THEORETICAL GROUNDWORK FOR GRAVITY MODEL

Theoretical Groundwork for Gravity Model

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ABSTRACT

The gravity model of international trade flows is a common approach to modeling bilateral trade flows. But it is criticized on the ground of weak theoretical base and poor micro-foundation. The gravity equation for describing trade flows first appeared in the empirical literature without much serious attempt to justify it theoretically. The theoretical support for the gravity model was originally very poor, but after the second half of the 1970s, several theoretical developments have filled this gap .In this study we endeavor to justify the specification of Gravity model of trade. We inferred from previous studied review that it is a strong empirical tool of analysis for international trade flow even though of some weakness it innate. There are different categories of empirical applications of the Gravity equation, which can be mentioned to investigate issues in international trade: that are estimating the cost of a border, explaining trade patterns, identifying effects related to regionalism and lastly tabulating trade potential. We found gravity model a strong tool of analysis for bilateral measurement analysis.

Key words; Gravity model, Theoretical background, Theoretical weakness

1. INTRODUCTION

The gravity model has been applied since early 1940's to a wide variety of goods and factors of production moving across regional and national boundaries under different circumstances (Oguledo and Macphee 1994). This model originates from the Newtonian Physics notion which states that two bodies attract each other proportionally to the product of each body's mass (in kilograms) divided by the square of the distance between their respective centers of gravity (in meters). The gravity model for trade is similar to this law. The similarity is as follows: "the trade flow between two countries is proportional to the product of each country's 'economic mass', generally measured by GDP, each to the power of quantities to be determined, divided by the distance between the countries' respective 'economic centers of gravity', generally their capitals, raise to the power of another quantity to be determined" (Christie 2002).

A considerable amount of literature has been published on the gravity model. In early versions of the model, Tin Bergen (1962) and Poyhonen (1963) concluded that exports are positively affected by income of the trading countries and that distance can be expected to negatively affect exports. Some studies attempted to add additional structural elements to the gravity model to better reflect the real word observations. A Parallel search of a solid theoretical foundation for the gravity model addressing several issues related to theoretical weakness has been started since 1970's. Researchers have examined the econometric issues that what is the correct way of specifying and estimating a gravity equation, to show how the specific effects turn out to be significant in empirical analysis? In the last decade, a lot of effort has been made in empirical research on international trade to explain the bilateral volume of trade through the estimation of a gravity equation [Disdier and Head (2004)]. As a reminiscence of Isaac Newton's law of gravity, the trade version represents a reduced form which comprises of supply and demand factors (GDP or GNP and population) as well as trade resistance (geographical distance, as a proxy of transport costs and home bias) and trade preference factors (preferential trade agreements, common language, common borders).

Anderson (1979) make the first formal attempt to derive the gravity equation from a model that assume product differentiation, Bergstrand (1985, 1989) also explore the theoretical determination of bilateral trade in a series of papers, in which gravity equations are associated with simple monopolistic competition models. Helpman (1987) use a differentiated product framework with increasing returns to scale to justify the gravity model. More recently, Deardorff (1995) has proven that gravity equation characterizes many models and can be justified from standard trade theories.

Anderson and Win coop (2003) derive an operational gravity model based on the manipulation of the CES expenditure system that can be easily estimated and that helps to solve the so-called border puzzle. In spite of tremendous work on this model there exists a criticism that theoretical foundation of gravity model is still very frail. In order to compile the issues of Gravity model we design this study, we are going to discuss the existing literature on proper econometric specification of the gravity model and its importance for the calculation of bilateral trade flows, vis-à-vis a healthy criticism on its modeling and specification. The main aim of this paper is to provide a theoretical explanation and justification for the research who applied Gravity model as a tool of analysis.

2. LITERATURE REVIEW

The gravity model using a trade-share-expenditure system is derived by Anderson (1979), which postulates identical Cobb-Douglas or constant elasticity of substitution (CES) preference functions for all countries, and utility functions weakly separable between traded and non-traded goods. In this case utility maximization under the income constraint produces traded goods shares that are functions of traded goods prices only. Prices being constant in cross-sections, using the share relationships along with trade balance identity, country j's (foreign country) imports are obtained and assuming log-linear functions in income and population for shares, one obtains the gravity equation for aggregate imports. Besides taking a close look at the identification issues of how to retrieve the structural parameters from the estimated equations, the study also notes the problem of endogeneity of income for which it proposes two alternate solutions. Both follow the Instrumental Variable (IV) approach, employing different instruments: one uses the lagged value of income as instruments and the other uses first stage estimations of shares by OLS and substitutes income values obtained from estimated shares for a second stage re-estimation of the gravity equation. Anderson model preferences over only traded goods. Anderson’s primary concern is to examine the econometric properties of the resulting equations, rather than to extract easily interpretable theoretical implications.

