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The gravity model and trade flows: Recent developments in econometric modeling and empirical evidence

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ABSTRACT

The existing trade literature on the gravity model is extensive. This paper aims to present a survey of the current gravity model by taking stock of the existing knowledge on the major theoretical and empirical aspects of the gravity model in the context of trade flows. It also analyzes issues of panel data econometrics and identifies the critical areas of empirical methods and data. Attention has been paid to the more recent developments in the subject while discussing the estimation procedures applied in the literature. Finally, the paper suggests several directions for future studies and provides guideposts for policy makers.

1. Introduction

The gravity model has emerged as a widely employed approach to analyze and predict economic variables, particularly bilateral trade flows. Contrary to what the majority of trade economists believe, the gravity equation was first used in the nineteenth century by Ravenstein (1885) and then by Zipf (1946). However, the formal usage of the model dates back to Tinbergen (1962a, b) and Pöyhönen (1963). According to the early version of the model, bilateral exports from origin to destination are explained by economic masses proxied by traders' income and geographical distance. Despite initial criticism that it is theoretical, the gravity model has gained wide usage in recent decades due to the rigorous theoretical foundation it has been given and its empirical success in predicting bilateral trade flows of various commodities under different situations (Deardorff, 1984).

For half a century, much effort has been paid to explaining bilateral trade volumes through the estimation of a gravity equation. The application of this equation has become enormously popular; Baier et al. (2014) said it "dominated the international trade literature as the main econometric approach". Studies seeking evidence of a trade-enhancing effect of countries' integration aim to predict the additional bilateral trade that might be expected if integration between two or more countries is fostered. The "gravity equation" has been used to econometrically estimate the *ex post* partial (or direct) effects of economic integration agreements, national borders, currency unions, language, and other measures of trade costs

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on bilateral international trade flows (Bergstrand and Egger, 2011). In the basic gravity equation, trade between a pair of countries is modeled as an increasing function of their sizes and a decreasing function of the distance between the two countries. As one of the most successful empirical economic models, the gravity model explains a considerable proportion of a variation with a single equation in which the coefficients are regarded as economically meaningful and statistically well determined (Frankel and Rose, 2002).

The gravity model states that the size of bilateral trade flows is determined by supply conditions at the origin, demand conditions at the destination and the driving forces of the trade flows. The early empirical use of the gravity model was criticized for its lack of theoretical foundation. However, since Anderson's (1979) seminal contribution, it has been widely recognized that the prediction of the gravity model can be derived from Ricardian approach, the Heckscher–Ohlin–Samuelson (HOS) model and New Trade Theory (NTT) based on increasing returns to scale (IRS) (*e.g.*, Bergstrand, 1990; Leamer, 1992; Deardorff, 1998; Eaton and Kortum, 2002). Although the gravity model cannot be used alone to test the validity of any of these trade theories, its empirical success is due to its ability to incorporate most of the empirical phenomena that are commonly observed in international trade. However, its high acceptance is due largely to its empirical success in understanding the impact of trade liberalization and in assessing the effects of geographic allocations and trade agreements on trade flows (Harris et al., 2012).

In addition to trade flow, gravity models are applied in a range of areas, which include, *inter alia*, environment, migration, transport, health and education and stock market behavior. Frankel and Rose (2005) adopt a gravity model to assess the trade-environment nexus and find an inverse relationship between air pollution and trade in global cross-sectional data for 1990. However, the study has been criticized for its lack of panel data.

Karemera et al. (2000) adopt a gravity model to examine the influence of political, economic and demographical factors on the size and composition of migration flows from 70 countries to Canada and the US during the 1976–1986 period. Conversely, Ramos and Surinach (2016) use a gravity model to analyze the trends in EU neighboring countries (ENC) and European Union (EU) bilateral migration for nearly 200 countries between 1960 and 2010. The results demonstrate a clear increase in migratory pressures from ENC to the EU.

To analyze urban transport, Tsekeris and Stathopoulos (2006) use a dynamic extension of the entropy-based gravity model of trip distribution for dynamic transport planning in urban networks. They adopt both single and double dynamic gravity models (DDGM) for the inter-period (long-term) and intra-period (short-term or within-day) evolution of travel demand. The results demonstrate that trip departure time and users' route choice behavior are important variables in the transport gravity model. Conversely, Grosche et al. (2007) present two gravity models to estimate air passenger volume between city-pairs, revealing general economic activity and geographical characteristics are important in explaining passenger volume.

The model is also used in health and education. Lowe and Sen (1996) use a gravity model to explain a hospital patient flow system using both spatial and non-spatial measures of separation. It forecasts the effects of health care financing reform and hospital closure on patient flows in an urban hospital market. Sá et al. (2004) identify the drivers of regional demand for higher education in The Netherlands by combining cross-sectional data on the region of origin of the high school graduate and the university destination region for first-year students in a production constrained gravity model. The results reveal that the behavior of prospective students is determined by a distance deterrence effect and a downward rent effect along with regional and urban amenities.

The gravity model has also been applied to assess stock market behavior. Flavin et al. (2002) reveal that geographical variables matter when examining equity market linkages. The number of overlapping opening hours and sharing a common border tend to increase cross-country stock market correlations.

Although there are applications of the gravity model in various areas of the economics literature, the focus of this paper, however, is to present a comprehensive survey of recent developments in econometric gravity modeling and its applications to trade flow analyses. However, the development and application of the gravity model to assess trade flows can be classified into the following four broad themes:

i. *Generalized gravity model*. This type of model explains bilateral trade flows based on the economic size (often using GDP measurements) and distance between two geographical units. It is based on a set of general equilibrium models (*e.g.*, Anderson, 1979; Anderson and van Wincoop, 2003) that derive specific inferences for bilateral trade. This model has been used to analyze the determinants of bilateral trade flows, such as common borders, common languages, common legal systems, common currencies, and common colonial legacies.
ii. *Intra-industry trade*. This type of model suggests that bilateral trade flows can be used to comprehend the trade flow in monopolistically competitive markets. The Heckscher–Ohlin–Samuelson (HOS) model and Linder hypothesis have been used in several studies (*e.g.*, Bergstrand, 1990; Helpman and Krugman, 1985; Helpman, 1987), while others show that the ratio of bilateral trade to the product of trading partners' income is increasing along the extent of specialization and the intensity of intra-industry trade.
iii. *Homogeneous and heterogeneous products*: Gravity equations are developed for both homogeneous and heterogeneous goods and preferences, along with complete and incomplete specializations. Several studies (*e.g.*, Feenstra et al., 1998, 2001; Melitz, 2003; Chaney, 2008; Melitz and Ottaviano, 2008) derive gravity equations for product differentiation stemming from differences in factor endowment and the effect of preferences, distance, price, and tariffs. Trade models with heterogeneous firms have indicated varied levels of productivity depending on their draws from a Pareto distribution. Heterogeneous firms are also exposed to the sunk costs of market entry, as explained by Helpman et al. (2008).