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Gravity model for Czech Republic - Test of the effects of indirect trade

Master Thesis

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Declaration of Authorship

1. Hereby I declare that I have compiled this master thesis independently, using only the listed literature and sources.

2. I declare that the thesis has not been used for obtaining another title.

3. I agree on making this thesis accessible for study and research purposes.

Prague, May 16, 2014 Marek Wlazel

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Abstract

The aim of this thesis is to incorporate the effects of the indirect trade into the gravity model for Czech Republic. Using data from the recently released OECD-WTO TiVA database, a panel of 56 countries in 5 years between 1995 and 2009 is constructed. The traditional approach of estimating the log-linear form of the equation is questioned and in line with current academic research, the Poisson Pseudo Maximum Likelihood method is applied. The empirical analysis does not reveal any unambiguous effect of adjusting the gross exports for their foreign content; it rather confirms that Czech exports are significantly driven by the demand for German exports and finds that they are the higher the greater is the share of services value added. Furthermore, it is found that the destination of Czech exports is not significantly determined by target country's participation in global value chains.

JEL Classification C13, C23, C67, F14, F60

Keywords gravity model, indirect trade, trade in value added, Czech Republic, Poisson regression, panel data

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Abstrakt

Cílem této práce je zahrnutí efektu nepřímého obchodu do gravitačního modelu pro Českou republiku. Za tímto účelem byl vytvořen datový panel vycházející z nedávno vydané databáze OECD-WTO TiVA, obsahující data pro 56 zemí v pěti letech mezi roky 1995 až 2009. Tradiční postup odhadování log-lineární formy rovnice je zpochybněn a v souladu se současným akademickým výzkumem je použita metoda Poissonovy pseudo-maximální věrohodnosti. Empirické výsledky neodhalují jednoznačný efekt očištění hrubých exportů o jejich zahraniční část; spíše potvrzují, že české exporty jsou signifikantně ovlivněny poptávkou po německých exportech, a nalézají pozitivní vztah s podílem služeb obsažených v přidané hodnotě. Navíc je zjištěno, že destinace českých exportů není determinována účastí cílové země v globálních hodnotových řetězcích.

Klasifikace JEL	C13, C23, C67, F14, F60
Klíčová slova	gravitační model, nepřímý obchod, obchod s přidanou hodnotou, Česká republika, Poissonovská regrese, panelová data

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List of Acronyms

DOX	Domestic Origin Exports
FE	Fixed Effects
GDP	Gross Domestic Product
GFCF	Gross Fixed Capital Formation
GVC	Global Value Chain
GX	Gross Exports
IX	Indirect Exports
OLS	Ordinary Least Squares
PPML	Poisson Pseudo Maximum Likelihood
RE	Random Effects
SGE	Share of German Exports
SVA	Services Value Added
TiVA	Trade in Value Added
VAEX	Value Added Embodied in Exports

Chapter 1

Introduction

"*Gravity explains the motions of the planets, but it cannot explain who set the planets in motion.*"

- Sir Isaac Newton, 1687

When Sir Isaac Newton originally formulated his Universal Law of Gravity back in the 17th century, he most likely did not realize how 'universal' his law was. It took almost three more centuries until Tinbergen (1962) utilized the gravity equation to describe international trade flows. A considerable amount of literature on this topic has been published since then; both theoretical, trying to describe the microeconomic foundations for the gravity model of trade, and empirical, applying the model on real data and focusing on its proper specification and estimation.

The traditional gravity equation from physics states that two objects are attracted to each other with a force that is directly proportional to their masses and inversely proportional to the distance between them. Reformulating this into economic terms, bilateral trade between two countries is directly proportional to their GDPs and inversely proportional to their mutual distance, where distance represents all the costs embodied in processing the transaction. This model has proven surprisingly stable over time and across different samples of countries and methodologies. "It stands among the most stable and robust empirical regularities in economics." (Chaney, 2011, p. 2)

Despite, and at the same time thanks to, the indubitable success of the model, there has always been demand for further improvement, especially in the perspective of globalization and related increase of the total volume of international trade. One of the aspects of the growing interdependence among national economies is the emerging importance of indirect trade. Illustrating this on the case of Czech Republic, it is not appropriate to measure the demand for Czech production only by gross trade flows, since a significant part of Czech exports enters the production process in Germany and continues further as German exports. To incorporate this phenomenon, also known as trade in value added, into the gravity model and to test whether it could possibly improve the model is the main motivation of this thesis. After an extensive literature review, no previous research has been found that combines the two topics - gravity model and indirect trade. Furthermore, Czech Republic has been chosen for the analysis as a suitable example, since it is a small open economy with one dominant export market and thus the effects of indirect trade are expected to be significant.

Measuring the trade in value added encounters several difficulties. The most fundamental problem is the necessity to estimate individual country's contribution to global value chain (GVC). These estimations are generally based on national input-output tables and since the quality of measuring GVCs recently attracts more attention even from outside the academia, the work on global synchronization of input-output tables is on-going within the statistical community. As a result of the increased demand for consistent indirect trade statistics, a joint OECD-WTO Trade in Value Added (TiVA) initiative has been established. It is the default source database for constructing the panels used in this thesis.

The thesis is structured as follows. Chapter 2 summarizes the relevant literature and is divided into two main sections: literature on the gravity model and indirect trade. The first section briefly introduces the history of gravity model and the issues it faced during its evolution, followed by the most recent literature focusing mainly on the methodology. Second section puts forward several papers that estimate the volume of indirect trade. Chapter 3 deals with the gravity model in general. It highlights the methodological problem of zero trade flows when estimating the equation and shows the most widely accepted theoretical justification of the model by Anderson and van Wincoop (2003) in the augmented form as presented by Baldwin and Taglioni (2006). Chapter 4 firstly refers to indirect trade as one of the main sources of statistical discrepancies. Secondly, it provides a comprehensive overview of the role of Czech Republic in GVCs, supported by a list of figures obtained mostly from the TiVA database. Chapter 5 begins with the description of the methodology employed. It presents both the input-output framework of measuring the indirect trade and the econometric techniques (OLS and PPML) applied on estimating the gravity model. The subsequent data description is then followed by the section with summarized results of individual models and methods. Chapter 6 concludes.

Chapter 2

Literature Review

This chapter provides an overview of the existing literature about the gravity model and indirect trade. As, to the author's knowledge, these two topics have been combined before, the literature review is divided into two subsections.

The first part deals with the historical development of the application of Newton's gravity equation in econometric modeling of international trade, followed by an insight into the recent studies on the difficulties and improvements of the gravity model. Many theoretical and empirical contributions have been made during the last 50 years that solved old issues and highlighted new ones.

The second part then presents literature concerning the topic of indirect trade. There are several papers indicating the significant volume of indirect international trade, pointing out the challenges and discrepancies that occur in the bilateral trade statistics.

However, none of these papers seem to have ever included the effects of the high volume of indirect trade into the variables of the gravity model.

2.1 Literature on gravity

2.1.1 History of gravity

The fundamental work on gravity was written by the English physicist and mathematician Sir Isaac Newton. He was one of the most influential scientist of all time, the founder of classical mechanics, and inventor of infinitesimal calculus. The foremost definition of the universal equation of gravitation was firstly formulated by Newton in his early work Philosophiæ Naturalis Principia Mathematica (Mathematical Principles of Natural Philosophy) which is "regarded as one of the most important works in the history of science" (Guicciardini, 2003). However, as brilliant and influential this masterpiece is, it took almost three centuries before Newton's findings were applied in the field of economics and, specifically, econometrics.

The history of the gravity model of the international trade goes back to Tinbergen (1962), a Dutch economist. Later in 1969, Jan Tinbergen was the winner of the first Nobel Prize for economics (together with Ragnar Frisch) for his work on developing and applying dynamic models for the analysis of economic processes. Before formulating the gravity model, Tinbergen had received a PhD in physics with a thesis entitled *Minimum Problems in Physics and Economics* under the supervision of Paul Ehrenfest, a close friend of Albert Einstein's (Szenberg, 1991).

It is not surprising that Tinbergen, a former student of physics, when facing the problem of how to "determine the normal or standard pattern of international trade that would prevail in the absence of trade impediments" (Benedictis and Salvatici (2011), chapter 4) came up with the idea of an econometric model based on the Newton's law of universal gravitation.

Indeed, Tinbergen was not the first one who used the gravity concept for research in a field outside of physics. Before him, for instance, Ravenstein (1885) and Zipf (1946) applied the gravity equation on migration flows. A similar study was introduced by Poyhonen (1963) who, independently from Tinbergen, used an analogical approach to describe the bilateral exchange of goods between countries. An important study of the early version of gravity equation has then become a PhD thesis of Linnemann (1966), a Tinbergen's former student, and Linder (1961).

Since the works of Tinbergen, Linder and Linnemann, the model was further applied by many in the 1960's (Leamer and Stern, 1970). This was followed by a decline of popularity (although practitioners continued to use it) in the 1970's and 80's, mainly due to the lack of solid micro-economic foundations, ending up with an again increased interest in 1990's after the fall of the Iron Curtain (see van Bergeijk and Brakman (2010), for a more detailed discussion and a list of references).

The development of multilateral trade among the Central and Eastern European countries since 1980 was measured using the gravity model for instance by Bussière et al. (2005). With the help of a relatively simple gravity model, they were able to identify which countries had already well advanced trade integration with the euro area and which still have significant scope for it. After adding to the basic model relating trade flows and economic size five new variables, such as common language, free trade agreements or common border, they pointed out the need of a very careful examination of the fixed effects of the model for a correct interpretation of the results.

2.1.2 Micro-foundations

Despite its popularity, the gravity model was mostly criticized for lacking proper theoretical background. Probably the first who provided some solid micro-foundations for the gravity model was Anderson (1979). He assumed a separable social utility function with respect to traded and non-traded goods, maximized the Cobb-Douglas homothetic function identical across all regions and extended the model with population variables and trade barriers. The second author who provided some theoretical foundations for the model was Bergstrand (1985), who highlighted price terms and included the supply side of the economy explicitly. The work of Bergstrand resulted into following contribution to the model - the income of the importer's country enters the equation in the form of demand, the income of the exporter's country in the form of supply capacity, and distance in the form of transportation costs.

One of the main references for further work on the gravity equation was then the paper of Anderson and van Wincoop (2003). In order to solve the famous McCallum border puzzle[1], they developed a method that consistently and efficiently estimates a theoretical gravity equation and pointed out two implications. First, estimation results are biased due to omitted variables. And second, perhaps even more important as the authors claim, one cannot conduct comparative statics exercise without being able to solve general-equilibrium model before and after the removal of trade barriers. As confirmed by Benedictis and Salvatici (2011), the flow of bilateral trade is influenced by both the trade obstacles that exist at the bilateral level and by the relative weight of these obstacles with respect to all other countries.

However, there occurred an undesirable side effect of the emergence of a "new trade theory". According to Baldwin and Taglioni (2006), the gravity model went from having too few theoretical foundations to having too many. They supported this statement with one of the main lessons by Deardorff (1998): "...it is not all that difficult to justify even simple forms of the gravity equation from standard trade theories" (p. 21). Nevertheless, Baldwin and Taglioni (2006) demonstrated how to apply the most accepted Anderson-Van-Wincoop's theory in a well-arranged six steps procedure. This procedure shows how starting from the expenditure share identity and the expenditure function, one can derive a micro-founded equation

[1] McCallum (1995) estimated a gravity model for trade between Canadian provinces and the U.S., finding a disturbing result that interprovincial trade is 20 times higher than the international.

(they call it the first-pass gravity equation) analogical to the basic gravity equation. This procedure is summarized in Section 3.2 of this paper.

2.1.3 Recent literature on gravity

The gravity model is a widely used tool to estimate the effects of various regional trade agreements, public export guarantees, barriers to trade and other determinants of trade. Although it has been utilized for decades, many questions remain unanswered until today. A fundamental challenge lies in the selection of the most suitable econometric estimation method. A very comprehensive overview of studies applying different methods to estimate the gravity equation is provided by Herrera (2010). By generally describing most of the methodology that has been applied in recent years, she compiled an extensive list of the recent research papers on this topic.

Others have compared alternative methods to estimate the gravity model and obtained divergent results; e.g. Burger et al. (2009), Westerlund and Wilhelmsson (2011), Martin and Pham (2008), Martínez-Zarzoso et al. (2007) or Siliverstovs and Schumacher (2008). Nevertheless, the most influential paper, since Anderson and van Wincoop (2003) introduced their micro-founded gravity model, seems to be the "Log of Gravity" by Silva and Tenreyro (2006). Almost every paper on gravity after 2006 refers to their work and if not directly applies, at least considers or discusses the estimation method proposed by the authors as most suitable - the Poisson Pseudo Maximum Likelihood method. An example of the confirmation of Silva and Tenreyro's results is the paper by Arvis and Shepherd (2013), who highlighted the desirable properties of PPML in comparison to traditional log-linearized OLS estimation. More information on the shortcomings of the linear methods is presented below in Section 3.1 and particularly in Section 5.1.2. One of the shortcomings, the zeros treatment problem, is thoroughly examined for instance by Burger et al. (2009) or Helpman et al. (2007). Although the arguments for the recommendation of PPML by Silva and Tenreyro are valid, several papers doubted them. Siliverstovs and Schumacher (2008) gave their paper a questioning subtitle "To log or not to log?", however the most vocal criticism occurred in the work of Martínez-Zarzoso et al. (2007) who found datasets for which there are better estimators than PPML. But as a matter of fact, Silva and Tenreyro never claimed that PPML always outperforms other estimators, only that it is consistent and is likely to do well in a variety of circumstances. Their work is on-going and PPML has been confirmed to generally behave well (Silva and Tenreyro, 2011).

