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Econometric Analysis of European Food and Agricultural Trade in a Liberalized and Integrating Global Economy

Insights from Gravity, PTM and Survival Models

Heiko Dreyer

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Justus Liebig University Giessen
Institute of Agricultural Policy and Market Research

Econometric Analysis of European Food and Agricultural Trade in a Liberalized and Integrating Global Economy

Insights from Gravity, PTM and Survival Models

Inaugural Dissertation to obtain the Doctoral Degree (Dr. agr.)
at the Faculty of Agricultural Sciences, Nutritional Sciences and Environmental Management

Submitted by

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Gießen, 2016

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Gießen, im Februar 2016 Heiko Dreyer

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1 Introduction

As indicated by the high level of food prices and volatility thereof (see e.g. Chavas, Hummels and Wright 2014), the international food and agricultural trade has been characterized by increasing uncertainty in recent years. Macroeconomic fluctuations seem to affect food and agricultural markets more strongly than in the past. Developments of these markets are nowadays more closely connected to developments in energy markets. Additionally, the liberalization of agricultural policy, especially in industrialized countries, and the integration of world markets expose actors on domestic as well as on foreign markets to increased exchange rate and price fluctuations. This thesis investigates the determinants of food and agricultural trade flows of European countries using various econometric approaches. Where each of the chapters focuses on a particular issue, the overall topic of the first part of this thesis is to identify by what means the trend towards general liberalization and especially European integration has affected the amount of bilateral trade. Moreover, in the second part the thesis investigates the strategic pricing behavior of European producers in a liberalized global economy and elaborates how this behavior effects trade flows. Following this introduction the thesis is structured into six chapters and a chapter containing overall conclusions. Each of the six chapters might stand for its own. For example, all the chapters contain a separate introduction, consideration of the chapter in the context of the literature and a discussion. Enthusiasts who read through the whole thesis might notice some doubling between chapters, e.g. in the explanation of econometric models or data and might prefer to skip some sub-chapters. For an overview the text below introduces each section separately.

A frequently used method to investigate determinants of international trade flows is the gravity equation. Since its introduction and first applications in trade analysis by Jan Tinbergen in the early 1960s, the gravity equation became the most prominent tool in the analysis of trade flows and is nowadays often called the ‘workhorse’ of trade analysis. Particularly in the new millennium, the gravity equation regained the interest of researchers as it is widely applicable to questions of international trade. This renewed interest was initiated by theoretical work of Alan V. Deardorff (1998) published in the influential book edited by Jeffrey A. Frankel called ‘The Regionalization of the World Economy’. Moreover, the joint work of James E. Anderson and Eric van Wincoop (2003) as well as empirical applications of Andrew K. Rose (2000) on the question whether using a common currency increases two countries’ bilateral trade fostered the dissemination of the gravity equation in economics. Following on from this introduction, **Chapter** 2 gives a literature based overview on the basics of the gravity model. The chapter starts with the origins and the theoretical foundations

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of the gravity equation followed by a closer look at today's nowadays most popular theoretical foundation introduced by Anderson and van Wincoop (2003). Afterwards, more practical hints for the preparation of data and estimation of the gravity equation are compiled. The last sub-section provides a comprehensive overview on applications of the gravity model. The focus here is on aspects of political and economic integration as it is the subject of investigation in Chapter 3.

In the past as well as the present, the agricultural sector is strongly affected by political trade-related interventions such as tariffs or non-tariff trade barriers. Thus, general market liberalization and integration of markets such as the foundation of the EU is expected to have a considerable influence on agricultural trade. With the foundation and expansion of the European Union, a large single European market has been created. "[The] Economic and monetary union (EMU) is the result of progressive economic integration in the EU. It is an expansion of the EU single market, with common product regulations and free movement of goods, capital, labour and services. A common currency, the euro, has been introduced in the eurozone, which currently comprises 19 EU Member States (European Parliament 2015 Chapter 4.1.1)". This integration of markets is supposed to strongly affect food and agricultural trade flows as trade costs decrease with the steps of integration. Some examples of a reduction in trade costs within the EU are the elimination of tariffs and non-tariff trade barriers and establishing of common rules and standards. As a significant and most recent step, European integration was fostered by the introduction of the Euro in 1999. The related elimination of transaction costs (e.g. omission of currency exchange, a greater price transparency, elimination of exchange rate volatility/risk) should have led to a further decrease in trade costs and, hence, a further increase in trade. The reduction in trade costs within the EU has a direct reducing effect of import and export price and, hence, has a direct trade-increasing effect. Additionally, the European integration has a trade-redirecting effect due to discrimination against non-member countries. This indirect effect occurs because trade between member states becomes favorable compared to trade with non-member countries.

