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MASTER'S THESIS

Exchange Rate Volatility Effect on Trade Balance in the Czech Republic

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Declaration of Authorship

The author hereby declares that she compiled this thesis independently; using only the listed resources and literature, and the thesis has not been used to obtain a different or the same degree.

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Prague, July 31, 2020 Anastasiia Naletova

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Abstract

This master's thesis investigates the impact of exchange rate volatility on trade balance of the Czech Republic during 2005-2016. The analysis is performed on the constructed panel dataset for 53 trading partners of the Czech Republic by estimating the trade gravity models. The realized volatility values are obtained for 43 Czech koruna pairs against the local currencies. The variables included into the empirical analysis are the GDP and population of the Czech Republic and its trading partners, realized volatility, weighted distance, contiguity, direct access to the sea and information on EU and OECD membership. The methodological approaches in the analysis are calculations of realized exchange rate volatility and for gravity models panel data estimation techniques: pooled OLS, fixed effects and random effects. The gravity models are compared by the formal tests, and the most efficient among them is the fixed effects. The results of the estimated augmented model reveal significant positive impact of exchange rate volatility on trade balance of the Czech Republic. The key variables that have the expected significant positive impact on trade balance are GDP of the Czech Republic and its trading partners in the basic model, population of the Czech Republic and EU membership in the augmented model.

JEL Classification	A12, C23, F14, F31
Keywords	gravity model, panel data, foreign trade, Czech Republic, exchange rate volatility
Title	Exchange Rate Volatility Effect on Trade Balance in the Czech Republic

Abstrakt

Tato diplomová práce se zabývá dopadem volatility směnného kurzu na obchodní bilanci České republiky v letech 2005-2016. Analýza je prováděna na sestavě panelového datového souboru pro 53 obchodních partnerů České republiky odhadem obchodních gravitačních modelů. Realizované hodnoty volatility jsou uplatňovány pro 43 českých měnových párů vůči lokálním měnám. Proměnné zahrnuté do empirické analýzy jsou HDP a populace České republiky a jejích obchodních partnerů, realizovaná volatilita, vážená vzdálenost, sousednost, přímý přístup k moři a informace o členství v EU a OECD. Metodickými přístupy v analýze jsou výpočty realizované volatility směnného kurzu a pro gravitační modely jsou to techniky odhadu dat panelů: sdružený OLS, fixní efekty a náhodné efekty. Rovněž gravitační modely jsou porovnány formálními testy a nejúčinnějším z nich jsou fixní efekty. Výsledky odhadovaného rozšířeného modelu odhalují významný pozitivní dopad volatility směnného kurzu na obchodní bilanci České republiky. Klíčovými proměnnými, které mají očekávaný významný pozitivní dopad na obchodní bilanci, jsou HDP České republiky a jejích obchodních partnerů v základním modelu, populace České republiky a členství v EU v rozšířeném modelu.

Klasifikace	A12, C23, F14, F31
Klíčová slova	gravitační model, panelová data, zahraniční obchod, Česká republika, volatilita směnného kurzu
Název práce	Dopad volatility směnného kurzu na obchodní bilanci České republiky

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Acronyms

CEPII The Centre d'Études Prospectives et d'Informations Internationales

CMEA Council for Mutual Economic Assistance

CZK the Czech koruna

CZSO Czech Statistical Office

EU European Union

FE Fixed Effects

FTC Foreign Trade Company

GDP Gross Domestic Product

GLS Generalized Least Squares

GNP Gross Natural Product

HS Harmonized Commodity Description and Coding Systems

IBRD International Bank for Reconstruction and Development

ICF International Currency Fund

LSDV Least Squares Dummy Variable

MA Moving Average

ML the Marshall-Lerner (condition)

OECD the Organisation for Economic Co-operation and Development

OLS Ordinary Least Squares

RE Random Effects

SITC Standard International Trade Classification

TiVA Trade in Value Added

USD The United States dollar

USSR Union of Soviet Socialist Republics

WITS World Integrated Solutions

WTO World Trade Organization

Master's Thesis Proposal

Author: Bc. Anastasiia Naletova
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Defense Planned: June 2019

Proposed Topic:

Exchange Rate Volatility Effect on Trade Balance in the Czech Republic

Motivation:

Nowadays due to globalization, international trade has become integral part of the modern world economy. Thus, the concept of trade balance can be referred to as inevitable part of economy in every country. Trade balance is of great significance since it is used as a tool for correct calculation of GDP, as an indicator of strength of national economy.

Trade balance is influenced by several factors: inflation, trade policies, government budget balance, real foreign and domestic GDP of trading countries. Exchange rate is one of them and its impact will be thoroughly studied in the thesis. Exchange rate volatility plays significant role in economic performance and growth of countries, in price stability and in international trade. Behavior of exchange rates is generally not constant, consequently, exchange rate volatility increases exchange rate risk and makes international trade more complicated.

The impact of exchange rate volatility on trade flows (including exports and imports) has been studied over the recent years. Most of the studies support the idea of the negative impact of exchange rate volatility on international trade. Thus, Chowdhury (1993) finds evidence of the significant and negative impact of exchange rate instability on international trade (net exports, in particular). Moreover, Rose (2000) supports the idea of negative effect of exchange rate volatility on international trade. However, there exist opposing view on this issue. For instance, Broll and Eckwert (1999) study the theoretical justifications of the idea that exchange rate volatility might have positive impact on international trade and conclude that uncertainty in behavior of exchange rates might make production more profitable. Thus, there is still no clear result of exchange rate volatility effect on trade.

Considering data from the Czech Republic, I will investigate interdependence between exchange rate volatility and trade balance between the Czech Republic and its trading partners. Thus, exchange rate from the Czech koruna (CZK) to Euro (EUR) is to be considered.

Exchange rate is connected with trade flow of goods and services of each country. Focusing on the Czech Republic in this work is crucial as this European country with developed market economy, various multinational companies is widely involved in international trade. Moreover, according to Šimáková (2014b), there are still not many studies considering data from the Czech Republic.

Hypotheses:

1. Hypothesis #1: Trade balance of the Czech Republic is not affected by exchange rate volatility.
2. Hypothesis #2: In simple gravity model distance and GDP of trading partners have insignificant impact on trade balance.
3. Hypothesis #3: In extended gravity model population, common border, EU membership, common language have significant effect on trade balance.
4. Hypothesis #4: Extended gravity model does not provide more clear results compared to the simple model.

Methodology:

Starting point of this research work is data collection. For this purpose, I will obtain exchange rate data from Eurostat database; data from Czech Statistical Office on Czech trade balance, GDP of Czech Republic and GDP of its trading partners with the aim to study the impact of exchange rate volatility on trade balance.The sample wiil include major trading partners on the Czech Republic. For the analysis I will use quarterly data from the period 1993 till 2016. The data of exchange rates will be of higher frequency to allow for GARCH model estimation. After that the data of exchange rate volatility will be transformed into quarterly data. The countries are likely to be heterogeneous, so they would be clustered accorging to common paremeters (for instance, trade regime (openness of a country), or EU membership). After that, to achieve more clear results the estimations will be performed for Czech Republic and each of its trading partner separately.

In my work I will use panel data and, consequently, imply estimation techniques consisten with this type of data: pooled OLS, fixed effect model, random effects model. In addition, gravity equations are generally presented in the form of multiplication which implies the necessity of their transformation into the log-linear form for estimation.

I will estimate the effect of exchange rate volatility on trade balance by gravity model for trade balance which will be extended for exchange rate volatility of the Czech Crown. Exchange rate volatility is going to be tested by GARCH model, following Bollerslev (1986), and observations will be added as explanatory variable to the gravity model. The dependent variable will be trade balance, the expalanory variables will include distance between Czech Republic and the trading country, GDPs of countries, population, common border, openess, common language, dummy variable of EU membership and exchange rate volatility. The simple gravity model will be also estimated to compare the results with those of the extended model. Thus, the comparision of the models will be performed by F-test and this provide evidence for the fourth hypothesis.

Expected Contribution:

This work aims to provide empirical contribution to the existing theoretical studies on the effect of exchange rate volatility on trade balance in the Czech Republic. Analyzing bilateral trade balance is beneficial compared to the aggregate approach as it reflects the detailed picture of the trade relationship between countries.

Analyzing data from the Czech Republic by gravity model is relevant, because this approach takes into consideration several socio-economic aspects, geographical position. Moreover, based on the estimation results, I will get evidence for the choice of the best estimation model for panel data analysis (among pooled OLS, fixed effects and random effects model). In addition, the results of the thesis might be applicable for explaining trade policies and making predictions concerning future behaviour of bilateral trade.

Outline:

1. Introduction. Motivation
2. Literature review
3. Data description
4. Methodology
5. Results. Analysis of regression output
6. Conclusion

Core Bibliography:

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1 Introduction

Nowadays due to globalization international trade has become an integral part of the modern global economy. Countries trade in same currencies within monetary unions or use some of the global currencies for foreign trade transactions. Also, international trade is held in local currency pairs that emphasizes the importance of exchange rates in foreign trade. Most of the world currencies are not stable so the risk resulting from unpredicted changes in exchange rates should not be omitted from foreign trade analysis. Changes in exchange rates, or volatility, acts as a source of currency risk and impacts both imports and exports, influences an economy and development of a country.

Foreign trade as a complex notion includes several concepts with trade balance among them. This notion serves as an indicator of economic performance of a country and it reveals the strength of a national economy compared to other states. Trade balance might be affected by several factors, such as inflation, trade policies and, undeniably, exchange rates. The goal of the thesis is to analyse foreign trade of the Czech Republic by focusing on the concept of trade balance and to reveal its relationship with exchange rate volatility of the Czech koruna pairs. This issue has already been discussed in existing research papers but mostly from the theoretical perspective, so the empirical analysis in the thesis contributes to the topic.

The thesis analyses foreign trade of the Czech Republic with its 53 trading partners and reveals the relationship between the national trade balance and exchange rate volatility of the 43 Czech koruna currency pairs between 2005 and 2016. In order to obtain the values of realized exchange rate volatility, historical exchange rate time series data is analysed, then the basic and augmented panel data gravity models are constructed and estimated. The key methodological approaches in the analysis are calculations of the realized exchange rate volatility and, for gravity models, the panel data estimation techniques that include the pooled OLS, fixed effects and random effects. Also, the models are compared, and the most efficient among them is selected based on the formal tests.

The proposed hypotheses for the analysis are stated in the negative form and they are formulated as follows:

- Trade balance of the Czech Republic is not affected by exchange rate volatility
- In simple gravity model distance and GDP of trading partners have insignificant impact on trade balance
- In extended gravity model population, common border, EU membership, have significant effect on trade balance
- Extended gravity model does not provide more clear results compared to the simple model

The thesis contributes to the research topic as most empirical papers investigate the relationship between exchange rate volatility and foreign trade without considering trade balance, the concept under analysis in the thesis. Moreover, not many of the existing studies focus on the Czech Republic, the country with open trade regime that is worth analysing due to several aspects, such as economic performance, geographical position, membership in the EU and others. The selected sample of currencies as well as the trading countries is diverse, and it captures the period of the global financial crisis of 2007-2008. The constructed augmented gravity model includes variables of GDP and population of the Czech Republic and its trading partners, realized volatility, weighted distance, and it is also extended for EU and OECD membership, contiguity and access of a country to the sea. Also, the implemented methodological approach of gravity equations is proved to be advantageous for foreign trade analysis and realized volatility is an informative and efficient volatility estimator.

Moreover, the results of the thesis might be applicable for explaining trade policies and making predictions concerning future behaviour of international trade of the country as it provides an overview of trade of the Czech Republic and the volatility analysis. Still, the research is subject to certain limitations, mainly because some of the analysed countries are selected based on data availability and, as discussed in the thesis, the dataset is subject to statistical discrepancies. The thesis is structured as follows:

Chapter 2 includes review of the empirical papers dedicated to the impact of exchange rate volatility on international trade and the discussed works are grouped according to the sign of the effect. This part is followed by description of the core theoretical approaches revealing the relationship between exchange rate and trade balance.

Chapter 3 is dedicated to the review of the theoretical assumptions related to international trade and analysis of foreign trade of the Czech Republic. This part discusses the theoretical concepts related to foreign trade, such trade in value added and intrafirm trade, strategic aspects, costs and barriers. The reviewed concepts are linked to foreign trade of the Czech Republic.

Chapter 4 contains overview of the data selected for analysis, describes the constructed dataset and introduces all variables included into regressions. Also, the possible statistical discrepancies in the data are discussed.

Chapter 5 describes the methodological approaches applied in the analysis and it is divided into two main sections: the first is dedicated to realized volatility measurement and the second is reviewing trade gravity equations and the estimation techniques applicable to panel dataset.

