

Taylor Approximation of Multilateral Resistance Term with Unilateral Variable in STATA

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Abstract

Purpose of the article The article presents the estimation of a gravity model on a bilateral data set of 132 countries. A multilateral resistance term (MRT) is included in the gravity equation. The paper demonstrates a solution using Taylor approximation of MRT with variables that are both bilateral and unilateral.

Methodology/methods The estimation of parameters in panel data is described in this paper. A Poisson pseudo maximum likelihood estimator (PPML) and Taylor approximation of MRT were used to estimate unknown parameters. All calculations were obtained using STATA software. Variable distance, regional trade agreements, common language and contiguity were used as gravity variables. Institutional variables were also included in the gravity model.

Scientific aim It has already become a standard routine to include typical gravity variables (distance or dummy variables of trade) into a multilateral resistance term. On the other hand, trade between two countries can also be influenced by institutional variables or by variables describing infrastructure. The aim of the paper is to estimate the gravity equation for panel data containing 132 countries over the period 2006–2015 and to include a unilateral variable into the multilateral resistance term.

Findings Although it is not possible to include a unilateral institutional variable directly into a multilateral resistance term and estimate its parameters due to problems with collinearity, this problem can be solved by using institutional distance. This variable is defined as the absolute value of the difference between the two institutional variables for the reporter and partner country. This simple procedure can be programmed, for example, in STATA.

Conclusions The common gravity variables affect the volume of trade between two countries as well as the selected institutional variables and GDP of the reporter and partner country.

Keywords: multilateral resistance term, Taylor expansion, gravity model, PPML

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Introduction

We suppose that trade flows between two countries are influenced by their sizes and by the distance between them. This theory is closely connected with Newton's gravity equation (Tinbergen, 1962). The gravity equation is used in its basic form defining mutual trade to be proportional to the GDP of both countries and influenced by the square of their mutual distance.

Gravity models of international trade have become widely used over the last fifty years (Anderson, 1979; Baldwin and Taglioni, 2007). On the other hand, several disputes have arisen in connection with this model (Trefler, 1995; McCallum, 1995; Deardoff, 1998; Helpman et al., 2008). The gravity equation is used to explain econometrically the effects of standard gravity variables (distance, national borders, currency unions, language and other "trade variables") on bilateral trade flows. In addition to these bilateral variables, there is a wide range of unilateral (country-specific) variables – institutional variables describing infrastructure – that can also affect the volume of trade (Alvarez et al., 2018; Yu et al., 2015; Gil-Pareja et al., 2017).

The debate has also focused on the performance of various estimation techniques. The traditional form of gravity model is log-linear. Such a model can be estimated using simple least squares (OLS) to obtain estimates of parameters by fixed effects. Although this method is very simple to implement, it has one serious drawback. We must drop any variables from the model that only vary by reporter (or partner) country and are constant in one dimension. Moreover, such specification is problematic in the case of zero observations (due to logarithms) and the OLS estimate may be inconsistent (Silva and Tenreyro, 2006 and Silva and Tenreyro, 2011). Nowadays, recent development is turning attention to the usage of the Poisson pseudo-maximum likelihood. This estimator allows the inclusion of zero values of trade flows into the estimation. An alternative to the fixed effect may be the approach of Baier and Bergstrand (2009) based on a first-order Taylor series approximation of two nonlinear multilateral resistance terms (MRT).

This paper describes an estimation of parameters in a gravity equation and we demonstrate a modeling of MRT by Taylor approximation in Stata. We adopt Taylor approximation strategies and discuss the possibility of inclusion of country-specific unilateral variables into the MRT. The model is estimated on a bilateral panel dataset of 132 countries between 2006 and 2015. Since we are working with bilateral data over a 10-year period, it is absolutely necessary to use advanced software, a suitable data structure and pre-prepared codes. In Section 2 we describe the gravity equation and discuss the methodology, in Section 3 we present Stata commands, and Section 4 concludes the paper.

