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Is gravity constant?

An investigation into key variables of the gravity equation of international trade.

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Abstract

The gravity equation has been a successful model in explaining international trade between nations. This paper aims to explore the behavior of the key variables across time. With a dataset consisting out of 41 countries and 31 years we find evidence that the coefficients of most variables have changed over time. Among others, we find that the negative distance parameter on trade has increased over time, and that a common language is decreasingly a relevant factor for exports.

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1. Introduction

The gravity equation has an excellent record in estimating trade flows between nations. It is remarkable that only the economic size of two nations and the distance between them explain more than 70% of the variation in trade. After the first mentioning of the gravity equation by Dutch Nobel laureate Jan Tinbergen (1964) the academic curiosity on this phenomenon, as well as the possibility to explore other influences on trade flows, has produced a wide range of literature on the workings of the gravity equation. Not only applicable in the area of international trade, but also in the fields of foreign direct investments and migration patterns. In these efforts, many variables have been investigated in having a possible effect on trade flows between nations. However, in the literature the possibility that the impact of the variables on trade could be different across time is often unreported.

In our paper we investigate several key variables in the gravity equation that regularly appear in the literature and explore their behavior over time. We expect that the effect of some of the variables will change over time, as advancements in technology or just the passing of time reduces the impact on trade. For example, it is plausible that because of the popularity of the English language in business, economics, but also pop culture, the official language of a country becomes less relevant in international trade. We explore these hypotheses using a balanced dataset consisting of 41 countries and 31 time periods, resulting in more than 40.000 observations. In our methodology we use two types of models to assess whether coefficients have changed over time.

We find evidence that the variables in standard gravity equations do have a different effect on international trade across different periods. Moreover, there is evidence that the negative influence of geographical distance on trade is increasing over time, against expectations in the literature. Furthermore, there is strong evidence that the effect of using identical languages in international trade is becoming less relevant.

In the next section we will introduce a theoretical framework that supports the gravity equation before we discuss the empirical literature on some of the key variables commonly used in gravity equation models. The third section will contain two sets of hypotheses that will be subject to tests we specify in the fourth section as well as the data we employ. Finally, we discuss the results and conclude by discussing our findings and the limitations of this paper.

2. Literature review

2.1 Introduction

The literature on the gravity equation can be roughly divided into two streams, one that focuses on the theoretical model, and one empirical stream. The former focuses on the underlying economic model that drives the gravity equation. A theoretical foundation provides the support and academic credibility for further empirical findings and economic policies derived from the gravity equation. The latter stream of research uses the gravity equation as a tool to explore the impact of particular forces on flows of goods, services, foreign direct investment or migration. In this section we will discuss both streams of literature and include a more elaborate discussion on the key variables that frequently appear in gravity estimations.

2.1.1 Origins

In his survey of several international economic policy topics, Nobel Prize winner Jan Tinbergen is the first to report and describe the gravity equation (Tinbergen, 1962). By combining the economic mass of both countries and the geographical distance from one another, the equation explains a large part of the variability in international trade volumes. Using a small dataset he finds supportive evidence that the gravity equation has a surprisingly high fit. Moreover, they find that additional variables that could affect trade, such as trade agreements, significantly explain part of the variation in trade volumes. It is the discussion and, more importantly, the empirical testing of the gravity equation that made Tinbergen (1962) the 'origin' of the gravity equation in international economics.

Curiously enough, at the same time, and independently from one another, a second paper was published that applied the same method. Poyhonen (1963) writes a similar analysis, incorporating the economic mass of both countries and the physical distance between the two as the main explanatory variables on variations in the bilateral trade volumes. His paper presents comparable empirical results, and together with the Tinbergen paper lies at the base of further research.

The name of the gravity equation is borrowed from physics as it bears a close resemblance to Newton's law of universal gravitation: the force between two masses is proportionate to the product of the mass of the two objects and inversely proportional to the distance between them (Figure 2.1).

Finally, it is worth mentioning that before Tinbergen (1962) Newton's Law of Universal Gravity has been used before beyond the realm of natural physics. To illustrate, Reilly (1931) explores the so-called 'retail gravitation', where two cities will have a share of the trade with a third city which is determined proportionate to each cities size and disproportionate to the distance between them and the third city.

Figure 2.1 - The universal law of universal gravity vs. basic gravity equation

Newton's law of universal gravity:	$F = G\frac{m_1 m_2}{r^2}$
Basic gravity equation:	$EX_{12} = \frac{Y_1 Y_2}{Dist_{12}}$

Note: The left hand side of the equation shows the force (trade) between two objects (countries), the left hand side tells how this is determined by the mass of the two objects (economic size) and the distance between them.

2.2 The Gravity Theory

2.2.1 A historic perspective

The findings by Tinbergen and Poyhonen have led to an increasing interest in the gravity model due to its simplicity and high fit with the observed trade flows. Critics, however, would argue that the gravity equation lacks any theoretical support and therefore not a suitable tool in academic research, nor should its implications be used in the development of economic policy (Anderson, 1979).

Anderson (1979) was one of the early papers that would provide a link between economic theory and the gravity equation to justify its existence in the academic world.[1] The starting point of his argument is loosely based on the well known Heckler-Ohlin (HO) model of factor endowments. Bergstrand (1985, 1989) provides additional support and show that the gravity equation can in theory be derived from variations of the HO models of factor endowments. Moreover, Deardorff (1995) presents additional evidence of a gravity equation derived differently from a Hecksler-Ohlin model. Helpman and Krugman (1985) argue that another international trade model, one of imperfect competition and product differentiation, provides theoretical support for the gravity

[1] Earlier papers including Leamer and Stern (1970) and Leamer (1974) discuss the link between the gravity equation and HO models; Anderson (1979) is the first to show how to do so.

equation. However, Deardorff (1995) states that: "*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.*". This statement proves that the gravity equation has a theoretical foundation from which empirical research could build. In the next section we will present such a theoretical model that has gained much support over time.

2.2.2 Theoretical Framework

In this section I will describe an improved version of the model by Anderson (1979) as is presented in the much cited Anderson and van Wincoop (2003) paper. In this paper they develop an improved theoretical foundation of the gravity equation as it explains what is called the 'Border Puzzle'. The origins of this problem stem from a paper (McCallum, 1995) that found that by estimating the gravity equation the trade between Canadian provinces was significant higher than the trade between US states and Canadian provinces at a factor of 22. This unexpected large border effect has puzzled economists for some time[2]. In response to McCallum (1995), Wei (2000) finds an average border effect of 2.5 after altering the empirical specification. Similarly, Evans (1999) finds effects between 3 and 12, which are still dramatically high.

Anderson and Van Wincoop (2003) improved the estimation approach by applying the theory "*seriously*", which leads to a model that correctly estimates the gravity equation, and a border effect of 20 to 50 percent. A more convincing number compared to the 2200 percent by previous estimates. The improved estimation is an adjusted version of the Anderson (1979) model, but has as a result a more accurate result that allows for empirical testing and hence a useful tool in international economics.

At the heart of the model is the realization that a trading country competes with other countries over trade deals, and therefore it is not only the trade barriers between the two countries that matter, but both their access to the rest of the world matters as well, the so-called 'multilateral resistance terms'. The model starts by assuming that goods are differentiated by their place of origin. Each region will allocate their resources to the production of one particular good in which it specializes. The supply of these goods is considered to be fixed. The second assumption is that of identical and homothetic preferences for all consumers as approximated by a Constant Elasticity of Substitution (CES) utility function. Independent from their income, consumers will consume a

[2] Obstfeld and Rogoff (2001) rank the 'border puzzle' as one of the six major macroeconomic puzzles of that time.

combination of goods at fixed proportions. Given these assumptions, consumers in region *j* will try to maximize their consumption of goods from region *j* and region *I,*(c_{ij}), as formally defined as:

$$\left(\sum_i \beta_i{}^{1/\sigma} c_{ij}^{(\sigma-1)/\sigma}\right)^{\sigma/(\sigma-1)} \tag{2.1}$$

$$\sum_i p_{ij} c_{ij} = y_j \tag{2.2}$$

Where (2.2) is the budget constraint. σ is the elasticity of substitution which indicates how easy consumers will switch between products after changes in relative price; y_j is the income of residents from region *j*; p_{ij} represents the price level of goods from region *I* which are sold in region *j*. The prices differ among regions because of trade costs that are incurred in trading between regions. These trade costs include transport costs, as well as other unobservable cost components. If $p_i$is the export price without trade costs (t_{ij}), the price upon arrival is $p_{ij} = p_i t_{ij}$.

