Methodology for Impact Assessment of Free Trade Agreements

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Introduction to the Gravity Model

- The gravity model is **an econometric** method of **estimating trade flows**. This model has been used to analyze the impact of not only FTAs, but also the effects of General Agreement on Tariffs and Trade–World Trade Organization (WTO) membership, currency unions, **migration flows**, **foreign direct investment**, and **even disasters**.
- The main benefit of the gravity model in evaluating an FTA is that it can control for the effects of as many other trade determinants besides the FTA as necessary, and can therefore isolate the effects of the FTA on trade.
- The gravity model is attributed to **Jan Tinbergen (1962),** who compared the **size of bilateral trade flows** between any two countries to the **gravitational force in physics between two objects**.
- Since Tinbergen, many authors have produced theoretical models that yield the gravity equation for trade (e.g., Anderson 1979 and Bergstrand 1985).

Introduction to the Gravity Model

- Many empirical papers have used the gravity model to study the economic implications of free trade agreement formation for international trade.
- Bayoumi and Eichengreen (1995) analyzed a sample of 21 industrial countries in the period 1953–1992 and found that the European Free Trade Association resulted in trade creation while the European Economic Community had both trade creation and diversion effects.
- They note that the accession of Spain and Portugal resulted in almost no trade diversion. In another study, Chang and Winters (1999) find that outsiders who export to a regional bloc are, on average, adversely affected by their exclusion from the regional agreement.
- The authors show that even if the regional agreement does not increase external barriers to trade, the excluded countries may still be negatively affected. This could arise from excluded exporters decreasing their prices to meet the competition from suppliers within the regional trading agreement.
- There are many gravity studies on the Association of Southeast Asian Nations (ASEAN) Free Trade Area (AFTA), and one by Manchin and Pelkmans-Balaoing (2008) uses a gravity model to estimate directly the impact of AFTA to date.
- They find that, in fact, AFTA preferential tariffs do matter for a range of products, particularly where the most-favored nation tariff and the AFTA preference tariff differ by a “critical” amount.

Theoretical Background

The basic gravity model of trade, which is analogous to Newton's law of universal gravitation in physics, relates the **imports of country *i* from country *j* (M_{ij})** positively to the **gross domestic product (GDP) of the importing country (Y_i)** and the **GDP of the exporting country (Y_j)**, but negatively to the **geographical distance** between the importing and exporting countries **(D_{ij}):**

$$M_{ij} = G\frac{Y_i Y_j}{D_{ij}} \qquad (1)$$

where
G is a constant

Expressed in logarithmic form and attaching a random error term (u_{ij}), the basic gravity equation becomes

$$\ln M_{ij} = G + \beta_1 \ln Y_i + \beta_2 \ln Y_j + \beta_3 \ln D_{ij} + u_{ij} \qquad (2)$$

where the β's are coefficients. Given the hypothesized relationships contained in the gravity model, β_1 and β_2 are expected to be positive, while β_3 is expected to be negative. In the gravity equation, **geographical distance** between the importing and exporting countries is actually **a proxy for trade costs**, which **impede bilateral trade**.

Other variables that capture trade costs (e.g., adjacency, common language, colonial links, common currency, or whether the importing or exporting countries are islands or landlocked) **may be added** to this basic equation along with other explanatory variables.

Theoretical Background

- Furthermore, recent theoretical work on the gravity equation has emphasized that bilateral trade is not only a function of distance between the two countries, but also the distance of the pair from other countries.
- Anderson and van Wincoop (2003) have coined the term "multilateral trade resistance" to denote the distance between the pair vis-à-vis the rest of the world: the higher the multilateral resistance, the more the pair of countries should trade with each other and vice versa.
- Multilateral resistance can be easily included in the basic gravity equation as a **set of fixed importer (MTR_i)** and **exporter effects (MTR_j)**. The gravity equation is thus

$$\ln M_{ij} = G + \beta_1 \ln Y_i + \beta_2 \ln Y_j + \beta_3 \ln D_{ij} + \mathrm{MTR_i} + \mathrm{MTR_i} + u_{ij} \qquad (3)$$

