993), we also include the sum of the black market premiums of the two trading partners, $bmprem_i + bmprem_j$, to measure the gap between the market exchange rate and the official exchange rate.

At the baseline, the coefficients for $volatility_{ij}$, $FLOAT_{ij}$ and $bmprem_i + bmprem_j$ are negative and $CURRENCY_{ij}$ is positive. The baseline results suggest that increases in exchange rate risk lower trade. However, the coefficients for all the variables except a common currency change sign at either the lower or upper bound are thus fragile. The baseline result implies that a common currency increases trade by 240 percent relative to a random pair of countries. The point estimate obtained here is very close to the estimate found in Rose (2000). The sensitivity analysis, however, shows that the trade creation effect of a common currency ranges from a low of 128 percent to a high of 832 percent.

Relative Factor Endowments

The absolute factor endowments are an important determinant of intra-industry trade. Using models of increasing returns to scale and imperfect competition, Helpman and Krugman (1985) showed that economies with larger factor endowments generate more trade within an industry. The core variable, GDP, measures absolute factor endowment. In contrast, *relative* factor endowments are an important source of inter-industry trade. In the Heckscher-Ohlin model, greater difference in factor endowments between the two countries increases specialization and thus raises the volume of trade across industries. Frankel, Stein, and Wei (1995) measured relative factor endowments as differences in the two countries' capital/labor ratios, educational attainments levels, and land/labor ratios. They find slight support that relative factor endowments are significantly related to bilateral trade.

We include three measures of relative factor endowments: abs($school_i - school_j$), abs($density_i - density_j$) and abs($K/L_i - K/L_j$). The variable abs($school_i - school_j$) is the absolute difference of average years of secondary schooling in the 25+ population and measures relative human capital endowments. The variable abs($density_i - density_j$) is the absolute log difference of the population density and reflects the relative endowment of land between the two countries. The variable abs($K/L_i - K/L_j$) is the absolute log difference in the capital-to-labor ratio and captures the relative endowment of physical capital. We find that for the relative endowments of physical and human capital the coefficients change signs at the extreme bounds and are thus fragile. However, relative land endowment retains its positive coefficient and is significant at both bounds. Therefore, abs($density_i - density_j$) is robust suggesting that differences in land endowment increases the volume of trade.

Regional Trading Arrangements

There has been much debate on whether regional trading arrangements or blocs are trade creating or trade diverting. Viner (1950) and Meade (1955) showed that the answer must be found on a case-by-case basis. In a trade model with preference for variety and increasing returns to scale, Krugman (1991a, 1991b) showed that the welfare effects of continental trading blocs depends upon transportation costs. If those costs fall below some critical value, then regional trading blocs are welfare-reducing—what Krugman called "super-natural." However, if those costs are high, then regional trading blocs are welfare-enhancing—what Krugman called "natural."

We consider twelve regional trading arrangements: European Community (EC), European Free Trade Arrangement (EFTA), European Economic Area (EEA), Latin America Integration Agreement (LAIA), Central American Common Market (CACM), Andean Pact (Andean), Caribbean Community (Caricom), North America Free Trade Arrangement (NAFTA), Mercado Común del Sur (Mercosur), Association of South-East Asian Nations (ASEAN), Australia-New Zealand Closer Economic Relations Trade Agreement (ANZCERTA), and Asian Pacific Economic Cooperation (APEC).[17] Appendix C lists the member countries of each RTA. The RTAs considered range in size from the biggest—APEC—whose members produce around half of the world's GDP to the smallest—Caricom—whose membership produces less than one percent of the world's output.[18]

We include a pair of dummy variables for each regional trading arrangement. The first dummy variable, RTA_{ij}, takes a value of one when both countries are current members of the bloc. The coefficient on RTA_{ij} is interpreted as the added volume of trade between two nations in the regional trading arrangement

[17] There are other regional trading arrangements in the Middle East, North Africa and Sub-Saharan Africa. We were unable to include RTAs in these regions due to limited data. See Appendix A in Frankel (1997) for a complete list of RTAs around the world.