The value of exports from region *i* to region *j* will be the price multiplied by the quantity of goods: $x_{ij} = p_{ij} c_{ij}$. As income in region *i* is derived from the exports of their goods, the national income of region *i* is the sum of all exports:

$$y_i = \sum_j x_{ij} \tag{2.3}$$

The value of x_{ij} depends on the demand for the products produced in region *i*, which is determined by maximizing (2.1) subject to the budget constraint (2.2):

$$x_{ij} = \left(\frac{\beta_i p_i t_{ij}}{P_j}\right)^{(1-\sigma)} y_j \tag{2.4}$$

P is an index for consumer prices in region j, and is defined as follows:

$$P_j = \left[\sum_i \left(\beta_i p_i t_{ij}\right)^{1-\sigma}\right]^{1/(1-\sigma)} \tag{2.5}$$

P_j is considered to be an indicator of trade resistance as it is composed of trade barriers with all the trading partners of region *j*. This means that the strength of the resistance term is expressed relative to other regions; the attractiveness of a region is dependent on the average of other regions.

By substituting (2.4) and (2.5) in to (2.3) we arrive at a new national income function:

$$y_j = \sum_j \left(\frac{\beta_i t_{ij} p_i}{P_j}\right)^{1-\sigma} y_i \tag{2.6}$$

Anderson and Van Wincoop (2003) show that by assuming symmetric trade costs between countries, ($t_{ij} = t_{ji}$), one can arrive at a simplification[3] at which:

$$x_{ij} = \frac{y_i y_j}{y_W}\left(\frac{t_{ij}}{P_j \pi_i}\right)^{1-\sigma}, \tag{2.7}$$

$$\text{where } \pi_i = \left(\sum_j \left(\frac{t_{ij}}{P_j}\right)^{1-\sigma} \theta_j\right)^{1/(1-\sigma)} \tag{2.8}$$

y_W is the aggregate world income, and θ_j is defined as the country income as share of the world income ($\theta_j = y_j / y_W$). Equation (2.7) presents the gravity equation as described earlier; equation (2.8) shows the trade resistance term, which includes distance, competitive prices and the countries world income share. Trade costs enter the equation twice, directly in the numerator of the third term, and indirectly in the trade resistance terms πi and Pj.

This equation will be the base of further analysis of the gravity equation. By taking the logs of (2.7), one arrives at an equation that can be easily adapted to an empirical testable specification:

$$\ln x_{ij} = \ln y_i + \ln y_j - (\sigma - 1)\ln t_{ij} + (\sigma - 1)\ln P_j + (\sigma - 1)\ln \pi_i \tag{2.9}$$

Equation (2.9) is the common representation of the gravity equation in which the relationships between trade flows, economic size, distance and sets of trade resistance variables are expressed.

The theoretical model as described above is a commonly used framework in the empirical literature using gravity models. However, some remarks have to be made regarding the validity and the use of the theory. First, in their well cited paper Anderson and Van Wincoop (2003) discuss the issue of unitary income elasticity's. In their theoretical model, as discussed above, the assumption is that the share of income spent on goods is the same for all goods, both traded and non-traded goods. However, it is very plausible that this is not the case, that the income elasticity's are not unitary. The authors acknowledge this as they point out that the Balassa-Samuelson theory tells that regions with higher productivity of tradable goods will have a relative higher price of non-tradable. This means that this region will spend more on tradable goods. This assumption, however, does simplify the theoretical framework and makes it a useful tool in estimating the gravity equation.

Furthermore, Anderson and van Wincoop (2003) admit that is possible to run into problems regarding the estimation of the multilateral resistance terms, as in equation 2.9. It is possible to run into troubles with a miss-specified estimation, as many of the terms in the multilateral resistance

[3] For the sake of clarity and readability of the text, we decided that the last step of the derivation by Anderson and van Wincoop (2003) is beyond the scope of this paper and it suffices to present the outcome.

terms are unobserved, and might be correlated to the error term. A solution to this problem is to use country fixed effects in the estimation (Rose and Van Wincoop 2001). These dummy variables will control for those characteristics that are specific to the country, circumventing the complex multilateral resistance terms. The use of country fixed effects has become almost a standard procedure in the empirical work, evidenced by its popular use.

Finally, for a more comprehensive discussion on the theoretical framework, Anderson (2010) provides a good overview of the development of the theoretical framework, the current state of affairs, and has suggestions for future research.

2.3. Empirical Literature

2.3.1 Introduction

Since the theoretical foundation laid by Anderson (1979), the gravity equation has become a much used tool to investigate international trade topics in a wide range of models. A great deal of papers has focused on factors that could possibly be having an effect on international trade, and the gravity equation provides an excellent framework to put these educated guesses to the test. For example the finding by McCallum (1995) that national borders have significant large negative effects on international trade is one of the many successful attempts to find additional barriers to trade besides distance. It is worth noting that in his first writing, Tinbergen (1962) already included barriers to trade, such as the common border, but also took the Common Wealth and Benelux countries as trade enhancing factors into account. In the literature a wide range of plausible factors have been investigated, ranging from geographical factors[4], to cultural[5] and institutional factors[6]. From these factors, the literature groups two sets of impediments to trade flows: natural trade costs, and unnatural trade costs (Bergstrand and Egger, 2009). The former relates to costs in trade that are largely due to geographical factors such as being landlocked and transportation distance, the latter refers to those trade costs that are man-made, shaped by political and cultural borders, institutions and more. In this section we will discuss the advancements in empirical testing and focus on the most commonly used variables.

[4] e.g. landlocked, island (Limao and Venables, 2001), (Jansen and Nordas, 2004)
[5] e.g. language, colonial ties (Anderson and Marcouiller, 2002), (Rauch, 1999), (Ku and Zussman, 2010)
[6] e.g. democracy (Yu, 2010); institutional quality (Groot et al., 2003)

2.3.2 Natural trade costs

Geographical Distance

The costs of trading goods over distances between industrialized countries are roughly estimated to a 170% tax (Anderson, van Wincoop 2004). These include border related barriers (44%), retail and wholesale distribution costs (55%), and transportation costs (21%)[7]. The distance parameter in the gravity equation is used as an approximation of the transportation costs of goods. As energy is likely to be the most expensive source of costs in total transportation costs, distance is therefore an excellent approximation of such costs.

The ever increase in international economic integration of markets and countries have lead to a large amount of publications exploring a relative old phenomenon: globalization. The increasing integration of world markets has made some to believe that the geographical distance has become less relevant compared to fifty years ago. In popular publications distance was declared 'death' (Cairncross, 1997), and some argue that globalization has made the world a 'global village' and distances obsolete (Friedman, 2005). The reasoning behind these strong statements was the advances made in transportation and, especially, communication technology. These innovations enabled easy communications and quick and cheap transportation routes to suppliers, partners and customers all over the world.

Coe et al. (2007) explore distance in the gravity equation using non-linear estimates on cross-section and panel data. They find evidence in both approaches that the distance effect is declining. Moreover, Brun et al. (2003) find similar results when expanding the trade cost function by including oil price, infrastructure quality index and differentiate freight costs between primary products and manufacturers. Using this specification they find evidence of a decreased distance effect.