Subsequent to Anderson (1979) whose theoretical analysis is at the aggregate level**,** Bergstrand (1985) give a microeconomic foundation to the gravity model within the framework of a general equilibrium model of world trade. The utility maximizing consumers are assumed to have a CES preference function and profit maximizing firms a (CET) production technology. The analysis produces import demand and export supply equations, which along with the equilibrium condition, lead to reduced form equations for quantities (exports/imports) and prices. However since the reduced form eliminates all endogenous variables out of the explanatory part of each equation, income and prices also cease to be explanatory variables of bilateral trade. Thus instead of substituting out all the endogenous variables, the study solves the general equilibrium system only partially retaining income and certain price terms as explanatory variables and treating them as exogenous. The resulting model is termed as a “generalized" gravity equation, which is then estimated for 15 countries at different points in time. Here the potential endogeneity of income (and prices) is not touched upon, though it can be tackled once again by using IV techniques instead of OLS that the study employees. Using GDP deflator to approximate these price indices, the study estimate its system in order to test the assumptions of product differentiation. For richness, CES preferences are nested, with a different elasticity of substitution among imports than the one between imports and domestic goods. The empirical estimates support the assumption that goods are not perfect substitutes and that imports are closer substitutes for each other than for the domestic goods.

A theoretical derivation of the gravity equation even within the framework of the Heckscher-Ohlin (HO) model in two cases is offered by Deardorff (1995).First with frictionless trade and identical preferences, where random choice of trading partners by consumers and producers is assumed and second with trade impediments assuming unequal factor prices. The study shows that, it is not at all that difficult to justify even simple forms of the gravity equation from standard theories.

Gravity model is also derived and discussed in Deardorff (1998). This study assumes that there exist barriers to trade for every single goods, so that they are strictly positive on all international transactions. The trade barriers are thought of being incidental and in the form of transport costs. The study applies that the HO model with perfect competition. (Under the condition of perfect competition producers in the local market cannot compete with producers in the foreign market, since exporters are faced with positive transport cost for every good). Factors prices are assumed to be unequal for each pair of countries to allow for non-FPE (factor price equalization theorem) between countries. If it is further assumed that there are many more goods than there are factors, then under the condition of frictionless trade, under unequal factor prices any pair of countries would only have few goods in common. However under the condition of restricted trade, goods can become non- traded and they can compete in the same market if the difference in production cost equals the transport cost between the two countries. Finally, Deardorff shows that the gravity model is consistent with several variants of the Ricardian and HO models.

While discussing about usefulness of gravity model, Helpman (1998) concludes that the primary advantage of using gravity models is to identify determinants influencing volume of trade, as well as some underlying causes for trade. Helpman believes that volume of trade is not considered by many trade theories, and that the gravity equation works best for similar countries with considerable intra-industry trade between them, rather than for countries with different factor endowments and a predominance of inter-industry trade. Helpman suggests that product differentiation can be considered above and beyond factor endowments.

Unified framework of the recent developments in the econometric methodology of Gravity model is thoroughly analyzed by Marks *et al.* (1998). They develop the estimation techniques to account for any possible simultaneity bias originating because of GDP and export flows correlation. This study contains result of Random Effect Models and The Fixed Effects results for gravity model. An important extension is also made by introducing lagged dependent variable as explanatory variable. There is strong evidence that current export flows are highly correlated with those of previous year. This variable is treated as an instrument for the problem of endogenity .All of these models and methods are illustrated with an application to exports flows in the APEC region. Important explanatory variable are found to be domestic and target country GDPs, local and domestic populations, the exchange rate and foreign currency reserves. Most of the data are taken from *The International Monetary fund* publications and *Direction of Trade Statistics*. The study use Hauseman's Specification test for fixed versus random effects. The study argues that care must be taken in specifying all of the likely effects; otherwise any further analysis is very likely to be flawed. The study suggests that one can elucidate on the "openness" of member countries, economies and moreover, specifically and separately, identify both propensities to export and import. There is compelling evidence that exports are strongly autoregressive. The paper suggests that it is important to properly specify the model, in terms of source, target and business cycle effects. If this is not the case, policies could be

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instigated that do not take into account all effects. All other estimations will also be biased and policy will be misguided. The study focuses on the random effect model.