[18] Percentages estimated using GDP measured at purchasing power prices in 1998.

relative to their trade with countries outside the bloc and thus a positive coefficient indicates trade creation. The second dummy variable, RTA_i, takes a value of unity if only one of the two countries is a current member of the bloc. The coefficient on RTA_i is interpreted as the extent of abnormal trade between nations in the trading bloc and a country outside the bloc relative to a random pair of countries. A positive coefficient indicates an open bloc, while a negative coefficient suggests trade diversion.

Using this dummy variable approach, previous researchers have found trade creation in almost all of the regional trading arrangements considered. The earliest papers by Aitken (1973), Bergstrand (1985), Thursby and Thursby (1987), Brada and Méndez (1988), and De Grauwe (1988) found strong evidence of trade creation in both the EC and EFTA during the 1960s and in the EFTA during the 1970s. Later work by Frankel and Wei (1995,1996) and Frankel (1997) found trade creation in the EC, EFTA, APEC, ASEAN, and NAFTA. Aitken and Lowry (1973), Frankel, Stein, and Wei (1985), Garman, Peterson, and Gilliard (1998), and Soloaga and Winters (2001) looked at regional trading arrangements in Latin America and show that the CACM, LAIA, Andean, and Mercosur create trade within each bloc.

The results of the sensitivity analysis indicate far less evidence of trade creation than found by most in the RTA literature. In the base regression, all 12 regional trading blocs have a positive sign for RTA_{ij} and thus create additional trade within the bloc. The point estimates imply that each RTA increases trade from a low of 52 percent (in LAIA) to a high of 13,506 percent (in Caricom). However, only five RTAs—CACM, Caricom, Mercosur, ANZCERTA and APEC—are robust. The other seven trading blocs—EU, EFTA, EEA, NAFTA, LAIA, Andean, and ASEAN—have a negative coefficient for the lower bound and are thus fragile. Therefore, as with the Bayesian extreme-bounds analysis of Ghosh and Yamarik (2004), we find that the trade creation result in most regional trading arrangements are not robust to changes in the conditioning set of variables.

Similarly, the results find little evidence of trade diversion. In the base regression, two trading blocs (CACM and LAIA) have a negative sign for RTA_{ij} and are trade diverting. Eight RTAs (EU, EFTA, EEA, Caricom, Mercosur, ASEAN, ANZCERTA, and APEC) are open blocs and the remaining two (NAFTA and Andean) are neither. In the sensitivity analysis, no RTA is found to be trade diverting and only two—EU and APEC—can be considered open blocs.

VI. A PREFERRED GRAVITY MODEL SPECIFICATION

The sensitivity analysis of Table II found that of the 47 variables of interest 20 are robustly linked to the volume of bilateral trade. Each measure of the level of development—log($GDPPPC_i$ $GDPPPC_j$), ($man/GDP_i + man/GDP_j$), ($man/exp_i + man/exp_j$)—and trade policy—$OPEN_i + OPEN_j$ and $tariff_i + tariff_j$—is robust. For linguistic and historical ties, two of the three variables—$COMLANG_{ij}$ and $COLONY_{ij}$—are robust. All the variables except $ISLAND_{ij}$ are robust for geographic factors. For exchange rate risk and relative factor endowments, only one variable in each category—$CURRENCY_{ij}$ and abs($density_i - density_j$)—is robust. Lastly, $CACM_{ij}$, $Caricom_{ij}$, $Mercosur_{ij}$, $ANZCERTA_{ij}$, and $APEC_{ij}$ are robust for tests of trade creation, while EU_i and $APEC_i$ are robust for tests of open blocs.

Next, we develop a preferred specification which can be used for future research. Besides the results in Table II, we consider two other factors:

(1) multicollinearity and
(2) data availability.