Chapter 3 empirically investigates the determinants of European food and agricultural trade flows in a gravity approach. It focuses on and emphasizes the relevance of the (European) market integration and liberalization, particularly on the foundation and extension of the EU and the Euro zone, and the effect of free trade agreements. Although the gravity equation was often applied to analyze food and agricultural trade flows (see Chapter 2 for a discussion) comprehensive results that compare among European countries are not yet available. In the recent political and economic discussion it is often stated that some countries

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benefit more from the European market integration than the others. This contribution also provides results on the differences of the trade-increasing effect across the EU-27 members. Additionally, the chapter complements existing literature by assessing the role of the duration of trading partners' common membership in the EU and Euro zone and investigates the timing effect of the European integration steps. This has not yet been done for food and agricultural trade.

Chapter 4 departs from the effects of economic integration and deals with another aspect that has not yet gained enough attention in food and agricultural trade analysis. In the traditional interpretation of the gravity model, distance between two countries is used as a proxy to measure transport costs. In Chapter 4 it is argued that distance in agricultural trade reflects more than transport costs. Countries are characterized by different growing conditions that act like differences in resource endowment. The more distant two countries are, the more different the growing conditions and the higher trade flows are between those countries. The gravity model introduced in the previous sections is enhanced by different variables capturing differences in growing conditions and is then estimated for an annual panel of trade flows of different product groups and levels of product aggregation. We show that the interpretation of the distance coefficient as a pure transport cost effect is misleading, as the related effect of distance is underestimated if the model does not account for differences in growing conditions. We solve the puzzle about agricultural goods being hardly affected by distance despite not being very worthy of transport. Moreover, we contribute to the discussion on the "death of distance" and show that distance elasticities for total and agricultural trade have converged over time.

Strategic pricing behavior of European producers and its effects on food and agricultural trade flows is of special concern in Chapters 5 and 6. Until this point in time, nearly the entire previous gravity literature has ignored exchange rates on the assumption that exchange rates are neutral in a static trade model setting. Moreover, gravity and pricing to market (PTM) models have been used to elaborate determinants of bilateral trade and export pricing for different countries and branches. Typically, only one of the two methods was chosen. **Chapter** 5 shows in a stepwise approach that a combination of both methods yields novel results on the determinants of exports and export pricing behavior. This section follows recent advances in the specification of the gravity equation of Anderson, Vesselovsky and Yotov (2013, 2014) who argue that in the presence of an incomplete pass-through of exchange rate fluctuations the standard gravity model has to be augmented with an exchange rate variable. For the case of German beer exports, it is shown that structural differences exist between

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markets on which exporters apply either PTM or non-PTM strategies. German beer exporters apply PTM strategies, in particular local-currency stabilization, on those markets where imports are very sensitive to exchange-rate changes. Non-PTM strategies, i.e. full exchange-rate transmission, occur on export markets with insensitive reactions. Apart from PTM strategies, German beer exports are strongly dependent on policy variables such as the introduction of the Euro and the partner country's membership in the EU.

Chapter 6 is an extension of Chapter 5 and additionally considers non-linear PTM effects in gravity equations. As argued in Chapter 5, in the presence of an incomplete pass-through the standard gravity model has to be augmented with an exchange rate variable. Since symmetry of pass-through has been questioned in recent empirical studies (e.g. Bussière 2013, Fedoseeva 2013) due to strategic pricing on international markets, this section argues that this asymmetric impact of the exchange rate on trade should be explicitly modeled within the gravity framework. This chapter is the first attempt to call attention to the fact that not only does exchange rate have to be included as a prominent part of a gravity model, but also the asymmetric impact of exchange rate changes needs to be considered. In this chapter, a way to integrate individual (asymmetric) long-run effects of currency appreciations and depreciations on trade flows into the gravity model is proposed. The approach is empirically tested for German beer exports. Decomposing the exchange rate in its negative and positive partial sums allows us to show that the impact of the exchange rate on exports is not similar in equations with export values and quantities used as dependent variables.