There are also papers that estimate the gravity equation specifically for the Czech Republic. For the sake of convenience, they can be also divided into two groups according to the estimation methods. Janda et al. (2012) and Pěchová (2013) studied the effects of credit support and government guarantees on Czech exports. Despite the fact that both came to the conclusion that the support of exports has a significant and positive effect on their volume, they used the logarithmic transformation which is shown to generate inconsistent estimates (see Silva and Tenreyro (2006) or Section 5.1.2 for explanation). A highly relevant paper for this study is the thesis by Bobková (2012), who examined the performance of PPML in comparison to traditional OLS and concluded that based on the Czech and German trade panel data, PPML is recommended as a more proper method for estimating the coefficients of the gravity equation.

2.2 Literature on the indirect trade

In the perspective of the historical development, one cannot overlook the rapidly increasing volume of global trade. Due to the effects of technological and political progress and respective scaling down barriers to trade worldwide, the growing importance of international trade for every single country's economy is evident.

Although the general definition of trade, an action of buying or selling goods and services, offers a wide variety of interpretations, the most common notion of international trade is a direct flow of goods (or services) from one country to another. This last definition is however incomplete. Trade flows are not only direct, but they can be indirect as well - the goods might travel via a third (or fourth, fifth, etc.) country to its destination. As simple as it sounds, it is a source of many discrepancies in the trade statistics and complications for policy makers, customs officers, businessmen and, most importantly, international trade economists.

Therefore, revealing true trade flows might potentially bring significant benefits and thus adjusting the trade volumes for indirect exports/imports in a model is both desirable and tempting. Apparently, it is the case of this paper.

Several studies have shown the distinct magnitude of indirect trade, for instance Ollus and Simola (2007), Ritter and Loschky (2006), or Wlazel (2012). Ollus and Simola (2007) analyzed the trade between Finland and Russia and focused on re-exports, specifically on how much of Finnish exports to Russia are not domestically produced but imported from other countries. They used a very simple but reasonable methodology; re-exports in their calculations are the difference between domestic production and exports. "Logically, if domestic production is less than exports to Russia, at least some of the exports must consist of imports" (p. 10). In the study, 30 largest export product groups (which account together for nearly two thirds of total exports) were examined based on industrial production figures for the years 2000 to 2005. The main conclusion is that, in 2005 for instance, the re-exports accounted for nearly a fifth of total Finnish exports to Russia. Based on this result, it would be reasonable to consider the "real" (or direct) exports to be much lower than reported in official statistics.

The other two studies, Ritter and Loschky (2006) and Wlazel (2012), focused on the trade that goes via Germany. While Ritter and Loschky

(2006) analyzed solely the import content of German exports, the study by Wlazel (2012) estimated how much of the exports of visegrad countries (i.e. Czech Republic, Hungary, Slovakia, and Poland) that is directed to Germany ends in third countries, with a special focus on the Chinese market. It concerned both types of indirect trade - re-exports with no processing in the transit country and indirect exports in which the imported goods enter the production process.[2]

The paper by Wlazel (2012) presents a different approach to estimating the re-exports than the one applied by Ollus and Simola (2007). It is based on the methodology originally proposed by Rezkova et al. (2011). Using the input-output analysis (specifically the import matrix), one might directly look up the volume of goods that were not used for domestic consupmtion or further processing but for re-exporting. Using a strong proportionality assumption about the geographical distribution of exports, it is then possible to estimate how much of exports are actually re-exports from a particular country of origin to a particular country of destination.

In the case of indirect exports, the calculations are slightly more complicated. Both above mentioned studies use the same approach to estimate the import content of German exports. A similar input-output approach is applied for instance by Machado et al. (2001) who estimated the amount of energy and carbon embodied in the international trade of Brazil. This example suggests that the technique does not have to be used only in international trade but has far more practical applications. It is based on the input-output matrix of intermediate consumption, the vector of technical coefficients and the so-called Leontief inverse. This methodology is described in Section 5.1.1 below in this paper.

[2]In fact, there is a third type of indirect trade, sometimes called transshipment. It is the situation when the goods are truly only 'transshipped' via the third country (e.g. with an important harbor). The difference between re-exports is then in reporting in the trade statistics. Transshipments are not reported in the foreign trade statistics and therefore are not relevant for further considerations.

The calculations of Ritter and Loschky (2006) have shown the extraordinary share of imported goods on total inputs in German domestic production, accounting for 42% of all exports in 2005. Furthermore, this share seems to be increasing over time and thus the importance of embodied trade is growing. The estimates made by Wlazel (2012) are even higher. The input-output analysis of trade that flows from visegrad countries to Germany revealed that the inclusion of re-exports and indirect exports via Germany increases the visegrad countries' exports to China by 68%, indicating a higher dependence of the region on the Chinese market than evident from the first look at the geographical distribution of exports. Moreover, the study has shown that 55% of visegrad exports to Germany are not intended to cover domestic consumption but for further exports.[3]

A completely different approach to calculate embodied trade is presented in the popular paper by Dedrick et al. (2010) called "Who profits from innovation in global value chains?: a study of the iPod and notebook PCs". This interesting and often-cited article illustrates the issue related to interconnections in global trade on a single product, the famous Apple iPod. The case study examines how much of this electronic device is actually produced in China where it leaves the assembly line as a finished product. It was found that to the $144 Chinese factory-gate price, China contributed by less than 10%. Most of the value added was imported from Japan, followed by the US and Korea. Despite the astonishing results of this study and it's undoubted illustrative power it is, however, irrelevant for the purposes of this study. Though tracing the global value chain of a single product would bring much more accurate numbers, it is impracticable on an aggregate level.

[3] These values are valid for years 2004 to 2007, aggregated for Czech Republic, Hungary, Slovakia, and Poland. The values for Czech Republic solely are even higher.

Chapter 3

The Gravity Model in General

3.1 Theoretical framework

The gravity equation was originally formulated by Newton (1687) and later developed into an international trade model by Tinbergen (1962). The gravity power between two objects is defined as directly related to their masses (or weights) and inversely to their mutual distance. When applied on bilateral trade, the very basic formula is following:

$$T_{ij} = G\frac{GDP_i^{\alpha}GDP_j^{\beta}}{D_{ij}^{\theta}} \tag{3.1}$$

where T_{ij} represents trade flow between countries i and j (the gravity power), G is a (gravity) constant, GDP_i indicates the weight of country i measured as it's economic size (the mass), and D_{ij} is the distance between countries i and j. The Greek letters α, β, and θ, as well as the constant G are then the coefficients to be estimated in the regression.

3.1.1 Problem of zero observations

When logarithmic transformation is used for the estimation, problems occur when the value of a particular variable (e.g. trade flow) is zero. There are several solutions proposed:

- Add a small value to the data before logarithmic transformation. However, different values can lead to different results (see, for instance, Jongman et al., 1995). In case there are many zero-value observations, it is advisable to replace zeros with a small value, such as 0.1, 0.5 or 1. See Porojan (2001) or Burger et al. (2009). This has been the case of the analysis by Janda et al. (2012) that aimed at testing whether the guarantees provided by Czech Export Bank support Czech export and faced the problem of the presence of many zeros. They found out that the choice of the small value (whether 0.1 or 0.5) does not affect the estimated coefficient.

- Another solution is proposed by Silva and Tenreyro (2006); instead of traditional log-linear OLS regression, it is reasonable to use the Poisson Pseudo Maximum Likelihood estimator. It is has been confirmed by Bobková (2012) or Arvis and Shepherd (2013) that the PPML estimation method is a more proper method for estimating the coefficients of the gravity equation.

- Remove zero observations from the sample. This is a pretty straightforward solution, however, if the zero observations constitute for a larger share of total observations, the gravity model would suffer of the lack of robustness. And more importantly, the model loses important information that is embodied in the presence of zero trade flows in the data.

As a matter of fact, all of the three solutions are applied in Section 5.3.2 with respective results summarized in Table 5.3.

Another problem that might appear when using the traditional log-linearized OLS on the gravity equation is that OLS might lead to inconsistent estimates, as described in Section 5.1.2 below. Nevertheless, this should be solved, again, by using PPML instead of OLS.

3.2 Baldwin and Taglioni's micro-founded derivation of gravity

This section provides the theoretical model derived by Baldwin and Taglioni (2006) who extended the methodological concept of Anderson and van Wincoop (2003) to allow for panel data. The model by Baldwin and Taglioni (2006) is based on the expenditure equation with the expenditure share identity as the cornerstone. The procedure follows six basic steps that are presented below. As Baldwin and Taglioni (2006) noted, there is nothing new in their theory; if there is any value added, it lies within the simple presentation.

The expenditure share identity

The derivation starts with the first step, the expenditure share identity for a single good exported from the country of origin to its destination. For clarity, the lower indices o and d are mnemonics for "origin" and "destination", respectively. The identity is following:

$$p_{od}x_{od} \equiv s_{od}E_d \tag{3.2}$$

where p_{od} is the price of the good inside the importing nation also called landed price, in terms of what price do customers in the country of destination have to pay; the price is measured in numeraire and as a matter of fact, there is no need to be specific about exactly which good is the numeraire. Next, x_{od} is the quantity of gross exports of a single variety from nation o to nation d. Hence, the product of p_{od} and x_{od} is the value of trade flow measured in terms of the numeraire. E_{od} is the destination nation's expenditure on goods that compete with imports, i.e. tradable goods, and s_{od} is, by definition, the share of expenditure on a typical variety made in the country of origin.

The expenditure function

According to microeconomic theory, expenditure share depends upon relative prices and income levels. Since the consideration of the income elasticity is postponed in the first-pass gravity equation, the expenditure shares are dependent on relative prices only. Assuming the constant elasticity of substitution (CES) function and that all goods are traded, the imported good's expenditure share based on its relative price is then expressed as:

$$s_{od} \equiv \left(\frac{p_{od}}{P_d}\right)^{1-\sigma} \tag{3.3}$$

where $P_d \equiv \left(\sum_{k=1}^{R} n_k \left(p_{kd}\right)^{1-\sigma}\right)^{1/(1-\sigma)}$ is the destination nation's ideal CES price index and thus the fraction p_{od}/P_d is the real price of the imported good. R stands for the number of nations from which the destination nation imports, including itself. n_k is the number of varieties exported from nation k, while all varieties from each nation are for simplicity assumed to be symmetric, avoiding the introduction of a variety index. Ultimately, σ is the elasticity of substitution among all varieties and it is assumed to be higher than one.

Plugging (3.3) into (3.2) yields:

$$p_{od}x_{od} \equiv \left(\frac{p_{od}}{P_d}\right)^{1-\sigma} E_d \tag{3.4}$$

which is the product specific import expenditure equation.

Adding the pass-through equation

The destination nation's landed price p_{od} consists of the production costs in the nation of origin, the bilateral mark-up and bilateral trade costs. Hence, it is defined as:

$$p_{od} = \mu \cdot \tau_{od} \cdot p_o \tag{3.5}$$

where μ is the bilateral mark-up, τ_{od} reflects all the costs of trade (transportation, insurance, etc.) and p_o is the producer price in the nation o. In reality, the prices p_o and p_{od} can be theoretically considered as the FOB and CIF prices[1], respectively. Moreover, since Dixit-Stiglitz monopolistic competition or the perfect competition with Armington goods is assumed, the bilateral mark-up μ is assumed to equal one. This eventually leads to the conclusion that the bilateral trade costs τ_{od} can be regarded as the so called CIF/FOB margin.

Aggregating across individual goods

As the next step in the theoretical derivation of the gravity model, the per-variety exports have to be aggregated in order to obtain the total gross bilateral exports from the origin nation to the destination. This is done by multiplying the expenditure share function by the number of symmetric varieties that the exporting nation supplies, namely n_o:

$$V_{od} = n_o p_{od} x_{od} \tag{3.6}$$

By plugging (3.4) and (3.5) into (3.6) we obtain an equation for total gross exports from o to d:

$$V_{od} = n_o \left(\frac{p_o \tau_{od}}{P_d} \right)^{1-\sigma} E_d \tag{3.7}$$

[1] See Section 4.1 for the definition of FOB and CIF prices and further discussion of the consequences of the difference between the two.

where V_{od} stands for the total value of exports. As the equation expresses all exports of nation o to one market, summing V_{od} over all d's would yield nation o's total output. This is used subsequently.

Using general equilibrium

This step assumes that markets clear. The assumption de facto means that the producer price p_o must adjust such that the exporting nation can sell all of its output, either home or abroad. In other words, wages and prices must adjust so the production of traded goods is equal to its sales. Hence, summing V_{od} over all markets R (that is, including nation o's own market) yields the total output $Y_o = \sum_{d=1}^{R} V_{od}$ in terms of numeraire. Using the equation (3.7) from above, the market clearing condition can be expressed as:

$$Y_o = n_o p_o^{1-\sigma} \sum_{d=1}^{R} \left(\tau_{od}^{1-\sigma} \frac{E_d}{P_d^{1-\sigma}} \right) \tag{3.8}$$

Solving this equation for $n_o p_o^{1-\sigma}$ yields:

$$n_o p_o^{1-\sigma} = \frac{Y_o}{\Omega_o} \tag{3.9}$$

where $\Omega_o = \sum_{d=1}^{R} \left(\tau_{od}^{1-\sigma} \frac{E_d}{P_d^{1-\sigma}} \right)$ measures what is called market potential (the sum of nation's trading partners' real gross domestic products divided by bilateral distance).