Chapter 6 includes discussion of estimation results for both the basic and the augmented gravity models. Regression results are reviewed corresponding to the research hypotheses. Moreover, comparison of the estimated models is provided based on the formal tests.

2 Literature Review

The following chapter provides analysis of both empirical and theoretical literature on the research topic. Firstly, empirical papers are reviewed, and they are grouped according to the sign of impact exchange rate volatility has on trade balance: negative, positive and ambiguous effects. Secondly, the main theoretical approaches revealing relationship between exchange rate and trade balance are discussed.

Thus, trade balance, as one of the concepts related to international trade, is used as an indicator of economic performance of a state and it reveals strength of a national economy compared to other countries. The term is defined in chapter 4.2 where it is discussed in further details.

As already stated, exchange rates are inalienable part of foreign trade, but their importance is not limited to international trade only. For instance, exchange rates might affect economic policy of a country and as Asteriou et al. (2016) state, exchange rate volatility might make a central bank modify expected inflation target in case a country follows inflation targeting regime. Moreover, Badinger and Fichet de Clairfontaine (2018) stress the importance of exchange rate for setting relative prices of both domestic and foreign goods. Also, the authors state that exchange rate affects global imbalances that are detrimental to economic stability in the world.

2.1 Empirical Literature Review

The impact of exchange rate volatility on international trade is analysed in scientific papers and the issue is significant not only for academic research but also from the perspective of macroeconomic policy. Still, the results of empirical works on the topic are heterogeneous: some of the papers prove the negative effect of exchange rate volatility on international trade, others, on the contrary, find evidence for the positive impact and several works confirm mixed results or state that the effect is not present at all. The variability of findings is explained by Ozturk (2006), who attributes the differences to the key factors: model specification, measurement of exchange rate volatility, duration of a sample period, type of countries under analysis.

2.1.1 Negative Effect of Exchange Rate Volatility on Foreign Trade

Most empirical studies on the topic support the idea that exchange rate volatility has a negative impact on international trade. Ozturk (2006) conducts literature survey of empirical papers on the topic together with the theoretical analysis and concludes that, despite the diversity among the analysed works, most of them prove the negative impact of exchange rate volatility on foreign trade.

Rose (2000) also confirms this assumption and, additionally, with the help of the gravity model, reveals that adoption of a common currency for a pair of countries significantly increases foreign trade. Also, Chowdhury (1993) performs analysis among the G-7 countries by extending an error-correction model with non-stationary properties of time-series and finds evidence of significant negative effect of exchange rate instability on international trade, net exports.

Moreover, Serenis and Tsounis (2012) analyse foreign trade of Sweden, the UK and Germany over the period 1973-2010 and prove the idea of significant negative effect of exchange rate volatility on international trade, exports. The authors emphasize that an approach applied for measuring exchange rate volatility influences overall findings of the analysis. Thus, while measuring volatility as standard deviation of effective exchange rate logarithm, only small impact of volatility on exports is revealed, whereas an alternative way of volatility measurement by focusing on effects of high and low values of exchange rate depicts a more significant effect.

Exchange rate volatility might negatively influence international trade of a country, for instance, through higher transaction costs. Greater transaction costs imply higher risk, so many works focus on the concept of firm-level risk aversion and consider hedging techniques against unpredictability. Thus, Hooper and Kohlhagen (1978) analyse the effect of exchange rate volatility on foreign trade of Germany and the USA with several industrial countries for the period 1965-1975. Focusing on the concept of risk aversion, the authors analyse the short run impact on prices and volumes of trade and conclude that increase of exchange rate risk leads to decrease in volume of foreign bilateral and multilateral trade if traders are risk averse. The authors examine the attitude towards exchange rate risk of both trading parties and conclude that price is expected to decrease if the risk is faced by importers and the price is supposed to rise in case of exporters who impose risk premium. Asteriou et al. (2016) also states that increase of exchange rate volatility leads to higher costs of performing international trade because of unpredictability on market, assuming economic agents are risk averse.

Most of the mentioned studies on the topic focus on industrialized countries but few papers among them consider the Czech Republic. One of the studies dedicated to the effect of exchange rate volatility on foreign trade of the Czech Republic is performed by Babecká Kucharčuková (2014). In this work the author applies different types of gravity models: dynamic and static ones for data in the period 1999-2008 and concludes that exchange rate volatility has a significant negative effect on international trade. Šimáková (2014a) also focuses on the Czech Republic in the research and applies extended gravity model approach for bilateral trade during 1997-2012. The author states that volatility of the nominal exchange rate of the Czech koruna influences bilateral trade significantly negatively. Consequently, the findings of Šimáková (2014a) are in line with conclusions of Babecká Kucharčuková (2014).

As already mentioned, volatility of exchange rates may influence prices of exports and imports, but not many works consider the impact on trade balance as it is. For instance, several papers analyse the effect of exchange rate volatility on trade balance in transition economies. Thus, Bakhromov (2011) considers the aggregate data from Uzbekistan from 1999-2009 and the key finding of this research is that in the long run, increase in real exchange rate volatility has significant negative impact both on exports and on imports of Uzbekistan in the period.

Other empirical studies focus on emerging or developing countries. Thus, Dhasmana (2012) analyses the relationship between trade balance and real exchange rate volatility in India via bilateral trade of the analysed countries with 15 trading partners during 1975-2011 period. The findings of the paper support the idea of negative long-term impact of real exchange rate volatility on trade balance. Also, Immaculate and Kwadzo (2017) analyse the data from Uganda since 1990 till 2015 and find statistically significant negative impact of exchange rate volatility on trade balance of the country. In addition, the authors support the idea of implementing stabilization policy for periods of high exchange rate volatility. Thus, the results of this work are similar to the conclusions by Dhasmana (2012).

To sum up, findings of the reviewed articles justify the idea of the negative impact of exchange rate volatility on foreign trade and the papers supporting the opposing point of view are presented further.

2.1.2 Positive and Ambiguous Effects of Exchange Rate Volatility on Foreign Trade

Even though most of the empirical works on the topic prove the idea of negative impact of exchange rate volatility on international trade or trade balance, there are papers that confirm the opposing point of view. However, those works usually do not justify presence of the positive effect only but rather state that the results are mixed or that no impact is revealed.

As already discussed, risk faced by trading partners influences their decision-making, thus, attitude of both parties to uncertainty should be considered. Firms involved in foreign trade are generally risk averse and, because of this, higher exchange rate volatility might lower volume of trade (Gunter, 1991). Even though the amount of trade deceases, Gunter (1991) considers exchange rate volatility to be the opportunity for generating income from uncertainty faced by exporters. Higher exchange rate volatility implies higher profit risk, consequently, firms that export goods might make profit from price differences since they are able to regulate the volume of their exports according to exchange rates. Export volume as well as the overall amount of foreign trade held by a firm increases together with exchange rate volatility. The findings of the paper contradict the widely confirmed assumption of negative impact of exchange rate volatility on trade.

De Grauwe (1988) also considers the role of risk and states that higher uncertainty motivates risk averse agents to switch to less hazard activities. The author analyses trade flows of ten industrialised countries and states that the results depend on the degree of risk aversion, as also concluded by Gunter (1991). Higher exchange rate risk decreases welfare, but at the same time motivates exporters to increase the amount of exports that results in positive impact on trade. The author although mentions the political effect according to which exchange rate risk has a negative impact on trade because of political protectionism of markets. The overall conclusion of the paper is similar to the finding by Gunter (1991) who claims that exchange rate risk has a positive impact on foreign trade.

Another study that considers a competitive firm making decisions upon its production is conducted by Broll and Eckwert (1999). The authors state that uncertainty in behaviour of exchange rates makes production more profitable. Higher exchange rate volatility increases the value of exports to the global market and, consequently, makes potential gains from trade greater. Still, the authors admit that higher uncertainty in exchange rate implies risk exposure for international firms, thus, has a negative impact on production and volume of trade. Consequently, the study provides ambiguous results on the impact of exchange rate volatility on foreign trade.

Mixed results on the research topic are also present in the work by Asteriou et al. (2016). The authors analyse the effect of exchange rate volatility on levels of international trade for MINT countries (Mexico, Indonesia, Nigeria and Turkey) for monthly data in period 1995-2012. In the paper volatility of both nominal and real exchange rates is estimated by the GARCH model and the findings differ for the long-run and for the short-run periods. Thus, in the long term the authors find no relationship between exchange rate volatility and foreign trade for the group of countries, except for the small impact of volatility in Turkey. However, in the short term, exchange rate volatility has an impact on export and import demand for Mexico and Indonesia in particular.

Variety of conclusions on the research topic is explained by Clark et. al (2004) who state that the impact of exchange rate volatility on trade differs according to the level of analysed data (bilateral or aggregate), specification of model, the type of reviewed countries (advanced versus developing). Thus, the authors state that the whole world is ambiguous, and the obtained results differ according to the analysed data. Thus, Clark et. al (2004) find no evidence of the negative impact of exchange rate volatility on international trade at aggregate level. However, the empirical results of bilateral trade relationship between a pair of countries support the negative impact of exchange rate volatility on bilateral trade. In addition, the authors state that exchange rate volatility should not be the main approach for boosting international trade.

Haile and Pugh (2011) conduct the meta-analysis of 89 econometric studies that provide evidence both for positive, negative, mixed results of the effect of exchange rate volatility on trade. In this meta-analysis the authors state that publication bias is present in the works, but it is moderate. They conclude that it is difficult to generalize and provide a concrete answer on the research topic because the effect of exchange rate volatility on international trade is of various size for different groups of countries and is conditional on modelling strategies.

Some of the works on the discussed topic find no impact of exchange rate volatility on international trade. Wilson and Tat (2001), following the model of Rose and Yellen (1989), analyse bilateral trade between Singapore as well as the USA and conclude that real exchange rate has no effect on real bilateral trade balance. In addition, the authors find weak proof for the presence of the J-curve. Also, Lotfalipour and Bazargan (2014) in their analysis focus on Iran for period 1993-2011 and state that real effective exchange rate depicts no significant impact on trade balance. The authors conclude that trade balance is influenced mainly by imports rather than by exports and based on this idea they provide advice that economic policy should be aimed at substituting imports to increase domestic income improve trade balance.

The impact of exchange rate volatility on trade balance is also analysed in empirical papers with respect to theoretical justifications. The key approaches are reviewed in chapter 2.2 and findings of several empirical papers, referring to the J-curve theory, are provided further. Thus, Rose and Yellen (1989) define the J-curve effect in the following way: depreciation of currency in the short run has a negative effect on trade balance of a country, whereas in the long-run the impact is opposite. Consequently, the cumulative effect of currency depreciation on trade balance should be positive. Rose and Yellen (1989) examine the U.S. bilateral and aggregate data but find neither evidence of the J-curve effect, nor they reveal impact of exchange rate volatility on trade balance. Another study on the topic is conducted by Šimáková (2014b) who analyses bilateral trade flows between the Czech Republic and its core trading partners during 1997-2012. The author focuses on the J-curve theory and states that in the long-run trade balance is supposed to improve because consumers will adapt to new prices of goods. Still, neither the effect of exchange rate volatility on foreign trade nor presence of the J-curve effect between the trading partners are discovered in the study. Thus, Šimáková (2014b) concludes that trade flows of the Czech Republic are influenced by other factors rather than exchange rate volatility.

To conclude, the empirical papers on the topic provide both evidence for negative and for positive impact of exchange rate volatility and international trade, trade balance. Also, some papers find ambiguous results, others find no evidence of the relationship at all, but most of the empirical studies confirm the negative impact.

2.2 Theoretical Approaches to Trade Balance and Exchange Rate Relationship

As already discussed in the first part of the chapter dedicated to empirical literature review, volatility of exchange rate affects foreign trade as currency risk increases. Volatility of exchange rate refers to the ability of a foreign currency to appreciate or depreciate, therefore, it affects foreign trade competitiveness of a country. In economic theory it is assumed that real depreciation of a currency involved in international trade leads to increase of exports and decrease of imports that in its turn ameliorates trade balance. Appreciation of a national currency is supposed to have an opposite effect, thus, deteriorate trade balance.

This subchapter provides an overview of the five key theoretical approaches that interpret the relationship between exchange rate and trade balance. Among the described theories are the elasticities approach, the Marshall-Lerner condition, the J-Curve theory, the absorption and monetary approaches. The theories are discussed in chronological order according to their appearance.

2.2.1 The Elasticities Approach

The elasticities approach, or the Bickerdike-Robinson-Metzler Condition, describes adjustments of trade balance from the perspective of import and export demand elasticities. Consequently, the logics is similar to the principle of demand price elasticity. Under the described approach, the elasticity of demand is understood as adjustments of demanded goods quantity to price movements (Ali et al., 2014). Also, perfect competition in foreign markets is assumed and markets of imports as well as of exports are analysed separately (Shao, 2009).