Trade literature has produced a multitude of models and insights to answer empirical research questions and to derive policy implications ranging from whether trade occurs or not, how much trade occurs, and what factors influence the general and more specific patterns of trade on the intensive margin (Helpman, Melitz and Rubinstein 2008). In contrast, the stability of trade on the extensive margin, particularly for commodity dependent exporters, has largely been neglected in the literature. As the cost of establishing new trade relationships can be prohibitive, the successful "maintenance" of existing trade – its survival over the long-term – can be rated crucial for successful commodity exporters and importers. The dynamics of trade on the extensive margin, whether trade flows survive or die is the focus of the still very young trade duration literature in economics that can be traced back to the seminal work by Besedeš and Prusa (2006a, b). **Chapter** 7 explores the trade duration of raw coffee exports into the European Union (EU) market comparing different discrete-time duration models. As coffee is an important export commodity and revenue generator for many developing and least developed economies, successful and long-term trade relationships are essential. Results

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reveal that trade is very short-lived with every second relationship lasting only one month. Major gravity model variables also explain the duration of EU coffee imports. Significant differences in the duration of trade are linked to the quality of coffee. Experience in growth, export and import of coffee turned out to play an outstanding role. Furthermore it is shown that both exporter and importer characteristics are important in explaining variations in trade duration. **Chapter** 8 summarizes the thesis and picks up each chapter's conclusions.

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2 The Gravity Model of International Trade

This chapter provides an overview on the basics of the gravity model[1] starting with the origins and the theoretical foundations of the gravity equation (GE) followed by a closer look at today's most popular theoretical foundation done by the seminal work Anderson and van Wincoop (2003). Afterwards, practical hints for preparing the data and estimating the GE are compiled. The last sub-chapter provides a comprehensive overview on applications of the gravity model. One focus here is on aspects of political and economic integration as it is subject of investigation in Chapter 3.

As the GE has a tradition of more than 50 years, introductions to the GE have often been written by several authors. Some of these authors are Head and Meyer (2014), Baldwin and Taglioni (2006), De Benedictis and Taglioni (2011), van Bergeijk and Brakman (2010), Head (2003) and Fratianni (2008).[2] All of them were very helpful while writing this chapter. Each of these authors concentrates on different aspects and explanations vary in the degree of detail. The intention is basically the same – as in this chapter: Introduce the reader to the GE and prevent her from making mistakes when working with the model. The reader may prefer another of these authors when working on the principles of the GE. I tried to compile the most important basics as concisely as possible without omitting relevant aspects. At some points this introduction goes deeper into detail, e.g. in Chapter 2.2.4 where exchange rate effects are introduced. However, this part might help the reader in understanding later chapters of the book.

2.1 Origins of the gravity model

The gravity model is often called the 'workhorse of trade analyses'. It is regularly used to estimate the impact of different factors on international and even intra-national trade flows. The gravity model became the workhorse of trade analysis due to its versatile application possibilities and nearly infinite number of includable variables that capture trade-hampering or trade-facilitating arguments. It is regularly used to estimate the impact of e.g., free trade agreements, tariffs, currency unions, exchange rate volatility, common languages, land borders – known as 'border effect' (McCallum 1995) – and a common religion of two countries. These arguments can be broadly summarized as political, ethological and geographical characteristics of the trading partners. According to Baldwin and Taglioni (2006: 1) the GE's popularity rests on three pillars. "First, international trade flows are a key element

[1] The terms gravity model (GM) and gravity equation (GE) are used interchangeably throughout this study.
[2] The studies are in order of author's preference.

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in all manner of economic relationships, so there is a demand for knowing what normal trade flows should be. Second, the data necessary to estimate it are now easily accessible to all researchers. Third, a number of high profile papers have established the gravity models respectability (e.g. McCallum 1995, Frankel 1997, Rose 2000) and establish a set of standard practices that are used to address the ad hoc empirical choices that face any empirical researcher." A further reason is that the gravity equation fits well to data of international trade. It exhibits a high explanatory power reaching regularly up to 80 % of the variation in trade flows.