A first-pass gravity equation

Substituting (3.9) into (3.7) results into what Baldwin and Taglioni (2006) call their "first-pass gravity equation":

$$V_{od} = \tau_{od}^{1-\sigma} \frac{Y_o E_d}{\Omega_o P_d^{1-\sigma}} \tag{3.10}$$

Note that this micro-founded gravity equation can be re-written to get a more familiar equation. Assume that Y_o can be proxied by GDP_o, which is reasonable since it represents the total production of traded goods. Furthermore, assume that GDP_d is a proxy for E_d, the importing nation's total expenditure on traded goods and that the trade costs τ_{od} are related only to geographical distance. Then, after defining $G = 1/\Omega_o P^{1-\sigma}$, the following equation appears:

$$V_{od} = G\frac{GDP_o GDP_d}{dist_{od}^{\sigma-1}} \tag{3.11}$$

Note that this is analogical to equation (3.1). The most important difference from the physical gravity equation, as emphasized by Anderson and van Wincoop (2003), the physical constant G is in fact not a constant in the economic gravity equation. In the international trade model, the "unconstant" G includes all the multilateral resistance terms and thus varies over time and trading partners. Therefore, including this term into the empirical model is crucial for proper specification of the model.

Chapter 4

The Indirect Trade

To the issue of what this study calls the *indirect trade* is often referred to as to the *trade in value added*. As has been already mentioned above in the chapter about the literature on the indirect trade, the continuing globalization of the world economy offers a broad variety of perspectives of looking at the global value chain. Since it is not exceptional that a single product passes many different countries during its production process until it reaches its final consumer, the relevance of traditional trade statistic based on direct exports and imports is decreasing. At the same time, there is growing demand for the ability to trace the production processes and to report these value adding chains into the trade statistics.

Nowadays, policy makers cannot rely purely on direct trade flows when estimating the effects of various trade policies. Firstly, there are many discrepancies in the trade statistics and secondly, the increasing interdependence among mutually trading economies changes the geographical structure of trade. Both reasons are explained in the following two sections.

4.1 Sources of statistical discrepancies

The undoubted fact that trade statistics are not absolutely accurate can be easily illustrated using the so-called mirror statistics. They show the differences between exports and imports as reported by both participants of the transaction. Although both values should be theoretically equal, they always differ. For illustration, a random sample of trading partners of Czech Republic and their bilateral trade flows in year 2009 is presented in Figure 4.1. Since the source database by IMF Direction of Trade Statistics declares that exports are valued in FOB prices and imports in CIF, the imports should, in theory, be higher than exports. However, as can be seen in Figure 4.1, the sign of the difference between exports and imports follows no observable pattern. This phenomenon is caused by many different effects (such as the Rotterdam effect) that are presented below.

Several papers can be found that summarize the theoretical and/or actual reasons why trade data as reported by exporters and importers may differ from each other. One of them is the study by Ferrantino and Wang (2007), another examples are the report by IMF (2000) or the work of Tsigas et al. (1992). Generally, it is agreed that the causes of discrepancies in trade statistics are following:

- **Pricing** - An important role in reported statistics is played by the transportation and insurance costs. "Remarkably, despite the likely importance of transport costs for economic growth, there are no adequate measures of transport costs for a large sample of developed and developing countries. The best that we could obtain for a large number of countries is the IMF estimates of the CIF/FOB margins in international trade." (Gallup et al. (1999), p. 18). The abbreviation CIF stands for Cost (or Carriage), Insurance, Freight and FOB stands for Free On Board. The FOB price is usually used by the exporter, as it reflects all costs including loading the goods in the exporter's port.

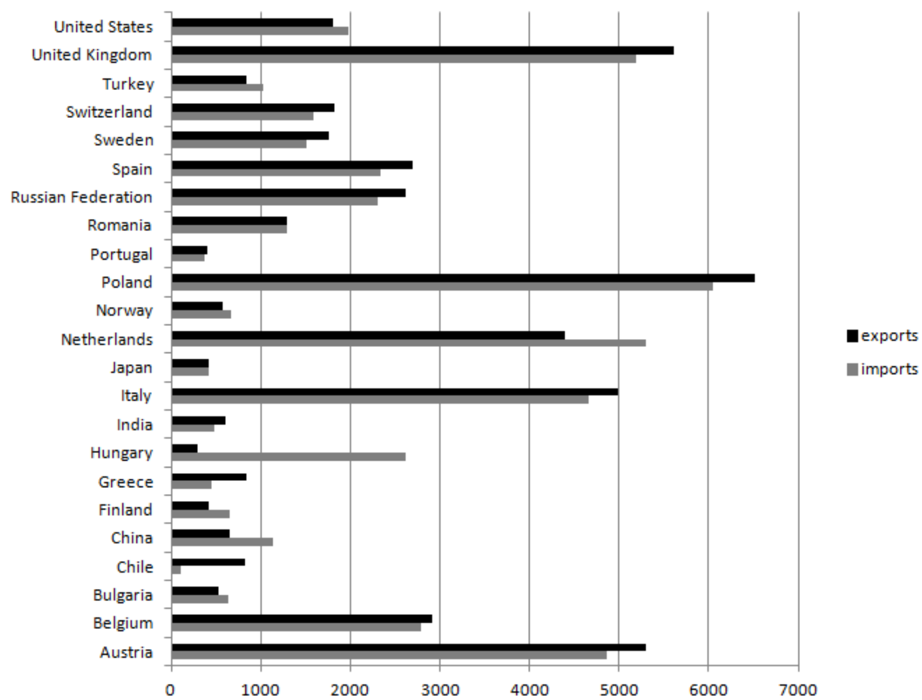

Figure 4.1
Mirror statistics
First row represents Czech exports to a partner, while second row represents imports from Czech Republic as reported by the partner. Values are in USD million valid for the year 2009. Source: IMF Direction of Trade Statistics

The CIF price, in addition, includes the shipping and insurance costs. These costs, which must be added to the value of the merchandise, create a systematic bias in the trade statistics, because the importer's data tend to be logically higher than the exporter's data. This problem cannot be simply solved, as it is often very difficult to separate the shipping and insurance costs from the actual cost of the good, since these costs are sometimes charged together with the value of the merchandise by the seller, sometimes the buyer pays the costs via a different invoice. It depends on the specific deal between the two particular trading partners and adopting some global standards would in this case cause administrative barriers to trade rather than bring substantial benefits. For illustration, the CIF/FOB margin for 1995 is 3.6 percent for the U.S., 4.9 percent for Western Europe, 9.8 percent for East Asia, 10.6 percent for Latin America, and 19.5 percent for Subsaharan Africa (Gallup et al., 1999).

- **Triangular trade** - The topic of this study is the indirect trade, to which is often referred as to the triangular trade when it comes to explaining statistical discrepancies. In the relevant literature, one might come across with the concept called "the Rotterdam effect". The problem is that the countries with a major shipping port (such as the Netherlands and the port of Rotterdam) account for higher volumes of import and export in the trade statistics due to the fact that they very often serve as a transit country for the goods traveling from one country to another. When country A exports to country C via country B, the exporter often reports an outflow of goods to country B while the importing country C usually reports inflow from the country of origin, which is country A. It all depends on how the transactions are processed (whether there is a middleman in the transit country or not) and it differs from case to case. Even if both partners report the transaction correctly, e.g. country A exports to B and country

C imports from B, the transit country B's trade volume is artificially increased since B did not actually "trade".

- **Timing** - A discrepancy caused by different timing of reporting occurs, when, for example, the exporter reports the outflow of goods at the end of a month and the importer reports the inflow at the beginning of the next month (different holidays might cause that as well). However, this is not a source of substantial discrepancy, as it is going to disappear after aggregating the monthly into yearly data and is likely to not occur at all if the shipping time is short enough.

- **Classification** - One of the marginal sources of statistical discrepancies is the inaccuracy of classification. According to the World Customs Organisation, over 98 % of the merchandise in international trade is classified in terms of the Harmonised System. However, there are still possible ways how the importer could classify the merchandise differently from the exporter. In particular, this considers the classes 98 and 99 - special and confidential transaction, e.g. army equipment or new technologies which have not been assigned a class yet. Nevertheless, this discrepancy is negligible in general, especially for the purposes of this study as it disappears after aggregating the data.

- **Mis-invoicing** - There are incentives for trading partners to falsify invoices. This is mostly done because of administrative reasons. For example, in order to get more government support, an exporter might tend to overvalue the invoices. On the other hand, an importer has an incentive to underprice the imported merchandise in order to avoid high import tariffs. This is a common practice e.g. in the case of the imports from China to the European Union that is being very protective. Different import tariffs on different groups of products force the businessmen to optimize the invoices by misclassifying and mispricing. Although this practice is regulated by setting standard prices on various products, a reason for minor inaccuracies in reporting to customs offices exist.

In fact, there are several more sources of statistical discrepancies than those listed above. However, their significance is marginal. The two most important causes of discrepancies are the CIF/FOB pricing issue and the Rotterdam effect. Unfortunately, it is not easy to distinguish between these two effects in the differences of mirror statistics. Otherwise, the CIF/FOB margin could be used as an explanatory variable in the gravity model as was done by Gaulier et al. (2008). In their model, this variable was found to be significant. Nevertheless, the issue of obtaining reliable data on CIF/FOB margin is an extensive topic and reaches outside the range of this study.

4.2 The role of Czech Republic in the indirect trade

The Czech Republic is a small open economy. This fact suggests that it is materially dependent on the global value chain. The country's major industries need to import from abroad for their own processing, since the economy is rather manufacturing-oriented. On the other hand, as an export-based economy, the Czech Republic supplies not only its domestic demand. Therefore, the effect of the indirect trade is expected to be important. This chapter brings a deeper insight in the role of Czech Republic as an intermediary in the global value chain.

As illustrated in Figure 4.2, the territorial structure of Czech exports is in accordance with the general theory of gravity of international trade. The greatest part of exports flows into the biggest and nearest economy - Germany. Other major exporting targets, are either direct neighbors (i.e. Slovakia, Poland, Austria) or considerably large and relatively close economies

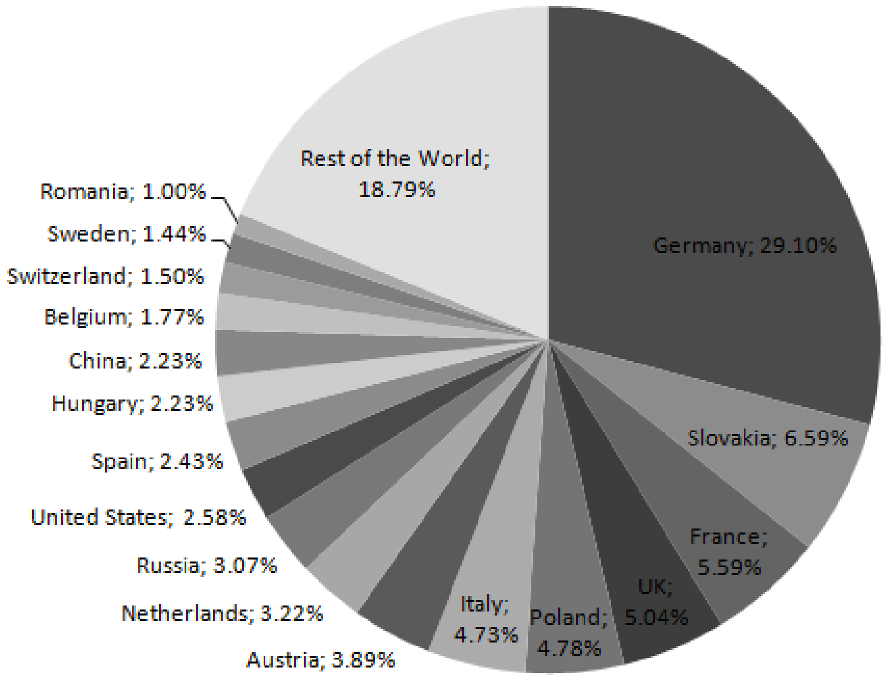

Figure 4.2
Geographical structure of Czech exports
As in 2009. Source: OECD-WTO TiVA database

(e.g. France, United Kingdom, Italy, the Netherlands). The largest countries, such as Russia, the United States or China, despite their potentially high demand, account for only 2-3% of Czech exports, because it is negatively affected by their geographical distance and other related factors - cultural and institutional barriers, trade agreements, etc.

The main trading partner of Czech Republic is Germany that accounts for 29.1% of total exports. The fact that Germany is one of the biggest exporters globally[1] further suggest that a major part of imported products is not intended to cover domestic consumption but enters the production process of German exports.

[1] Ritter and Loschky (2006): In the year 2005, Germany exported for the third time in a row more goods than any other country in the world.

	2004	2005	2006	2007	total
X	218.2	240.2	315.6	505.0	1279.0
IX	203.6	204.8	299.7	373.4	1081.5
IX/X	93.3%	85.3%	95.0%	73.9%	84.6%

Table 4.1
Czech indirect export to China via Germany
Variable X represent Czech gross exports to China, IX (indirect export) is the Czech content of German exports to China. Values are in EUR million. Source: Author's own calculations.

Using basically the same methodology as the OECD-WTO TiVA database (presented in Section 5.1.1), it is possible to estimate the import content of German exports. This has been done by Ritter and Loschky (2006). Nevertheless, one might continue with calculations and estimate how much of the indirect exports that pass Germany originated in the Czech Republic. This method relies on a strong assumption about constant proportions in the geographical structure of German imports. This has been done by Wlazel (2012) and the results are summarized in Table 4.1. The estimated values of indirect trade that is led via Germany revealed the very strong connection between the Czech and German economy.

In fact, this is the main motivation of this paper for choosing Czech Republic as the exporting country in the indirect-trade-augmented gravity model. Specifically, the importance of the German economy for Czech exports is included in the gravity model by introducing the explanatory variable SGE - share of German exports. The variable, its significance and the results are presented later.