Generally, the response of volume and value of trade to movements in real exchange rates are the key aspects for the elasticities approach. Thus, after depreciation of home currency, domestic goods become cheaper while foreign products get more expensive. In case foreign demand is elastic, the volume of home country exports is likely to increase. Also, the value of exports together with the volume of imports is expected to decrease, leading to improvement of trade balance (Jha, 2003). Otherwise, if foreign demand is inelastic, the volume of exports stays unchanged and the value of exports decreases.

What is more, the elasticities approach might be implemented in the real word by policymakers, for instance, if trade balance of a country is in deficit. In this case it would be essential to estimate responsiveness of imports and exports to exchange rate movements in order to assess the potential impact of devaluation on trade balance (Ali et al., 2014). The elasticities approach is fundamental for several other theories, for instance, the Marshall-Lerner condition is considered to be an extension of the elasticities approach.

2.2.2 The Marshall-Lerner Condition

Under the Marshal-Lerner condition, demand for national exports as well as for imports should be adequately elastic in order to enhance trade balance under depreciation (Ali et al., 2014). Moreover, the trade and current accounts need to be balanced and the sum of the import and export demand price elasticities, both in absolute values, should be greater than one. In that case, trade balance ameliorates under depreciation in the long-term perspective. Otherwise, if the sum of both elasticities is lower than one, trade balance is supposed to deteriorate in case of depreciation (Lerner, 1944).

Generally, for the ML condition Ali et al. (2014) state the following essential assumptions. Firstly, trade should be initially balanced before deprecation so that currency values of imports and exports are equivalent. Secondly, prices are set in currency of a seller, implying that the supply elasticities should be infinite. The Marshal-Lerner condition takes into consideration quantity responses of demand for both export and import with respect to changes in relative prices caused by devaluation. Consequently, key idea of the approach is that movements of the nominal exchange rate might influence trade balance just by altering the real exchange rate (Kenen, 1989).

Moreover, it is assumed that income stays unchanged after devaluation so that there are no income related adjustments to trade balance after depreciation (Salasevecius and Vaicius, 2003). Also, the ML condition reveals stability and it is assumed that only a stable exchange rate might improve trade balance. Also, in case summation of both import and export demand elasticities is less than one, the equilibrium is supposed to be unstable and that might lead to inefficient economic model for estimating impact of depreciation on trade (Borkakati, 1998).

2.2.3 The J-Curve Theory

The J-Curve concept, that is theoretically based on the elasticities approach, is sometimes viewed as a dynamic version of the Marshall-Lerner condition. Thus, key feature of the J-Curve theory is that it indicates how depreciation of real exchange rate impacts trade balance of a country over time (Magee, 1973). Generally, according to the J-Curve approach, trade balance of country deteriorates in the short run, right after depreciation of a national currency, and later ameliorates in the long run (Jha, 2003).

As for the short term, import prices in national currency are expected to increase faster than the export prices after devaluation, however, trade volume does not react immediately. Existence of such time-lag in trade volume response diverges the J-Curve concept from other theoretical approaches. In the long-term perspective, trade balance is expected to improve after initial deterioration, for instance, export volume starts to rise due to decline in export prices (Ali et al., 2014). Also, in the long-run, domestic production is encouraged and substitutes to expensive imports are manufactured instead, that induces improvement of trade balance. This stage when the described conditions are met is known as the volume adjustment period and is characterized by improvement of trade balance (Gärtner, 1993).

Moreover, according to the J-Curve theory, trade balance is expected to improve in the long-run to a level that is higher than the initial one, before the depreciation (Ali et al., 2014). Still, devaluation might cause decrease in investments, that might have a negative impact on economic development. Finally, if trade balance of a country is plotted overt time, its behaviour especially after devaluation resembles the letter “J” and that reveals the logics behind the name of the theory.

2.2.4 The Absorption Approach

The next theoretical explanation of relationship between exchange rate and trade balance is the absorption approach, introduced by Sidney Alexander in 1952. Under the absorption approach trade balance is defined as difference between what the economy produces, or aggregate domestic income, and what the economy absorbs, or total expenditure. Consequently, trade balance is understood in a new way, different from the standard assumption of the difference between exports and imports.

According to the theory, increase in real income or decrease in expenditures or both would lead to trade balance amelioration. In case domestic consumption is constant and an economy is not at full employment, devaluation would cause improvement of trade balance (Ali et al., 2014). Thus, trade balance is enhanced by devaluation or appreciation only if there is no full employment in economy and, in case there is full employment, trade balance might not be improved (Mankiw, 2003). Also, if government expenditures are constant, net exports rise under devaluation regardless of the sign of changes in real income (Kutlu, 2013).

Thus, the key assumption of the absorption approach is that after improvement of trade balance, for instance, after devaluation, increase in income is required so that it prevails over the rise in aggregate expenditures. Also, in terms of the economic policy, the absorption approach allows to create models revealing how fiscal and monetary policies on shortening expenditure should be modified to allow for expenditure-switching impact of an exchange rate (Kenen, 1989).

2.2.5 The Monetary Approach

The last theory to be discussed is the monetary approach under which trade balance is interpreted from the perspective of excess demand and supply of money, regulated by a government via a central bank.

According to the approach, if a country experiences significant domestic demand for money, higher than a monetary authority might provide, trade balance is likely to improve as there will be demand for money from foreign countries to cover the gap. Thus, devaluation influences trade balance by impacting the real supply of money: depreciation ameliorates trade balance by increasing home prices that causes decrease in the real money supply.

In the opposite situation, if there is excess money supply in an economy, i.e. more than demanded by a central bank, trade balance is expected to deteriorate as money are likely to outflow from an economy (Duasa, 2007). The described ideas are considered to be key conclusions of the monetary approach.

To sum up, the described theoretical approaches provide an overview of how exchange rates might influence trade balance of a country. In particular, the elasticities approach is treated as a microeconomic view to relationship between exchange rate and trade balance. However, the theory is sometimes criticized for considering only behaviour of value and volume to movements in price.

The absorption and the monetary approaches, in comparison, might be referred to as macroeconomic theories (Ali et al., 2014). Under those approaches it is assumed that exchange rate depreciation has a positive impact on trade balance. Also, the absorption approach, in comparison to the elasticities approach, combines both the substitution and income effects of movements in exchange rates (Kutlu, 2013). As for the J-Curve theory, it is widely justified as the only dynamic approach to investigate the relationship between trade balance and exchange rate depreciation, it is applicable for estimating the elasticities approach as well as the Marshal-Lerner condition. Thus, the reviewed theories provide insight into the relationship between exchange rate behaviour and trade balance.

3 Foreign Trade of the Czech Republic

In the following chapter overview of international trade of the Czech Republic is provided. Foreign trade is reviewed from historical perspective leading to its current stage, also focusing on the global financial crisis of 2007-2008. Then, description of international trade structure with classification of traded goods is presented. The chapter also includes review of the theoretical concepts related to international trade, such as costs, barriers and strategic aspects, trade in value added and intrafirm trade. The concepts are discussed with focus on foreign trade of the Czech Republic.

3.1 History of Foreign Trade of the Czech Republic

The history of the Czech Republic consists of diverse periods when the country used to be part of the Austro-Hungarian Empire, the Czechoslovak Republic and as an independent state at its present stage. Each timeline of history was marked with political events that had an impact on foreign trade of the country.

For instance, during the First Czechoslovak Republic (1918–1938) the focus of the country's production was mainly the industrial sector. Generally, the period was tough because of the Second World War and the Great Depression of the 1930s. In addition, in 1934 as a result of a depression culmination, the Czechoslovak koruna devalued, resulting in foreign trade decreasing to almost zero. During the analysed period industrial production prevailed in the country and the core trading partners at the time were France, England and the USA.

The next significant stage in history of the country was the socialist planning period (1948–1989), characterized by considerable impact of the USSR, leading to liquidation of the private sector, nationalization of the economy, monopolization of foreign trade by FTCs. Moreover, during this period Czechoslovakia was a member of the CMEA, founded in 1949 in Moscow, and that led to decrease in technological development as well as to worsening of produced goods quality. Thus, during the epoch, the key trading partners of Czechoslovakia were formed under the influence of the political circumstances and included mainly the former socialist countries. The focus of production was equipment, machinery and industrial consumer goods.

The next significant stage of the state history was initiated by the Velvet Revolution of 1989. The period was characterized mainly by the transition of a centrally planned economy into a marked one. Competition was encouraged, the process of privatization was initiated. Dissolution of the CMEA was also remarkable for this period and this implied loss of the previous socialist trading partners. Consequently, the amount of exports considerably decreased whereas the imports increased. The crucial year for that period was 1990 when the country again become a member of ICF and IBRD.

The Czech Republic as an independent country counts its history since January 1, 1993 when disintegration of Czechoslovakia took place. In 2004 the Czech Republic became a member of the European Union and this had a significant influence on the present stage of the country's economy. Foreign trade of the Czech Republic improved so that the country had positive trade balance. EU membership also allowed the Czech Republic to trade in the Common Market and to have trade arrangements, such as the Central European Free Trade Agreement. Moreover, as a member of OECD, the Czech Republic trades extensively with other member countries: 80% of its trading partners are OECD members.

3.2 Economic Crisis of 2007-2008 and Foreign Trade of the Czech Republic

The global financial crisis of 2007-2008 is a significant issue of modern world economy that also had an impact on economy of the Czech Republic and its international trade. Thus, based on the CSO data, the real GDP and overall production of companies reduced because of decline in investments after global uncertainties. Moreover, the country experienced decrease in foreign trade flows.

Before the global financial crisis, during 2004-2008, the economy of the Czech Republic experienced steady and significant growth, partially due to increase in amount of its exports. Moreover, during those years the country received a lot of foreign direct investments that encouraged trade integration. However, despite successful macroeconomic situation in the country, the Czech Republic still undergone spillover effects of the global crisis: fall of its export volumes.

After the crisis, automotive and manufactured metals production used to be key areas for improvement of national economy in the Czech Republic (Tvrdon, 2010). For instance, respective measures were taken to save the automobile industry that is the leading sector the country's production: governments were asked to help manufacturers. Thus, the neighboring countries, Germany and Slovakia in particular, established the measures to scrap cars so that to mitigate the negative impact of the crisis. This resulted in increase of sales for the short term, for instance, Škoda Fabia became the leading selling auto in Germany for the year 2009 (Tvrdon, 2010).

Generally, starting with the end of 2009, the real GDP of the Czech Republic became positive again after a period of stagnation and starting with the year 2014, economic growth took place.

3.3 Foreign Trade Theory: Cross-border and National Concepts

International trade is commonly understood as the process of transferring goods, services and capital across borders of countries and it is more complicated, compared to internal trade. Thus, under the traditional model of foreign trade, an exporter acts as a seller together with an importer in the role of a buyer of a commodity, as depicted in figure 1. In this fundamental model transfer of money does not take a long period and might occur at the time of delivery or close to it. Change of ownership for tradable commodities depends mainly on contract terms and payment agreements (Rojíček, 2011).

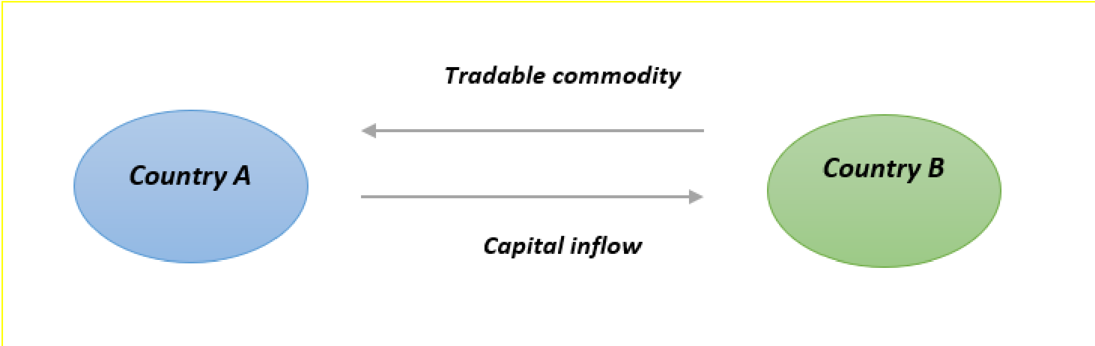

Figure 1: Traditional foreign trade model

Source: author's computations.

Despite its seeming simplicity, external trade has become a considerably more complex process nowadays. Due to globalization, for instance, a commodity might cross several countries during its production phase until it reaches the final stage. Components might be produced worldwide, so the role of intermediaries is increasing. For instance, according to the review provided by the company CzechInvest in 2009, around 20% of total exports of the Czech Republic in 2007 belongs to car-components and the country is among the world leading manufacturers in the automotive sector.