2.1.1 Transferring Newton's law to economics

The GE is based on Newton's law of Universal Gravitation known from physics. Newton's law of 1687 states that any two bodies in the universe attract each other with a force (*F*) that is directly proportional to the product of their masses (*m*) and inversely proportional to the square of the distance (*r*) between them. The force *F* is proportional to the gravitational constant *G*:

$$F = G\frac{m_1 * m_2}{r^2}. \tag{2.1}$$

The gravity equation was first applied to trade analysis by Jan Tinbergen (1962) and its group at the Nederlands Economisch Instituut. The Finnish economists Pöyhönen (1963) and Pullianen (1963) worked on the same topics at the same time. The text book of Linnemann (1966), who was a follower and PhD student of Jan Tinbergen, became a standard reference to early versions of the gravity equation. In its first and easiest transferred version to explain trade, the two masses are referred to as countries and the force between the countries are bilateral trade flows (*T*). The (economic) mass (*m*) of these countries is measured by the GDP.

$$T = \frac{GDP_1 * GDP_2}{r^2}. \tag{2.2}$$

While distance is interpreted as a proxy for transport costs and, thus, is supposed to have a negative influence on trade flows, larger economies are supposed to trade more. Moreover, economic growth, i.e. growth of the GDP, is supposed to have a positive effect on trade.

The GE has not exclusively been used to explain trade flows. Probably the first application of the gravity model outside physics was the usage of the model to explain migration by Ernst G. Ravenstein (1885). More recent application to migration include Rodrique, Comtois and Slack (2006) or Helliwell (1997). Other applications closer to the field of economics and trade include Portes and Rey (1998, 2005) who use a gravity equation to explain bilateral equity

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flows. Several authors, including Head and Ries (2008), Gast (2006), Brenton, Di Mauro and Lucke (1999) and Eaton and Tamura (1994) apply the gravity equation to FDI flows. Okawa and van Wincoop (2012) provide the theoretical framework to consider asset holdings by the means of the GE. Head, Mayer and Ries (2009) apply the GE to trade in service and find that distance costs are also large for offshoring threat. Arkolakis, Costinot and Rodriguez-Clare (2012) show that is possible to calculate welfare gains from trade within a gravity framework.

2.1.2 A brief history of micro-foundations of the gravity equation

The first applications of the GE on trade flows were intuitively and empirically motivated without a sound micro-founded theoretical base. Tinbergen (1962) only provides a common sense explanation in the manner that trade is determined by supply potential (measured by exporter's GDP), market demand potential (importer's GDP) and transportation cost (distance). Linnemann (1966) tries to deliver a foundation of the GE in the light of a quasi-Walrasian general equilibrium system. According to Deardorff (1989), Linnemann's model turned out to include too many explanatory variables to be reduced to the GE. Leamer and Stern (1970) pick up these first attempts and provide three different approaches to discuss the GE in the light of economic theory.[3] According to Baldwin and Taglioni (2006: 1) the best of these foundations is based on the so-called 'potluck assumption'. "Nations produce their goods and throw them all into a pot; then each nation draws its consumption out of the pot in proportion to its income. The expected value of nation-i's consumption produced by nation-j will equal the product of nation-i's share of world GDP times nation-j's share of world GDP. In this way, bilateral trade is proportional the product of the GDP shares."

Perhaps the lack of a sound theoretical foundation was the reason why the gravity equation appeared in a disgraceful light in the 1970s and 80s. For example Deardorff (1984: 503) states that the gravity equation has a "somewhat doubtful theoretical heritage". However, the empirical success was overwhelming[4], letting economists start to search for theoretical explanations. Because of this, the situation has changed dramatically since the 1980s. Around 15 years after his statement on the doubtful heritage, Deardorff (1998: 21) concludes "First, it is not all that difficult to justify even simple forms of the gravity equation from standard trade theories. Second, because the gravity equation appears to characterize a large class of models, its use for empirical tests of any of them is suspect." Frankel, Stein and Wei (1997: 53) state that "The equation has […] gone from an embarrassing poverty of theoretical foundations to

[3] According to van Bergeijk and Brakman (2010), Leamer and Stern (1970) were the first to explicitly refer to the work of Tinbergen and Linnemann as 'gravity models'.
[4] Anderson (1979) starts his article with sentence "Probably the most successful empirical trade device of the last twenty-five years is the gravity equation."

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an embarrassment of riches!" Today, the GE was derived from a wide range of models of international trade.[5] The span of models reaches from classical trade theories such as comparative-advantage and factor-endowment theories (Heckscher-Ohlin models) to more recent models including the 'new trade theory' models as well as models of heterogeneous firms. Generally, demand-side as well as supply-side derivations prevail.