In order to analyze two main theories of international trade, the Heckscher Ohlin theory and Increasing Return to trade theory, the work of Evenett and Keller (1998) is worth noting, it explains whether the two theories can account for the empirical success of the so called Gravity equation. The study shows that the version of both models can generate this prediction. There are three major findings: First, little production is perfectly specialized due to factor endowment differences, making the perfect specialization version of the H-O model an unlikely candidate to explain the empirical success of the gravity equation. Second, increasing returns are important cause for perfect product specialization and the gravity equation, especially among industrialized countries. Third; to the extent that production is not perfectly specialized across countries, the study supports for both H-O and increasing return models. Based on these finding, it is concluded that both model explain different components of the international variation of production patterns and trade volumes with important implications for productivity growth, labor and macroeconomics.

The theoretical foundations for the gravity equation are proposed in Feenstra *et al.* (1998). The study suggests that the empirical performance of the gravity equation is specific to the type of goods examined. The study shows that the existing theory for the gravity equation depends on the assumption of differtiated goods but it is concluded that the gravity equation can also be derived from a reciprocal dumping model of trade in homogeneous goods. Theoretically, the gravity equation should have lower domestic income elasticity for exports of homogeneous goods than of differtiated goods, because of a “home market” effects which depends on barriers to entry. The study quantifies the home market effect empirically using cross-sectional gravity equations, and finds that domestic income export elasticities are indeed substantially higher for differtiated goods than for homogenous goods.Another study by Feenstra (2002) analyzes the CES monopolistic competition model to derive the gravity equation, especially when transport cost and other trade barriers are allowed. The study shows that while including transport cost and trade barriers, one needs to take account of the overall price indexes in each country.

Silva and Tenreyo (2003) argue that the standard empirical methods used to estimate gravity equations are inappropriate. The basic problem is that Log-Linearization of the empirical model in the presence of heteroskedasticity leads to inconsistent estimates. This is because the expected value of the logarithm of a random variable depends on higher-order moments of its distribution. Therefore, if the errors are heteroskedastic, the transformed errors will be generally correlated with the covariates. An additional problem of log-linearization is that it is incompatible with the existence of zeroes in trade data, which led to several unsatisfactory solutions, including truncation of the sample and further non-linear transformations of the dependent variable. The study stresses that even assuming that all observations on dependent variables are positive; it is not advisable to estimate independent variables from the log-linear model. Instead, the non-linear model has to be estimated using non-linear least squares (NLS) (see Frankel and Wei,1993). However; the NLS estimator ignores the heteroskedasticity. Therefore, the implementation of the Poisson pseudo-maximum likelihood estimator is straightforward, even when the dependent variables are not integers and when trade data suffers from errors.study carries out two sets of experiments. The first set is aimed at studying the performance of the estimators of the multiplicative and log-linear models under different patterns of heteroskedasticity. The second set studies the estimator's performance in the presence of rounded errors in the dependent variable. The results clearly indicate that estimation based on the log-linear model cannot be recommended, except that under very special circumstances. Otherwise, the estimates obtained provide very little information on the parameters of interest. One remarkable result of this set of experiments is the extremely poor performance of the standard NLS estimators, and very encouraging performance of the Poisson pseudo-maximum likelihood estimator.

Among the studies using gravity framework, a large percentage of them share the research or institutional task of predicting trade Potentials. Those studies look for evidence of a trade enhancing effect of countries' integration, their aim being the prediction of the additional bilateral trade that might be expected if integration between two countries (or more than two countries) is fostered. A different use of the gravity equation has been put forward by the U.S. Trade Commission (Rivera, 2003) to quantify the trade effects of liberalization. After the fall of the Iron Curtain, gravity equations applications have been largely used to evaluate the trade potential of preferential agreements.

As far as the data structure is concerned, early empirical studies used Cross-section data to estimate a gravity model, while in most recent years researchers tend to use panel data [(Baldwin (1994), Gros and Gonciarz (1996), Brenton and Di Mauro (1999), Egger(2000) and Nilsson (2000)]. Both kinds of analyses are mainly static and they refer to long run relationships.

Along the years two main strategies have been selected in order to calculate trade potentials. The first one derives out-of-sample trade potential Estimates [(Wang and Winters (1992), Hamilton and Winters (1992) and Brulhart and Kelly (1999)]. The second strategy derives in-sample trade Potential estimates [(Baldwin (1994) and Nilsson (2000)]. Among the many studies using the gravity framework, a high percentage share goes to the research for the task of predicting trade potentials. Whichever specification of the augmented gravity model is used, the main purpose of this specification is to allow for non-homothetic preferences in the importing country and to proxy for the capital/labor ratio in the exporting country (Bergstrand, 1989).