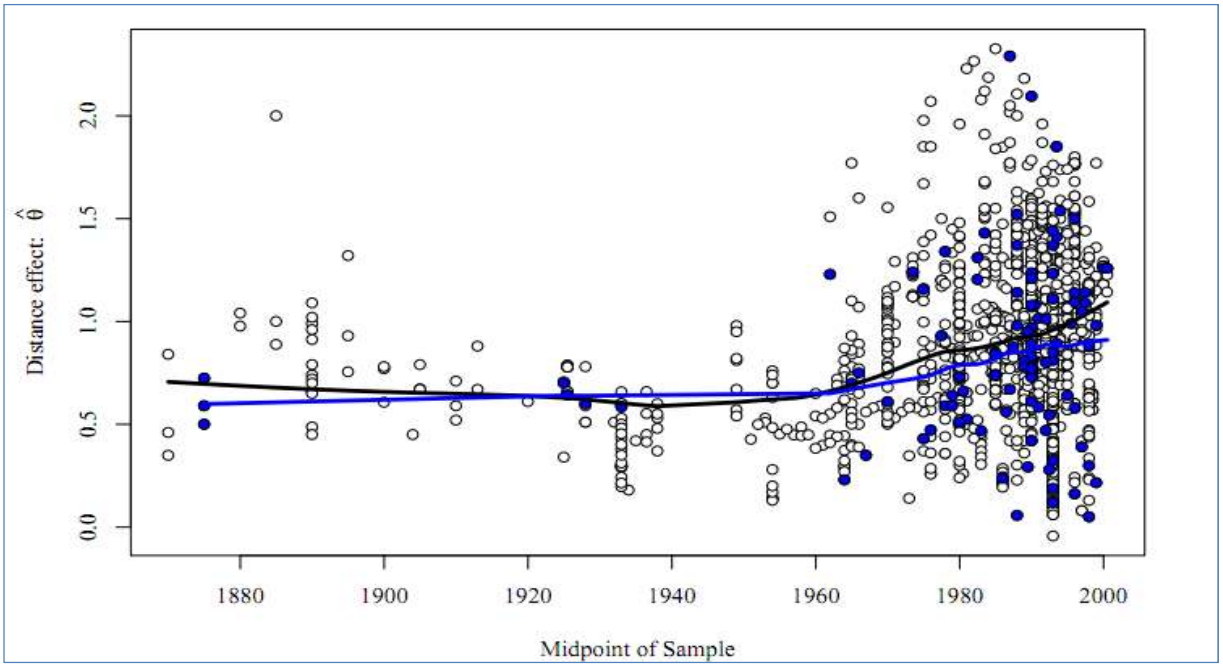
On the other hand, Disdier and Head (2008) examine the distance effect by means of a meta-analysis that examines 1467 distance estimations from 103 papers. They find that the distance parameter has a significant negative effect on trade volumes, and has an average estimated effect of 0.9 (a 10% increase in distance reduces bilateral trade by 9%). Moreover, by analyzing the estimated distance coefficients the authors find that across time the distance effect is slightly increasing when using recent data (figure 2.2). The results suggest that despite technological advances, distance still affects the trade intensity between partners.

[7] 2.7=1.21*1.44*1.55

Similarly, Hummel (2007) find that innovations in transportation have an impact on the aviation and marine transport sector. Trade by planes propelled in the 1970's and 1980's, and has ever increased. The introduction of the container has lead to a revolution in logistics, and trade volumes by ships increased dramatically. However, these innovations did not materialize in the form of significant transport price reductions as increased fuel prices and port congestion costs, among others, offset any gains (Hummel, 2007). They do not find evidence that the distance effect decreases despite advancements in communication and transportation technology.

Moreover, increases in trade volumes can not only be attributed to the innovations in transportation and communication technology, but also by the increasing level of income worldwide. Leamer (2007) explains that the large flows of Asian products to Europe or the US is not due to technological advances, but rather by the economic growth of the Asian countries that allow them to produce these products competitively. Furthermore, he points out that as production chains become more fragmented over the world, companies seeking the most efficient production locations, distance has never been more important[8].

Figure 2.2 – Meta-analysis results on distance coefficient



Source: Head and Disdier (2006)

[8] The location of firms and geography are core to the New Trade Theory and Geographical Economics (See Brakman, Garretsen and Van Marrewijk 2009)

There are several explanations suggested on why distance maintains to play a dominant role as a determinant of trade costs. First, there is a possible overestimation of the technological progress and its effect on trade. Leamer notes that in a transaction trust and understanding are of primary importance, yet there have been no significant improvements in innovations that stimulate trust and understanding over long distances. Internet surfing behavior is extremely biased towards a regions own website and language.[9] Secondly, the factor 'time' has become more important in the complex global supply chains that depend heavily on just-in-time schemes (Hummels, 2001).

All these findings do not point to conclusive evidence that geographical distance has become less important a factor in international trade. Nor is there a commonly shared understanding regarding the trend of the distance effect.

Finally, distance as an approximation of trade costs is a disputable assumption as it does not include other factors associated with distance that still have an impact on the trade costs, e.g. tariffs. Moreover, distance itself is suspect to different types of definitions[10]. Most often the greater circle distances are used as a measurement of distance. However, these do not take in to account geographical obstacles like landmasses, oceans or mountain ranges. By using the shipping routes as an indicator one overcomes previous barriers, yet some countries are landlocked and/or lack efficient roads and harbor infrastructure.

Geographical disadvantages

Remote and/or isolated countries have difficulties participating in the international markets and have therefore a disadvantage in their economic development. Those regions might be difficult to reach because of their large distance from other regions, or because of geographical barriers such as mountain ranges, or because of country borders drawn historically that limits the countries size and/or access to harbors. Countries that are landlocked are reliant on their neighboring countries in having access to the international markets. Imports are therefore dependent on trade routes across land or air. Both are costly alternatives and require excellent contacts with adjacent regions,

[9] Blum and Goldfarb (2005) find that internet surfing behavior of Americans follows a pattern close to the gravity equation; they are more likely to visit websites from regions that are located physically close to the USA relative to more distant regions.

[10] Bosker and Garretsen (2008) discusses the trade costs function used in geographical economics closely related to the theory of the gravity equation.

and put a large 'tax' on import prices. Limao and Venables (2001) report that for 1995 data landlocked countries have an import share in GDP of only 11% and 28% for non-landlocked countries. In addition, they find that landlocked countries experience 50% more transport costs than coastal nations. Moreover, in gravity estimates, the landlocked parameter is found to have a significant negative effect on exports: Rose and van Wincoop (2001) find a coefficient of -.32; Linders et al. (2005) find -0.57 and -0.64 for exporting and importing countries respectively; Rabbaland (2003) reports -0.8; Bosker and Garretsen (2012) find a dramatic effect of -0.84 and -1.25 for exporting and importing countries respectively.

On the other hand, where the absent access to the oceans is a barrier for landlocked countries to access international markets, islands have difficulties in trading due to their remote location with respect to the large markets and their relative small size. Otherwise, one could argue that islands are heavily dependent on trade as domestic production will be very limited to the scarce resources available at the island. The literature does not point to any origin of the use of the island variable, and neither discusses in detail the expected sign of the variable. For example Bosker and Garretsen (2012) find that being an island has a negative effect in terms of trade compared to non-island regions, the island effect is estimated at -0.8 for its exports, and -0.34 for its imports of goods. Linden et al. (2005) find no significant effect, while Ku and Zussman (2010) find a strong positive effect of 2.26.

2.3.3 Unnatural trade costs

Common border

Besides the natural barriers to transport good across regions, there are barriers to trade shaped by the political relations and cultural differences between regions. The most tangible barrier to trade between countries is the borderline that distinguishes the regions from each other, each with its own set of rules and laws and institutions to which the trading companies have to comply. As discussed in the previous section, the border effect between Canada and the US has a significant negative effect on the flow of goods between the countries compared to within-country trade (McCallum 1995) and Anderson and van Wincoop (2002). However, when focusing only on the cross-country trade, two adjacent countries will trade more goods than one would expect based on their close proximity. In the literature Linders (2004) find a positive impact of 70% on trade, while Anderson and Marcouiller (2002) find an effect ranging between 95% and 75% depending on the empirical specification. Oh, Selmier and Lien (2011) find similar strong impacts between 85% and

90%. Because the common border has such strong positive effects on exports between countries, it has become one of the common dummy variables used in the empirical specification. A plausible explanation for such strong effects could lie in the close historical ties between neighboring countries and the familiarity with each other's culture, language, and institutions.

Common Language

Cultural differences between trading partners are identified in the literature as factors that determine bilateral trade. Large differences in culture complicate mutual understanding which is the base of communication and trade. Though culture has many aspects, language is commonly used in the gravity equation literature as a substitute. A common language between countries is expected to foster trade as it allows for better communication and mutual understanding. Though in economics trade is expressed in aggregate volumes or values, one would forget that every transaction is based on the interaction of at least two parties and formulated in contracts, and that export figures are an aggregation of thousands and millions of transactions. Such transactions are the product of communication; a common language will only increase the chance of a successful exchange of knowledge and goods.

English, Spanish, and French have been the predominant languages in the world for several centuries. Especially English has become a *lingua franca* in the business environment. The reason is the large number of English speaking countries that have a large economic and political influence on the world. Moreover, English as a language dominates in popular culture, science and technology. On the other hand, the emerging markets of China and South America have increased the role of Chinese and Spanish in the world of business, reducing the relative importance of English.

Within the gravity equation language has been used in early publications, though we could not identify the original source. In recent research the variable is included with little discussion. The coefficient of a shared language on trade volumes is estimated around 0.3. Anderson and Marcouiller (2002) estimate 0.31; Francois and Manchin (2007) find 0.61 and 0.3, depending on the empirical specification; Linders (2004) finds a coefficient of 0.3.