James E. Anderson (1979) provides the first clear, micro-founded derivation of the GE (see Chapter 2.2). Andersons derivation is based on a model of complete specialization and uses "…properties of expenditure systems with a maintained hypothesis of identical homothetic preferences across regions. Products are differentiated by place of origin […]." Nowadays the assumption that products are differentiated by countries is known as the 'Armington assumption'. Moreover, he uses the assumption of Cobb-Douglass preferences and constant-elasticity-of-substitution (CES).

It was Jeffrey E. Bergstrand who provided in a series of papers a connection between the 'old' trade theories and the gravity equation. Bergstrand (1985) is the earliest derivation that is based on monopolistic competition (Dixit and Stiglitz 1977). Moreover, Bergstrand managed to connect the GE with the factor endowment theory. In Bergstrand (1989) and (1990) the author incorporated the one-sector monopolistically competition model of Krugman (1979). In this derivation monopolistic competition, i.e. product differentiation among firms rather than countries, is assumed. The model was embedded in a model with sectors that are characterized by different factor proportions. This makes his model what Deardorff (1989: 10) calls a "[…] hybrid of the perfectly competitive HO model and the one-sector monopolistically competitive model […]". Evenett and Keller (2002) provide a further hybrid model of factor proportions and product differentiation.

Especially the emergence of the 'new trade theory' originated by Paul Krugman (1979) and Elhanan Helpman (1981) and their joint work (Helpman and Krugman 1985: Chapter 8) lead to an increase of the theoretical work that found the GE in microeconomics. Based on the joint work with Krugman, Helpman (1987) develops a GE that addresses intra-industry trade. Bergstrand (1990) also picks up the framework of intra-industry trade in the gravity framework.

Deardorff (1998) provides the first derivation of the GE directly based on a Heckscher-Ohlin model of international trade in the case of frictionless and impeded trade. By doing so, the author proves that the GE also works in a world of neoclassical trade models. Haveman

[5] A detailed explanation of the different derivations of the GE is beyond the scope of this study. Head and Mayer (2013), Deardorff (1998) and Fratianni (2008) explore derivations in a subsuming manner.

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and Hummels (2004) provide a model of incomplete specialization and trading costs. Eaton and Kortum (2002) consider the GE in the supply-driven framework of Ricardian trade.

A most recent development in the theoretical foundation of the GE is the convergence of the theoretical as well as empirical gravity studies with the 'heterogeneous firms' literature. The heterogeneous firms literature was spearheaded by Bernard et al. (2003) and Melitz (2003)[6]. Contrary to what is implied in monopolistic competition models, not all firms participate in international trade and not all firms export to every foreign market. According to Bernard et al. (2003), Bernard et al. (2007) and Melitz (2003), heterogeneity in firm behavior is caused by (market-specific) fixed entry costs that are especially high for foreign markets. Only productive firms are able to deal with the costs of market entry and, thus, only these firms export. Moreover, from these studies it is known that firm productivity is positively correlated to size, innovativeness and the intensity of human and physical capital.

The seminal work of Chaney (2008), Helpman, Melitz and Rubinstein (2008) and Melitz and Ottaviano (2008) united work on heterogeneous firms with the determinants of bilateral trade. With these new considerations the GE became useful to measure the distinction between the intensive and extensive margins of trade[7]. According to Head and Mayer (2014) the new insights have implications on the way GE should be estimated and how the results should be interpreted. One implication is that "… the matrix of bilateral trade flows is not full: many cells have a zero entry. This is the case at the aggregate level and the more often this case is seen, the greater the level of disaggregation" (De Benedictis and Taglioni 2011: 65). The existence of zeros in trade flows has important implication as it may signal a selection problem. As Chaney (2008) and Helpman, Melitz and Rubinstein (2008) note, standard OLS estimates of the GE are inappropriate if the zero trade flows are a result of firms choice not exporting specific goods to a specific market. We will discuss these data and estimation-related issues in Chapter 2.3. However, exploring the growth of agricultural trade in the extensive and extensive margin is for the most parts beyond the scope of this thesis.

2.2 The Anderson and van Wincoop (2003) gravity model

Nowadays the most popular and frequently used derivation is Anderson and van Wincoop (2003). The basic theory of this derivation is quite similar to Anderson (1979) but the value added is large as it provides a practical way of using the full expenditure system to estimate

[6] For an overview see Melitz and Redding (2014).