Moreover, nowadays the timing of payment has become more flexible and it is not limited to transfer of goods, but might be held in advance, according to contract terms. What is more, change of ownership has become an essential issue related to foreign trade analysis and based on it, international trade of goods is classified by the Czech Statistical Office into cross-border and national concepts.

The cross-border notion includes movement of tradable commodities out of the Czech Republic and into the country from abroad, i.e. across state borders, without change of ownership and foreign trade statistics is mostly calculated based on this concept. Moreover, transactions performed by non-residents of the country are also included into the cross-border concept. Trade by non-residents, is understood as international trade carried out by foreign companies on a territory of a country, values of transactions between residents and non-residents, or amount of exported and imported goods declared on national borders (Rojíček, 2011). Key reasons behind non-residential trade are the logistical ones, tax optimization, access to other countries. In this case the balance of exports and imports is affected and might differ.

Rojíček et al. (2012) state that the Czech Republic is a country with plenty of storage facilities that promote extensive trade flows across national borders. Thus, trade balance of the Czech Republic hugely depends on ownership of trading enterprises: in case trade is performed by residents of the country, there is no inconsistency problem. Otherwise, if trade is carried out by foreign companies that are non-residents, the value is recorded to accounts of another trading party leading to possible inconsistency.

The national concept, as compared to the cross-border approach, is more complicated because it also captures ownership changes. For instance, trade of the Czech Republic as an EU member, does not always include change of ownership within the EU region. This approach is associated with balance of payment and national accounts concepts. Generally, transactions performed without change of ownership are more complicated and include additional operations.

3.4 Foreign Trade of the Czech Republic Overview

Foreign trade plays an essential role in economy of any state as well as in its internal development. Currently the Czech Republic as a country with open trade regime (Šimáková, 2014a) is widely involved in international trade and locates various multinational companies due to its convenient geographical position, membership in international organizations, political and economic factors.

According to the data provided by WITS, in 2017 total amount of exports equals 182,231,360 and of imports 162,898,931 both in thousands USD that account for a positive trade balance, or trade surplus. Moreover, trade growth of the country in the same year comprises 4.41%. The amount of GDP for the Czech Republic in 2017 is 215,726 million USD with 79.45% as percentage of total GDP standing for exported goods and services and 72.24% of total GDP for imports.

Moreover, currently the economy of the Czech Republic is characterized by an increasing ratio of international trade to GDP. This indicator, revealing trade as a share of GDP, depicts openness of a country to foreign trade and level of globalization of a national economy. Thus, following the global economic crisis of 2008, there was a decrease in the ratio of international trade to GDP with gradual improvement in 2010. Also, in 2017 the trade-to-GDP ratio for the Czech Republic, or foreign trade as percentage of GDP, experienced a small increase and was equal 151.70% that is comparatively high.

Another aspect to consider is trade relationship of the Czech Republic with other countries. Thus, in 2017 the core trading partners of the Czech Republic for exports are Germany, Slovakia, Poland, United Kingdom and France, whereas imports entered the country mainly from Germany, Poland, Slovakia, China and Italy. Thus, the most significant trading partners of the Czech Republic are mostly its neighbors. This fact is in line with the trade gravity model assumption that foreign trade of a country is shaped by the geographical factors. Trade with the neighboring countries is also promoted by the Central European Free Trade Agreement that is concluded by the Czech Republic, Hungary, Poland and Slovakia. It should also be noticed that the biggest world economies, for instance, the USA, are not among key trading partners of the Czech Republic. The reason for this might be significant geographical distance and costs associated costs with that, trade agreements, institutional and other differences. Still, all those assumptions are in line with gravity equations assumptions that are discussed further in the thesis.

3.5 Foreign Trade Composition. Classification Systems

Foreign trade analysis of a country might be also performed by classifying exports and imports into product categories according to systems, such as the Harmonized Commodity Description and Coding Systems, the Standard International Trade Classification, the Broad Economic Categories, the Combined Nomenclature.

Thus, the Harmonized Commodity Description and Coding Systems is a unified worldwide nomenclature applied by trading countries for categorization of products. HS contains around 5,300 detailed descriptions of goods that are grouped into 99 chapters with 21 sections and the system is unified to make comparison across countries clear. For instance, in 2017 under HS6 digit level, exports of the Czech Republic equal to 4,384 goods and they were transported to 214 countries; the number of imported products equals 4,510 and they were coming from 235 trading partners.

Another applicable system is the Standard International Trade Classification. SITC is maintained by the United Nations and includes data on exports and imports with the aim to compare international trade of countries across years. Thus, all traded goods are categorized into key ten groups, provided in table 1.

Table 1: Standard International Trade Classification, 1 section

0: Food and live animals
1: Beverages and tobacco
2: Crude materials, inedible, except fuels
3: Mineral fuels, lubricants and related materials
4: Animal and vegetable oils, fats and waxes
5: Chemicals and related products, n.e.s.
6: Manufactured goods classified chiefly by material
7: Machinery and transport equipment
8: Miscellaneous manufactured articles
9: Commodities and transactions not classified elsewhere in the SITC

Source: CZSO.

Analyzing foreign trade data of the Czech Republic, it is clear that the largest share in it belongs to the automotive industry. As visible from figure 2, the SITC 7 category "Machinery and transport equipment" has the highest value among other classes in foreign trade composition of the Czech Republic in 2017.

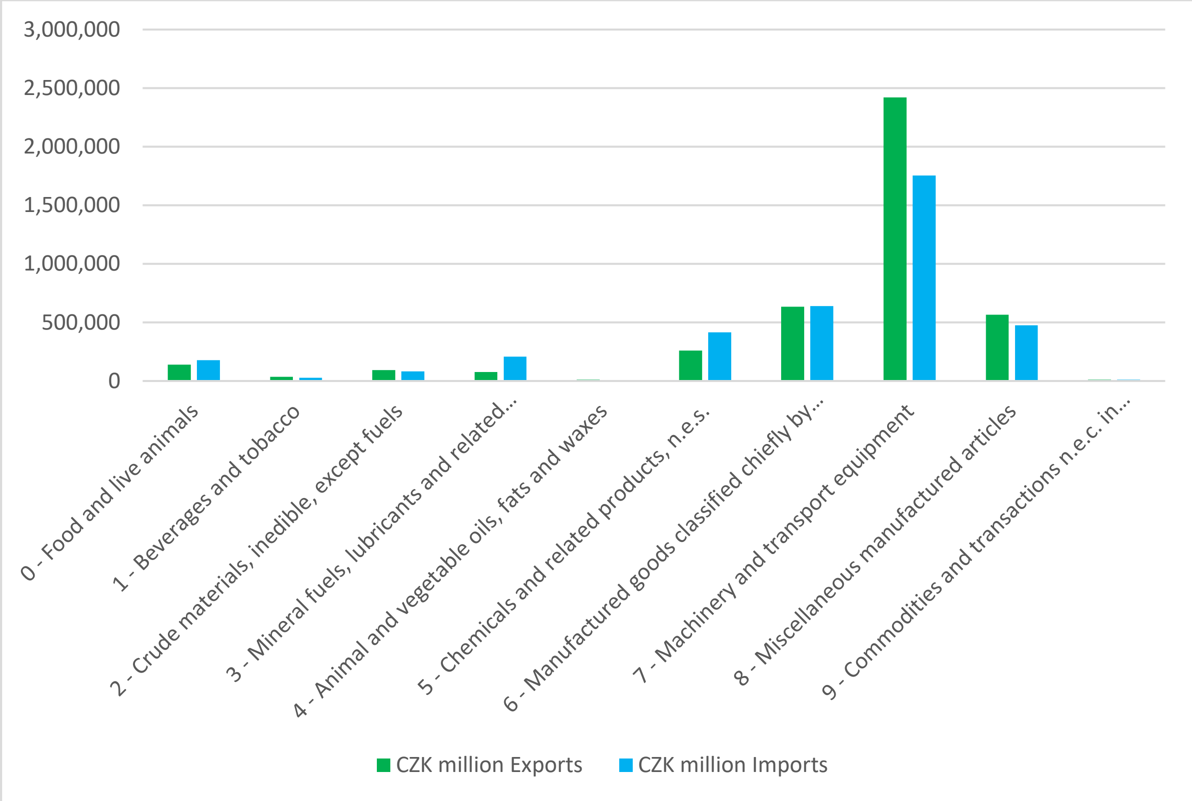

Figure 2: Foreign trade of the Czech Republic 2017 under SITC classification, million CZK

Source: CZSO database.

Thus, in 2017 machinery and transport equipment are the core tradable goods of the Czech Republic and have the highest portions of both exports and imports, compared to other product categories, according to the data from CZSO public database. Moreover, this category is also the most tradable group for foreign trade (both among exports and imports) of the Czech Republic during the period 2005-2017 (according to the SITC), as visible from figures 3 and 4.

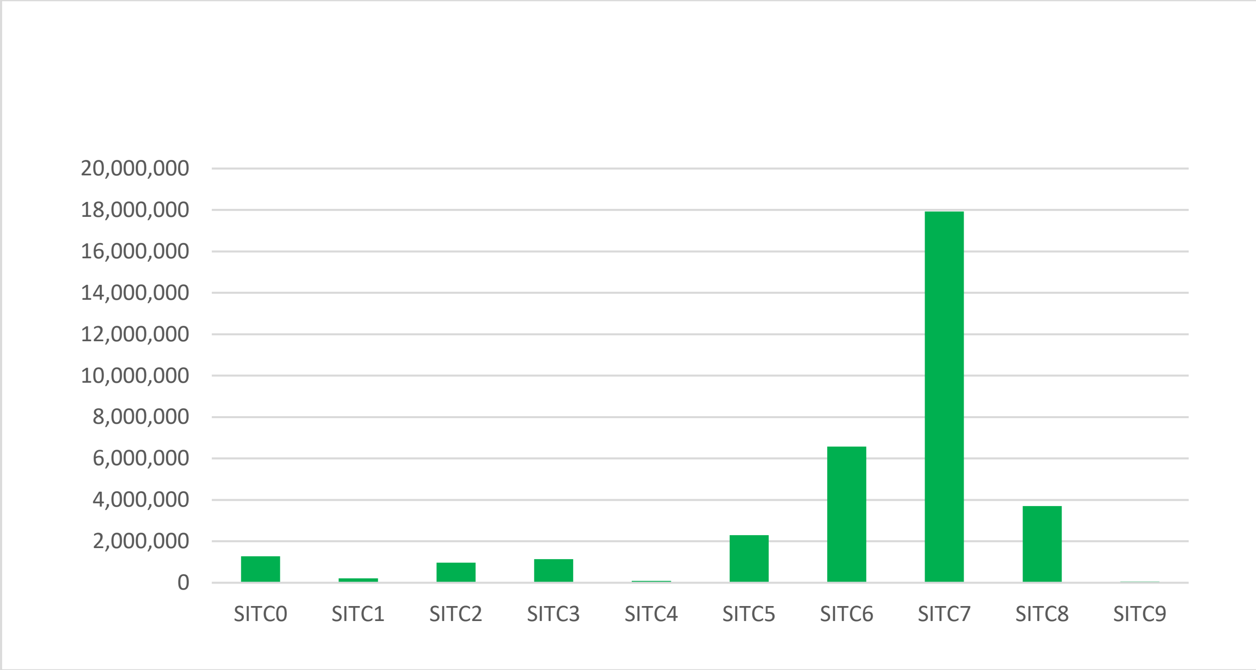

Figure 3: Exports of the Czech Republic by commodity groups 2005-2017, CZK

Source: CZSO database.