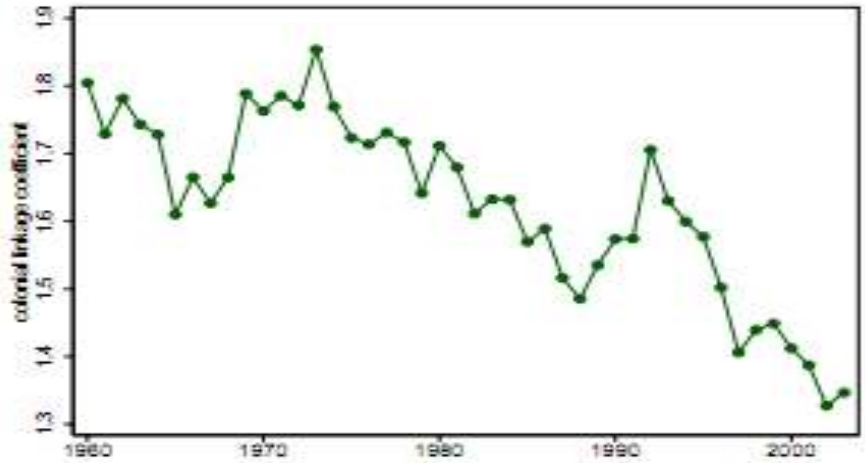
Melitz (2003) explores the impact of a common language on trade flows and differentiates between different languages. In addition, the paper inspects the channels of communication through direct communication, and those based on translation. He finds that indeed a common language in direct communication is very important in international trade. However, communication through

translation contributes to trade as well. This tells us that impact of language goes beyond the ordinary common language variable.

Colonial ties

The twentieth century is characterized by the rise of many new nations, for the most part through independence of former colonies of European countries. Though independent, it is likely that the 'new' countries remain strong relations with their former colonizer, both politically and economically. Such historic relationships could have a positive impact on trade through different channels. Disdier and Mayer (2005) mention the emergence of trade networks prior to the independence that remains intact after the colonization. Moreover, the former colonies are likely to maintain the institutional frameworks that their former colonizers have built. By having similar institutions contracts are more easily drawn and trade between the countries is maintained at high levels.

Figure 2.3: Point estimate ex-colony dummy effect on trade (1960-2003)



Source: Head and Mayer (2011)

Eichenberg and Irwin (1998) investigate the effect of history on trade between countries that have a shared history. They find that countries with a colonial connection trade more, even after independence. However, they find that his effect is diminishing over time. They performed estimates at three different points in time and compared. The low number of observations does not allow, however, for strong conclusions; it is not a sound method to discern any time trends. The estimated effect of colonial ties on trade volumes is estimated in several other papers. The coefficient of the colonial past affects trade positively around 0.45. Head and Mayer (2010) find an

average effect of 0.4; Linders (2004) finds 0.48 to 0.68; Francois and Manchin (2007) find a colonial dummy effect of about 0.37.

Head and Mayer (2011) present a graphical illustration (figure 2) of a time trend of the 'colony' effect for the period of 1960 to 2003. It is clearly visible from the graph that the relationship between former-colony and colonizer is reducing over time. However, as the sample pool includes many countries that all became independent at different times, these observations do not tell the complete story. During the sixties, for example, most of the colonies in Africa under British and French rule became independent, which is the natural starting point of the ex-colony relationship between the two nations. These events are represented in the graph as pikes, as of course trade after the declaration of independence remained high. The increase in the colony effect is therefore the result of an increase in the number of former colonies, rather than a sudden increase in trade between the already existing former colonies. The second spike can be connected to the fall of the Sovjet Union and the consequential formal independence of dozens of nations. Despite this notion, the graph does hint a decreasing trend in the trade volumes between the colonizer and colonized nation. Moreover, in a follow-up paper Head, Mayer and Ries (2010) find that trade between colony and former colonizer has dropped by 65% four decades after independence. In addition, they find that the type of independence, hostile and friendly, have different effects on trade levels, yet the erosion over time is similar.

Economic Integration

The first extension to the three core variables of the gravity equation by Tinbergen (1962) is the addition of variables that measure the effect of trade agreements on trade, in this case the Benelux and Common Wealth membership. In the following decades the effect of economic integration agreements has been studied to a great extent, and the gravity equation has been a popular tool to use. The three most common used variables that measure economic integration are the free trade agreements (fta), being an EU member country and the use of a common currency. All three suggest that by being a member the barriers to trade with respect to rules and tariffs are smaller and enhance the trade between countries. Glick and Rose (2002) for prove of a strong currency effect on trade, Bun et al. (2006) for the euro currency specifically

Bergstrand and Egger (2011) provide an overview of the literature and focus on the recent works that use primarily panel data. The literature finds in general positive effects of economic integration, especially in the European Union, although long lasting effects of that agreement is not always

observed (Baier and Bergstrand, 2007). Moreover, Baier and Bergstrand (2007) find that trade almost doubles 10 years after a trade agreement between two countries.

One of the issues with the use of economic integration variables is that of endogeneity. Countries that trade a lot are likely to form trade agreements, which make it difficult to capture the additional trade stemming from the trade agreement. This leads to a possible overestimation of the trade agreement parameter. A possible tool to overcome this issue is the use of instrumental variables (Baier and Bergstrand, 2002), or in the case of panel data the use of exporter, importer, time and country-pair fixed effects as discussed in Baldwin and Taglioni (2007).

2.4. Concluding remarks

Understanding the relevance of a particular variable on international trade is not an end station per se. An interesting question is to what extent the impact of the variable is constant over time. An interesting question not only from an academic point of view, but from a trade policy perspective as well.

This paper aims to explore the time changing impact the variables might have over time. Although several papers have included time analysis to their results, the discussion is often limited to particular variables. For example Disdier and Head (2008), explore distance; Head, Mayer and Ries (2010) discuss the colonial ties between countries; Brun and Klaassen (2006) on the euro. An exception to this is Coe et al. (2007) that reports despite its focus on distance on other variables as well. We add to that paper an analysis with a different dataset consisting of 41 countries and a long timeframe of 31 years (1980-2010). Moreover we formulate clear hypothesis regarding the expected signs of the variables and their behavior over time. By using a model based on the theoretical framework we introduced in the first section we will able to test these hypotheses.

Before moving on to the next section we would like to point out that the above discussion is limited to the focus of this paper. For an extensive discussion on the gravity model, both theoretical and empirical, we refer to Bergstrand and Egger (2011), who give a most elaborate discussion on the gravity equation, its history, the theoretical developments, the empirical research and its correct use with regard to the correct specification.

3. Hypotheses

3.1. Basic gravity hypotheses

The first logical step in exploring the time-varying variables in the gravity equation is to investigate the expected signs of the coefficients in question, to test the validity of the database against the existing results in the literature. Based on the literature and economic intuition we can formulate hypotheses regarding the most common variables in gravity estimations (figure 3.1). The core variables GDP and distance are expected to have respectively positive and negative effects on the exports between the two countries (H1.1-H1.3), as increases in economic size increases the demand for foreign goods, as well as the supply of goods at more competitive prices. Increases in distance will increase the cost of trading and negatively affect trade. Geographical determinants affect the accessibility of a region negatively when having limited access to seaports (H1.3-landlocked), or when being surrounded by only water (H1.4-island). Common features of two regions are expected to have positive effects on trade as it increases familiarity and thus reduces uncertainty (H1.5-H1.9).

Table 3.1 Hypotheses key variables gravity equation –

	Variable	Expected sign
H1.1	GDP	Positive
H1.2	Distance	Negative
H1.3	Landlocked	Negative
H1.4	Island	Negative
H1.5	Common Border	Positive
H1.6	Common Language	Positive
H1.7	Colonial Ties	Positive
H1.8	Free Trade Agreement	Positive
H1.9	European Union	Positive

In the common application of the gravity equation there is little room for the time-varying effect of the variables on exports. However, it is very plausible that some effects do not have a constant effect on exports over time. For example, the meta-analysis by Head and Disdier (2008) and the study by Head, Mayer and Ries (2010) show that the coefficients vary over time, and show a positive trend for the distance variable, and a decreasing effect for the colonial ties on export flows. In the next subsection we will quickly discuss our hypotheses for each of the variables. Figure 3.2 summarizes.

3.2. Extended hypotheses

For each variable the underlying cause of the changing effect is different, as they affect the barriers to trade differently. However, we can assume that the GDP levels will remain to have a positive effect on trade flows and are unlikely to change over time (H2.1). Distance (H2.2), however, is likely to change over time. As pointed out before, some argue that transportation costs will diminish through innovations in technologies, and innovations in communication technology will make distance obsolete. However, we follow recent findings by, for example, Head and Mayer (2006), that distance will become increasingly important to trade due to the fragmentation of supply chains and increasing wealth in large populated countries.