[7] The term trade growth at the 'intensive margin' means that an already existing bilateral trading relationship increases through time. If trade increases due to a newly established relationship between countries that have not traded with each other in the past, it increases at the so-called extensive margin. For a discussion on the extensive and intensive margin of world trade see e.g. Felbermayr and Kohler (2007).

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key parameters on cross-section data (Baldwin and Taglioni 2006). The theory in the study shows clearly that the gravity equation can be expressed by an expenditure equation with an imposed market-clearing condition. This theory also explains why the empirical estimations of the GE fit the data so well, as expenditure equations explain expenditure patterns rather well, and as markets generally do clear (Baldwin and Taglioni 2006). However, it also shows that the GM can be seen not as an economic model in the usual sense but as a regression of endogenous on endogenous variables (Baldwin and Taglioni 2006).

2.2.1 A derivation in seven steps

The Anderson and van Wincoop derivation of the GE from an expenditure system can be explained in seven steps.[8]

Step 1: The expenditure share identity

$$p_{od}x_{od} \equiv share_{od}E_d \, , \qquad (2.3)$$

where x_{od} is the quantity of bilateral exports of a single product from the origin country o to the destination country d[9]. p_{od} is the price of the product that the consumer faces inside the importing country, also called the 'landed price'. Thus, $p_{od}x_{od}$ is the value of the trade flow measured in terms of the numeraire. E_d is the destination country's expenditure on goods that compete with imports, i.e. tradable goods. *Share*$_{od}$ is share of expenditure in country d on a typical item made in nation o.

Step 2: The expenditure function

As known from microeconomics, expenditure shares depend on relative prices and income levels (and preferences…). For simplicity, we do not first consider the income elasticity. Assuming a constant elasticity of substitution (CES) demand function and that all goods are traded, the expenditure share of the imported good is linked to its relative prices p_{od}/P_d by:

$$share_{od} \equiv \left(\frac{p_{od}}{P_d}\right)^{1-\sigma} \, , \qquad (2.4)$$

where

$$P_d \equiv \left(\sum_{k=1}^{R} n_k \left(p_{kd}\right)^{1-\sigma}\right)^{1/(1-\sigma)} \, , \quad \sigma > 1 \, . \qquad (2.5)$$

P_d is the destination country's ideal/exact CES price index with the assumption that all goods are traded. R is the number of countries from which country d imports goods (including itself)

[8] The presentation is based on Baldwin and Taglioni (2006) and van Bergeijk and Brakman (2010).

[9] Throughout the whole study we keep the convention of writing country indices as subscripts o and d and putting the source country first and the destination country second. Thus, for example, x_{do} is the quantity of exports from country d to country o.

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and n_k is the number of goods exported from nation k. σ is the elasticity of substitution among all varieties. Symmetry of varieties by source-nation is assumed to avoid the introduction of a variety index.

Inserting Eq. 2.4 in Eq. 2.3 yields in a product specific import expenditure equation. If good data are available this equation could be estimated directly. However, as good data especially on trade prices are rare some more assumption need to be made.

Step 3: Adding the pass-through equation with trade costs

The major elements in all GEs are trade costs (TCs). TCs are easily introduced by a pass-through equation. The landed price in country d of an item produced in country o (p_{od}) is linked to the production costs in country o (p_o), the bilateral markup (μ_{od}) and TCs[10] (τ_{od}):

$$p_{od} = \mu_{od}\, p_o\, \tau_{od}\ . \qquad (2.6)$$

To keep things simple, μ is often assumed to be one and, thus, neglected in the presentation. This is assumption holds true, for example, in Dixit-Stiglitz monopolistic competition or perfect competition with Armington goods. τ reflects all kinds of trade costs, natural and manmade. p_o is the producer price/ mill price in the origin country.