In simple expressions we can form the correct econometric representation of gravity model in a triple-indexed notation. Matyas (1997) argued that the proper specification of gravity model takes the following representation:

$$T_{ijt} = \alpha_i + \gamma_j + \lambda_t + \beta' x_{ijt} + \delta' z_{ij} + u_{ijt} \qquad (1)$$

Where

α_i, γ_j and λ_t are well- known specific effects attributed to the panel data modeling approach. If only cross section data are used, $\lambda_t = 0$ and when only time series data are used then $\alpha_i, \gamma_j = 0$. Finally when panel data are used, there are no restrictions. From an econometric point of view, $\alpha_i, \gamma_j = 0$ and λ_t specific effects can be treated as random variables. Matyas

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was not specific about fixed and random effect model estimation in case of above mentioned model. It is observed that gravity model works well at product or sectoral levels.

Model (1) should be viewed as the generic form of all gravity models and is a direct generalization. When cross-section data are used then T=1 and implicitly restriction $\lambda_t = 0$ is imposed on the model [(e.g.; Aitken (1973), Bergstrand (1985), Brad (1994), Oguledo and Macphee (1994), and Frankel *et al*, (1995)].

From the above simplest equation modification we can address the several issues of measurement in trade by far as follows:

Cost of the border

Although the presence of a common border may facilitate bilateral trade between nations. The same border is also a hindrance to trade. This is the so called "border effect". Anderson and van Wincoop (2003) suggest that national borders pose on average a barrier to trade.

Explaining trade patterns

Trade patterns have also been investigated using gravity-type equations. The trade overlap (i.e. two-way trade within industries) is examined in Bergstrand (1989) and Hummels and Levinsohn (1995). The studies tabulate bilateral indices of intra-industry trade at the industry level. These indices are then aggregated and their weighted average is explained using a gravity equation. Trade types, an alternative method used to disentangle intra-industry and inter-industry trade flows, are explained in Fontagné, Freudenberg and Péridy (1998). They calculate trade types at the 8-digit product level and aggregate the results at the industry level. These trade types are explained using equations integrating gravity-related variables. However, these three studies consider trade shares rather than trade volumes, which depart slightly from the bulk of work on gravity equations.

Regionalism effects

Trade creation versus trade diversion Gravity models have been used extensively to address the issue of the impact of trade policies on trade flows, like the impact of regional trade agreements. Commonly, regional trade agreements are reflected in a gravity approach by introducing a binary variable, taking on the value 1 for members of the regional agreement and 0 otherwise. A positive and significant coefficient of the binary variable is seen as an indication for trade creation taking place due to regional trade integration. This exercise is equivalently used in order to simulate trade potentials corresponding to any regional integration scheme between any groupings of countries.

Calculation of trade potentials

The estimation of trade potentials within the gravity framework is a line of research that has been studied extensively. This methodology has been in particular used for Central and Eastern European Countries, [(Wang and Winters (1991), Havrylyshyn and Pritchett (1991), Baldwin (1993), Gros and Gonciarz (1995), Schumacher (1995) and (1997) and Festoc (1996)]. The gravity equation, explaining observed bilateral exports within a sample of countries chosen, is used to obtain potential bilateral trade flows between any pair of countries within the sample, given that the required data are systematically available. Such simulated bilateral exports are compared with observed ones in order to infer bilateral export potentials. Such a methodology can be applied either at the aggregated or industry level.

At the end we wrap up the discussion and surmise that greatest challenge to new research about the issue of trade is to find conceptually distinct measures of trade that better explains how to approach the trade enhancing efforts and minimize trade inhibiting factors. Gravity model is a one of the appropriate means of investigation.

3. CONCLUSION

From above discussion we figure out that Gravity equation has several weaknesses inherent yet model is usable to measure bilateral trade flows in all types of market structure and conditions. There are different categories of empirical applications of the Gravity equation, which can be mentioned to investigate issues in international trade: that are estimating the cost of a border, explaining trade patterns, identifying effects related to regionalism and lastly tabulating trade potentials. Because of its appeal as an empirical strategy the application of gravity model is becoming enormously popular. Quoting Eichengreen and Irwin (1997), the gravity model is nowadays "... the workhorse for empirical studies ..." in international trade. Since the early 1990s, the large availability of international data necessary to fill the standard specification of the model, the relative independence from different theoretical models, and a bandwagon effect has made the gravity model the empirical model of trade flows (Evenett and Keller, 2002).

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