As for the geographical variables, unless significant developments in the mode of transportation materialize, landlocked countries will continue to be in a disadvantaged position in having access to world markets (H2.3). In addition, the effect of being an island on trade is also unlikely to change over time (H2.4). However, the colonial ties that have shaped global trade flows in the last centuries are likely to diminish over time in the years after independence. Whether they part in conflict or in agreement, it is likely that the connection that bounds a former colony with its former ruler diminishes over time (H2.7). This could be because of changes in culture and institutions, or a changing attitude to each other.

Although it is plausible that cultural differences between former colony and ruler might evolve over time, at the same time cultural differences across the globe could be diminishing as technical improvements in communication and media has made the interaction across borders much easier, and information more accessible. As a consequence, the cultural barrier between countries could diminish and possibly affect trade. Moreover, the wide-spread use of English and Spanish in the world has enabled traders to find possibilities to communicate through languages besides their own. This could mean that the advantage of sharing a common language becomes less pronounced and diminishes over time (2.6). The same holds true for the common border effect. The increased awareness and understanding of faraway cultures, institutions, languages trough further economic and cultural integration could reduce the initial advantage countries have that share borders (2.5).

Table 3.2 Hypotheses key variables gravity

	Variable	Expected trend
H2.1	GDP	Constant
H2.2	Distance	Changing/positive
H2.3	Landlocked	Constant
H2.4	Island	Constant
H2.5	Common Border	Changing/negative
H2.6	Common Language	Changing/negative
H2.7	Colonial Ties	Changing/negative
H2.8	European Union	Changing/positive

The positive effect of being an EU member is possibly increasing as integration effects starts having an impact on trade between member countries. The benefits of the European single market become more pronounced as the single market become more dominant in member countries, a process that will need time. Therefore it is plausible that the EU effects become stronger over time (H2.8). However, current economic woes in the European continent do seem to put a halt or pause on the economic integration project.

In the remainder of this paper we will test whether these hypotheses hold or not. In the next section we will introduce the methodology we will apply for testing and we will discuss the dataset we constructed to arrive at a representable sample of countries over a long timeframe.

4. Methodology and Data

4.1 Empirical Strategy

The aim of this paper is to test whether the key variables in the gravity equations change over time. Most papers do not take into account the possibility that some phenomena can have an effect on trade that changes over time. In the previous section we formulated a set of testable hypotheses regarding these variables and whether it is likely for them to vary over time. We follow the paper by Coe et al. (2007) to investigate the change of parameters over time in a straightforward method. It is a combination of both a panel data set and a cross section data set. The empirical testing of the hypotheses we formulated in the previous section is based on equation 2.9, which is derived from the theoretical framework by Anderson and van Wincoop (2003).

First, we will execute a series of annual estimates to investigate the coefficients for all variables for each year, in order to discern any pattern or trend over time. We use a dataset that consists of observations for 41 countries over a 31 year period. From the resulting set of coefficients we can discern any possible change of the coefficients in that 31 year period. The log-linear estimation will be slightly different from (4.1) and is specified as follows:

$$(4.1) \quad \ln EX_{ij} = \beta_0 + \beta_1 GDP_i + \beta_2 GDP_j - \beta_3 DIS_{ij} + \beta_4 LL_{ij} + \beta_5 ISL_{ij} + \beta_6 Border_{ij} + \beta_7 Lang_{ij} + \beta_8 Col_{ij} + \beta_9 EU_{ij} + IM_{ij} + EX_j$$

On the left hand side of the equation the variable *EX* is the exports between country i and j at time t. At the right hand side of the equation, the country's economic mass is approximated by *GDP*, and *DIS* stands for the distance between the two regions. *LL* and *ISL* are dummy variables representing landlocked and island nations respectively. The common border effect and common language effect are represented as *Border* and *Lang*, whereas *Col* represents colonial ties, and the *EU* denotes European member states. In addition, we add country fixed effects to control for any unobserved effects that we are missing that are specific to a particular country and constant over time.

Next to the cross section estimation we will use the same dataset in a panel format to gain a better insight in the relations between the independent variables and the trade between countries over time. The first basic panel data specification will test whether the strength and sign of the coefficients match the findings in the literature and our first set of hypotheses and reads as follows:

(4.2) $$Log\ EX_{ijt} = \beta_0 + \beta_1\, LogGDP_{it} + \beta_2\, LogGDP_{jt} - \beta_3\, LogDIS_{ijt} + \beta_4\, LL_{it} + \beta_5\, ISL_{it} + \beta_6\, Border_{it} + \beta_7\, Lang_{it} + \beta_8\, Col_{it} + \beta_9\, EU_{it} + FE + \varepsilon_{ijt}$$

This specification allows incorporating the time dimension of our dataset in the analysis of our variables. Observations are not only marked by country and country partner, but also by the year of the observation. We include fixed effects to the specification to control for influences on trade that are not caught by independent variables. First, we include time fixed effects to control for the global economic environment that is specific for a particular year and affects all nations similarly. Second, we control for nation specific effects that are specific to the nation. And finally we will run a model that includes country pair fixed effects to control for the variables that affect international trade that are specific to the country pair, yet unknown to us. The correct use of the fixed effects model lies at the hearth of the paper by Baldwin and Taglioni (2006), who show that by using country specific dummies, country pair dummies, and time dummies, several estimation problems can be overcome, especially with respect to the multilateral resistance term as described in section 2. In the case of a panel dataset, the authors advocate the use of country pair dummies and time effects. However, among those variables that are specific to the pair of countries and invariant over time are distance, language, island, border, landlocked, and colonial ties. Running a model with country pair fixed effects demands that we exclude those variables in our estimation, leaving only three variables left, namely GDP levels and being an EU member as they change over time. The three specifications are as follows:

(4.2) $$Log\ EX_{ijt} = \beta_0 + \beta_1\, LogGDP_{it} + \beta_2\, LogGDP_{jt} - \beta_3\, LogDIS_{ij}t + \beta_4\, LL_{it} + \beta_5\, ISL_{it} + \beta_6\, Border_{it} + \beta_7\, Lang_{it} + \beta_8\, Col_{it} + \beta_9\, EU_{it} + T_t + \varepsilon_{ijt}$$

(4.3) $$Log\ EX_{ijt} = \beta_0 + \beta_1\, LogGDP_{it} + \beta_2\, LogGDP_{jt} - \beta_3\, LogDIS_{ij}t + \beta_4\, LL_{it} + \beta_5\, ISL_{it} + \beta_6\, Border_{it} + \beta_7\, Lang_{it} + \beta_8\, Col_{it} + \beta_9\, EU_{it} + T_t + IM_i + EX_j + \varepsilon_{ijt}$$

(4.4) $$Log\ EX_{ijt} = \beta_0 + \beta_1\, LogGDP_{it} + \beta_2\, LogGDP_{jt} + \beta_3\, EU_{it} + T_t + CP_{ij} + \varepsilon_{ijt}$$

To test the set of hypotheses regarding the behavior of the variables over time we use a specification in which we use a time dummy variable to single out the effect of a variable in a specific subset of the sample:

$$(4.5)\quad \log EX_{ijt} = \beta_0 + \beta_1\, log\ GDP_{it} + \beta_2 \log GDP_{it} * D_1 + \beta_3\, log\ GDP_{jt} * D_2 - \beta_4\ Log\ DIS_{ijt} - \beta_5\, Log\ DIS_{ijt} * D_1 - \beta_6\, Log\ DIS_{ijt} * D_2 + \beta_7 LL_{it} + \beta_8\, LL_{it} *\ D_1 + \beta_9\, LL_{it} *\ D_2 + \beta_{10} ISL_{it} + \beta_{11}\, ISL_{it} * D_1 + \beta_{12}\, ISL_{it} * D_2 + \beta_{13}\, Border_{it} + \beta_{14}\, Border_{it} * D_1 + \beta_{15}\, Border_{it} * D_2 + \beta_{16}\, Lang_{it} + \beta_{17}\, Lang_{it} * D_1 + \beta_{18}\, Lang_{it} * D_2 + \beta_{19}\, Col_{it} + \beta_{20}\, Col_{it} * D_1 + \beta_{21}\, Col_{it} * D_2 + \beta_{22}\, EU_{it} + \beta_{23}\, EU_{it} * D_1 + \beta_{24}\, EU_{it} * D_2 + FE + \varepsilon_{ijt}$$

The dummy variable D represents either the period 1990-1999 or 2000-2010. By making a comparison between the coefficients of the first period and the second, we obtain some information regarding the slope of the variable over time. We will perform three tests that are similar to (4.2), (4.3) and (4.4) following the structure of (4.5)

We used statistical software programs Eviews7 and SataS11 to estimate all the specifications. The output is presented in section 5 of this paper.