Theoretical Background

- At a minimum, the model is estimated with data on bilateral trade, GDP, and distance, using linear regression (ordinary least squares), which is a procedure performed by any statistical software package.
- The sample should not be restricted only to countries in which the researcher is interested, but it should include as many countries as possible so that the regression is based on the maximum information available.
- The gravity equation can be estimated with data across pairs of countries from just one year (cross section) or for pairs of countries observed over multiple years (panel data).
- Panel data is preferable because, then, the effects of particular years on global trade can be controlled for. With panel data, the gravity equation is

$$\ln M_{ij}^{t} = G + \beta_1 \ln Y_i^{t} + \beta_2 \ln Y_j^{t} + \beta_3 \ln D_{ij} + \mathrm{MTR_i} + \mathrm{MTR_j} + \mathrm{YEARS} + u_{ij}^{t} \qquad (4)$$

where the *t* superscript denotes the year of the observation and YEARS is a set of indicator variables for all the years in the sample except the first.

Theoretical Background

- For the analysis of an FTA, we add two variables to the gravity equation.
- The first is an indicator variable (*TradeCreate*) for observations where both the importing and exporting countries are members of the FTA in year *t*, while the second is an indicator variable (*TradeDivert*) for observations where the importing country is a member of the FTA in year *t*, but the exporting country is not.
- As the variable names suggest, the first variable measures trade creation, which is expected to be positive under the FTA, and the second, trade diversion, which is expected to be negative under the FTA. The gravity model for evaluating an FTA is therefore

$$\ln M_{ij}^{t} = G + \beta_1 \ln Y_i^{t} + \beta_2 \ln Y_j^{t} + \beta_3 \ln D_{ij} + TradeCreate + TradeDivert + \mathrm{MTR_i} + \mathrm{MTR_i} + \mathrm{YEARS} + u_{ij}^{t} \quad (5)$$

Theoretical Background

- It is noted that a fixed effect is a binary variable that indicates whether or not an observation is of an individual country.
- For example, to construct a fixed importer effect for Cambodia, we set a variable equal to 1 whenever the importing country is Cambodia and zero otherwise.
- When these fixed effects are included, it is not possible to estimate the effects of time-invariant country-specific characteristics, such as being an island or being landlocked.
- Instead of using fixed effects to control for multilateral trade resistance, one could use a formula that measures the average distance to other trading partners or use iterative methods to construct estimates of the price-raising effects of barriers to multilateral trade (Anderson and van Wincoop 2003).

Sources of Data

- Estimation of a gravity equation requires data on bilateral trade, GDP, distances, and possibly other determinants of bilateral trade including contiguity (common border), common language, colonial ties, and exchange rates.
- **Bilateral trade flows** can be found in the International Monetary Fund Direction of Trade Statistics; the United Nations Commodity Trade (Comtrade) Statistics Database; or the World Bank Trade, Production, and Protection database by Nicita and Olarreaga (2006).
- Data on **GDP** in current US dollars, converted at current exchange rates, can be found in the International Monetary Fund's International Financial Statistics, or the World Bank's World Development Indicators.
- Data on **distances**—typically the geodesic distances between capitals or the largest cities of each country by population—are available from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII), along with other geographic and trade-related variables. The CEPII database can be accessed at www.cepii.fr/anglaisgraph/bdd/distances.htm

Example 1

- To illustrate, a gravity model was estimated with data from 177 importing countries and 193 exporting countries over the period 1988–2007.
- The **trade data** is sourced from Comtrade, **GDP** from the World Development Indicators, and the **distance** variable from CEPII.
- The gravity model is estimated first **without any FTA-related** variables as in equation (4), and then **with FTA-related** variables as in equation (5).
- The trade effects of AFTA are evaluated next. AFTA, as mentioned in previous sections, was signed by the original six members in 1992 and joined subsequently by Viet Nam in 1995, the Lao People's Democratic Republic (Lao PDR) and Myanmar in 1997, and Cambodia in 1999.

Example 1

- The following table shows output from having used the Stata software package to estimate the gravity model as formulated in equation (4).
- Only the results for GDP and distance are shown as these are the key explanatory variables in the gravity model. The coefficient estimates, since the variables are in logarithmic form, can be interpreted as elasticities.
- For example, the coefficient estimate on the importing country's GDP is equal to 0.865, which implies that a 1.0% increase in the GDP of the importing country raises its imports by 0.865%.