4.2.1 Czech Republic in the TiVA database

This section provides a general overview about the role of Czech Republic in the global value chains according to the data acquired from the OECD-WTO Trade in Value Added database. The general methodology of decomposi-

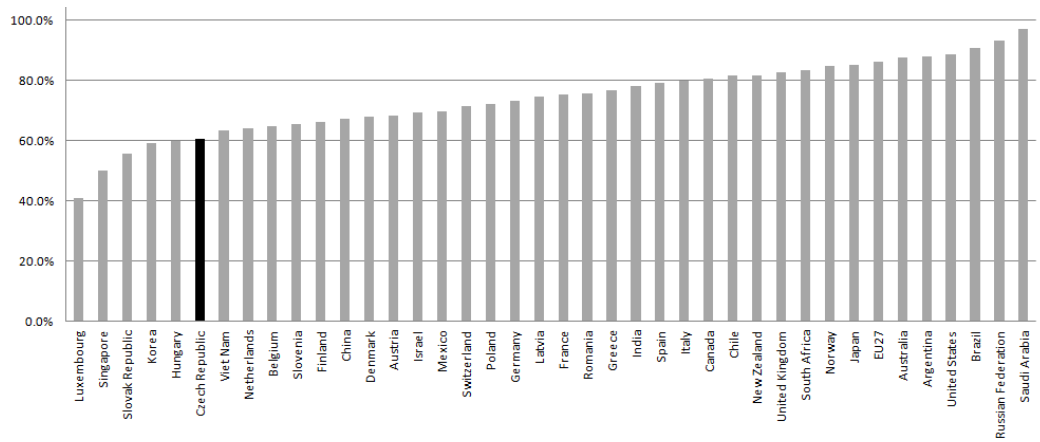

Figure 4.3
Domestic value added content of gross exports by countries
Values for 2009 in %. Source: OECD-WTO TiVA

tion of gross exports into domestic and foreign value added is described in Section 5.1.1.

In 2009, the domestic value added in gross exports of Czech Republic was 60.6%, which is below the OECD average. This relatively low value indicates the substantial participation of Czech Republic in the global value chains - countries with a high share of domestic content of exports are considered to be self-sufficient in the production of their own exports. In 1995, the domestic value added share of Czech exports was 67.9%, singalling that the interdependence of the country with its trading partners is increasing over time. Between 2005 and 2009, the value has changed by some 1 percentage point, suggesting this indicator was not affected by the financial crisis. Comparing the values for Czech Republic with other countries, a clear trend is observable; the smaller an economy the lower its domestic content of exports. An explanation of this relation is straightforward; larger economies' industries are interconnected within national borders while the smaller ones are more dependent on their foreign relations.

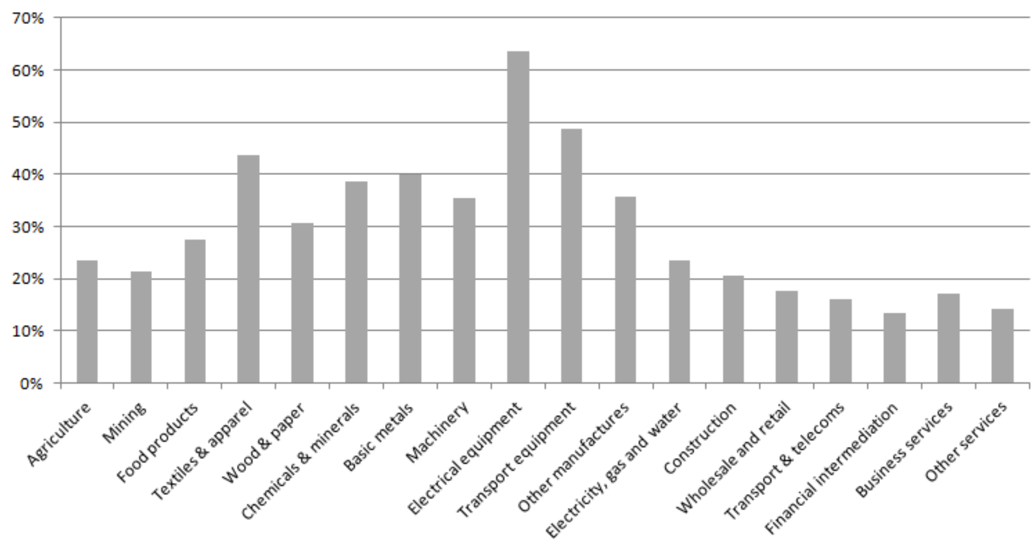

Figure 4.4
Foreign value added content of gross exports by industries
Values for Czech Republic in 2009 in %. Source: OECD-WTO TiVA

The indicator presented in the Figure 4.3 is used as the explanatory variable $VAEX$ in the gravity model below. It is expected to be significant, as it should represent the countries' participation in the global value chains - a similar variable as the trade openness.

Figure 4.4 illustrates the foreign value added content of Czech gross exports decomposed into industry level. The TiVA database uses the ISIC Rev 3.1 classification and further aggregates it into 18 industries (see Table A.1 in the Appendix).

The highest share of foreign value added content reported the *Electrical equipment* industry that accounted for 63.5% of its exports being not of domestic origin. This fact is not surprising, considering the nature of the industry.

An excellent example of the character of the production process of electrical equipment is the case of Apple iPhone. This popular cellphone is generally considered to be manufactured in the People's Republic of China.

However, the belief that iPhones are simply "made in China" is false. The whole story behind the production of Apple's popular equipment is much more complex and nicely illustrates the increasing importance of studying the global value chains.

While the study by Dedrick et al. (2010) revealed the true origin of the iPad (see the literature review in Section 2.2), Xing and Detert (2010) and Inomata (2013) applied similar techniques to unveil the value adding chain of the iPhone. According to their results, out of the USD 500 retail price of iPhone in 2009, the People's Republic of China, which is the largest producer and exporter of iPhones, received only USD 7. An analysis based on decomposing the cost structure of separate parts shows that, for example, flash memories and touch screens are products of Toshiba, so the Japanese contribution to one iPhone is known to be around USD 61. Other major shares in the iPhone manufacturing cost distribution pie-chart are assigned to Germany, Korea, the United States, and others.

In terms of the variable presented in Figure 4.3, the domestic value added content of Chinese export of iPhone would account for only some 3.6% (Xing and Detert, 2010). But as we can see in Figure 4.3, the aggregated domestic value added content of total Chinese gross exports is 67.4%. The large difference is not caused only by very high values for other products and industries, but by the different approach that has to be used on the aggregated level. An estimation based on the input-output analysis is advisable, although its accuracy is limited by the two strong assumptions about production homogeneity and proportionality (see Section 5.1.1).

Another industries in which Czech Republic reports high content of foreign value added are *Transport equipment* and *Textiles and apparel* with the 2009 values of 48.7% and 43.7%, respectively. The case of the *Transport equipment* industry can be explained by its high interconnection with the automobile industry in Germany.

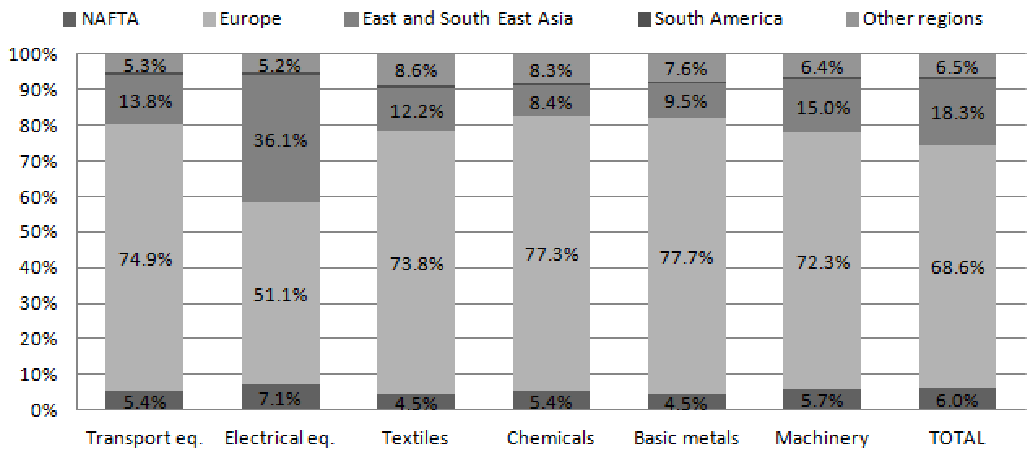

Figure 4.5
Regional origin of foreign content of exports
Values for Czech Republic in 2009 in %, by selected industries with lowest share of domestic value added content. Source: OECD-WTO TiVA

The geographical structure of the origin of the foreign content of Czech exports is presented in Figure 4.5. Only industries with high relative share of foreign content of their exports are selected. Clearly, most of the foreign content consists of European intermediates (68.6% for all industries in total), second most important contributors (with 18.3%) in the production of Czech exports are countries from East and South East Asia, and 6% originated in NAFTA countries. The geographical structure of the origin of foreign value added varies the most in the *Electrical equipment* industry that reports the highest share (36.1%) originating in East and South East Asia.[2] Considering the specifics of the industry, it is not surprising that one of the biggest contributions comes from Japan that accounts for 6.86% of the total Czech exports of electrical equipment.

[2]East and South East Asia includes Japan, Korea, Brunei Darussalam, Cambodia, China, Chinese Taipei, Hong Kong, Indonesia, Malaysia, Philippines, Singapore, Thailand and Viet Nam.
NAFTA countries are the United States, Canada and Mexico.

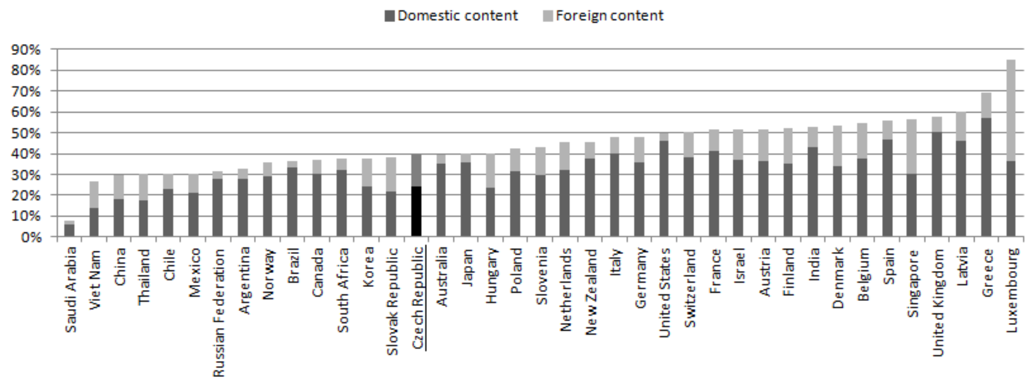

Figure 4.6
Services content of gross exports by countries
Values for 2009 in %. Source: OECD-WTO TiVA

Figure 4.6 reflects the services value added embodied in gross exports and provides a simple measure that illustrates the shares of domestic and foreign underlying contribution made by services to exports. In the case of Czech Republic, 39.5% of exports reflected services in 2009, which is relatively low compared to the OECD (48.3%) and even lower compared to the EU27 average (54.1%). It confirms the fact that Czech Republic specializes rather in manufacturing activities than in services.

The services content of exports in Figure 4.6 is decomposed into domestic and foreign origin part. Out of the selected countries, Czech Republic belongs to countries with the highest share of foreign to total services content embodied in exports (38.7%). An interesting case is Luxembourg that is the only country whose exports reflected more foreign than domestic services, while having noticeably the highest contribution of services in its exports at the same time. The explanation is that Luxembourg is, in comparison to for example the Czech Republic, rather services than manufacturing oriented and simultaenously more participating in the global value chains - see Figure 4.3: Luxembourg has the highest foreign value added content of exports.

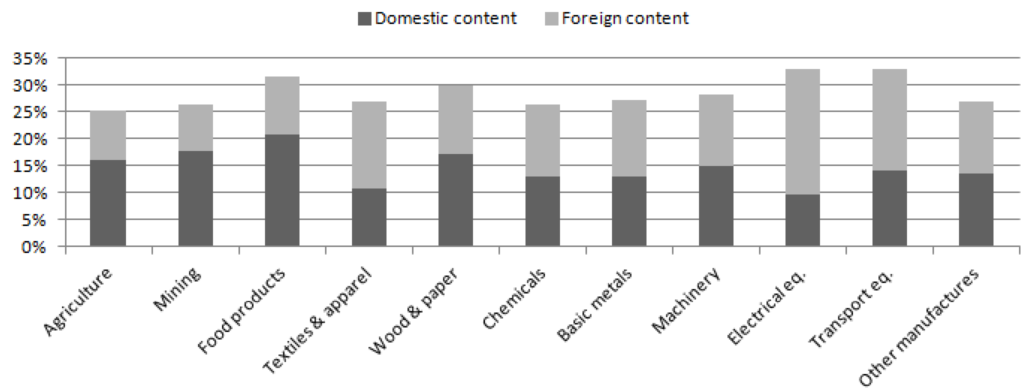

Figure 4.7
Services content of gross exports by industries
Values for Czech Republic in 2009 in %. Source: OECD-WTO TiVA

The services content of exports structured by manufacturing industries is shown in Figure 4.7. The contribution of services is a bit lower than the OECD average (35%), being close to the average only in *Electrical equipment*, *Transport equipment* and *Food products* industries.

For each industry's exports, using the input-output methodology, the foreign content of services can be structured by the country of the service's origin. This vector is then used as an explanatory variable in the gravity model below in this study and is expected to be significant.

Chapter 5

Empirical Analysis

This chapter introduces the empirical estimation of the gravity model for Czech Republic. It is divided into three main sections with the following structure.

First section describes the methodology that consists of two separate parts; one part presents how the input-output framework is applied to decompose trade flows into foreign content and the domestic value added; and the other part presents the econometric framework - that is, the regressions that are used to estimate the coefficients of the gravity equation based on the panel data analysis.