4.2 Data description and discussion

The data we used to perform the two set of regressions is constructed around a balanced set of 41 nations. To be sure the sample of nations is diverse, yet likely to have data available; we selected these nations based on their economic size and their geographical location. Due to the nature of the specifications above, the size of the dataset can easily expand rapidly as we have to report trade for each country with all other countries. In this case, the 41 countries lead to 1640 export figures for one year. Expanding furthermore by including several years of observations, the panel dataset grows fast, as in our case to more than 40.000 observations. In addition, as we add control variables, such as importer and exporter fixed effects, time fixed effects, and country pair fixed effects, the number of variables is large as well: 124 in our panel data set, and 192 variables for our set we will be using for our annual regressions.

Because of our selection of countries the dataset is not suspect to zero trade between countries. However, for some country-pairs we find small values of trade at levels below then thousand US

dollars. However, this does not lead to the problem of zero trade that datasets have with more countries.

The data for the variables was gathered from several sources. First of all, the export figures are collected from the International Monetary Funds' Direction of Trade Statistics (DOTS). These export figures include only the value of the aggregated goods traded and does not specify specific groups of goods, e.g. agriculture and manufacturing. A breakdown of sectors would of course provide a better insight as the trade dynamics are probably different for agriculture products and manufacturing goods. However, as the gravity equation itself is already a rough approach in estimating trade flows –only the three variables explain already on average 80% of trade variation—and keeping in mind the goal of this paper, investigating the sector specifics is beyond the scope of this paper

Table 4.1 Summary statistics

	Unit	Mean	Maximum	Minimum	Std. Dev.
(Log)Exports	USD millions	2.37	5.55	-3.71	1.10
(Log) GDP destination	USD millions	11.47	13.12	9.83	0.62
(log) GDP origin	USD millions	11.46	13.12	9.83	0.63
(log) Distance	Kilometers	3.63	4.29	1.72	0.47
Landlocked	numeric	0.23	1.00	0.00	0.42
Island	numeric	0.29	1.00	0.00	0.46
Common border	numeric	0.05	1.00	0.00	0.21
Language	numeric	0.06	1.00	0.00	0.24
Colonial ties	numeric	0.02	1.00	0.00	0.13
EU member	numeric	0.14	1.00	0.00	0.35

The World Bank 's Development Indicators provide us with the gross domestic product figures of our sample nations. For those countries that were part of the Soviet Union we have missing GDP figures, however, after the collapse in 1991 such data became available.

The distance between regions is calculated by using the so-called greater circle distance approach. This method calculates the shortest distance between two points on a sphere. Using a software program[11] we obtained the distances between each country pair, after we gathered the coordinates of the capital cities of all the countries. This approach raises several topics that need to be addressed. First, greater-circle distances do rarely reflect the actual shipping route between two

[11] The Geographic Distance Matrix Generator (see the literature section)

nations. Most goods are exported by shipping, which is subject to the availability of water and harbors, and the occasional continent blocking the route. For example, the distance between Chile and Argentina is small using the greater circle distance approach, yet the shipping route will be much longer, as ships have to pass either the Panama Channel, or the very south of the South American continent. Similarly, transport by train is limited to the availability of land and is also suspect to geographical limitations, such as mountain ranges and water. In the case of exporting by air, the greater-circle approach seems to be more consistent.

The second point worth mentioning is the use of the capitals as the origin and destination of all trade. It is unlikely that most trade origins at or is shipped to the capital cities of the two regions. Indeed, many capital cities are not coastal, or are not the largest transport hub of the country. For example, the capital of China, Beijing, is not the centre of trade as China's largest ports are Hong Kong and Shanghai. This deviation between the capital city and the actual centre of imports/exports of a country is increasing with country size: although in the Netherlands the capital Amsterdam is not the largest centre of trade, the large port of Rotterdam is only an hour from the capital. However, in order to have a consistent rule regarding the origin and destination of trade, we have chosen the location of the capital city of our regions.

The landlocked variable is a dummy variable that takes the value of either 1 when one or both of the two countries are landlocked and 0 if otherwise. Similarly, the island variable is a dummy that takes the value of 1 if one or both of the countries are an island, and a value of zero if otherwise. These values are consistent over time as none of the countries in the dataset have changed to or from being landlocked or an island. For the sake of clarity, the United Kingdom is an island, and Australia is not.

The common border is a dummy variable that takes the value of 1 when both countries are adjacent to each other by land. Countries that are next to each other, yet separated by sea are not considered to have a common border, e.g. Australia and New Zealand.

When both countries in the country-pair have the same language as their official language, the dummy variable language will have the value of 1, and zero when otherwise. Although some countries do not have an official language, we took the language that is most frequently used in the country. The CIA World Factbook has this information. This, however, is a crude definition of language, as it does not capture the ability of a countries people to speak multiple languages. The United States, for example, has a very large Spanish speaking community. However, we decided to follow the literature in selecting only the official language.

When both countries have had colonial ties within the last hundred years the dummy variable Col has the value of 1, otherwise 0. Throughout history most countries have been ruling or have been ruled by other countries at some point. Therefore an arbitrary line has to be drawn to decide whether countries have colonial ties or not. Our sample is characterized by the dominance of affluent nations and does not include many third world countries. This results in a small amount of colonial ties between nations and therefore it is necessary to use a broad definition of colonial 'ties', i.e. broad time frame. Therefore we had to include colonial relationships between nations that origin far in the past. For example the historic colonial ties between the U.S.A. and the United Kingdom are included. On the one hand this results in an unlikely significant coefficient in the estimation as any possible effect of such ties could have become irrelevant by now. On the other hand, a significant coefficient would provide strong evidence that such connection by former colonizer and colonized country has a long lasting effect on international trade patterns.

The European Union membership variable is a dummy variable that takes the value of 1 when both countries are a member of the European Union, and a zero if otherwise.

Table 4.2 Correlations matrix

	Export	GDP O	GDP D	Distance	Language	Landlocked	Island	EU member	Colonial ties	Shared border
Export	1.00									
GDP O	0.57	1.00								
GDP D	0.51	-0.02	1.00							
Distance	-0.31	0.08	0.08	1.00						
Language	0.15	0.10	0.09	0.03	1.00					
Landlocked	-0.08	-0.15	-0.14	-0.28	-0.04	1.00				
Island	-0.09	-0.01	-0.01	0.21	0.11	-0.15	1.00			
EU member	0.30	0.04	0.05	**-0.51**	-0.04	0.06	-0.04	1.00		
Colonial ties	0.10	0.07	0.07	0.04	**0.42**	-0.07	0.13	-0.02	1.00	
Shared border	0.17	0.03	0.03	**-0.29**	0.09	0.10	-0.10	0.11	-0.02	1.00

Table 4.2 presents the correlations matrix and tells us multicollinearity is not a problem in our dataset. We do find that distance is correlated with the EU membership variable, yet at a relative low level. This can be explained by noting that the EU is a small region and distances between member states are small. Moreover, the variable language is also correlated with colonial ties, for the obvious reason that many former colonial countries maintained the language of the former ruler as their national language. Despite that there is some correlation between the independent variables, the correlations do not cause alarm regarding multicolinearity.

5. Results

5.1 Results

As specified in equation (4.1) we executed 31 annual estimations for the period of 1980 to 2010 on our 41 selected nations. A selection of the results is presented in table 5.1. In appendix B we present a graph with the whole set of results.