Table 1 : Regression Results from Gravity Model Estimation with Trade Creation and Trade Diversion—Original Six ASEAN Members and Cambodia, the Lao People's Democratic Republic, and Viet Nam

Linear regression				Number of obs.	= 260,119
				F(382,259736)	= 2,271.82
				Prob > F	= 0.0000
				R squared	= 0.7312
				Root MSE	= 2.0943

ln*Mij*	Coef.	Robust Std. Err.	t	P>| t |	(95% Confidence Interval)	
ln*Yi*	.8561031	.0259124	33.04	0.00	.8053155	.9068908
ln*Yj*	.3612175	.0233257	15.49	0.00	.3154998	.4069352
ln*Dij*	(1.691341)	.0058937	(286.98)	0.00	(1.702892)	(1.67979)

( ) = negative, obs. = observations, coef. = coefficient, MSE = root mean square error, std. Err. = standard error.

Source: Authors.

Example 1

- The coefficient estimates and their standard errors can be used to test certain hypothesized relationships.
- For example, suppose we state a null hypothesis that bilateral trade is unrelated to the GDP of the importing country (β_1 equals zero).
- The regression results show that the coefficient estimate on the importing country's GDP (β_1) is 0.865 with a standard error of 0.026. To test the stated null hypothesis, we first choose a level of statistical significance—the maximum probability that the null hypothesis can be mistakenly rejected.
- This level is often set at 5% (or 1% for a more stringent test). Using 5%, a t-statistic is computed according to the following formula:

$$t\text{-}statistic = \left| \frac{\hat{\beta}}{\hat{\sigma}_{\beta_1}} \right| = \left| \frac{0.865}{0.026} \right| = 33.4$$

Example 1

- This t-statistic is computed automatically by most regression software packages. Once the value for the t-statistic is determined, it can be compared to the critical value, which is a cutoff value for the t-statistic corresponding to the chosen significance level.
- The critical value can be found using a table of values from Student's t-distribution. To consult this table, we need to compute the degrees of freedom, which is the number of observations (n) minus the number of explanatory variables (k) minus 1 ($n - k - 1$), or in this example: 260,119 – 382 – 1 = 259,736. This example contains a large number of explanatory variables because of the importer and exporter fixed effects as well as the year indicator variables.
- The critical value for this test with a significance level of 5% is 1.96. As the computed t-statistic is more than the critical value, the null hypothesis is rejected.
- Therefore, a statistically significant relationship exists between bilateral trade and the importing country's GDP.

Example 1

- Most statistical software packages also produce a p-value, which is the probability of finding, due to random sampling, as large a difference between the estimated and hypothesized values as the difference actually found given that the hypothesized value is true.
- A smaller p-value implies a smaller probability that random sampling caused as large a difference between the estimated and hypothesized values to be found, therefore a higher likelihood that the values are indeed different, and a firmer basis to reject the null hypothesis.
- An alternative method of hypothesis testing that yields the same result as using the t-statistic is to check if the p-value is below the chosen significance level. If this is so, then the null hypothesis is rejected.
- In the regression results above, the p-value for each explanatory variable is an extremely small number, so we can safely reject the null hypothesis that these variables are unrelated to bilateral trade. Moreover, the coefficient estimates have the expected sign.

Example 2

- Table 2 shows Stata output from having estimated the gravity model as formulated in equation (5). This estimation differs from the previous one in that variables for AFTA trade creation and diversion are included. The results for GDP and distance are almost the same as from the previous estimation.
- However, the estimated coefficient on *TradeCreate* is negative and that for *TradeDivert* is positive, which is the opposite of what was expected.
- Their signs and statistical significance suggest that AFTA actuallyreduced intraregional trade and increased extraregional trade.

Example 2

Table 2 : Regression Results from Gravity Model Estimation with Trade Creation and Trade Diversion

Linear regression				Number of obs.	= 260,119
				F(382,259734)	= 2,261.09
				Prob > F	= 0.0000
				R squared	= 0.7312
				Root MSE	= 2.0941

ln*Mij*	Coef.	Robust Std. Err.	t	P>| t |	(95% Conf. Interval)	
ln*Yi*	.8463466	.0260789	32.45	0.00	.7952326	.8974605
ln*Yj*	.3625608	.0233251	15.54	0.00	.3168443	.4082774
ln*Dij*	(1.69801)	.006006	(82.72)	0.00	(1.709781)	(1.686238)
TradeCreate	(.3190286)	.08031	(3.97)	0.00	(.476434)	(.1616232)
TradeDivert	.2274481	.0531532	0.28	0.00	.1232693	.3316269

( ) = negative, obs. = observations, coef. = coefficient, MSE = root mean square error, std. Err. = standard error.
Source: Authors.