Table III
Results of the Preferred Gravity Model Specification
(Dependent variable = natural log of bilateral trade)

	Original Dataset		Expanded Dataset	
	Coefficient	t-Statistic	Coefficient	t-Statistic
Variable				
$\log(GDP_i GDP_j)$	0.9119	94.28	0.9077	105.58
$\log(distance_{ij})$	−1.2690	−58.47	−1.2267	−65.90
$\log(GDPPC_i GDPPC_j)$	0.4362	26.33	0.3674	25.89
$OPEN_i + OPEN_j$	0.4353	15.16	0.5267	21.31
$COMLANG_{ij}$	0.5208	12.05	0.5757	14.78
$COLONY_{ij}$	1.5279	20.88	1.5334	20.83
$BORDER_{ij}$	0.4827	5.03	0.7082	8.13
$1/(remote_i remote_j)$	385.1005	10.12	269.0333	8.44
$LANDLOCK_{ij}$	−0.2500	−6.94	−0.2763	−9.30
$\log(area_i area_j)$	−0.0548	−7.53	−0.0703	−11.56
$CURRENCY_{ij}$	1.8285	6.00	1.9627	9.80
$\text{abs}(density_i - density_j)$	0.2227	19.18	0.2488	25.97
$CACM_{ij}$	1.9460	14.47	1.7787	12.47
$Caricom_{ij}$	2.6180	5.30	2.9283	10.20
$Mercosur_{ij}$	1.8675	6.27	1.7472	5.91
$ANZERTA_{ij}$	1.0952	4.42	1.4225	5.53
$APEC_{ij}$	1.2200	14.92	1.2549	16.11
EU_i	0.6027	20.88	0.6060	23.39
$APEC_i$	0.4438	9.15	0.4617	10.38
Summary Statistics				
Observations	14,522		21,061	
R-squared	0.7360		0.7031	
Root MSE	1.6904		1.7774	
F-test	1906.41		2438.87	

Notes: Estimation is by ordinary least squares. t-statistics have been corrected for heteroscedasticity and serial correlation using the method of Arellano (1987). The coefficients for the intercept term and the time dummies are not shown. The original dataset contains the 14,522 observations used in the extreme bounds sensitivity analysis, while the expanded dataset contains the maximum 21,061 observations.

Each of the 15 robust variables for linguistic and historical ties, exchange rate risk, relative factor endowments, and regional trading categories measure something different and thus have little correlation between them.[19] Also, these variables contain data across a broad sample of countries for each year. However, the variables $\log(GDPPPC_i GDPPPC_j)$, $(man/GDP_i + man/GDP_j)$, and $(man/exp_i + man/exp_j)$ in the level of development category and the two trade policy variables, $OPEN_i + OPEN_j$ and $tariff_i + tariff_j$, are highly correlated.[20] Of these five variables, only $\log(GDPPPC_i GDPPPC_j)$ and $OPEN_i + OPEN_j$ have broad coverage in our data set.

Therefore, we propose an "extended" gravity model which contains the two core factors, $\log(GDPPPC_i GDPPPC_j)$ and $OPEN_i + OPEN_j$, and the other 15 robust variables. This preferred specification not only includes those variables that are robustly linked to trade, but it also contains 21,061 observations across 185 countries. In Table III, we report the estimation results of the preferred gravity model specification. The first column presents the results for our original data set of 14,522 observations, while the second column reports the results for an expanded data set of 21,061 observations. We find that all variables are significant at the 1 percent level. Moreover, all variables retain the same sign and magnitude they achieved in the sensitivity analysis of Table II.

VII. CONCLUSION

For the past 40 years, the gravity model has been widely used to estimate the empirical determinants of bilateral trade.

[19]Of the 105 correlation coefficients, all but 12 have absolute values below 0.10.

[20]The correlation coefficients between the three levels of development variables are 0.32, 0.30, and 0.12 and the correlation coefficient between the two trade policy variables is −0.61 in value.

However, beyond the core variables of GDP and distance, there is little consensus on which variables to include and which to omit. In this article, we conducted a sensitivity analysis to assess the robustness of 47 commonly used control variables. We found that many of these variables—including those measuring relative development, exchange rate risk, relative factor endowments, and most regional trading arrangements—are fragile to changes in the specification of the gravity equation. Moreover, we found that the magnitude of many of the coefficients depends critically upon which variables are included and which are left out.