1 Gravity equation

Anderson (1979) was the first to provide a microfoundation of the gravity equation. Bergstrand (1985) continued and supported his theory. We suppose that trade flows depend on reporter (or domestic) and partner (or foreign) GDP and on the distance between these two economies representing trade costs.

A classical form of gravity equation widely presented in the literature (Anderson and Wincoop, 2003; Head and Mayer, 2014; Shepherd, 2013) is the following:

$$X_{ijt} = \frac{Y_{it} \times Y_{jt}}{Y_t} \left(\frac{t_{ijt}}{p_{it} \times p_{jt}} \right)^{(1-\sigma)} \quad (1)$$

where X_{ijt} in equation (1) represents mutual trade flows from country i (reporter) to country j (partner). The total number of countries is N . Y_t denotes world GDP computed as the sum of GDP for all countries in the sample, Y_{it} and Y_{jt} are the GDP of reporter and partner countries i and j respectively, t_{ij} is the cost in partner country j of importing a type of goods from reporter country i , $\sigma > 1$ is the elasticity of substitution and p_{it} and p_{jt} represent exporter and importer ease of market access or country i 's outward and country j 's inward multilateral resistance terms.

The standard linear gravity equation presented by Anderson and van Wincoop (2003) is as follows:

$$\log X_{ijt} = \beta_0 + \log Y_{it} + \log Y_{jt} + (1 - \sigma) \times (\log t_{ijt} - p_{it} - p_{jt}) \quad (2)$$

or alternatively

$$\log x_{ijt} = \beta_0 + (1 - \sigma) \times (\log t_{ijt} - p_{it} - p_{jt}) \quad (3)$$

where $\beta_0 = -\ln Y_t$, the variables p_{it} and p_{jt} are the multilateral resistance terms and are defined as a function of each country's full set of bilateral trade resistance terms, $\log x_{ijt} = \log X_{ijt} - \log Y_{it} - \log Y_{jt}$. Multilateral terms p_{ij} and p_{jt} are not observable and should be estimated. Baier and Bergstrand (2009) proposed the estimation of MRT from equations (2) and (3) by first-order log-linear Taylor-series expansion:

$$p_{it} = \sum_{j=1}^N \theta_{jt} \ln t_{ijt} - \frac{1}{2} \sum_{i=1}^N \sum_{j=1}^N \theta_{it} \theta_{ijt} \ln t_{ijt} \quad (4)$$

$$p_{jt} = \sum_{i=1}^N \theta_{it} \ln t_{ijt} - \frac{1}{2} \sum_{i=1}^N \sum_{j=1}^N \theta_{it} \theta_{ijt} \ln t_{ijt}$$

where the second term in both equations is a constant across country pairs and $\theta_{jt} = \frac{Y_{jt}}{Y_t}$, $\theta_{it} = \frac{Y_{it}}{Y_t}$ are defined as GDP weights. To deal with the problem of endogeneity, Baier and Bergstrand (2009) and Egger and Nelson (2011) recommend using simple averages $\theta_{it} = \theta_{jt} = \frac{1}{N}$ instead of GDP weights. Equation (3) yields the model:

$$\log x_{ijt} = \beta_0 + (1 - \sigma) \times \left(\log t_{ijt} - \sum_{j=1}^N \theta_{jt} \ln t_{ijt} = \sum_{i=1}^N \theta_{it} \ln t_{ijt} + \sum_{i=1}^N \sum_{j=1}^N \theta_{it} \theta_{ijt} \ln t_{ijt} \right) \quad (5)$$