Section two summarizes the data coverage of this paper. The main source database is introduced and how its results are exploited to adjust the dependent variable. By cleansing the gross exports of the foreign content, a new variable is created that represents the trade flows in terms of value added. Subsequently, all the explanatory variables are listed together with their descriptive statistics, sources of data and expectations about the sign of their coefficients. These regressors consist of standard macroeconomic variables and on top of that, new variables reflecting the value added trade are included.

The last section of this chapter then provides mainly tables with results of individual models. Essentially, there are three types of model - the aggregated, the disaggregated and the models for a specific industry. All of these models are always presented twice. Firstly with standard dependent variable of gross exports and secondly with the adjusted one.

5.1 Methodology

5.1.1 The input-output framework of value added trade

In order to estimate the magnitude of indirect trade between several countries, one requires their appropriate input-ouput tables. When the matrix of intermediate consumption is available, standard techniques of the input-output analysis are to be employed. This includes creation of the so called matrix of technical coefficients describing the interrelationships between industries. In the input-output framework, following equality holds:

$$y = A \cdot y + f \tag{5.1}$$

where y is a $(n \times 1)$ vector of the output of n industries within an economy, A is the $(n \times n)$ technical coefficients matrix with the element a_{ij} standing for the ratio of inputs from domestic industry i used in the output of industry j (in other words, how much of the output from industry i is necessary to produce one unit of output of industry j), and f is a $(n \times 1)$ vector of final demand for domestically produced goods and services, including exports.

In the document published by OECD-WTO (2013), a joint Organisation for Economic Cooperation and Development and the World Trade Organisation co-work, the methodology to calculate import content of exports (IX) is described as following:

$$IX = m \times (I - A)^{-1} \times e \tag{5.2}$$

where m is a $(n \times 1)$ vector with components m_j (the ratio of imports to output of industry j), e is the $(n \times 1)$ vector of exports by industry, and I is the $(n \times n)$ identity matrix. The matrix $(I - A)^{-1}$ is called the *Leontief inverse* of the input-output matrix. The Leontief inverse tells us how much output from each industry is required to produce a given vector of final goods, where in this case the vector of final goods is the vector of exports.

Although there are several technical differences from the approaches of various researchers, the methodology proposed by OECD-WTO is the most valid for the purposes of this study, as the datasets used for testing the effects of indirect trade on the gravity model in this analysis are mostly acquired from the OECD-WTO on-line database.

Assumptions There are two main assumptions used in estimating the values of import content of exports:

- The first is the *homogenity* assumption, which assumes, in very simple terms, that for a given industry, all firms allocated to that industry use the same goods and services to produce the same outputs. It is usually used to disaggregate the use of imported intermediate goods. This is a very strong assumption, as firm level data reveal a large heterogeneity in the import penetration rates of firms, between those actively engaged in trade and those producing only for the domestic market.

- Nevertheless, the second assumption is probably even stronger. It is the *proportionality* assumption, which assumes that the proportion of intermediates that an industry purchases from abroad is equal to the ratio of imports to total domestic demand in that product. "Indeed this is also an assumption that is widely used by national statistics offices in constructing tables. This hypothesis is acceptable for industrialised countries, where there is little product differentiation between what is produced for export and what is produced for the domestic market" (OECD-WTO, 2013).

5.1.2 The econometric framework of estimating the gravity

The methodology used to estimate the coefficients of the gravity equation of bilateral trade is based on standard econometric tools for panel data analysis. In its most general form, the fundamentals of panel data analysis are summarized by Wooldridge (2010), who came up with a very comprehensive overview in his well-known textbook. For the purposes of this study, a practical guideline by Park (2011) has been used in order to deal with the technical issues when programming in the Stata software. Since this thesis assumes general knowledge of econometrics and specifically the characteristics of regressing panel data, the methodological framework presented below starts with the application of the panel data analysis on the gravity equation.

The traditional gravity equation as described in (3.1) can be re-written in order to match with the requirements of econometric estimation in the following form:

$$T_{ij} = \beta_0 GDP_i^{\beta_1} GDP_j^{\beta_2} D_{ij}^{\beta_3} \epsilon_{ij} \tag{5.3}$$

where T_{ij} represents the bilateral trade flow from country i to country j, GDP is the proxy for a country's market size, its total expenditure or its output as in (3.11), D_{ij} is the mutual geographical distance of the two objects (in terms of physics) or a variable composed of several regressors proxying the bilateral trade costs between countries, including physical distance, ϵ_{ij} is the error term and β is the vector of coefficients to be estimated.

Since the error term is assumed to be statistically independent on the other explanatory variables and its mean is assumed to equal one ($E(\epsilon_{ij}) = 1$), following equality holds:

$$E\left(T_{ij} \mid GDP_i, GDP_j, D_{ij}\right) = \beta_0 GDP_i^{\beta_1} GDP_j^{\beta_2} D_{ij}^{\beta_3} \tag{5.4}$$

This is called the multiplicative form of the gravity equation that, unfortunately, does not allow to apply standard techniques of linear regression. The standard approach to deal with this problem is using the logarithmic transformation of the equation in order to obtain linear form of the model:

$$ln(T_{ij}) = ln(\beta_0) + \beta_1 ln(GDP_i) + \beta_2 ln(GDP_j) + \beta_3 ln(D_{ij}) + ln(\epsilon_{ij}) \tag{5.5}$$

In this form, the gravity equation can be estimated using standard panel data analysis. It is a common practice in the trade literature employed by most of researchers (e.g. Moser et al. (2006), Bussière et al. (2005), Pěchová (2013), Janda et al. (2012) and many others), albeit several recent studies suggest that the log-linear transformation is not advisable, as described below. A study by Herrera (2010) provided a list of the most widely used alternative estimation methods of the gravity model based on a survey of the recent literature concerning this topic. This paper then follows Herrera (2010) who in addition applied two methods out of his list - panel OLS and Poisson Pseudo Maximum Likelihood estimator - on a dataset covering 80% of world trade. These two methods are also employed in this analysis to show that the effects of indirect trade are not dependent on the choice of the estimation method.

5.1.2.1 Estimation of the log-linear equation

There are three basic estimation methods of the linear form of the gravity equation, as in (5.5), namely Pooled OLS, Random effects and Fixed effects.

- Pooled OLS is to be used if individual effects (cross-sectional or time-specific) do not exist. The equation takes the general form of $y_{it} = \alpha + X'_{it}\beta + \varepsilon_{it}$ and must fulfill the well known core assumptions to obtain consistent results. That is however a very specific case when using panel data, since disturbances usually vary across individuals and thus cause heteroskedasticity and autocorrelation. Pooled OLS is then no longer the best unbiased linear estimator.

- For panel data, the Random effects and Fixed effects estimators are usually employed as they examine the effects of individual or time. The core difference between the two lies in the role of dummy variables. The functional forms are $y_{it} = (\alpha + u_i) + X'_{it}\beta + v_{it}$ and $y_{it} = \alpha + X'_{it}\beta + (u_i + v_{it})$, where the first equation is fixed effects and the second random effects. u_i is the estimated parameter of the dummy variable, whereas in the fixed effects model it is a part of the intercept and an error component ($\epsilon_{it} = u_i + v_{it}$) in the random effects model. A fixed group effect examines individual differences in intercepts, assuming the same slopes and constant variance. Since the individual effect is time invariant and a part of the intercept, u_i is allowed to be correlated with other regressors. The fixed effects are estimated by least square dummy variable regression, i.e. an OLS with dummy variables for group- and/or time-effects. On the other hand, random effects model assumes no correlation of the individual effects with other regressors and estimates individual error variances. Hence, u_i is a group (or time) specific component of the composite error term, not a part of the intercept.

There are several commonly used methods to determine the right model, although Judson and Owen (1999) suggest directly that the fixed effects are generally more appropriate than the random effects. They argue that a typical macro panel contains most of the countries of interest, which is the case of this study.

Nevertheless, for the comparison between fixed effects and random effects models, the Hausman specification test (Hausman, 1978) is applied. The test's null hypothesis is that the individual effects are not correlated with the other regressors. Thus, if null is rejected, employing the fixed effects model is favored.

To determine if pooled OLS is more appropriate, standard F-test is applied on the coefficients of the dummy variables in the fixed effects model and Lagrange multiplier (LM) test (Breusch and Pagan, 1980) on the random effects model. If the null hypothesis is rejected, the pooled OLS estimator is not advisable.

Shortcomings of the linear estimation

Although the estimation method based on the linear equation is commonly used, recent literature suggests alternative approaches in order to prevent well-known shortcomings of the OLS estimation of the gravity model. As Herrera (2010) points out, log-linearisation of the gravity equation changes the properties of the error term. In the presence of heteroskedasticity, which is usual for trade data, the OLS estimation is inconsistent. Although the estimated coefficients remain unbiased, it biases the variances of the parameters and consequently, the t-values cannot be trusted.

Apparently, in contrast with physics, the zero flows are often present in the trade data. This could be caused by rounding errors, lack of reporting or actual zero trade flows. See more on the zero observations issue in Section 3.1.1 and on the statistical discrepancies in Section 4.1. The problem with the log-linearisation of the gravity equation lies then simply in the fact that the logarithm of zero is not defined. The traditional approach in the literature that uses OLS techniques is either to drop the observations or replace them with a small value. According to Silva and Tenreyro (2006), both of the two solutions are however highly misleading.

One of the most evident shortcomings of the linear estimation is based on the well-known Jensen's inequality. In the case of the gravity model, the inequality can be employed on the following. Recalling the linear equation (5.5) and applying the standard properties of expected value of a variable, it can be written that:

$$E\left(ln(T_{ij})\right) = ln(\beta_0) + \beta_1 ln(GDP_i) + \beta_2 ln(GDP_j) + \beta_3 ln(D_{ij}) + E\left(ln(\epsilon_{ij})\right) \tag{5.6}$$

This leads to the conclusion that the coefficients $ln(\beta_o)$, β_1, β_2 and β_3 can be estimated consistently only if:

$$E\left(ln(\epsilon_{ij})\right) = 0 \tag{5.7}$$

This conclusion is crucial, since to derive the equation (5.4) above, it is assumed that $E\left(\epsilon_{ij}\right) = 1$ which ultimately yields:

$$ln\left(E\left(\epsilon_{ij}\right)\right) = 0 \tag{5.8}$$

Finally, according to the findings by Jensen (1906), we know that:

$$ln\left(E\left(\epsilon_{ij}\right)\right) \geq E\left(ln\left(\epsilon_{ij}\right)\right) \tag{5.9}$$

This inequality holds since logarithm is a concave function. It implies that the condition for consistent estimators of the regression's coefficients as expressed in equation (5.7) is met only in a very specific case.

5.1.2.2 Estimation of the multiplicative equation

This section follows Wooldridge (2010) and Silva and Tenreyro (2006), summarizing the basic methodology behind the Poisson Pseudo Maximum Likelihood estimation. The multiplicative form of the equation (5.5) can be written as:

$$T_{ij} = exp\left(ln(\beta_0) + \beta_1 ln(GDP_i) + \beta_2 ln(GDP_j) + \beta_3 ln(D_{ij}) + ln(\epsilon_{ij})\right) \tag{5.10}$$

where can be directly avoided the problem of zero trade flows which do not need to be log-transformed. Generalizing this equation, it can be formulated as the following stochastic model:

$$y_i = exp(x_i\beta) + \epsilon_i \tag{5.11}$$

with $y_i \geq 0$ and $E\left(\epsilon_i \mid x\right) = 0$, where y represents the dependent variable T of bilateral trade flows, x is the set of regressors, β are the coefficients to be estimated and ϵ is the error term. According to Wooldridge (2010), the Poisson Pseudo Maximum Likelihood estimator β is the one that solves:

$$max \sum_{i=1}^{N} l_i(\beta) \tag{5.12}$$

where the log likelihood function $l_i(\beta)$ is defined as $l_i(\beta) = y_i log\left(m\left(x_i, \beta\right)\right) - m\left(x_i, \beta\right)$. Since the PPML estimator is applied on the gravity equation as in (5.11), the mean function m is considered as the exponential function $exp(x_i\beta)$. The log likelihood function can be then re-written as:

$$l_i(\beta) = y_i x_i \beta - exp(x_i\beta) \tag{5.13}$$

As Silva and Tenreyro (2006) point out, all that is needed for this estimator to be consistent is the correct specification of the conditional mean, i.e. $E\left(y_i \mid x\right) = exp(x_i\beta)$. Furthermore, the data do not have to be Poisson at all and y_i does not have to be an integer.[1]

[1] As a matter of fact, that is why the estimator is called the "pseudo" (or "quasi") maximum likelihood.

5.2 Data

In order to estimate the parameters of the gravity equation, standard panel data are used. In econometrics, it is generally desirable to have a sufficient amount of observations to get as accurate results as possible. In terms of panel data, one has to acquire a number of individuals N in a number of time periods T. These are called the cross-section and time-series dimensions of the panel, respectively. The total number of observations is then NT.

Since the standard gravity datasets consist of macroeconomic data (exports, gross domestic product, etc.) and other variables such as population or geographical distance that are available for a large number of observations in relatively long time periods, the gravity model is usually estimated on thousands of observations (over hundred of countries and tens of years). Since this study aims to test the effects of indirect trade, it is limited by the availability of relevant data - the data on trade in value added.

As explained in Section 5.1.1, the decomposition of gross trade data into foreign and domestic value added origin is based on national input-output tables. The harmonization of national input-output tables is currently an on-going process, hence the number of reliable data is limited. Nevertheless, the latest release of the joint OECD-WTO TiVA initiative from 21st May 2013 provides an already sufficiently large sample of observations.