Table 5.1 Annual coefficients cross-section data

	1980	1985	1990	1995	2000	2005	2010
GDP Origin	1.13***	1.19***	1.16***	1.22***	1.21***	1.17***	1.13***
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
GDP Destination	0.93***	1.06***	1.00***	1.04***	1.04***	0.99***	0.94***
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Distance	-1.02***	-1.02***	-1.01***	-1.24***	-1.21***	-1.09***	-1.16***
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Language	0.26***	0.23***	0.23***	0.13**	0.09*	0.11**	0.06
	(0.00)	*(0.00)*	*(0.00)*	*(0.03)*	*(0.05)*	*(0.01)*	*(0.18)*
Landlocked	-0.15	-0.16	-0.13	-0.18***	-0.35***	-0.28***	-0.23***
	(0.47)	*(0.46)*	*(0.47)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Colonial Ties	0.38***	0.36**	0.27**	0.31***	0.29***	0.32***	0.32***
	(0.00)	*(0.01)*	*(0.01)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*
Shared Border	-0.02	-0.03	0.01	0.14**	0.12**	0.14***	0.13**
	(0.77)	*(0.73)*	*(0.93)*	*(0.02)*	*(0.02)*	*(0.00)*	*(0.01)*
Island	-0.06	-0.13	-0.14	-0.01	-0.17***	-0.22***	-0.38***
	(0.54)	*(0.27)*	*(0.12)*	*(0.88)*	*(0.00)*	*(0.00)*	*(0.00)*
EU member	-0.19**	-0.04	-0.01	-0.11**	-0.10**	0.18***	-0.16***
	(0.03)	*(0.64)*	*(0.91)*	*(0.02)*	*(0.01)*	*(0.00)*	*(0.00)*
Time fixed effects	yes	yes	yes	yes	yes	yes	yes
N	1098	1113	1131	1420	1622	1626	1629
Adj. R^2	0.81612	0.803086	0.852844	0.876274	0.892857	0.884972	0.878853

Note: p-values reported in parentheses. Significance levels of >1, >0.5 and >0.1 are denoted by ***, ** and * respectively.

The results in table 5.1 are not conclusive evidence of changes in the variables, yet do provide a hint of evidence that variables change over time. The language variable, for example, shows a steady decline in significance over time, as we expected. Similarly, sharing a border has become more

relevant to international trade, as its coefficient becomes significant at acceptable levels after 1990. The same holds true for being and island, and being part of the European Union. However, these results have to be considered with caution, as any apparent decline or increase might not be statistically significant from zero. Therefore we estimated the significance of our 31 results per variable and present them in table 5.2.

Table 5.2 Regressions on coefficients cross-section data (1980-2010)

	Reference year	Slope estimates					
	1980	**1980-2010**		**1980-2000**		**1990-2010**	
GDP Origin	1.127***	-0.001	(0.22)	0.002*	(0.06)	-0.005***	(0.00)
GDP Destination	0.930***	-0.001	(0.29)	0.003*	(0.05)	-0.004***	(0.00)
Distance	-1.018***	-0.004**	(0.02)	-0.013***	(0.00)	0.004	(0.20)
Language	0.263***	-0.006***	(0.00)	-0.008***	(0.00)	-0.005***	(0.00)
Landlocked	-0.144	-0.006***	(0.00)	-0.010***	(0.00)	-0.003	(0.16)
Colonial Ties	0.380***	-0.000	(0.67)	-0.004**	(0.01)	0.002**	(0.04)
Shared Border	-0.024	0.007***	(0.00)	0.010***	(0.00)	0.005***	(0.00)
Island	-0.061	-0.008***	(0.00)	-0.001	(0.62)	-0.015***	(0.00)
EU member	-0.186**	0.007***	(0.00)	-0.001	(0.51)	0.014***	(0.00)

Note: p-values reported in parentheses. Significance levels of >1, >0.5 and >0.1 are denoted by ***, ** and * respectively. Data is based on the outcome of 31 gravity estimates.

The first column presents the estimates based on the whole sample set, and shows that most variables have significantly changed over time. For example, distance appears to be decreasing over time. Similarly the coefficients for language, landlocked and island are negative. On the other hand, the coefficient of being an EU member increases over time, as does sharing a border. GDP levels and colonial ties appear to have not changed statistically.

When we look at other time sections of our sample in the second and third column, we find that the slope of the coefficients is not the same for all time periods. We find that the sign of the coefficients differ strongly across time periods, as do their significance levels. For example, distance is increasing in the 1980-2000 period, yet is not different from zero in the third period. Furthermore, GDP levels do in fact vary, yet in opposite directions in both time periods, cancelling each other out in the full sample estimation. Nevertheless, for some variables we find the same sign of the coefficients across time periods, though not always statistically significant. For example, language has negative and statistically significant coefficients in all the three sets of time periods. Similarly, in the two subsets having a common border is increasingly beneficial for trade between countries.

We can conclude from this exercise that first of all the coefficients of the variables of the gravity equation do change over time. Although the direction of change is ambiguous for some variables, for others the direction of change of the coefficient is consistent over several time periods.

5.2 Panel data results

In table 5.3 we present the results of estimating (4.2), (4.3) and (4.4), in which we employ a panel dataset with several fixed effects. From the results we learn that in all three columns the signs of the variables are in line with our expectations. Moreover, in all three specifications all variables are found to be significant in explaining the variation in trade between nations. Distance has a strong negative effect on trade, as does trading with a landlocked nation and with an island nation. Cultural similarities such as sharing a language and having colonial ties have a positive effect on trade between the pair of countries. Being a member of the EU free trade zone adds beneficially to the amount of trade. And finally, sharing a border increases significantly the amount of trade between nations. These results support our hypotheses we formulated and are indeed in line with findings in the gravity equation literature.

Controlling for the country specific effects does not affect the results much in terms of validity and the correctness of the signs. However, the model does seem to increase the strength of the model as the R-square parameter indicates. Moreover, despite the limited variables in the country pair fixed effects model, controlling for the country pair specific characteristics that affect trade increases the explanatory strength of the model to 90% of the variation in the data.

Table 5.3 Standard results panel data

	(1)	(2)	(3)
	Time fixed effects	Time & country fixed effects	Time & Country pair fixed effects
Distance	-0.85***	-1.10***	
	(0.00)	*(0.00)*	
GDP origin	1.01***	1.46***	1.30***
	(0.00)	*(0.00)*	*(0.00)*
GDP destination	0.92***	0.89***	1.22***
	(0.00)	*(0.00)*	*(0.00)*
Colonial Ties	0.16***	0.32***	
	(0.00)	*(0.00)*	
EU	0.13***	0.10***	0.19***
	(0.00)	*(0.00)*	*(0.00)*
Landlocked	-0.12***	-0.24***	
	(0.00)	*(0.00)*	
Language	0.23***	0.14***	
	(0.00)	*(0.00)*	
Island	-0.02***	-0.19***	
	(0.00)	*(0.00)*	
Common border	0.25***	0.09***	
	(0.00)	*(0.00)*	
Importer/exporter effects	No	Yes	No
Time effects	Yes	Yes	Yes
Country pair effects (ij=ji)	No	No	Yes
number of observations	42792	42792	42792
Adj. R2	0.78	0.86	0.9

Note: p-values reported in parentheses. Significance levels of >1, >0.5 and >0.1 are denoted by ***, ** and * respectively.

5.3 Panel data and time dummies

When including time dummies in the specification to explore the variation of our explanatory variables over time, we find that the coefficients of the variables change over time (Table 5.4). The estimated coefficients of the interaction terms show how the slope of the variable changes when that particular period is included in the sample. Similarly to the previous estimations we control for three different types of fixed effects, namely time fixed effects, country fixed effects, and country pair fixed effects. In the first column we find that when controlling for time fixed effects that the variables have the expected signs as we found in the previous section, except for being an island which seems to have a positive impact on trade. By adding the interaction terms with the two time periods, we find that in most cases the slope of the coefficients change, as most interaction term are found to be significant. This proves that the impact of, for example, colonial ties on exports change over time.

The results suggest that the GDP levels at the destination of the export flow are becoming more relevant as time progresses. The impact of the economic size at the origin of the trade appears at first to decrease, and to increase again in the last decade of our sample. The negative effect distance has on trade is, according to the results, becoming stronger over time. This means that distance is becoming more relevant to trade, as we expected. The colonial ties between countries have a positive effect on trade, yet this effect is decreasing over time. The apparent positive effect of an being an island on trade decreases strongly when we include the 2000-2010 period to our sample. Being landlocked, however, becomes more a burden to international trade over time. Language, on the other hand, has a positive effect on trade, yet its impact is waning as reported by the significant negative interaction terms. Finally, sharing a border is increasingly beneficial for trade, as the coefficient becomes larger as we broaden our time dimension of the sample.

In the second column in which we include country fixed effects, we find mostly similar results as in the first column, with a few exceptions. First we find that the variable colonial ties does not seem to change over time. And second we observe that being an island has a negative effect on its international trade. However, these country fixed effects, together with the time fixed effects, does have a larger explanatory power which speaks in favor of this model specification.