Nevertheless, we did identify 20 variables as robust. These variables measure level of development, trade policy, linguistic and colonial ties, geographic factors, relative population density, common currency, and membership in five regional trading arrangements—CACM, Caricom, Mercosur, ANZCERTA, and APEC. After considering multicollinearity and data availability, we then developed a preferred specification that can be used for future research.

The results of this study found that a common language, common currency, common border, colonial ties, an open trade policy, remoteness, and greater differences in population density are positively linked to trade, while higher tariffs, greater surface area, and being landlocked are negatively related to trade. Furthermore, we found little evidence of trade creation, with membership in five of the twelve regional trading arrangements leading to greater trade within the trade bloc. However, issues such as causality, coefficient size, and potential multicollinearity prevent us from completely answering the question of what determines bilateral trade. Nonetheless, the set of robust variables identified in this study do provide researchers with a suitable starting point in which to examine *new* potential determinants of international trade flows.

VIII. ACKNOWLEDGMENTS

We would like to thank Jeffrey Bergstrand, Drusilla Brown, Michael Klein, Raymond Reizman, Mike Ryan, and seminar participants at the 2001 Midwest Economic Association Meetings in Cleveland and 2002 Midwest International Economics Group Meetings at Northwestern University for their comments and suggestions. We would also like to thank Andrew Rose for use of his data. All remaining errors are, of course, our own.

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APPENDIX A
Description and Sources of Data

Variable	Description	Source
Dependent Variable		
$\log(trade_{ij})$	Natural log of real bilateral trade (international prices)	Frankel and Rose (2002)
Core Factors		
$\log(GDP_i GDP_j)$	Natural log of the product of real GDP (international prices)	Frankel and Rose (2002)
$\log(distance_{ij})$	Natural log of the bilateral distance between the two capital cities	Frankel and Rose (2002)
Level of Development		
$\log(GDPPC_i GDPPC_j)$	Natural log of the product of real GDP per capita	Frankel and Rose (2002)
$(man/GDP_i + man/GDP_j)$	The sum of value added in manufacturing (% of GDP)	WDI (2004)
$(man/exp_i + man/exp_j)$	The sum of manufactures exports (% of merchandise exports)	WDI (2004)
Relative Development		
$\text{abs}(GDPPC_i - GDPPC_j)$	The absolute log difference of real GDP per capita	WDI (2004)
$\text{abs}(man/GDP_i - man/GDP_j)$	The absolute difference of value added in manufacturing (% of GDP)	WDI (2004)
$\text{abs}(man/exp_i - man/exp_j)$	The absolute difference of manufactures exports (% of merchandise exports)	WDI (2004)
Trade Policy		
$OPEN_i + OPEN_j$	The sum of the Sachs-Warner index of an open trade policy (0,1,2)	Sachs and Warner (1995)
$tariff_i + tariff_j$	The sum of the mean tariff rates (imports duties/imports)	WDI (2004)
Linguistic and Historical Ties		
$COMLANG_{ij}$	Dummy (1 if the two countries share a common language and 0 otherwise)	Frankel and Rose (2002)
$COMCOL_{ij}$	Dummy (1 if the two countries share a common colonizer and 0 otherwise)	Frankel and Rose (2002)
$COLONY_{ij}$	Dummy (1 if one country was a former colony of the other and 0 otherwise)	Frankel and Rose (2002)
Geographic Factors		
$BORDER_{ij}$	Dummy (1 if the two countries share a common land border and 0 otherwise)	Frankel and Rose (2002)
$1/(remote_i remote_j)$	The inverse of the product of the average distance of each country i from all trading partners other than country j	Frankel and Rose (2002)
$LANDLOCK_{ij}$	Number of landlocked countries (0,1,2)	Frankel and Rose (2002)
$ISLAND_{ij}$	Number of island countries (0,1,2)	Frankel and Rose (2002)
$\log(area_i area_j)$	Natural log of the product of the surface area of the two countries	Frankel and Rose (2002)

(continued)

APPENDIX A
(*Continued*)