Step 4: Aggregating across individual goods

So far, exports of a single variety were considered. Aggregating across varieties leads to total bilateral exports T_{od}. To get total bilateral exports the expenditure share function is multiplied by the number of symmetric varieties that country o has to offer (n_o):

$$T_{od} = n_o\, share_{od}\, E_d\ . \qquad (2.7)$$

Inserting Eq. 2.4 and Eq. 2.6 in Eq. 2.7 leads after some algebra and with the assumption μ=1 to:

$$T_{od} = n_o\, (p_o\, \tau_{od})^{1-\sigma} \frac{E_d}{P_d{}^{1-\sigma}}\ . \qquad (2.8)$$

Step 5: Using general equilibrium to eliminate nominal prices

As data on the number of varieties n_o and producer price p_o are not available, country o's general equilibrium condition is used to eliminate both of them. The producer price in the exporting country o must adjust so that o can sell all its output, either in the home market or via exports. As Eq. 2.8 describes country o's sales to each market, summing up over all

[10] In trade cost literature this kind of trade costs are sometimes called 'iceberg' trade costs.

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markets results in total sales of country o's goods. All goods are traded and market clears.[11] Hence, total sales to all destinations (including country o itself) equal country o's output Y_o:

$$Y_o = \sum_{d=1}^{R} T_{od} \,. \qquad (2.9)$$

Combining Eq. 2.8 and Eq. 2.9, the market clearing condition for the exporting country o is

$$Y_o = n_o \, p_o{}^{1-\sigma} \sum_{d=1}^{R} \left(\tau_{od}{}^{1-\sigma} \frac{E_d}{P_d{}^{1-\sigma}} \right). \qquad (2.10)$$

Eq. 10 can be rewritten as

$$n_o \, p_o{}^{1-\sigma} = \frac{Y_o}{\Pi_o}, \qquad \text{where} \quad \Pi_o = \sum_{d=1}^{R} \left(\tau_{od}{}^{1-\sigma} \frac{E_d}{P_d{}^{1-\sigma}} \right). \qquad (2.11)$$

Π_o measures what is similar to a kind of market potential in the economic geography literature. A country's market potential is often measured by the sum of its trade partners' real GDPs divided (weighted) by the bilateral distance. In more general terms, Π represents the average of all importers' market demand weighted by the TCs. Π can also be referred to as country's 'openness', since it measures the openness of its exports to the world markets. Head and Mayer (2014) and Helpman, Melitz and Rubinstein (2008) name Π 'market potential' and Anderson and van Wincoop originally call it 'market openness'.

Step 6: A first-pass gravity equation

Substituting Eq. 2.11 into Eq. 2.8 results in the first-pass gravity equation:

$$T_{od} = \tau_{od}{}^{1-\sigma} \left(\frac{Y_o \, E_d}{\Pi_o \, P_d{}^{1-\sigma}} \right) = Y_o \, E_d \left(\frac{\tau_{od}}{\Pi_o P_d} \right)^{1-\sigma} \qquad (2.12)$$

This micro-founded GE is identical to Anderson and van Wincoop's (2003) expression 9 and has become the standard formulation in applications of the GE.[12] The main difference of Eq. 2.12 compared to the historical/initial GE adopted from Newton's Law of Universal Gravitation is the introduction of the price terms Π_o and P_d. They are the so-called 'multilateral resistance' terms. Intuitively, multilateral resistance captures the fact that bilateral trade between two countries does not only depend on bilateral variables related to these two countries, but also on the countries' position relative to the world economy. Two states that are (geographically) close to each other but isolated from other large markets would, *ceteris paribus,* trade more with each other than two states that are similar close to

[11] Note that this requires adjustment of country o's wages and prices.

[12] Anderson and van Wincoop (2003) use symbol y to indicate expenditures and they multiply and divide by world income/expenditure once in the expression and once in their definition of Π.

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each other but lie within a large market. The latter pair of countries faces tougher competition from other nearby countries, both on the supply and the demand side. As an example trade between two countries of the EU, e.g. Spain and Poland is, *ceteris paribus*, smaller than trade between Australia and New Zealand that are more isolated and that face higher multilateral resistance (Π_o and P_d). The multilateral resistance term are sometimes called 'relative-prices-matter terms'.[13]

Taking the GDP of country *o* as a proxy for its production of (traded) goods and *d*'s GDP as a proxy for its expenditures on traded goods and ignoring the multilateral resistance would lead to an equation looking very similar to Newton's Law of Universal Gravitation.