The TiVA database is constructed from input-output tables of 57 reporting countries in 5 years ranging from 1995 to 2009 (namely 1995, 2000, 2005, 2008 and 2009). This leads to the total number of observations of 280.[2] The set of included countries is listed in Table A.2 in the Appendix. Although national input-output tables are available for more countries in more years, this study relies on the consistency of the OECD-WTO estimates and its strongly balanced panel.

[2]Since Czech Republic is one of the reporting countries, $N = 57 - 1$. Whilst $T = 5$, the number of observations is $NT = 56 \times 5 = 280$

Since the data from the TiVA database are broken down into industry level, it is possible to obtain a higher number of observation by using the disaggregated dataset. The classification based on ISIC Rev. 3.1 splits the data into 18 industries, including manufacturing and services. The OECD-WTO's classification with respective ISIC codes is presented in Table A.1 in the Appendix. The final number of observations is then 5040 $(= 18 \times 280)$ and the results of the model based on the disaggregated dataset are presented in Section 5.3.2.

5.2.1 Adjusting the dependent variable

The import content of exports, as defined by OECD-WTO (2013) above in equation (5.2), is what in the TiVA database is called the *foreign value added embodied in gross exports* (see Figure 4.4). To formalize this, the relative share of foreign content in a country's export can be defined as IX/GX, where GX is the vector of total gross exports. Thus, the expression $1 - IX/GX$ then represents the relative share of domestic content of export (see Figure 4.3). Rearranging this, we define the Domestic Origin Exports[3] (DOX) as the difference between gross exports and their imported content:

$$DOX = GX - IX \tag{5.14}$$

The variable DOX is then one of the key variables in this study; it is used below with the intention to improve the gravity model for Czech Republic. It is expected to be a more relevant variable representing the trade flows in the gravity model - the variable T_{ij} in equation (3.1).

In the models below, the dependent variable is transformed in order to match with the equation's requirements. That is, in the case of the log-

[3] In the study by Johnson and Noguera (2012), the variable VAX - Value Added Exports is used. Since they use the same input-output approach as OECD-WTO, it is indeed the same variable with different name.

linearized form of the gravity model (i.e. the random-effects GLS estimation), the natural logarithms $ln(GX)$ and $ln(DOX)$ are used. Since the logarithm of zero is not defined, a problem occurs when there are zero trade flows for particular importers in particular years. See the discussion on solution of this problem in Section 3.1.1. The Poisson Pseudo Maximum Likelihood estimator is based on the multiplicative form of the gravity equation and does not count on logarithms, therefore the zero observations issue is considered in the linear estimations only.

For the linear estimation, this study solves the problem by both adding a small value (namely 0.01) to the variable and dropping the observations. Although Burger et al. (2009) argue that the choice of the value biases the results significantly, their estimations are based on a much larger dataset with a higher proportion of zeros in their trade flows observations. For instance, Janda et al. (2012) did a sensitivity analysis of the choice of the small value to be added instead of zero in their gravity model for Czech Republic and concluded that it does not affect their estimated coefficients. In fact, in the aggregated model in this study, there are no zero trade flows observed. In the disaggregated model, zero trade flows account for only 137 out of the total 5040 observations. And in the industry-specific models, there are 3 zeros out of 280 observations in the case of *Electrical equipment*, *Textiles & apparel*, *Basic metals*, *Chemicals* and *Machinery* industries and only 2 zeros in the *Transport equipment* industry.

In the case of the Poisson Pseudo Maximum Likelihood estimation of the multiplicative form of the gravity equation, Silva and Tenreyro (2006) point out that the algorithm may not converge if the regressors have different scales[4], which concerns the models below. They suggest to solve the problem by re-scaling or standardizing the variables. In order to remain

[4]In fact, Silva and Tenreyro (2006) have written their own "ppml" command that bypasses the convergence problems when using the standard "poisson" command in the Stata software. See http://privatewww.essex.ac.uk/~jmcss/LGW.html. Their "ppml" command is exploited in this study.

consistent throughout the research, the latter solution is employed in this analysis. With the exception of the dummy variables, all the regressors in the models estimated with PPML are standardized. A variable x is standardized by subtracting its mean value and dividing the difference by the standard error, i.e. $(x - E(x))\,/SE(x)$. By standardizing, the regressors are automatically re-scaled.

5.2.2 Explanatory variables

This section contains the summary of the explanatory variables exploited in the models below. The list includes names, labels, descriptive statistics, source databases and expectations about the sign of the coefficient. It is structured as follows: At first the standard macroeconomic variables for a gravity model are introduced. Secondly, there are dummy variables standing for whether the importing country is in a trade agreement (or has a common border) with Czech Republic. The dummies are followed by variables representing the indirect trade and thus are most relevant for this analysis. In addition, two more variables, inspired by other researches (e.g. Janda et al. (2012) or Pěchová (2013)), are included in order to prevent omitted variable bias.

- GDP_{it} **- Gross Domestic Product**; The key variable is a proxy for market size of country i in time t. Its values are in USD billions and are obtained from the International Monetary Fund's on-line database. Since the gravity model generally assumes that the larger the country's market the more exports it demands, the coefficient is expected to be positive and very significant. An additional rationale for the positive sign are e.g. economies of scale and increasing experience when dealing with familiar markets.

- Pop_{it} - **Population**; Similarly as the gross domestic product, the variable is a proxy for market size of country i in time t. Its values are in millions and are obtained from the International Monetary Fund's online database. The higher the country's population, the more Czech exports are assumed to be attracted, since the exporters have more opportunities to sell their products in larger markets. Therefore, expected coefficient is positive.

- $Dist_i$ - **Distance**; The variable stands for not only geographical distance in its literal sense (as employed by Newton (1687) in his original model of the actual "gravity") but it also proxies transportation as well as information costs. It is calculated as the distance between the capital of country i and Prague. Values in kilometres based on the equation $dist(i, cz) = r \cdot cos^{-1}(sin\delta_{cz} \cdot sin\delta_i + sin\delta_{cz} \cdot sin\delta_i \cdot cos(\phi_{cz} - \phi_i))$, where δ andϕ are latitude and longitude, respectively, and r is the radius of the earth (= 6,378 km), are obtained from http://www.timeanddate.com/worldclock/distance.html. The expected sign of the coefficient is negative. On the other hand, as noted by Moser et al. (2006), a positive sign could also be rationalized should the correlation of a country's business cycle with the Czech economy's business cycle decrease with distance.

- EU_{it} - **European Union**; The dummy variable takes on value 1 if country i was a member of the European Union in year t, and 0 otherwise. The sign of the coefficient is expected to be positive.

- $V4_i$ - **Visegrad Four**; The dummy variable takes on value 1 if country i is a member of the Visegrad Four (i.e. Czech Republic, Slovakia, Poland and Hungary), and 0 otherwise. The sign of the coefficient is expected to be positive.

- $Border_i$ - **Common border**; The dummy variable takes on value 1 if country i shares a common border with Czech Republic (i.e. Germany, Austria, Poland and Slovakia), and 0 otherwise. The sign of the coefficient is expected to be positive.

- $OECD_i$ - **Organisation for Economic Co-operation and Development**; The dummy variable takes on value 1 if country i is a member of the OECD, and 0 otherwise. There are 33 member countries and 23 non-members in the sample (see Table A.2 in the Appendix). The sign of the coefficient is expected to be positive.

- SVA_{it} - **Services Value Added**; The variable measures the services value added embodied in Czech exports to country i in year t, as the share of gross exports. Its values for the year 2009 are illustrated in Figures 4.6 and 4.7. The source is the OECD-WTO TiVA database. Since such variable has never been included as a regressor in the gravity model before, there are no certain expectation about the sign of the coefficient and testing its significance is in the heart of this study.

- SGE_{it} - **Share of German Exports**; The variable measures the share of German gross exports to country i on the total exports to countries in the sample (Table A.2) in year t. In order to remain consistent, the source is the OECD-WTO TiVA database. As illustrated in Figure 4.2, Germany attracts the far highest share of total Czech exports whilst being the leading exporter globally. Ritter and Loschky (2006) estimated that a non-negligible part of German exports consists of imported intermediates and Wlazel (2012) has shown that a significant amount of Czech exports is led indirectly via Germany (Table 4.1). The variable SGE should thus proxy the indirect exports. Since given the specific territorial structure of Czech exports, the higher share on German exports should de facto mean higher demand for Czech products. Hence, the expected sign of the coefficient is positive.

- $VAEX_{it}$ - **Value Added Embodied in Exports**; The variable represents the percentage share of country i's domestic value added embodied in its gross exports in year t. It is a proxy for a country's participation in the global value chains and takes on values between 0% and 100%. A value of 100% indicates that a country (or industry) produces all of its exports domestically and therefore does not participate in the trade in value added. Vice versa, a value of 0% implies that there is no domestic value added and it is clearly a re-export. Nevertheless, the boundary values of 0% and 100% are only theoretical and by definition could not occur in the dataset (see Figure 4.3). The source is the OECD-WTO TiVA database. Since higher participation of a country in the global value chains should increase its demand for Czech exports, the sign of the coefficient is expected to be negative.

- $Open_{it}$ - **Openness**; The variable is an economic metric calculated as the ratio of country i's total trade in year t to the country's gross domestic product. The total trade, the sum of gross exports plus gross imports, is obtained from the OECD-WTO TiVA database, while the country's GDP is obtained from the International Monetary Fund's on-line database. The index measures how much is a country open to trade, in terms of the higher the index is the greater are the market opportunities. Thus the expected sign of the coefficient is positive.

- $GFCF_{it}$ - **Gross Fixed Capital Formation**; The variable is calculated as the ratio of country i's gross fixed capital formation to the country's gross domestic product in year t, the so called rate of investment. It is measured as total value of additions to fixed assets purchased by businesses, government and households minus the disposals of fixed assets sold off or scrapped.The sign of the coefficient is expected to be positive. The values of GFCF are obtained from the World Bank's World Development Indicators database with the exception of Taiwan, whose values are missing. Taiwan's GFCF is obtained separately from the National Statistics of Taiwan database at

Variable	Mean	Std. Dev.	Min.	Max.	N
GX	1319.986	3690.18	0.1	38886.6	280
DOX	799.021	2225.785	0	23530.9	280
GDP	765.322	1819.212	3.419	14720.25	280
Population	80.862	221.994	0.267	1334.5	280
Distance	4737.071	4598.164	252	17859	280
SVA	0.25	0.489	0	3.38	280
SGE	1.648	2.343	0	12.63	280
VAEX	71.821	11.968	40.5	98.210	280
Openness	843.22	471.65	159.589	3113.6	280
GFCF	224.581	53.391	113.55	459.67	280

Table 5.1
Descriptive statistics of the variables in the aggregated model

http://eng.stat.gov.tw/ and converted into USD with the appropriate exchange rates from oanda.com.

All the explanatory variables except for the dummies are transformed as needed by the model. For the estimation of the log-linearized gravity equation, natural logarithms are used and for the Poisson Pseudo Maximum Likelihood estimation of the multiplicative form of the equation, standardization is applied. See previous Section 5.2.1 for a more detailed explanation.

5.3 Results

This section provides an overview of the results of the estimated gravity model. It is divided into three subsections according to the level of aggregation of the dataset. The first subsection summarizes the results of the "aggregated" model, in terms of industries. That is, the variables describe relationships between the whole economies - all their industries. On contrary, the second subsection refers to what is called the "disaggregated" model, i.e. for every country in the sample, the variables (for which it is possible) are broken down into industry levels, yielding 18 times higher number of observations in total, since the dataset is decomposed into 18 different industries (see Table A.1 in the Appendix). Last but not least, the third subsection presents the results for selected industries with the highest foreign value added content of their exports.

In each of the subsection, a table of estimated coefficients and other descriptive statistics is provided. Although the tables differ in the particular models used, they have one in common. For every model (or specific industry), there are two columns. The first column represents the original model with the dependent variable of gross exports. In the second column, values estimated after adjusting the dependent variable for domestic/foreign content are shown - instead of gross exports (GX), the so called domestic origin exports (DOX) are estimated. Both the original and the adjusted model are presented next to each other in order to emphasize the difference made by adjusting the dependent variable.

Considering the explanatory variables, the most relevant for the purposes of this study are three regressors referring to the indirect trade - $VAEX$, SGE, and SVA - and their significance. Furthermore, it is important to note that the constant is not included in the results, since in the case of the Fixed effects model, for instance, multiple constants are included in the form of additional dummy variables. The standard errors are estimated robust and the variance is adjusted for 56 clusters.

The type of R^2 reported in Tables 5.2 to 5.5 differs across methods applied. For the sake of clarity, it is denoted simply as R^2, although it is the overall-R^2 in the case of the Random effects model and the standard R^2 for the PPML and the Fixed effects estimated with the LSDV method. It serves rather for evaluating the effects of adjusting the gross exports than as a overall measure of goodness of fit.

5.3.1 The aggregated model

For the estimation of the gravity model based on the aggregated data, two methods are used, despite the fact that in the discussion above it has been advised to estimate the multiplicative form of the gravity equation using maximum likelihood estimator. Firstly, the data on exports do not suffer from the zero trade flows problem. On the aggregated level, there are no observations equal to zero in the dataset. Therefore, all values can be transformed using logarithms and do not have to be dropped or replaced. Secondly and more importantly, since this research is focused on the effect of indirect trade, both linear and PPML methods are employed in order to test the effect of adjusting the gross exports independently on the estimation method.

As described in Section 5.1.2, there are generally three basic methods of estimating the linear form of the gravity equation - Pooled OLS, Random effects and Fixed effects. The Breusch-Pagan Lagrange multiplier has been applied to examine if any random effects exist. The null hypothesis is that individual-specific or time-specific error components are zero. The calculated χ^2 statistic is equal to 139.21 with the p-value of almost zero. Thus, the null hypothesis can be rejected in favor of the random effects model.