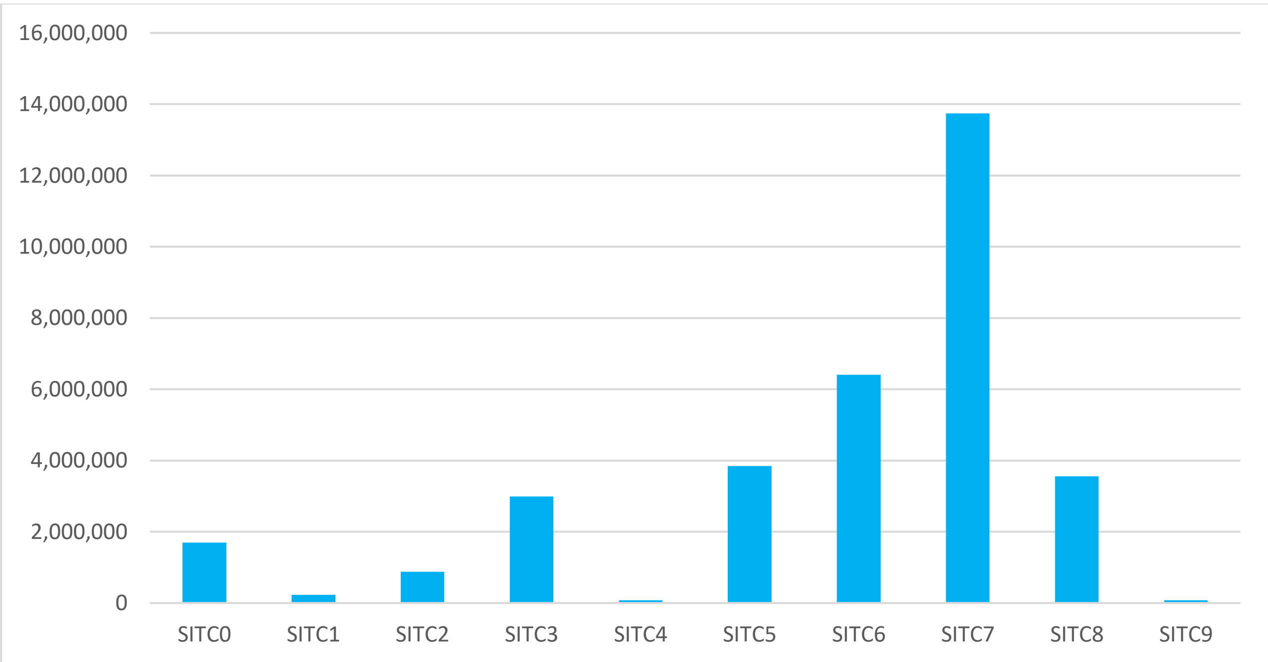

Figure 4: Imports of the Czech Republic by commodity groups 2005-2017, million CZK

Source: CZSO database.

Other significant categories in exports composition are production of spare parts for cars, machinery; among imports: vehicles, medical and telecommunication devices. Thus, based on the CZSO data, foreign trade of the Czech Republic depicts stable tendencies in terms of good composition for a comparatively significant period of time.

3.6 Strategic Aspects of Foreign Trade, Costs and Barriers, Trade in Value Added

International trade might be defined as a strategic process that involves decision making activities of firms, consumers and governments. Thus, consumers shape a demand for foreign goods and services based on their preferences: identical or heterogenous ones. Their choice might be also influenced by a government that in its turn might take control over sectors in economy, for instance, increasing demand for imports. In such situation preference of a government automatically becomes preference of a whole country. Consequently, politicians might act as rule setters in determining foreign trade: their actions influence institutions and trade costs so that foreign trade is stimulated or discouraged. Nowadays governments are mostly motivated to promote international trade, especially exports, with the aim to strengthen a national economy.

Another issue to be discussed in foreign trade analysis are trade costs that are understood as expenses related to the process of receiving a good by a consumer, excluding marginal costs of good creation. Among them are, for instance, exchange rate costs, policy barriers; transportation, information, legal costs etc. (Anderson and van Wincoop, 2004). Moreover, the costs might include insurance and eventual storage for goods. Also, possibility of risks belongs to additional costs, as potential hazards include risk of losses because of criminal activity, expropriation etc. Consequences of those processes might be mitigated with the help of insurance that, however, creates additional costs.

Trade costs differ according to the type of a country: developing countries are exposed to higher charges compared to industrialized countries because of institutional and infrastructural quality. Trade costs are essential for a welfare of a whole country. Thus, as proved by Anderson and van Wincoop (2004), costs implied by policy constitute over ten percent of national income. For instance, tariffs for tradable goods are frequently decreased to almost zero, especially in the developed countries, and reduction of such costs might be an effective and implementable measure for overall decrease in trade costs.

Generally, international trade is beneficial for both involved parties, so countries tend to have trade relationships with their allies, while trade with rivals is mostly limited and trade barriers are implied. Currency barrier is a frequent issue related to international trade as foreign transactions are often performed in national currencies of trading partners. Trade barriers related to exchange-rate systems belong to direct policy instruments among which are also tariffs and quotas. Certain countries belong to currency unions, others may select any of the world currencies for trade operations.

The economy of the Czech Republic, as a member of the European Union, depends on the euro even though the official currency of the country is the Czech koruna. Also, in recent years there has been a tendency among firms operating in the Czech Republic to take loans and do transactions in euros, in order to minimize the number of operations in the local currency. Still, those non-koruna transactions of companies are not considered to be a frightening sign for the Czech koruna and the motivation behind using the euro is lower interest rate in the euro area, high costs of hedging especially for small firms and fluctuation of the Czech koruna against the euro.

Foreign trade of the Czech Republic, especially its exports, is mainly oriented towards the eurozone and the EU. According to the CZSO cross-border trade data, summarized in table 2, total trade turnover of the Czech Republic with the EU members is almost three times higher than trade with non-EU countries. For instance, in 2017 external trade of the Czech Republic within the EU equals 6,063,044 million CZK whereas foreign trade of the country with non-EU partners comprises 1,958,171 million CZK.

Table 2: Total trade turnover of the Czech Republic, 2015-2018

Year	Trade turnover with EU countries (million CZK)	Trade turnover with non-EU countries (million CZK)
2015	5,507,807	1,825,662
2016	5,668,735	1,774,632
2017	6,063,044	1,958,171
2018	6,295,208	2,111,324

Source: CZSO database.

According to the data in table 2, around 80% of the total trade turnover of the Czech Republic belongs to trade within the EU. Also, the total amount of foreign trade gradually increased over the period 2015-2018.

Generally, the common assumption about foreign trade is that an exported good is produced in one country and is then sold to another state where it is finally consumed. Still, the actual process is not that straightforward as more intermediaries are involved and countries tend to specialize in production. Thus, fragmentation implies that components of one good are created in different locations and producers add value to a product at a certain stage of manufacturing. For instance, in the Czech Republic foreign value is added mainly in the automotive industry as a result of close trading relations with Germany.

Also, Rojíček (2011) discusses inward processing: export of tradable commodity to another country with the aim to modify it and later transport it back to the origin country. Those activities are performed under the contract by another firm without change of ownership. Inward processing is more cost effective compared to specialization, for example.

To sum up, foreign trade is a complex notion that is significantly related to national economy. Direct exports and imports review might not provide the most accurate information on international trade, so the described notions in the chapter provide a clearer picture to the area. Currently, foreign trade of the Czech Republic is an integral part of the national economy and the sector is expanding. Thus, the core trading partners of the Czech Republic are determined by its geographical position as well and include Germany, Slovakia, Poland. The Czech Republic, as a member of the EU, conducts trade within the group and with other countries as well. Generally, foreign trade of the country enlarges as the total turnover has been increasing over the last years. Mainly, the trade balance of the Czech Republic is characterized by growth for the last period between 2005-2016 period.

4 Data

In the following chapter the data used for empirical analysis, the variables included into the models as well as possible statistical issues are described. Generally, the choice of dataset type is essential for any econometric research and modern empirical papers, in which foreign trade is analyzed via gravity equations, differ in types of estimated datasets. Thus, panel data is frequently preferred over cross-section due to its structure that allows to control for both time-variant and time-invariant variables, i.e. for observations changing over time, such as GDP, population, exchange rate volatility and for those that remain constant, such as distance. As Greene (2003) states, the sample in panel data includes various observations for each of the included units. Panel dataset is advantageous as it combines features of both cross-section and time-series data; it contains observations for a set of individuals, or countries, (N) over a certain number of periods (T) with total number of observations NT.

In the thesis the main panel dataset is constructed over the period 2005-2016 for 53 heterogeneous countries that vary in economic and geographic terms but are all involved in foreign trade with the Czech Republic. The countries are selected according to their relevance in trade relations with the Czech Republic and based on the availability of data for the included variables. The selected trading partners constitute the largest share in foreign trade of the Czech Republic. For instance, in 2016 the proportion of exports constitutes around 86% of total amount and the imports account for around 72%. Also, as visible in figure 5, the key trading partners of the Czech Republic are the neighboring states and the EU members.

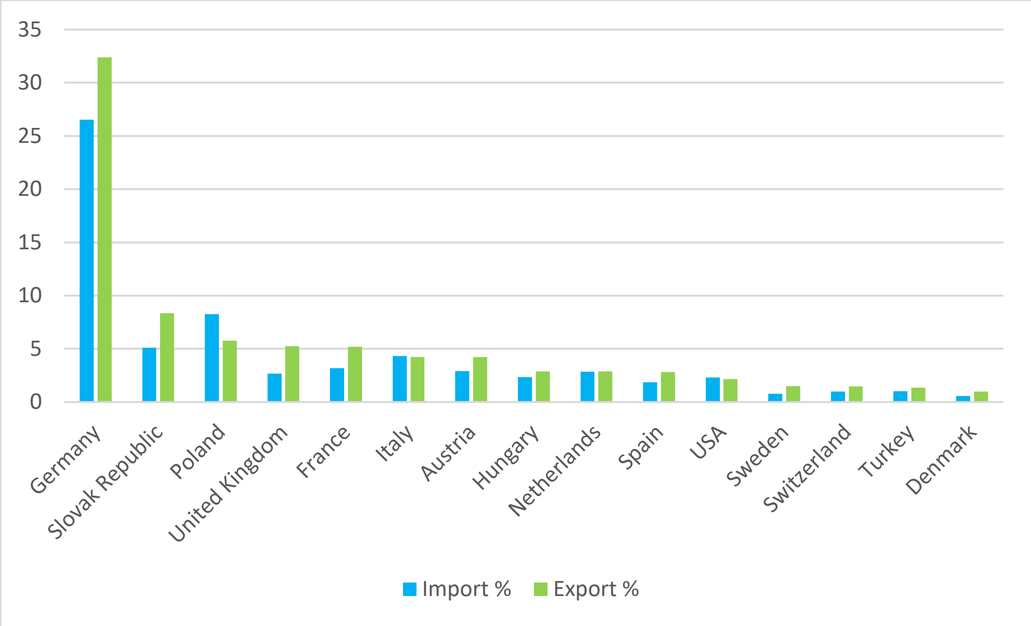

Figure 5: Top 15 trading partners of the Czech Republic in 2016 by import and export shares

Source: WITS database.

Another type of dataset in the empirical analysis is time series that is used to acquire the realized volatility values. Thus, the historical monthly exchange rate data of the Czech koruna pairs against 43 world currencies during 2005-2016 are analyzed and the obtained realized volatility values are introduced into the main panel dataset.

The analyzed panel dataset consists of annual macroeconomic values: GDP and population of the Czech Republic and its trading partners; geographic characteristics, such as weighted distance, contiguity, direct access to the sea and information on EU and OECD membership. Trade balance values are obtained from the total amounts of imports as well as exports of the Czech Republic and its trading partners. Also, realized volatility is calculated from monthly historical exchange rate data of the Czech koruna relative to local currencies of the trading partners. The dataset covers the time period 2005-2016 and is constructed without missing observations. The included variables are adjusted into the logarithmic form, but they are non-stationary except for the exchange rate realized volatility. The full list of analyzed countries in alphabetical order together with the codes of local currencies and export as well as import shares per country is provided in the "Appendix A".

4.1 Statistical Discrepancies in Foreign Trade Data

Accuracy of trade statistics is one of the main issues related to foreign trade analysis as the observed external trade data might not correspond with actual economic inputs and outputs of a country. Revealed data on volumes of external trade commonly includes mirror national statistics but it might provide misleading results. Mirror statistics serves as a useful tool, allowing for the real overview of trade transactions and enabling to identify the reasons for mismatches in statistics (Eurostat, 2005). Still, records of exports and imports by both trading parties might not be equal and this issue is known as bilateral trade asymmetries.

For instance, as already mentioned in subchapter 3.1, after joining the EU, the Czech Republic experienced trade surplus, but Rojíček et al. (2012) declare that the positive balance of trade appears due to value generated from non-residential transactions that should not be included into the value added of the national economy. Thus, according to the authors, key concerns related to statistical discrepancies are impact of non-residents on trade flows and transitions of commodities occurring without change of ownership.

Another example of statistical discrepancies in volumes of trade is revealed in the data from WITS for the year 2017 between the Czech Republic and its 18 trading partners. As visible in figure 6, the upper rows depict amount of exports from the Czech Republic to a trading partner and the below rows illustrate amount of imports received by a trading partner from the Czech Republic. The values should be equal, but the amounts are not the same, according to figure 6.