Table 5.4 Results panel with time interaction term

	(4)		(5)		(6)	
	Time fixed effects		Time and country fixed effects		Time & country pair fixed effects	
GDP destination	0.89***	*(0.00)*	0.95***	*(0.00)*	1.01***	*(0.00)*
gdp_d x D (1990-1999)	0.04**	*(0.03)*	-0.01	*(0.33)*	-0.00	*(0.78)*
gdp_d x D (2000-2010)	0.05***	*(0.00)*	-0.03***	*(0.00)*	-0.02***	*(0.00)*
GDP origin	1.03***	*(0.00)*	1.51***	*(0.00)*	1.53***	*(0.00)*
gdp_o x D (1990-1999)	0.03***	*(0.00)*	0.00	*(0.79)*	-0.02***	*(0.00)*
gdp_o x D (2000-2010)	-0.04***	*(0.00)*	-0.06***	*(0.00)*	-0.09***	*(0.00)*
Distance	-0.81***	*(0.00)*	-1.06***	*(0.00)*		
Distance x D (1990-1999)	-0.08***	*(0.00)*	-0.09***	*(0.00)*		
Distance x D (2000-2010)	-0.05**	*(0.01)*	-0.03*	*(0.09)*		
Colonial ties	0.21***	*(0.00)*	0.34***	*(0.00)*		
Colonial ties x D (1990-1999)	-0.07*	*(0.09)*	-0.04	*(0.21)*		
Colonial ties x D (2000-2010)	-0.09**	*(0.01)*	-0.03	*(0.26)*		
EU member	0.07***	*(0.00)*	-0.01	*(0.33)*	0.16***	*(0.00)*
EU member x D (1990-1999)	0.03	*(0.12)*	0.03*	*(0.07)*	0.04***	*(0.00)*
EU member x D (2000-2010)	0.07***	*(0.00)*	0.14***	*(0.00)*	0.01	*(0.14)*
Island	0.04***	*(0.00)*	-0.14***	*(0.00)*		
Island x D (1990-1999)	-0.03*	*(0.09)*	-0.01	*(0.31)*		
Island x D (2000-2010)	-0.13***	*(0.00)*	-0.10***	*(0.00)*		
Landlocked	-0.06***	*(0.00)*	-0.23***	*(0.00)*		
Landlocked x D (1990-1999)	-0.09***	*(0.00)*	-0.04***	*(0.00)*		
Landlocked x D (2000-2010)	-0.07***	*(0.00)*	0.03**	*(0.02)*		
Language	0.28***	*(0.00)*	0.21***	*(0.00)*		
Language x D (1990-1999)	-0.05**	*(0.03)*	-0.06***	*(0.00)*		
Language x D (2000-2010)	-0.10***	*(0.00)*	-0.13***	*(0.00)*		
Shared border	0.16***	*(0.00)*	-0.03	*(0.16)*		
Shared border x D (1990-1999)	0.12***	*(0.00)*	0.14***	*(0.00)*		
Shared border (2000-2010)	0.14***	*(0.00)*	0.18***	*(0.00)*		
Importer/exporter effects	No		Yes		No	
Time effects	Yes		Yes		Yes	
Country pair effects (ij=ji)	Yes		No		No	
R2	0.78		0.87		0.94	
N	42792		42792		42792	

Note: p-values reported in parentheses. Significance levels of >1, >0.5 and >0.1 are denoted by ***, ** and * respectively.

These results indicate that in line with our expectations, the variable coefficients of the gravity equation do change over time. As with respect to our hypothesis we find mixed results. In contrast to our expectations it seems that the coefficient of GDP levels differ across time periods. Moreover, the increasingly negative island coefficient runs against to what we expected. The common border coefficient is increasing over time, which suggests that its positive impact on trade becomes larger. In accordance to our hypothesis we do find that distance becomes more relevant as a factor that reduces trade flows. In addition, as we expected, the benefit of having both the same official language on trade is reducing over time, as indicated by the interaction terms.

5.4 Results Discussion

In both the cross section examination as in the longitudinal dataset we found evidence that the key variables of the gravity equation differ significantly across time. This means that depending on the time period of the sample, results will differ. Moreover, executing a model using a long timeframe without acknowledging the fact that the coefficients of the variables change over time, leads to misleading results regarding their importance as determinants of exports. We found, for example, that the language parameter is decreasing in importance regarding international trade, which is a development not captured by a standard gravity equation estimation. The results suggest that this is the case for most of the selected key variables that frequently appear in the literature.

Besides evidence of the time variation of the coefficients, we predicted the direction of that change in accordance to economic intuition and the literature. The results are ambiguous and not always consistent across specifications. For three of our nine variables we observe supportive evidence of our hypotheses. First, the distance coefficient does in both the cross section approach, and the two panel data specifications, increase over time, indicating that distance does become more relevant to trade. This runs against the popular literature in which distance was considered to become obsolete in a world with better technology and communication advancements. Second, in all estimates the language variable is decreasing over time, which indicates that the advantage of two countries having the same official language is less of importance as time progresses. This development could origin from the fact that only a few languages dominate international business environments, and though perhaps not the official language, they are familiar among the people. And third, being a member of the EU does not only increase trade with other EU members, the size of traded goods increase as well over time, according to our results. Whether this is the result of the ongoing integration of markets or the accession by new member states remains unclear.

Contrary to our expectations we find that the common border effect becomes stronger over time. It appears that increased economic integration of markets does not negatively affect the position neighboring countries have in terms of exports, but rather enhances the benefits of not only being close to each other, but being neighbors as well. A plausible explanation could be the fact that businesses do aim at international markets, but prefer to be in the comfort zone of a familiar environment in bordering countries. The increased international awareness of businesses might be more beneficial for neighboring countries. Furthermore, we find that in all our results islands experience an increasing disadvantageous position in international trade, while it is unclear what the underlying factor could be. Finally, for the remaining variables we find ambiguous results that do not point towards a clear direction.

6. Conclusion

In this paper we have showed that the key variables of a gravity equation have a time varying effect on international trade. These effects are often ignored in the literature, and this paper aims to add to the understanding that the results of gravity estimates are suspect to the period from which the data origins. We used a panel dataset of 41 countries and their bilateral trade flows over a period of 31 years (1980-2010) in order to obtain an insight in the development of nine variables that frequently appear in international trade gravity literature. We used two methods to extract a meaningful result on which we could draw conclusions. First we estimated annual estimates of each coefficient and estimated the annual change for a subset of periods. Second, we used a fixed effects model including time and country effects, and time dummies to obtain coefficient estimates specific to a subset of periods.

Using these two methods we found evidence that the coefficients of the variables change over time, and for some variables the direction in which they are moving. Most notably, we found that distance is becoming an increasingly significant factor in exports. Moreover, sharing a common official language has become less of a significant determinant in explaining trade between nations. And a third positive finding is the increased trade between EU members as either the markets become more integrated, or as more countries join the single European market.

Despite the supportive evidence found in the data, this research has its limitations. First of all, the data selection procedure is suspect to several discussion points. Despite the fact that the aim of this paper is limited to exploring the behavior of the variables over time, and not to construct an all-encompassing gravity model, the data is possibly suspect to selection bias. The subset of nations consists mostly out of OECD countries, a group of affluent industrialized countries. This draws a certain bias to the results as they do not reflect the factors that are relevant to the larger group of developing nations. However, the limited availability of data for a larger set of countries would pose difficulties in correctly estimating the gravity models through the possible appearance of zero trade flows. In addition, the time period we used can be considered a relative short time period for a paper that investigates coefficients across time. A longer time period would be preferable to obtain more reliable results.

Secondly, a second concern to the results might be the exclusion of other key variables that are frequently used in gravity estimations. For example, we did not include more variables regarding free trade agreements, or population sizes. By excluding these variables we might have lost valuable information regarding their behavior over time. On the other hand, our models were found

to be significant as evidenced by the high r-square values. Moreover, the inclusion of time and country fixed effects possibly captured parts of the excluded variables in the estimations.

Thirdly, although the results point towards supportive evidence of our research question, the underlying factors that cause the coefficients to change over time remain hidden. Further research should investigate what exactly causes a common language to have a less significant contribution to trade. Furthermore, we would to suggest looking at whether these underlying factors are correlated with other variables as well. For example the relation between the decreasing coefficient of language and the colonial ties coefficient.

Concluding, advancements in the gravity equation should contain the notion that the variables that determine trade change over time, as has trade itself changed over time; gravity is not constant.

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Software

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Appendix A

Country list

Countries				
Argentina	Egypt	Israel	Slovakia	United States
Australia	Estonia	Italy	Slovenia	
Austria	Finland	Japan	South Africa	
Belgium	France	Luxembourg	South Korea	
Brazil	Germany	Mexico	Spain	
Canada	Greece	Netherlands	Sweden	
Chile	Hungary	New Zealand	Switzerland	
China	Iceland	Norway	Thailand	
Czech Republic	India	Poland	Turkey	
Denmark	Ireland	Portugal	United Kingdom	

Appendix B

Key variable coefficients (1980-2010)