To compare fixed and random effects model, the Hausman specification test has been applied. It examines if the individual effects are correlated with other regressors in the model. According to results of the test, the null hypothesis that the individual effects are not correlated could not be rejected at a satisfactory level of significance. Hence, random effects model is, again, favored over the fixed effects.

Furthermore, the correlation matrix (see Table A.3 in the Appendix) shows that variables $Openness$ and $VAEX$ are correlated. This is not surprising given their nature. $VAEX$, as a proxy for country's participation in the global value chain, is very similar to country's openness to trade. Therefore, both variables are not included in the linear equations simultaneously. For the sake of brevity, the Table 5.2 presents results of gross exports regressed without $VAEX$ whilst domestic origin exports are regressed without $Openness$.

There are several concluding remarks considering the results in Table 5.2. Firstly, the results differ from each other when applying different estimation method. It has to be emphasized that the difference in values of the coefficients is not relevant, since the Random effects model estimates the log-linear form and the PPML the multiplicative form of the gravity equation. It is the sign of the coefficient and its significance that has to be examined. Secondly, the difference made by adjusting the dependent variable is in the scope of this study.

One noticeable result is that the Random effects model, unlike the PPML, is not in line with the expectations. That is, the variables $Population$, EU and $OECD$ have a negative coefficient, which contradicts the theoretical assumptions. On the other hand, one of the variables of our interest, $VAEX$, has been estimated as a very significant variable explaining the volume of domestic origin exports. The possible interpretation is that the less a country participates in indirect trade, the less it imports the products of Czech origin. Nevertheless, this interpretation might be misleading, since the better performing PPML method did not confirm the significance of $VAEX$ on the aggregate level. Generally, the PPML estimates are more reliable in comparison to OLS, according to both theory and the empirical findings. For instance, it would be very difficult to explain a negative effect of the membership in the European Union, as predicted by the Random effects. Therefore, the last two columns of Table 5.2 deserve more attention.

There are two main conclusions from the aggregated model, as estimated by PPML. Firstly, there is no significant difference between the model with gross exports and the domestic origin exports. This is not surprising, considering the fact that the two dependent variables are strongly correlated (99%) on the aggregate level. Secondly, the variables SGE and SVA

are significant. The positive coefficient of SVA indicates that the Czech Republic tends to export more goods with a higher content of services added. What is more interesting is the significant positive coefficient of SGE, the proxy for the indirect trade that goes via Germany. It confirms the expectation that the more a country imports from Germany in relative terms, the more it imports from the Czech Republic.

	Random effects		PPML	
	GX	DOX	GX	DOX
GDP	1.579	1.586	0.232	0.223
	[17.33]***	[12.16]***	[3.10]***	[2.96]***
Population	-0.206	-0.269	0.206	0.208
	[2.84]***	[3.45]***	[2.48]**	[2.60]***
Distance	-1.156	-1.177	-0.72	-0.639
	[10.48]***	[10.02]***	[2.79]***	[2.61]***
Border	-0.115	0.126	0.678	0.761
	[0.31]	[0.39]	[4.43]***	[4.91]***
EU	-0.347	-0.386	0.758	0.75
	[3.25]***	[2.87]***	[3.43]***	[3.54]***
V4	1.69	1.6	0.741	0.705
	[3.92]***	[4.23]***	[3.76]***	[3.55]***
OECD	-0.601	-0.791	0.028	0.045
	[3.21]***	[3.88]***	[0.07]	[0.12]
GFCF	0.979	1.02	0.015	0.04
	[6.06]***	[5.56]***	[0.12]	[0.35]
Openness	0.878		-0.018	0.024
	[7.56]***		[0.08]	[0.11]
VAEX		-2.173	-0.019	0.012
		[5.73]***	[0.08]	[0.05]
SGE	-0.115	-0.072	0.177	0.175
	[1.28]	[0.92]	[3.67]***	[3.71]***
SVA	-0.139	-0.192	0.356	0.353
	[1.51]	[1.86]*	[8.08]***	[8.19]***
N	280	280	280	280
R^2	0.9183	0.9156	0.8129	0.8113
χ^2	2465.59	1580.19	4215.47	4243.33
$Prob > \chi^2$	0	0	0	0

Table 5.2
The aggregated model
Robust t-statistics in brackets. Asterisks: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors adjusted for 56 clusters. All variables (excl. dummies) are in logarithms (for Fixed effects) or standardized (for PPML).

5.3.2 The disaggregated model

Similarly as in the previous section, the disaggregated model has been estimated with various methods - linear regression and Poisson Pseudo Maximum Likelihood. The basic motivation is the same: to show the effect of adjusting the dependent variable independently on the estimation method. Nevertheless, in the case of the disaggregated panel, some zero trade flow observations occur, particularly 137 for the gross exports and 252 for the adjusted exports. Based on this fact, the effect of different treatment of zeros can be illustrated. As described above in Section 3.1.1, zero observations cause problems when estimating the log-linearized gravity equation. All three methods how to deal with zeros are applied with results in Table 5.3. First solution is to drop the concerned observations as in the "truncated" model (first two columns of Table 5.3). Second solution, replacing the zero observations with a small value (0.01 in this case specifically), is applied subsequently. And the third solution is estimating the gravity equation in its multiplicative form that does not require special treatment of zeros at all.

To determine the proper method of the linear estimation of the disaggregated model, alike the aggregated, following statistical tests are applied. Firstly, Hausman specification test rejects the null hypothesis that country specific effects are not correlated with the other regressors, implying that random effects estimates are biased and hence, fixed effects are preferred. Secondly, suitability of the fixed effects has to be tested in comparison to pooled OLS. Since the linear model in Table 5.3 is estimated using the least square dummy variable method, standard F test is applied. That is, the hypothesis that the dummy variables representing individual effects are jointly significant is tested against the null hypothesis that they are all equal to zero. As there are more individual effects - country, time, and industry specific - all of them are tested both separately and combined. In all cases, the test's p-value is almost zero and thus individual fixed effects can be considered as significant.

What else is different from the aggregated model is that on the disaggregated level, variables $VAEX$ and $Openness$ are no longer strongly correlated (correlation decreases to -0.4). Therefore, both variables are included in the linear regression, as the multicollinearity assumption is not violated.

Again, the results differ according to the estimation method. One of the secondary conclusions is that the way how zeros are treated substantially affects the results. Comparing the truncated FE model to the FE model with zeros replaced, the estimated coefficients differ not only in values, but also in their signs and significance. This confirms the results of Silva and Tenreyro (2006), Westerlund and Wilhelmsson (2011) and Bobková (2012) that the logarithmic transformation is not advisable for estimating gravity models. The results of the PPML estimation seem to be much more reliable.

Several patterns are observable from the empirical results of the disaggregated model. First, the model is in accordance with the predictions of the theory of gravity. That is, both GDP and $Population$, serving as proxies for the importing country's demand, are positive and significant determinants of Czech exports. The same holds for $Distance$ with opposite sign. Furthermore, the positive effect of being a member of the EU or having a common border is confirmed. On the other hand, the membership in the Visegrad Four or in the OECD does not seem to have a significant effect on the volume of exports.

For the purposes of this study, the attention should be focused on the variables $VAEX$, SGE and SVA. Similarly as in the aggregated model, country's participation in GVCs measured by the proportion of domestic content of exports ($VAEX$) is not significant. The coefficients of SGE and SVA are significant and positive, supporting the results of the aggregated model. Another noticeable result is that adjusting the dependent variable affects the values of the coefficients and increases the $R^2$of the PPML model. This leads to the conclusion that on the disaggregated level, the gravity model explains better the domestic origin exports than the gross exports.

	FE - Truncated		FE - Zeros replaced		PPML	
	GX	DOX	GX	DOX	GX	DOX
GDP	0.458	0.66	0.634	0.811	0.304	0.349
	[8.05]***	[9.14]***	[10.15]***	[10.65]***	[3.46]***	[3.50]***
Population	-0.366	-1.206	-0.071	-1.069	0.283	0.327
	[1.46]	[3.78]***	[0.27]	[3.24]***	[2.46]**	[3.17]***
Distance	-1.054	-2.226	-0.5	1.88	-0.591	-0.783
	[3.97]***	[6.64]***	[0.70]	[2.14]**	[1.70]*	[2.42]**
Border	0.331	-0.236	1.45	9.656	1.165	1.338
	[1.12]	[0.63]	[0.74]	[4.01]***	[3.05]***	[3.93]***
EU	-0.101	-0.371	-0.154	-0.472	0.653	0.887
	[2.04]**	[6.07]***	[2.74]***	[6.77]***	[2.15]**	[3.60]***
V4	-0.597	-3.214	1.365	5.506	0.253	0.242
	[0.79]	[3.40]***	[1.33]	[4.33]***	[0.83]	[0.74]
OECD	-0.533	-1.806	0.006	2.083	-0.043	0.121
	[0.94]	[2.49]**	[0.01]	[2.80]***	[0.08]	[0.29]
GFCF	0.607	1.05	0.431	0.945	-0.065	-0.081
	[8.69]***	[11.38]***	[5.32]***	[10.73]***	[0.48]	[0.60]
Openness	0.061	0.03	0.072	0.021	0.128	0.031
	[5.94]***	[2.32]**	[5.96]***	[1.47]	[2.60]***	[0.73]
VAEX	-0.256	-0.556	-0.373	-0.614	0.13	0.012
	[3.37]***	[5.46]***	[4.69]***	[5.91]***	[0.71]	[0.10]
SGE	0.108	0.195	0.096	0.212	0.105	0.101
	[12.27]***	[16.57]***	[9.96]***	[16.59]***	[2.31]**	[2.42]**
SVA	0.4	0.093	0.353	0.104	0.177	0.161
	[18.04]***	[3.45]***	[15.20]***	[3.69]***	[2.80]***	[2.81]***
Country effect	√	√	√	√	×	×
Time effect	√	√	√	√	×	×
Industry effect	√	√	√	√	√	√
N	4903	4788	5040	5040	5040	5040
R^2	0.9327	0.8876	0.9356	0.902	0.6219	0.6939
F	1075	647.99	964.56	634.6		
$Prob > F$	0	0	0	0		
χ^2					26279.2	49093.68
$Prob > \chi^2$					0	0

Table 5.3
The disaggregated model
Robust t-statistics in brackets. Asterisks: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors adjusted for 56 clusters. All variables (excl. dummies) are in logarithms (for Fixed effects) or standardized (for PPML).

5.3.3 The model for selected industries

In the previous two sections, the gravity model has been applied on the whole economies. Since this analysis focuses on the value added trade, it is reasonable to test the effect of adjusting gross exports for its foreign content in different industries. It is logical that considering the nature of specific industries, their participation in the global value chains differs substantially. This fact is illustrated in Figure 4.4. The highest share of foreign content embodied in exports (more than 60%) reports the *Electrical equipment* industry, which is not surprising given the level of sophistication of its production. On the contrary, e.g. the *Agriculture* sector's participation in global value chains is much lower (foreign content of exports lower than 25%) and thus the gravity equation would not be affected significantly.

For the sake of brevity, not all 18 industries are examined. Six industries with the highest share of foreign content embodied in their exports are chosen for the estimation, i.e. *Electrical equipment*, *Transport equipment*, *Textiles*, *Basic metals*, *Chemicals*, and *Machinery*. The resulting coefficients estimated using the PPML method are presented in Tables 5.4 and 5.5. It should be noticed that, in comparison to previous two models, the industry-specific models are more affected by adjusting the dependent variable.

In the case of *Electrical equipment* industry, the gravity model seems to be better describing the flows the value added exports (DOX) than the gross exports. Both the number of significant coefficients and R^2 increased after adjusting the gross exports. Furthermore, the value added by services is no longer significantly explaining the volume of exports after the adjustment. This suggests that services contribute only to the foreign content of exports of electronics. Moreover, the *Electrical equipment* industry is the only one that does not report significant coefficient of SGE. The interdependence with the German economy is estimated to be higher for other industries. In the case of *Transport equipment, Textiles, Basic metals* and *Chemicals* industries, the indirect trade via Germany proxied by SGE accounts for higher volumes.

Interesting results show the coefficients of the regional dummy variables $Border$, EU and $V4$. For instance, the *Transport equipment* industry's exports are determined by the common border, while *Electrical equipment* industry's exports are determined by the membership in EU. The other examined industries seem to be more interconnected within the Visegrad Four. Nevertheless, it is difficult to asses the effect of adjusting the dependent variable, since the results are ambiguous. Although the values of the coefficients change and certain differences in their significance occur after the adjustment, there is no clear pattern to be observed.