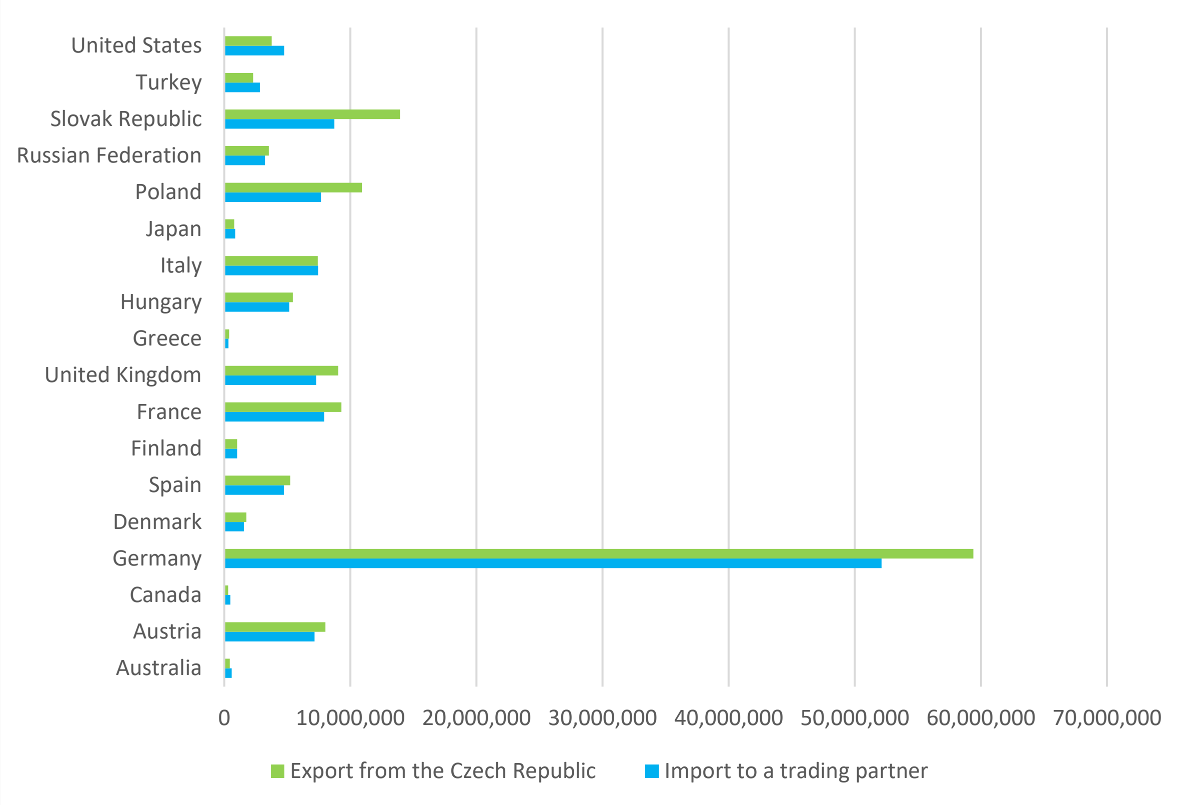

Figure 6: Foreign trade data of the Czech Republic in 2017, USD thousands

Source: WITS database.

Key reasons behind those statistical discrepancies include timing and pricing issues, classification concerns, possible falsification of invoices and other points. Also, the Eurostat (2005) mention the necessity to ensure that comparable data are of the same notions: for instance, incorrect comparison of international trade with balance of payments. Thus, it is essential to acknowledge that the constructed dataset might be subject to statistical limitations that might also affect the empirical results.

4.2 Dependent Variable and its Adjustment

$\boldsymbol{TB_{ijt}}$ – *Trade balance in year t.* The dependent variable of the estimated equations is trade balance *(*TB_{ijt}*)* and it is commonly defined as the difference between exports and imports of a reporting country and its trading partner, measured in monetary value. The dependent variable is adjusted for empirical analysis, following the definition by Šimáková (2014b) so that trade balance is understood as the ratio of exports from the

Czech Republic to a country *f* over the amount of exports from country *f* to the Czech Republic. The values are recorded in thousands of US Dollars with Czech Republic as a reporting country. The observations are obtained from the WITS database (https://wits.worldbank.org/).

Generally, there are two main types of trade balance: positive and negative. Trade surplus, or the situation when amount of exports of a country exceeds its imports is defined as positive trade balance and it is characterized by inflow of domestic currency. Trade surplus is beneficial for an economy of a country as it allows to strengthen domestic currency relative to foreign money. Trade deficit is the opposite situation, when a country imports more than it exports, thus, leading to a negative trade balance. This case is usually considered to have a negative impact on a national economy, but sometimes a country might benefit from this situation, especially if it is developing and requires imports.

Considering trade balance of the Czech Republic, this indicator is characterized by trade surplus over the analysed period of 2005-2016, as visible in figure 7. Positive trade balance indicates high competitiveness of a national economy and might lead to appreciation of a national currency. According to the CZSO database, before 2005 the country experienced trade deficit and only after 2005 the amount of exports exceeded the imports in the Czech Republic, accounting for a positive trade balance. Improvement of this indicator is explained by the fact that the Czech Republic joined the EU in 2004 and as a result, became operating in the single European market. Also, trade surplus is justified by the fact that the total trade turnover of the Czech Republic increased, and growth rates of exports exceeded the rates of imports. Improvement of trade balance is also explained by the gradual transition of the economy to a market type and due to foreign direct investments to the Czech Republic.

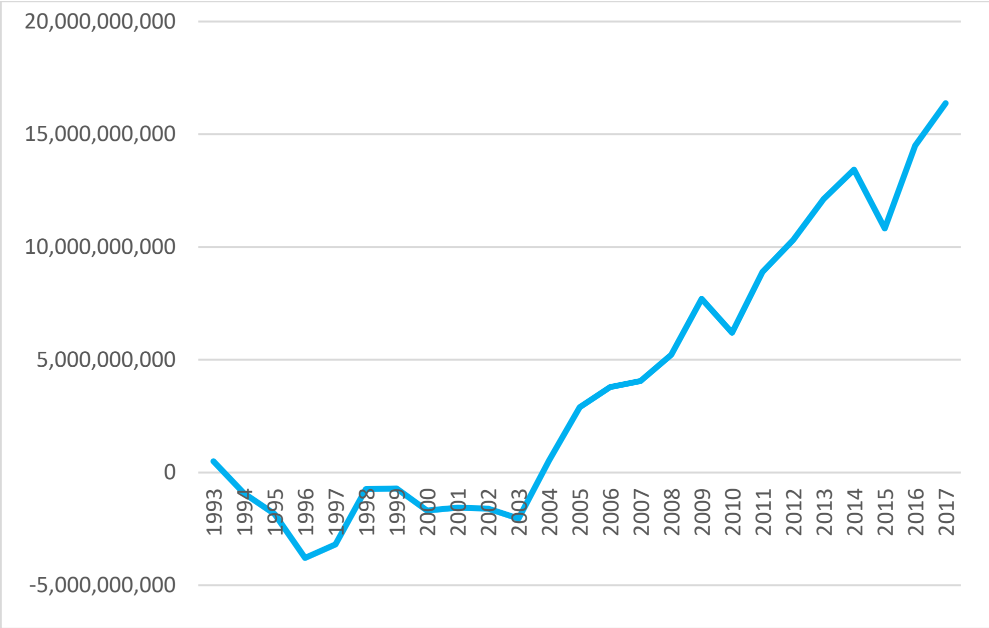

Figure 7: Trade balance of the Czech Republic 1993-2017, USD

Source: World Bank database.

4.3. Independent variables

$\boldsymbol{RV_{ijt}}$ – *Realized volatility of the Czech koruna against a currency of country i in year t*. Results from realized volatility estimation, obtained from analysis of historical exchange rate data of monthly frequency. The data are gathered from the official webpage of the Czech National Bank (https://www.cnb.cz/en/financial-markets/foreign-exchange-market/central-bank-exchange-rate-fixing/central-bank-exchange-rate-fixing/selected_form.html) and from the global financial markets platform Investing.com (https://www.investing.com/). The detailed methodological approach for realized volatility calculation and the theoretical foundations of the technique are described in chapter 5.1. Also, the obtained values are included into the “Appendix C”.

$\boldsymbol{GDP_{it}}$ – *GDP of country i in year t*. Values for the gross domestic product are in US dollars and are gathered from the World Bank database (http://www.worldbank.org/). This variable represents market size of a country *i* at time period *t* and is used as an indicator of national income. Generally, according to the gravity equations assumptions, the estimated coefficient of GDP is expected to be positive and significant. GDP is one of the key indicators for international trade analysis of a country.

$\boldsymbol{POP_{it}}$ – *Population of country i in year t*. Observations for total population of the analysed countries in midyear estimates are gathered from the World Bank database (http://www.worldbank.org/). The values are based on the de facto definition of population, according to which all residents of a country that are geographically located on its territory at a specified time are counted, without distinction of citizenship or legal status. This variable represents market size of country *i* at time period *t*, similarly to the GDP, and it is considered that higher population, as an indicator of market size, increases the amount of imports to the country.

$\boldsymbol{WDIST_{ij}}$ – *Weighted distance between country i and the Czech Republic.* The impact of distance on trade balance is measured with the help of weighted distance variable. It is defined by the formula

$$WDIST_{ijt} = \frac{Distance_{ij} * GDP_{it}}{\sum GDP_{it}} \quad (1)$$

where $Distance_{ij}$ is a geographical interval in kilometres between the Czech Republic and its trading partner, calculated upon geographical coordinates of capital cities. GDP_{it} represents GDP value of a trading partner at year *t* and $\sum GDP_{it}$ is the summation of GDP values for all the countries under analysis at a particular year. The data on geographical distances is collected from the CEPII database (http://www.cepii.fr/). In the analysis the variable serves as an indicator of transportation costs. The aim for using weighted distance values in the analysis instead of the common geographical measures is to make distance a time-varying variable. Otherwise, its effect is omitted in the fixed effects model.

$\boldsymbol{GDPCZ_{jt}}$ – *GDP of the Czech Republic in year t.* GDP data for the Czech Republic are collected from the World Bank database (http://www.worldbank.org/) and are recorded in USD. According to figure 8, the total GDP of the Czech Republic in 2016 increased by 59 billion USD, as compared to the same value in 2005. Increase in GDP of the Czech Republic indicates rise in economic wealth of the country, that in its term indicates enhancement of foreign trade.

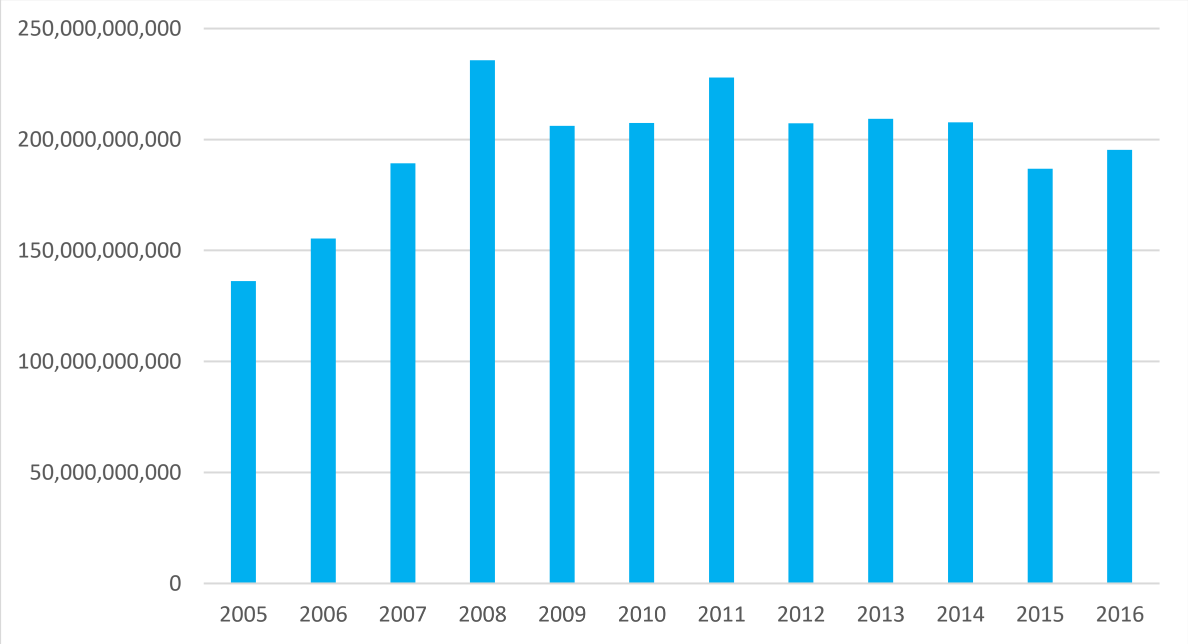

Figure 8: GDP of the Czech Republic 2005-2016, USD

Source: World Bank database.