As mentioned above, the log-linear form of the model can lead to inefficient estimations since the properties of the error term are changed (Silva and Tenreyro, 2006). The variance of the estimated parameters obtained by standard OLS can be biased and there can be problems with the t-values of estimated parameters. Hence, there is a necessity for other estimation techniques for estimating the gravity equations. There are many possibilities for obtaining estimates: Nonlinear Least Squares (NLS), Feasible Generalized Least Squares (FGLS), Gamma Maximum Likelihood (GPML) or Poisson Pseudo-maximum Likelihood (PPML). The Poisson pseudo-maximum likelihood preserves total trade flows, i.e. the sums of the actual and predicted trade flows are identical (Arvis and Shepherd, 2012). PPML is an estimation method for gravity models. This estimator is a generalized linear model and is estimated via GLM using the quasipoisson distribution and a log-link. The PPML estimator has a number of additional desirable properties for applied policy researchers using gravity models. Its main advantage is that the Poisson estimator naturally includes observations for which the observed trade value is zero, interpretation of the coefficients is straightforward and follows the same pattern as under OLS.

2 Estimation in Stata

In this section we demonstrate the estimation of MRT in Stata. For these empirical examples we use a dataset on bilateral trade panel data for the 132 countries over the period 2000–2015. We use the COMTRADE data on export and import flows representing our dependent variable, WDI WB data on the GDP of the reporter and partner countries. For estimation purposes, we specify the last part of the model (5) as the trade cost function t_{ij} . This function is defined as follows:

$$\log t_{ijt} = \alpha_1 \log \text{dist}_{ij} + \alpha_2 \text{contig}_{ijt} + \alpha_3 \text{comlang}_{ijt} + \alpha_4 \text{colony}_{ijt} + \alpha_5 \text{RTA}_{ijt} + \alpha_6 \text{Institutional_variable}_{ijt} \quad (6)$$

Dist is the geographical distance between the reporter and partner country, *contig* is a dummy (=1 for countries that share a land border), *comlang* is a dummy (=1 for countries that have a common official language), *colony* is a dummy (=1 for countries which were in a colonial relationship in the past), and *RTA* is a dummy (=1 in the case that regional trade agreements exist between countries). Moreover, we also decided to include institutional variables: Trade Freedom (*TF*), Investment Freedom (*IF*) and Business Freedom (*BF*) to demonstrate that it is possible to have a country-specific variable in a multilateral resistance term. To avoid the problem of multicollinearity, we have defined this variable as the absolute value of the difference between two unilateral variables for reporter and partner country in each year:

$$TF_difference_{ijt} = |TF_{it} - TF_{jt}|$$

$$IF_difference_{ijt} = |IF_{it} - IF_{jt}| \quad (6)$$

$$BF_differ_{ijt} = |BF_{it} - BF_{jt}|$$

The source of all these variables is Heritage Foundations. Hence, our database contains 276,672 rows for 11 different variables. For this reason, it is very important to work with the data file carefully, save the data in the appropriate format, and choose the appropriate software to process it. There are many options for the choice of which statistical software to use for data processing. The R program works very well with large data (it makes it possible to process terabyte data, for example; pbdR represents a package for statistical computing with data using high-performance statistical computation. However, our data is not of such size, and for the purposes of economic interpretation of the results, the STATA program allows you to read data directly on-line. In our case, we use preprepared codes that can be changed as needed.

As mentioned above, OLS is an estimation strategy for a variety of gravity models. On the other hand, OSL is subject to criticism from the econometric point of view. Therefore, we present the alternative estimator PPML where we assume that a country's share in world GDP at time t is equal ($\theta_{it} = \theta_{jt} = \frac{1}{N}$) to avoid problems with endogeneity (Baier and Bergstrand, 2009).

Table 1 Simplified output from STATA: PPML estimates of a simple gravity model according to the Baier and Bergstrand (2009) methodology.

```

g theta = 1/132
g theta2 = 1/(132*132)

local bilateral_vars TF_differ IF_differ BF_differ lndist contig comlang colony
rta
foreach var of local bilateral_vars{
    g `var' _r=theta * `var'
    g `var' _p=theta * `var'
    g `var' _rp=theta2 * `var'

    egen MR`var'1=total(`var' _r), by(partnercode years)
    egen MR`var'2=total(`var' _p), by(reportercode years)
    egen MR`var'3=total(`var' _rp), by(years)

    generate MR`var'N=`var' - MR`var'1 - MR`var'2 + MR`var'3

ppml ln_X lnGDP_X lnGDP_M MR_lndist MR_contig MR_comlang MR_colony MR_rta
MR_BF_differ years*, cluster (distw)

ppml ln_X lnGDP_X lnGDP_M MR_lndist MR_contig MR_comlang MR_colony MR_rta
MR_TF_differ years*, cluster (distw)

ppml ln_X lnGDP_X lnGDP_M MR_lndist MR_contig MR_comlang MR_colony MR_rta
MR_IF_differ years*, cluster (distw)
}