Example 2

- The percentage reduction in intraregional trade can be computed as $e^{-0.319} - 1 = -27\%$, while the percentage increase in extraregional trade is $e^{0.2275} - 1 = 26\%$.
- Although the proportions of changes in intra- and extraregional trade are estimated to be about the same, extraregional trade of ASEAN countries was about four times that of intraregional trade during the period, suggesting that the net effect of AFTA was an absolute rise in trade.
- Nevertheless, the strange results for trade creation and diversion suggest either that preferential AFTA tariffs were ineffective or there were specification problems in the model, such as omitted variables.

Example 3

- The next regression is conducted to investigate if AFTA had a different effect on newer ASEAN members. It also includes separate trade creation and diversion indicator variables for two groups:

  (i) the original six members (*OrigTradeC* and *OrigTradeDivert*)

  (ii) newer members (*CLVTradeC* and *CLVTradeD*)

Table 3 : Regression Results from Gravity Model Estimation with Trade Creation and Trade Diversion—Original Six ASEAN Members and Cambodia, the Lao People's Democratic Republic, and Viet Nam

Linear regression					Number of obs. = 260,119 F(382,259734) = 2,252.18 Prob > F = 0.0000 R squared = 0.7313 Root MSE = 2.0939	
ln*Mij*	Coef.	Robust Std. Err.	t	P>| t |	(95% Conf. Interval)	
ln*Yi*	.845397	.0260671	32.43	0.000	.7943063	.8964878
ln*Yj*	.3632986	.0233275	15.57	0.000	.3175774	.4090198
ln*Dij*	(1.698416)	.0060065	(282.76)	0.000	(1.710188)	(1.686643)
Orig6TradeC	(.7267084)	.0986292	(7.37)	0.000	(.920019)	(.5333978)
Orig6TradeD	.0406138	.0672881	0.60	0.546	(.0912691)	.1724967
CLVTradeC	.6353428	.118895	5.34	0.000	.4023118	.8683738
CLVTradeD	.585979	.0803296	7.29	0.000	.4285351	.7434229

( ) = negative, obs. = observations, coef. = coefficient, MSE = root mean square error, std. Err. = standard error.

Example 3

- Again, the results for GDP and distance are almost the same as in previous estimations. However, by breaking down the trade creation and diversion variables by groups of ASEAN countries, we can see that **AFTA affected these groups differently**.
- The original six members experienced a reduction of 52% ($e^{-0.7267} - 1$) in intraregional trade, while extraregional trade did not change significantly.
- Interestingly, the intraregional trade of newer ASEAN members rose by 89% ($e^{0.6353} - 1$) and their extraregional trade rose by 80% ($e^{0.586} - 1$) as a result of AFTA.
- Although the sign on *Orig6TradeD* is positive, which would indicate that the original ASEAN six experienced a rise in extraregional imports, the result is **not statistically significant** because of the small t-statistic (or high p-value).
- To gain some perspective on these numbers, consider the case of Cambodian imports. In the third year after becoming an ASEAN member and participating in AFTA (2002), the country's intraregional imports were $598 million and extraregional imports were $1,067 million.
- The estimates above suggest that without AFTA, Cambodia would have imported only $316 million ($598 million/1.89) from other ASEAN countries and $593 million ($1,067 million/1.80) from countries outside the region.
- In other words, Cambodia experienced an increase in trade in that third year of close to $1 billion due to AFTA.

Strengths and Limitations of the Gravity Model

- The gravity model is used as a workhorse for analyzing trade because data for it is widely available, the model has high explanatory power, and there are established standard practices that facilitate the work of researchers.
- Its main strengths in evaluating an FTA are that it allows the analyst to control for other trade-related variables and quantify any changes in a country's trade due to the FTA.
- These quantitative estimates may then be used in welfare calculations. However, the model may yield misleading results **if the data is inaccurate** or **important variables are omitted** from the estimation.
- Further, although the method of estimating the gravity model presented above addresses most of the basic data and specification issues that arise in implementation, other **more complicated problems exist**.
- The analyst should refer to the recent literature for potential solutions to these problems.