$\boldsymbol{POPCZ_{jt}}$ – *Population of the Czech Republic in year t.* Total population values of the Czech Republic in midyear estimates are gathered from the World Bank database (http://www.worldbank.org/). Over the period 2005-2016 population of the Czech Republic is characterized by a gradual increase by 355 166 inhabitants, as visible in figure 9. Rise of population of the Czech Republic indicates economic sustainability of the country that in its turn has a positive impact on the foreign trade market.

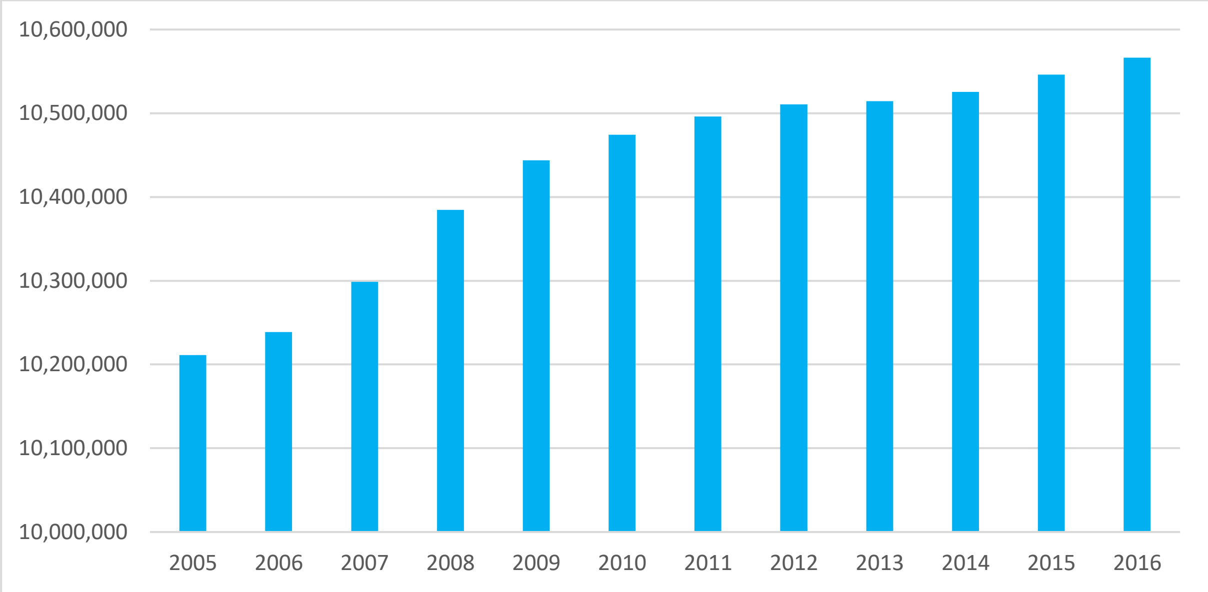

Figure 9: Population of the Czech Republic 2005-2016

Source: World Bank database.

$\boldsymbol{CONTIG_i}$ – *Dummy variable: geographical contiguity (country i and the Czech Republic).* This time-invariant dummy variable depicts whether a trading partner is contiguous with the Czech Republic or not. This variable takes the following values: 1 in case the countries share a common border, 0 otherwise. Thus, for the four neighbouring countries: Austria, Germany, Poland and Slovakia the value equals 1, for other countries the value is 0.

$\boldsymbol{LANDL_i}$ – *Dummy variable: country i is landlocked or has access to a coastline.* This time-invariant dummy variable illustrates whether a country is enclosed by land (1 in this case), 0 if a country has access to a coastline. Values for this variable are obtained from CEPII database.

$\boldsymbol{EU_{it}}$ – *Dummy variable: EU membership of country i in year t.* Dummy variable that equals 1 if the country is a member of the European Union at a particular year, zero otherwise. In the constructed panel dataset 16 countries are members of the European Union and that constitutes approximately 30% of all included trading partners of the Czech Republic.

$\boldsymbol{OECD_{it}}$ – *Dummy variable: membership of country i in OECD in year t.* Time-variant dummy variable that equals 1 if a country belongs to the OECD, 0 otherwise. The dataset includes 23 countries (Australia, Austria, Canada, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Netherlands, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States of America) that are members of the OECD or became its members during the analysed period 2005-2016.

5 Methodology

The following chapter describes the methodological approaches applied for the analysis: firstly, the concept of realized volatility is provided; secondly, the theory of trade gravity equations is reviewed.

5.1 Realized Volatility

Generally, volatility is understood as a measure of variation in asset prices over a particular period of time and it might be treated as a primary indicator of risk or uncertainty. This financial concept is crucial for determining values of stocks, bonds and assets, especially the risky ones, with exchange rates among them. Behaviour of exchange rates is generally not constant, and they are expected to move up and down because of such reasons as inflation, interest rates, political turmoil etc. According to Ozturk (2006), volatility of exchange rate is understood as the risk resulting from unpredicted changes in exchange rate. Also, among the sources of exchange rate volatility Ozturk (2006) mentions balance of payments, inflation and interest rates.

Traditionally volatility used to be measured as a standard deviation of returns (*SD*), calculated under the following formula:

$$SD = \sqrt{\frac{\sum_{i=1}^{n}(r_i - \bar{r}_t)^2}{n_t - 1}} \quad (2)$$

with r_i – observed return, $\bar{r}_t$ – average return for the specified period, n_t – amount of observations for the period *t* and *i* – depending on the sampling approach.

Estimation of volatility is essential not only for economic research but also for financial decision-making. Still, this concept cannot be observed directly and the existing approaches for measuring volatility are classified into two broad categories: parametric and non-parametric methods. Most of empirical studies until recently applied the parametric approach for analysis, considering volatility as an unobservable, or a latent variable.

The parametric methods include, for instance, ARCH-GARCH class of models developed by Engel (1982) and stochastic volatility models introduced by Clark (1973). In those models the expected, or ex-ante, volatility is estimated parametrically based on returns for settled frequency. Still, those models are not ideal instruments for volatility estimation as they might not fully reflect financial data properties because of misspecifications and complexity in estimation. For instance, Zheng (2014) admits, that those models have become restrictive and complicated in application and notices that recently there has been a tendency of applying more flexible and computationally straightforward nonparametric measurements.

Consequently, realized volatility has been introduced by Andersen and Bollerslev (1998) as an alternative approach to measure ex-post volatility. This model-free estimator is based on easier techniques and serves as a non-parametric approach to volatility measurement. The technique assumes volatility to be an observable rather than a latent process due to similarity of volatility estimates to an integrated volatility (Andersen et. al., 2001). The notion of realized volatility is based on the quadratic variation theory proposed by Andersen et. al. (2003) and the described methodological approach in the chapter mainly follows this work.

As mentioned in several empirical works, realized volatility has become an informative and efficient volatility estimator. Moreover, Andersen et. al. (2003) state that, in forecasting, for instance, models with realized volatility outperform traditional GARCH and stochastic volatility models. Also, essential for analysis are distributional properties of realized volatility. Thus, returns are assumed to be normally distributed with a stochastic standard deviation. Additionally, Andersen et.al. (2003) state that jumps might appear under the no-arbitrage condition, leading to a non-normal distribution of returns. Still, realized variance, that is understood as summation of squared returns within a period, remains unaffected in this case.

As stated by Eriksson et. al. (2019), realized volatility might be estimated in a model-free framework by applying quadratic variation as an empirical measure of underlying price process. Under the theory of quadratic variation and with appropriate conditions, realized volatility might be an unbiased and efficient estimator of return volatility. Thus, the quadratic variation theory, introduced by Andersen et. al. (2003), is essential as the concept of realized volatility is based upon it. The quadratic variation theory is presented in the "Appendix B" where propositions and theoretical assumptions from the work by Andersen et. al. (2003) are discussed. The results of quadratic variation theory are relevant for creating framework for estimation, modelling as well as for forecasting volatility. The process of realized volatility calculation is described in the next subchapter.

5.1.1 Realized Volatility Measurement

As already mentioned, realized volatility serves as a practical approach to analyse ex-post volatility by treating it as an observable variable. Realized volatility is a consistent non-parametric, model-free estimator especially applicable for measuring volatility over a discrete time interval. Nowadays realized volatility is often used for examining historical changes in prices and this method of volatility estimation is applied for analysis in the thesis.

Observations in the analysis belong to the discrete time interval (2005-2016), so realized volatility might be additionally classified as local. Analysis of local observations is mostly advantageous compared to review of values outside of an interval as local ones are asymptotically unbiased as well as fast adjusting. Still, there is limitation to the analysis as potentially relevant information from the neighbouring time intervals might be omitted.

The logics behind the method of realized volatility is clear and comparatively straightforward, but despite its seeming practical simplicity, there is an important theoretical foundation of the approach and the details are discussed further.

Let $p(t)$ denote a logarithm of asset price (P) at time t: $p(t) = ln_t P$. The cumulative return process is respectively defined as $r(t) \equiv p(t) - p(0)$ (Busch et. al., 2011). Thus, the continuously compounded intra-period returns are $r_{t,j} = p_{t,j} - p_{t,j-1}$, j = 1, . . . , M , t = 1, . . . , T, with T – number of period belonging to the sample; M + 1 are equally allocated intra-period values at time period t (Busch et. al., 2011). Also, as previously stated, returns are supposed to be normally distributed with stochastic standard deviation.

Application of returns for analysis instead of raw prices is justified by Campbell et. al. (1997) who state the key reasons for that. Firstly, returns are useful as a full and scale-free overview of the investment perspective. Secondly, returns possess statistical properties: stationarity and ergodicity that are preferable for analysis compared to prices. Thus, the simple net return, R_t, is defined as $R_t = \frac{P_t}{P_{t-1}} - 1$, where P_t is the price of an asset at time t and the simple gross return specified as $1 + R_t$.

Since the focus of the analysis in the thesis is dynamics of exchange rates over time, continuously compounded returns are preferred over the simple ones that are used for cross-sectional analysis of assets. Thus, "the continuously compounded or log return r_t of an asset is defined to be the natural logarithm of its gross return $1 + R_t$: $r_t \equiv log(1 + R_t) = log\frac{P_t}{P_{t-1}} = p_t - p_{t-1}$, where $p_t = log\, P_t$" (Campbell et. al., 1997). Continuously compounded returns are advantageous due to their logarithmic form that allows to calculate multiperiod returns by summing up single period returns instead of multiplication. The additive operation allows to obtain time-series properties because multiperiod compounded return is directly defined as summation of continuously compounded returns for separate periods.

Thus, realized variance is defined by the equation: $RVar_t = \sum_{i=1}^{N} r_t^2$ and is assumed to be normally distributed. Realized variance includes summation of obtained squared returns for the analysed period, in particular, calculations of annual values from monthly exchange rate returns. Then, realized volatility is understood as the square root of realized variance $RV_t = \sqrt{RVar_t}$. It is essential to distinguish between the concepts of realized variance ($RVar$) and realized volatility (RV_t) as they are sometimes confused.

Finally, logarithmic transformation is performed to realized volatility values so that $ln(RV_t)$ is obtained. Logarithmic specification, as proved by Chevallier and Sevi (2011) and in other empirical works on the topic, is preferable over the raw realized volatility values because of its statistical properties. Thus, the logarithmic realized volatility is characterized by an unconditional distribution that is close to Gaussian, compared to the skewed and kurtosed unconditional distribution of the raw realized volatility.

In the analysis the process of obtaining realized volatility values is unified and is applied to all included 43 Czech koruna pairs against the selected local currencies. The analysed sample is restricted to the period 2005-2016 and the full list of analysed countries with the respective currencies is included in the “Appendix A”. The Czech koruna has been the official currency of the Czech Republic since 1993 and its exchange rate has become floating since 1997, while previously it was fixed. The transition from one type of exchange rate regime to another served as a reason for increase in exchange rate volatility of the Czech koruna. What is more, the euro is analysed as the currency for the eurozone and is related to 12 out of the 53 selected countries. Also, the Slovak koruna is treated a special case in the estimations as the Slovak Republic joined the eurozone in 2009. Thus, for Slovakia during the period 2005-2008 the values of realized volatility are obtained for SKK and starting with 2009 the values are taken from EUR. The values of realized volatility obtained from the historical exchange rate time series data and are provided in the “Appendix C”.

5.2 Gravity Equations in International Trade

International trade is a complex notion that cannot be straightforwardly explained by any concrete model or equation. Currently, gravity equations have become widely applied as a technique for analysis of international trade flows, so this approach is used for the analysis.

Initially the law of universal gravitation was formulated by Sir Isaac Newton and according to the theory, gravitational force between two objects is directly proportional to multiplication of weights and inversely proportional to the square of distance between those objects. The gravity equation is specified as

$$F_{ij} = G\frac{M_i M_j}{D_{ij}^2} \tag{3}$$

where F_{ij} is gravity force, $M_{i(j)}$ represents weights of objects i and j, D_{ij} is distance between the objects i and j, G is the constant for gravity.