```

Source: own calculation

We have run several experimental estimates which are presented in Table 2. We estimated three specifications of a model with a multilateral resistance term where we approximated parameter θ by $1/N$. We also included three different institutional variables. The economic theory underlying the gravity model suggests that the estimated parameters of the GDP-level variable should be approximate unity with bilateral dependent variable trade. Although we did not apply any constraints to GDP coefficients to be equal to unity, the values of the estimated parameters are very close to 1. Both reporterter and partner GDP are significant across all three models. Geographical distance has the expected sign and magnitude. This variable is negative and significant and has a negative impact on trade for all three models.

Some of the bilateral gravity variables selected as trade variables and included in the multilateral resistance term are significant. Since variable *MR_contig* is significant, we can conclude that higher trade is observable between countries that share a land border or a border across a small body of water. A similar relationship exists between volume of trade and variable *MR_RTA*. Regional trade agreements such as EU, NAFTA etc. also have a positive impact on exports from reporter to partner country. On the other hand, a common language or colonial history between two countries does not have an influence on trade flows.

We also included three institutional variables. Of the many possibilities, we chose trade, investment and business freedom. All these three variables were measured as an institutional distance and its estimated parameters are significant. Hence, institutions also have some impact on trade volumes.

Table 2 Estimation Results

Variable name (dep.var: trade flowsijt)	(Model I)	(Model II)	(Model III)
Log_GDP_partner	0.77527*** (0.8676)	0.75934*** (0.0413)	0.76854*** (0.0432)
Log_GDP_reporter	0.86768*** (0.0435)	0.85781*** (0.0391)	0.85467*** (0.0340)
Log_distance	-0.43197*** (0.0814)	-0.41017*** (0.0726)	-0.40629*** (0.0785)
MR_contig	1.30262*** (0.1885)	1.30010*** (0.18053)	1.3138*** (0.1907)
MR_comlang	0.20010 (0.1506)	0.19653 (0.1476)	0.21358 (0.1504)
MR_colony	-0.12279 (0.1670)	-0.04370 (0.1606)	-0.08235 (0.1630)
MR_RTA	0.45782*** (0.1371)	0.48928*** (0.1201)	0.45400*** (0.1262)
MR_TF_differ	0.01980** (0.0091)		
MR_IF_differ		0.00195*** (0.0030)	
MR_BF_differ			0.00950** (0.0043)
No.obs	237866	237866	237866
R-squared	0.7664	0.7909	0.7713

PPML regressions with time fixed effects and multilateral resistance terms. Numbers in parentheses are robust standard errors of the estimates. Asterisks denote a level of significance: * of 10 %, ** of 5 %, *** of 1 %.

Source: own research

3 Conclusion

In this paper we have analyzed a panel of bilateral trade flows to show how to estimate the coefficients of a multilateral resistance term in STATA. If we have a well-organized dataset, then it is not too complicated to estimate the gravitational model with a multilateral resistance term in STATA. For this purpose, we can use a predefined function to calculate the estimates by command ppml. Moreover, we have demonstrated that it is possible to include institutional variables among other gravity factors. We have found that exports depend on geographical distance, with a negative relationship, as well as on the GDPs of the reporter and partner countries. Exports are also influenced by institutional variables. Finally, it should be noted that it would be possible to include a larger number of institutional variables in the model. Similarly, it would also be possible to examine the infrastructure of a selected country in addition to its institutions. This topic may be the subject of further research.

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