Step 7: Solving the multilateral resistance terms

However, Eq. 2.12 is not the final expression of Anderson and van Wincoop (2003). The authors use their method for cross-section data. Thus, in their last step Anderson and van Wincoop are allowed to assert that $\Pi_i = {P_i}^{1-\sigma}$ for all nations. The definition of the price index then yields

$$\Pi_o = \sum_k {\tau_{ok}}^{1-\sigma} \frac{Y_k}{\Delta_k} \qquad \Delta_o = \sum_k {\tau_{ko}}^{1-\sigma} \frac{Y_k}{\Pi_k} \qquad \forall\ o = 1, \ldots R \qquad (2.13)$$

Any set of Π and $P^{1-\sigma}$ that solves this set of equations must be proportional. According to Baldwin and Taglioni (2006: 5) "[t]his proportionality is obviously correct and indeed intuitively obvious. Since Π[14] measures the openness of the world to a nation's exports and $P^{1-\sigma}$ measures the openness of a nation to imports from the world, these two will be related when all bilateral trade costs are symmetric. If nation-*o* finds itself located in a place that has good market access (which makes exporting easy), then it will automatically be in place where foreign exports find it easy to sell into nation-*o*." However, since this method is used for panel data, trade costs are varying and the assumption $\Pi_\mathrm{i} = {P_i}^{1-\sigma}$ does not hold at all (Baldwin and Taglioni 2006). Hence, the last step is only valid for cross-section data.

Anderson and van Wincoop (2003) introduce a further very strong simplification: symmetry of trade costs, i.e. $\tau_{od} = \tau_{do}$. This critical assumption is necessary to solve the problem of circular dependency. However, by making these assumptions, Anderson and van Wincoop are able to solve for the multilateral resistance terms in specialized customized nonlinear least square programming. Their model simplifies to a system of K^2 equations in

[13] Note that these terms do not exclusively emerge in the Anderson and van Wincoop derivation. Price indices also occur e.g. in Bergstrand (1985). In this study GDP deflators are used to capture the price indices. Feenstra (2004) notes that that earlier GEs assumed identical prices across countries. Once transport costs or other components of border-related trade costs are introduced, prices must differ between countries. This makes it necessary to account for overall prices indices in all countries.

[14] Baldwin and Taglioni (2006) indicate price terms with Ω instead of Π.

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$K(K-1)$ endogenous trade flows and K endogenous price terms (P). However, according to Feenstra (2004), the requirement of custom programming is an important drawback.

2.2.2 Omitted variables and omission of the multilateral resistance terms

There will always be omitted variables in the regression as bilateral TCs are determined by a nearly infinite number of factors ranging from personal relationships among business leaders that were developed as school children on cultural exchange programs to convenient flight schedules (Baldwin and Taglioni 2006). The problem of omitted variables will become larger the more disaggregated and heterogeneous the products and countries under investigation are. However, this is not a problem and will not cause biases of the estimated coefficients unless the omitted variables are correlated with the included explanatory variables. Indeed, Baldwin and Taglioni (2006) state that the omitted multilateral resistance terms are correlated with trade costs since τ_{od} enters Π_o and P_d directly.

A crucial example in this context is that the formations of economic integration areas and currency unions are not at all random but rather driven by many factors. If these factors are omitted in the regression and positively correlated with e.g. the currency-union variable, the estimated trade impact of the currency union will be upward biased, too. Additionally, Baldwin (2005) claims the point whether currency unions are the reason for higher trade or whether currency unions are created due to a strong linkage of countries. Are these unions the reason for or the result of increased trade? If nations, that are idiosyncratically open, are more likely to engage in pro-trade policies, e.g. in the foundation of currency unions or free trade agreements, there will be a positive correlation between CUs and relative-prices-matter term. Thus, the trade-facilitating effect of CUs is upward biased. Generally speaking, neglecting the multilateral resistance terms lead to upward biased coefficients (Rudolph 2011; Baier and Bergstrand 2009a).

2.2.3 Solutions of the multilateral resistance and omitted variables problem

Since the problem of omitted multilateral resistance terms has been spread by Anderson and van Wincoop (2003) some attempts have been made to deal with it. The first approach is to proxy multilateral resistance with so-called remoteness terms. Control variables for remoteness had already been part of gravity studies (e.g. Frankel 1997, Wei 1996) prior to the work of Anderson and van Wincoop (2003). Remoteness (*REM*) is typically defined as GDP-weighted averages of a country's distance (*Dist*) from all of its trading partners *d*:

$$REM_o = \sum_d \frac{Dist_{od}}{Y_d} . \qquad (2.14)$$

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