Variable	Description	Source
Exchange Rate Risk		
$volatility_{ij}$	The standard deviation of the first difference in the monthly bilateral exchange rate during the previous five periods	IMF
$CURRENCY_{ij}$	Dummy (1 if the two countries share a common currency)	Frankel and Rose
$FLOAT_{ij}$	Number of countries with a floating exchange rate (0,1,2)	IMF
$bmprem_i + bmprem_j$	The sum of the black market premium (%, 0 means zero)	WDI
Relative Factor Endowments		
$\text{abs}(school_i - school_j)$	The absolute log difference in the average years of secondary schooling in the 25+ population	Barro and Lee
$\text{abs}(density_i - density_j)$	The absolute log difference in population density	WDI
$\text{abs}(K/L_i - K/L_j)$	The absolute log difference in the capital-to-labor ratio	Penn World Tables
Regional Trading Arrangements		
RTA_{ij}	Dummy (1 if both countries are members of the RTA in question and 0 otherwise)	Frankel (1997), Mattli (1999), Soloaga and Winters (2001)
RTA_i	Dummy (1 if one and only one country is a member of the RTA in question and 0 otherwise)	Frankel (1997), Mattli (1999), Soloaga and Winters (2001)

Notes:
The variables denoted in capital letters are discrete variables, while those denoted in lower case letters are continuous.

The Frankel and Rose data are from Frankel and Rose (2002) at (http://www.haas.berkeley.edu/∼arose/GravData.zip). The errors in the data set identified at (http://www.haas.berkeley.edu/∼arose/errors.html) have been corrected.

The WDI data are taken from the World Development Indicators (2004).

The Sachs-Warner index of openness to trade (*OPEN*) is from Sachs and Warner (1995) at (http://www.bris.ac.uk/Depts/Economics/Growth/open.csv).

The IMF data on exchange rate risk are taken from various issues of *International Financial Statistics*.

The education (*school*) data are from Barro and Lee (2001) at (http://www.cid.harvard.edu/ciddata/barrolee/panel_data.xls).

The capital-to-labor ratio (K/L) data are taken from the Penn World Tables, Mark 5.6a.

The regional trading arrangement (RTA) variables are constructed by authors using information from Frankel (1997), Mattli (1999), and Soloaga and Winters (2001). See Appendix C for details.

APPENDIX B
Sample Countries

Afghanistan
Albania
Algeria
American Samoa
Angola
Anguilla
Antigua and Barbuda
Argentina
Aruba
Australia
Austria
Bahamas, The
Bahrain
Bangladesh
Barbados
Belgium
Belize
Benin
Bermuda
Bhutan
Bolivia
Brazil
Brit. Indian Ocean Territory
British Virgin Islands
Brunei
Bulgaria
Burkina Faso
Burundi
Cambodia
Cameroon
Canada
Cayman Islands
Central African Republic
Chad
Chile
China
Colombia
Comoros
Congo, Republic
Cook Islands
Costa Rica
Cuba
Cyprus
Czechoslovakia, Former
Denmark
Djibouti
Dominica
Dominican Republic
Ecuador
Egypt
El Salvador
Equatorial Guinea
Ethiopia
Falkland Islands
Fiji
Finland
French Guiana
France
Gabon
Gambia, The
German, Former East
Germany, West
Ghana
Gibraltar
Greece
Greenland
Grenada
Guadeloupe
Guam
Guatemala
Guinea
Guinea-Bissau
Guyana
Haiti
Honduras
Hong Kong
Hungary
Iceland
India
Indonesia
Iran
Iraq
Ireland
Israel
Italy
Cote d'Ivoire
Jamaica
Japan
Jordan
Kenya