	Electrical eq.		Transport eq.		Textiles	
	GX	DOX	GX	DOX	GX	DOX
GDP	0.297	0.419	0.292	0.418	0.165	0.284
	[4.29]***	[3.30]***	[3.67]***	[3.79]***	[3.36]***	[4.03]***
Population	0.343	0.337	0.302	0.339	0.202	0.065
	[2.80]***	[1.77]*	[2.38]**	[2.47]**	[2.67]***	[0.62]
Distance	0.034	-0.994	-0.624	-1.45	-0.717	-1.18
	[0.14]	[2.07]**	[1.60]	[2.66]***	[3.38]***	[3.71]***
Border	0.416	0.679	0.683	0.791	0.199	0.216
	[0.73]	[1.74]*	[3.45]***	[3.37]***	[0.85]	[0.85]
EU	0.924	1.398	0.244	0.078	0.358	0.413
	[2.53]**	[3.44]***	[0.56]	[0.18]	[1.67]*	[1.75]*
V4	0.226	0.056	0.141	-0.124	0.762	0.759
	[0.51]	[0.15]	[0.42]	[0.39]	[2.58]***	[2.37]**
OECD	0.338	0.449	-0.391	-0.951	0.001	0.134
	[0.81]	[1.11]	[0.64]	[1.56]	[0.00]	[0.29]
GFCF	-0.081	-0.191	-0.181	-0.271	0.105	0.089
	[0.54]	[0.86]	[1.08]	[1.62]	[1.42]	[1.00]
Openness	0.198	0.088	0.292	0.405	-0.142	-0.009
	[1.41]	[0.33]	[2.81]***	[4.29]***	[1.05]	[0.06]
VAEX	-0.074	0.102	0.019	-0.017	0.111	0.023
	[0.40]	[0.42]	[0.10]	[0.10]	[1.24]	[0.20]
SGE	0	0.054	0.239	0.28	0.304	0.302
	[0.00]	[0.65]	[3.37]***	[3.57]***	[5.34]***	[4.98]***
SVA	0.352	0.174	0.31	0.273	0.442	0.412
	[2.66]***	[1.56]	[6.16]***	[4.47]***	[7.28]***	[6.32]***
N	280	280	280	280	280	280
R^2	0.503	0.6011	0.7724	0.7804	0.8183	0.7724
χ^2	1402.53	966.05	2636.23	3411.07	2638.45	1245.74
$Prob > \chi^2$	0	0	0	0	0	0

Table 5.4
The model for selected industries
Electrical and optical equipment, *Transport equipment*, and *Textiles, textile products, leather and footwear*. Robust t-statistics in brackets. Asterisks: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors adjusted for 56 clusters. All variables (excl. dummies) are standardized. Equations estimated using the PPML method.

	Basic metals		Chemicals		Machinery	
	GX	DOX	GX	DOX	GX	DOX
GDP	0.228	0.31	0.135	0.19	0.247	0.26
	[3.49]***	[4.48]***	[2.30]**	[3.06]***	[5.14]***	[4.58]***
Population	0.202	0.166	0.19	0.179	0.285	0.32
	[2.59]***	[1.92]*	[2.95]***	[2.27]**	[2.53]**	[2.85]***
Distance	-0.719	-0.776	-0.699	-0.681	-0.592	-0.722
	[2.91]***	[3.51]***	[2.87]***	[3.11]***	[2.04]**	[2.57]**
Border	0.605	0.799	0.226	0.451	0.391	0.543
	[3.47]***	[3.91]***	[1.25]	[3.14]***	[2.38]**	[3.22]***
EU	0.457	0.77	0.348	0.682	0.494	0.609
	[2.67]***	[4.19]***	[2.07]**	[3.54]***	[2.05]**	[2.94]***
V4	0.435	0.448	1.213	1.329	0.437	0.264
	[3.32]***	[2.43]**	[7.39]***	[9.34]***	[2.46]**	[1.83]*
OECD	-0.022	0.408	-0.223	0.176	0.067	0.223
	[0.07]	[1.30]	[0.67]	[0.55]	[0.14]	[0.53]
GFCF	-0.057	0.029	-0.005	0.018	-0.074	-0.08
	[0.66]	[0.33]	[0.06]	[0.20]	[0.58]	[0.58]
Openness	0.231	0.114	0.09	-0.116	0.557	0.541
	[2.94]***	[1.31]	[0.76]	[0.91]	[3.26]***	[3.04]***
VAEX	0.208	-0.021	0.015	-0.251	0.451	0.401
	[1.51]	[0.24]	[0.10]	[2.41]**	[2.44]**	[2.53]**
SGE	0.155	0.132	0.238	0.216	0.11	0.127
	[2.85]***	[2.64]***	[3.45]***	[3.62]***	[1.29]	[1.77]*
SVA	0.421	0.385	0.522	0.453	0.293	0.277
	[6.32]***	[7.04]***	[9.29]***	[10.32]***	[5.77]***	[5.79]***
N	280	280	280	280	280	280
R^2	0.863	0.9161	0.8415	0.8982	0.7944	0.8502
χ^2	13467.27	2757.01	2600.21	4125.7	3616.57	2185.95
$Prob > \chi^2$	0	0	0	0	0	0

Table 5.5
The model for selected industries (continued)
Basic metals and fabricated metal products, *Chemicals and non-metallic mineral products*, and *Machinery and equipment*. Robust t-statistics in brackets. Asterisks: * significant at 10%; ** significant at 5%; *** significant at 1%. Standard errors adjusted for 56 clusters. All variables (excl. dummies) are standardized. Equations estimated using the PPML method.

Chapter 6

Conclusions

This thesis analyzed the effects of indirect trade on the gravity model for the Czech Republic. Firstly, it introduced the gravity model in general. A brief insight into the history of the model was followed by a review of the recent literature on this topic, tracing the development of the model from its original formulation by Newton (1687), the first application on international trade by Tinbergen (1962) and its theoretical derivation by Anderson and van Wincoop (2003). The thesis followed the influential paper by Silva and Tenreyro (2006), who questioned the long tradition of estimating the log-linear form of the gravity equation and proposed the Poisson Pseudo Maximum Likelihood to be a more proper estimator.

The gravity model is a frequently used tool to study various aspects of international trade. One of the aspects is the rapidly growing interest in global value chains in the last years. Therefore, the Czech Republic was chosen for the analysis, as it is a small open economy strongly interconnected with other countries, especially Germany. The role of the Czech Republic in global value chains was analyzed in Chapter 4 that provided comparison across countries and industries. It was focused mostly on the decomposition of export into its domestic and foreign content. The methodological framework of estimating the trade in value added based on national input-output tables was described subsequently. The econometric methods applied on the panel data were presented in Chapter 5 together with the explanation of the shortcomings of the traditional log-linear estimation methods.

The thesis aimed at incorporating the emerging importance of indirect trade into the gravity model and the following was tested. Does the gravity model performs better in explaining the domestic origin exports in comparison to gross exports? Are there any significant explanatory variables related to indirect trade? Since there are no accurate data measuring the volume of indirect trade, estimates were employed. These estimates were obtained from the OECD-WTO TiVA initiative, a recently published database with the largest datasets related to this topic.

The empirical results were structured as follows. First, the model based on the aggregated data was introduced. Second, the disaggregated model was shown with industry specific fixed effects estimated on data broken down into 18 industries. And third, the same model was applied for selected industries individually. The estimated coefficients were summarized in well-arranged tables in the last section.

There are two subsidiary contributions of this thesis to current academic research. One is the confirmation of the fact that the treatment of zero trade flows observations, an often discussed problem of gravity models, does matter. This is particularly visible in Table 5.3; multiple methods were applied with results that significantly differ from each other. The other contribution is that the empirical analysis of this thesis supports the recent papers claiming that PPML is a more consistent estimator of the gravity in comparison to the linear estimations of the logarithmic equation.

However, the results of the test of indirect trade are ambiguous. The original intention was hoping to reveal some solid improvement to the gravity model by adjusting the gross exports and estimating only the domestically produced exports. Although minor changes after the adjustment are observable, there is no clear sign of a negative or positive effect. Several remarks could be concluded from the gravity models for selected industries. According to the results, some industries seem to be less interconnected with Germany than others. Czech exports of transport equipment, textiles, basic metals and chemicals are driven by the demand for German exports, which does not hold for electrical equipment or machinery. Moreover, the effects of regional trade agreements differ across industries. The positive effect of having a common border, being a member of the EU or the Visegrad Four is significant only for some industries, as illustrated in Tables 5.4 and 5.5. Nevertheless, one result related to indirect trade is common to all models that have been estimated. The share of services value added embodied in export is a significant explanatory variable in all the gravity models. It suggests that products with a higher value added by services tend to be more easily exported.

The main contribution of this thesis is twofold. Firstly, the gravity model does not generally perform better in explaining the domestic origin exports than the gross exports. This could be explained by the fact that the indirect exports have to be estimated from input-output tables using strong proportionality assumptions. And secondly, the empirical analysis confirmed the phenomenon of the high dependence of the Czech Republic on the German market. Even on the aggregate level, the demand for German exports is a significant determinant of Czech exports.

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Appendix A

Complementary Tables

ISIC Rev 3.1	Industry	Short label
01-05	Agriculture, hunting, forestry and fishing	Agriculture
10-14	Mining and quarrying	Mining
15-16	Food products, beverages and tobacco	Food products
17-19	Textiles, textile products, leather and footwear	Textiles & apparel
20-22	Wood, paper, paper products, printing and publishing	Wood & paper
23-26	Chemicals and non-metallic mineral products	Chemicals
27-28	Basic metals and fabricated metal products	Basic metals
29	Machinery and equipment, nec	Machinery
30-33	Electrical and optical equipment	Electrical equipment
34-35	Transport equipment	Transport equipment
36-37	Manufacturing nec; recycling	Other manufactures
40-41	Electricity, gas and water supply	Electricity, gas and water
45	Construction	Construction
50-55	Wholesale and retail trade; Hotels and restaurants	Wholesale and retail
60-64	Transport and storage, post and telecommunication	Transport & telecoms
65-67	Financial intermediation	Financial intermediation
70-74	Business services	Business services
75-95	Other services	Other services

Table A.1
Classification of industries

OECD member countries		Non member economies	
AUS	Australia	ARG	Argentina
AUT	Austria	BRA	Brazil
BEL	Belgium	BRN	Brunei Darussalam
CAN	Canada	BGR	Bulgaria
CHL	Chile	KHM	Cambodia
CZE	Czech Republic	CHN	China
DNK	Denmark	CYP	Cyprus
EST	Estonia	TWN	Taiwan
FIN	Finland	HKG	Hong Kong
FRA	France	IND	India
DEU	Germany	IDN	Indonesia
GRC	Greece	LVA	Latvia
HUN	Hungary	LTU	Lithuania
ISL	Iceland	MYS	Malaysia
IRL	Ireland	MLT	Malta
ISR	Israel	PHL	Philippines
ITA	Italy	ROU	Romania
JPN	Japan	RUS	Russian Federation
KOR	Korea	SAU	Saudi Arabia
LUX	Luxembourg	SGP	Singapore
MEX	Mexico	ZAF	South Africa
NLD	Netherlands	THA	Thailand
NZL	New Zealand	VNM	Viet Nam
NOR	Norway		
POL	Poland		
PRT	Portugal		
SVK	Slovak Republic		
SVN	Slovenia		
ESP	Spain		
SWE	Sweden		
CHE	Switzerland		
TUR	Turkey		
GBR	United Kingdom		
USA	United States		

Table A.2
List of countries covered in the dataset

Variables	GDP	Population	Distance	Border	EU	V4	OECD	SVA	SGE	VAEX	Openness
GDP	1.000										
Population	0.294	1.000									
Distance	0.068	0.145	1.000								
Border	0.017	-0.059	-0.266	1.000							
EU	-0.066	-0.213	-0.633	0.241	1.000						
V4	-0.080	-0.068	-0.224	0.550	0.109	1.000					
OECD	0.189	-0.246	-0.336	0.232	0.412	0.199	1.000				
SVA	0.530	0.103	-0.216	0.484	0.234	0.045	0.249	1.000			
SGE	0.591	0.140	-0.268	0.048	0.304	-0.015	0.380	0.435	1.000		
VAEX	0.299	0.194	0.278	-0.082	-0.302	-0.181	-0.078	0.161	0.176	1.000	
Openness	-0.332	-0.262	-0.160	0.022	0.161	0.133	-0.104	-0.212	-0.279	-0.785	1.000
GFCF	0.029	0.414	0.160	0.027	-0.139	0.074	-0.157	-0.077	-0.070	-0.194	0.140

Table A.3
Correlation matrix for the aggregated data

Appendix B

Thesis Proposal

Marek Wlazel

Academic year: 2012/2013
Date: October 22, 2013

Institute of Economic Studies

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Master Thesis Proposal

Gravity model for Czech Republic: Test of the effects of indirect trade

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Defense Planned:	June 2014

Topic Characteristics

The gravity model is a well-known and one of the most used tools in estimating the relationships within international trade. Based on the elementary Newton's equation for gravity, it describes the interaction between small and large economic clusters, assuming that nearby ones attract each other more than far-off ones. Despite its quite simple usage combined with substantial power of explaining the flows in general, there are many practical problems arising when estimating the gravity model. The discussion of the concept of the model will be one of the core topics in the paper.

Nevertheless, the main contribution of the thesis should be the incorporation of indirect trade into the model. The indirect trade (both re-exports/imports and indirect exports/imports), the topic I have examined in my bachelor thesis, plays an important role as a discrepancy in trade statistics and thus adjusting the data for the estimations could improve the results of the model.

Hypotheses

1. Including the estimated values of re-exports of Czech republic via its main trading partner in the Czech export structure decreases Germany's share significantly.
2. Including the estimated values of indirect trade in the gravity model of Czech republic (that is, adjusting the dependent variable for re-exports and indirect exports) improves the results of the model.
3. The proportion of indirect trade of Czech republic relative to the total volume of trade is not marginal.

Methodology

The method for estimating the gravity model is based on the direct proportion of two trading partners' GDP's and the inverse proportion of their distance. The distance, however, cannot be measured only in kilometers, but other variables such as lingual and other institutional differences have to be included; in form of dummies for instance.
Due to the fact that the more observations the better, the dataset should cover as many trading partners of the Czech republic as possible. However, the range will be limited by the availability of trading data suitable for the estimations of indirect trade - i.e. adequate import I-O matrices.
Moreover, I will probably not use the conventional log-linear regression, but the Poisson pseudo maximum likelihood estimation technique instead, as there are indications that it provides better results when panel data are employed.

Expected Structure

1. Introduction
2. Literature review
3. Gravity model and its theoretical derivation
4. Indirect trade - Methodology and computations of re-exports/imports and indirect exports/imports
5. Empirical Analysis - Estimating the gravity model for Czech republic using the data adjusted for indirect trade
6. Conclusions

Core Literature

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