Kiribati
Korea, South
Kuwait
Laos
Lebanon
Liberia
Libya
Madagascar
Malawi
Malaysia
Maldives
Mali
Malta
Martinique
Mauritania
Mauritius
Mexico
Mongolia
Montserrat
Morocco
Mozambique
Myanmar
North Korea
Nauru
Nepal
Netherlands
Netherlands Antilles
New Caledonia
New Zealand
Nicaragua
Niger
Nigeria
Niue
Norway
Oman
Pacific Islands Trust
Pakistan
Panama
Papua New Guinea
Paraguay
Peru
Philippines
Poland
Portugal
Qatar
Reunion
Romania
Rwanda
South Yemen, Former
Saudi Arabia
Senegal
Seychelles
Sierra Leone
Singapore
Solomon Islands
Somalia
South Africa
St. Pierre and Miquelon
Spain
Sri Lanka
St. Helena
St. Kitts and Nevis
St. Lucia
St. Vincent and the Grenadines
Sudan
Suriname
Sweden
Switzerland
Syrian Arab Republic
Taiwan, China
Tanzania
Thailand
Togo
Tonga
Trinidad and Tobago
Tunisia
Turkey
Turks and Caicos Islands
Tuvalu
United Kingdom
United States
U.S.S.R., Former
Uganda
United Arab Emirates
Uruguay
U.S. Virgin Islands
Venezuela
Vietnam
Western Samoa
Western Sahara
Yemen, Former North
Yemen
Yugoslavia, Former
Zaire
Zambia
Zimbabwe

APPENDIX C
Membership in the Regional Trading Arrangements Considered

Name of RTA	Abbreviation	Start	Member Countries
European Community	EC	1957	Austria (1995), Belgium, Denmark (1973), Finland (1995), France, Germany, Greece (1981), Luxembourg, Ireland (1973), Italy, Netherlands, Portugal (1986), Spain (1986), Sweden (1995), United Kingdom (1973)
European Free Trade Arrangement	EFTA	1960	Iceland (1970), Liechtenstein (1991), Norway, Switzerland Former: Denmark (1960–72), United Kingdom (1960–1972), Portugal (1960–85), Austria (1960–94), Sweden (1960–94), Finland (1986–94)
European Economic Area	EEA	1994	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Luxembourg, Iceland, Italy, Ireland, Liechtenstein, Netherlands, Norway, Portugal, Spain, Sweden, United Kingdom
Central American Common Market	CACM	1960	Costa Rica (1963), El Salvador, Guatemala, Honduras, Nicaragua
Caribbean Community/Carifta	Caricom	1973	Antigua and Barbuda, Bahamas (1983), Barbados, Belize (1995), Dominica (1974), Guyana (1995), Grenada (1974), Jamaica, Montserrat (1974), Saint Kitts and Nevis, Saint Lucia (1974), Saint Vincent and the Grenadines, Suriname (1995), Trinidad and Tobago
Canada-US Free Trade Arrangement/North American Free Trade Agreement	NAFTA	1988	Canada, United States, Mexico (1994)

(*continued*)

APPENDIX C
(Continued)

Name of RTA	Abbreviation	Start	Member Countries
Latin America Free Trade Association/Latin America Integration Agreement	LAIA	1960	Argentina, Bolivia (1967), Brazil, Chile, Colombia (1961), Ecuador (1961), Mexico, Paraguay, Peru, Uruguay, Venezuela (1966)
Andean Pact/Andean Community	Andean	1969	Bolivia, Colombia, Ecuador, Peru, Venezuela (1973) Former: Chile (1969–76)
Mercado Comùn del Sur	Mercosur	1991	Argentina, Brazil, Paraguay, Uruguay
Association of South East Asian Nations/ASEAN FTA	ASEAN	1967	Brunei (1984), Cambodia (1998), Indonesia, Laos (1997), Malaysia, Myanmar (1997), the Philippines, Singapore, Thailand, Vietnam (1995)
Australia-New Zealand Closer Economic Relations Trade Agreement	ANZCERTA	1983	Australia, New Zealand
Asia Pacific Economic Community	APEC	1989	Australia, Brunei, Canada, China (1991), Chile (1994), Taiwan (1991), Hong Kong (1991), Indonesia, Japan, South Korea, Malaysia, Mexico (1993), New Zealand, Papua New Guinea (1993), Peru (1998), Philippines, Singapore, Thailand, United States, Vietnam (1998)

Sources: Frankel (1997), Mattli (1999), and Soloaga and Winters (2001).