The above-mentioned Newton’s law of gravity might be also applicable in economics for explaining international trade. The gravity equation (3) is defined as a model of bilateral trade interactions, so it accounts for the size and distance effects between trading partners (Head & Mayer, 2013).

Gravity model as a tool for international trade analysis was introduced by Tinbergen (1962) with the aim to explain various economic policies and promote international trade among countries. Accordingly, Tinbergen (1962) defined the trade flow equation in its simplest form in the following way:

$$E_{ij} = \alpha_0 Y_i^{\alpha_1} Y_j^{\alpha_2} D_{ij}^{\alpha_3} \tag{4}$$

where

E_{ij} = exports of country i to country j

Y_i = GNP of country i

Y_j = GNP of country j

D_{ij} = distance between country i and country j

$\alpha_0, \alpha_1, \alpha_2, \alpha_3$ = unknown parameters

Thus, in the gravity equation bilateral trade between countries is directly proportional to the size of their economies (also understood as national income or GDP) and inversely proportional to the distance between them.

The simple, or basic form of gravity model explains trade flows between a pair of trading countries by assuming positive dependence on the product of their GDPs and negative effect of distance between those trading countries (Clark, 2004). Also, Feenstra (2004) states that larger countries tend to trade more with each other, and countries which are more similar in their relative sizes also have more developed trade interactions.

The proposed empirical relationship (4) by Tinbergen (1962), however, has been criticised for not having enough theoretical justifications. Since that time the model has been modified and extended so that the principle of those equations is not only economic intuition, but also theoretical background.

Feenstra (2004) derives another version of the gravity equation, based on the assumption of free trade, so that all countries have identical prices. However, this assumption is later loosened, and the author takes into consideration variability of prices due to trade barriers between countries. Exports of product k from country i to country j are given by the equation:

$$X_k^{ij} = s^j y_k^i \quad (5)$$

Also, bilateral trade between two countries equals:

$$X^{ij} + X^{ji} = \left(\frac{2}{Y^w}\right) Y^i Y^j \quad (6)$$

The gravity model with identical prices is later extended by Feenstra (2004) with an assumption about border effects (including transport costs or tariffs) which means that prices are not equalized across the countries. This leads to a more sophisticated equation compared to (6) and the resulting gravity equation takes the following form:

$$X^{ij} = N^i Y^j \left(\frac{p^{ij}}{P^j}\right)^{1-\sigma} \quad (7)$$

where the total value of exports from country *i* to country *j* is $X^{ij} \equiv N^i p^{ij} c^{ij}$.

Egger and Nigai (2005) also stress the importance of trade costs and admit the problem of gravity equations estimation with unobservable costs as those components arise bias in the estimation.

Application of gravity equation has certain advantages: by using the real-world data this model provides clear view of the sensitivity of bilateral relations among countries taking into consideration various socio-economic factors. Moreover, they include micro-foundations and analyse trade as a dynamic process, compared to previous static models (Head and Mayer, 2013). In addition, gravity equations might be used not only for trade analysis, but also for policy implications.

5.2.1 Model Specification

As previously discussed, the international trade gravity equation in its basic form is defined in equation (4) and in the analysis exports are replaced with trade balance. Also, natural logarithms are taken on both sides of the equation as a common econometric technique. Thus, the basic model to be estimated first is specified in the following way:

$$ln(TB_{ijt}) = ln\,\beta_0 + \beta_1\, ln(GDP_{it}) + \beta_2\, ln(GDPCZ_{jt}) + \beta_3\, ln(WDIST_{ij}) + ln\,u_{ijt} \quad (8)$$

where the included variables denote:

TB_{ijt} – Trade balance in year *t*

GDP_{it} – GDP of country *i* in year *t*

$GDPCZ_{jt}$ – GDP of the Czech Republic in year *t*

$WDIST_{ij}$ – Weighted distance between country *i* and the Czech Republic

According to the theory of trade gravity equation, the impact of GDPs is supposed to be positive and the effect of distance to be negative.

Compared to the basic equation, modern gravity models analyse trade not only by focusing solely on size and distance, but are extended for various socio-economic explanatory variables, such as population, trade regime (openness), institutional quality of a country (presence of corruption, government effectiveness index), trade barriers and costs, common borders and language, membership in currency unions and regional integration agreements etc.

The effect of exchange rate movements is also frequently included into a model to test for the impact of currency risk on international trade. For instance, Tichý (2007) specifies the model that examines exchange rate volatility on foreign trade as follows:

$$X_{ij} = \alpha Y_i^{\beta_1} Y_j^{\beta_2} Pop_i^{\beta_3} Pop_j^{\beta_4} ER_{ij}^{\beta_5} D_{ij}^{\beta_6} e^{\beta_7(ER_{ij})} \prod_l Dum_l^{\gamma_1} u_{ij} \tag{9}$$

Generally, gravity equations are presented in a multiplicative form, so it is required to transform them into a log-linear form for estimation. Tichý (2007) applies the same logics and the model in equation (9) is transformed into a log-linear form where the small leters stand for logarithms of original values:

$$x_{ij} = ln(\alpha) + \beta_1 y_i + \beta_2 y_j + \beta_3 pop_i + \beta_4 pop_j + \beta_5 er_{ij} + \beta_6 d_{ij} + \beta_7 V\left(ER_{ij}\right) + \sum_l \gamma_l dum_l + ln(u_{ij}) \tag{10}$$

X_{ij} - the volume of trade from country *i* to *j* (imports and exports)

$Y_{i(j)}$ - GDP per capita of country *i* or *j*

$Pop_{i(j)}$ - population of country *i* or *j*

ER_{ij} - spot exchange rate

D_{ij} - distance between trading countries

Dum_l - dummy variables (common border, currency union membership, time dummies)

$\alpha, \beta_k, \gamma_l$ - parameters of the model

$V(ER_{ij})$ - exchange rate volatility for a pair of countries i and j

Thus, based on equation (10), the following augmented model with natural logarithms of the included variables is constructed for the analysis in the thesis:

$$\ln(TB_{ijt}) = \ln\beta_0 + \beta_1 \ln(GDP_{it}) + \beta_2 \ln(GDPCZ_{jt}) + \beta_3 \ln(WDIST_{ij}) + \beta_4 \ln(RV_{ijt}) + \beta_5 \ln(POP_{it}) + \beta_6 \ln(POPCZ_{jt}) + CONTIG_i + LANDL_i + EU_{it} + OECD_{it} + \ln u_{ijt} \quad (11)$$

with t = 2005, 2006,…,2016

i = 1, 2,…,53

t - time, i – country that is a trading partner, j – the Czech Republic.

The included variables denote:

TB_{ijt} – Trade balance in year t

GDP_{it} – GDP of country i in year t

$GDPCZ_{jt}$ – GDP of the Czech Republic in year t

$WDIST_{ij}$ – Weighted distance between country i and the Czech Republic

RV_{ijt} – Realized volatility of the Czech koruna against a currency of country i in year t

POP_{it} – Population of country i in year t

$POPCZ_{jt}$ – Population of the Czech Republic in year t

$CONTIG_i$ – Dummy variable: geographical contiguity (country i and Czech Republic)

$LANDL_i$ – Dummy variable: country i is landlocked or has access to a coastline

EU_{it} – Dummy variable: EU membership of country i in year t

$OECD_{it}$ – Dummy variable: membership of country i in OECD in year t

u_{ijt} – error term

In addition, β_0 is a constant and the error term u_{ijt} is assumed to be normally distributed with mean zero as well as constant variance. The included variables are described in more details in the chapter "Data".

5.2.2 Gravity Model Estimation Techniques

Gravity equations are commonly estimated by the standard panel data approaches: pooled OLS, fixed effects and random effecs model. As, Greene (2003) states, a panel dataset is advantageous compared to a cross section as it captures flexibility when modeling differences in behavior across individuals. Also, Greene (2003) defines a regression model for panel data analysis in the following way:

$$y_{it} = x_{it}'\,\beta + z_i'\alpha + \varepsilon_{it} \tag{12}$$

where $z_i'\alpha$ is the heterogeneity, or an individual effect.

Also, cruscial for analysis are assumptions on the unobserved effects of panel data (Greene, 2003), including strict exogeneity for independent variables:

$$E[\varepsilon_{it}|x_{i1}, x_{i2}, \dots,] = 0 \tag{13}$$

and mean independence:

$$E[c_i|x_{i1}, x_{i2}, \dots,] = \alpha \qquad (14).$$

5.2.3 Pooled OLS

As already discussed, the multiplicative form of gravity equations is usually log-linearly transformed, and this allows to estimate the model by pooled ordinary least squares method. Also, for OLS estimates to be unbiased and consistent, the assumptions on linearity of parameters, random sampling of observations and zero conditional mean must hold. According to Greene (2003), in case z_i (equation 7) includes only a constant term, pooled OLS is consistent and efficient estimator of α and β. However, this is not always true for panel data estimation, which means that pooled OLS might not be the best estimator under the structural gravity (Head & Mayer, 2013).

One of the issues related to OLS estimation is heteroscedasticity: violation of homoscedasticity of the error term. Heteroscedasticity is common for trade data and it is present even in the traditional gravity equation proposed by Tinbergen (1962). Heteroscedasticity implies that variance of the error is not constant over time and this might cause biased results. Heteroscedasticity leads to inconsistent coefficient estimates in linear (in logs) regression (Silva and Tenreyro, 2006). Thus, in case the assumption of homoskedasticity is violated, robust standard errors are applied as a possible remedy.

Generally, pooled OLS is considered a simple estimation technique and it serves mainly as a benchmark for more complex methods. Moreover, it disregards panel data features as it does not consider heterogeneity across countries.

5.2.4 Fixed effects

Compared to the pooled OLS, fixed effects model considers the individual and time effects in data by allowing the intercept to differ for individual and time dimensions. According to Greene (2003), if z_i (equation 12) is unobserved, but correlated with x_{it}, OLS estimator of β becomes biased and inconsistent because of an ommitted variable. In this case the fixed effects approach is applied and it is specified in the following way:

$$y_{it} = x'_{it}\,\beta + \alpha_i + \varepsilon_{it} \tag{15}$$

where $\alpha_i = z'_i\alpha$ is assumed to be group-specific constant term. Also, α_i contains the observable effects to be estimated.

Generally, the described estimation technique has a strong advantage over other methods as it accounts for unobservable fixed effects at each country. This approach is widely used in empirical papers analysing international trade and is assumed to be one of the most popular tools for gravity equations estimation (Head & Mayer, 2013).

Still, fixed effects model has a drawback as might not capture the effect of time invariant variables in x_{it}, such as distance, so they might not be included into estimation. In order to overcome this issue in the analysis, weighted distance is included into estimated models instead of the common time-invariant distance measures.

5.2.5 Random effects

The next approach for panel data estimation is random effects model and under this method an intercept is considered as a random variable. Generally, this estimation technique is applied for panel data analysis in case z_i (equation 12), that is heterogeneity of individuals, is not correlated with included variables (Greene, 2003). The model is specified as follows:

$$y_{it} = x_{it}' \beta + E[z_i'\alpha] + \{z_i'\alpha - E[z_i'\alpha]\} = x_{it}' \beta + \alpha + u_i + \varepsilon_{it} \qquad (16)$$

where u_i is a group specific random element.

As highlited by Greene (2003), key difference between the fixed and random effects models is whether an unobserved individual effect includes elements correlated with regressors in a model, not if these elements are stochastic or nonistochastic.

The random effects and fixed effects estimation methods are frequently compared in empirical papers. For instance, Judson and Owen (1999) mention the arguments in favour of the fixed effects model. Firstly, assuming an individual effect is described by omitted variables, country-specific features will be correlated with other regressors. Secondly, the authors doubt randomness of a selected sample of countries as most macro panels include countries of interest that have common features rather than randomly chosen ones (for instance, OECD panel includes mostly OECD countries).

Generally, comparison of the pooled OLS, fixed effects and random effects models is performed by the formal tests that are described further.

1. *F-Test* is performed to choose between the pooled OLS and FE models under the following hypotheses:

H_0: pooled OLS is preferred over the fixed effects model

H_a: fixed effects model is more efficient than pooled OLS

2. *The Hausman test* is used to determine between the FE and RE models.

H_0: random effects estimation is preferred over fixed effects

H_a: fixed effects model is more efficient than random effects

3. *Breusch-Pagan Lagrange Multiplier* test compares pooled OLS and RE model.

H_0: pooled OLS is chosen instead of the RE model

H_a: random effects model is more efficient compared to pooled OLS

Thus, the specified gravity models are first estimated by the proposed panel data techniques and then the discussed formal tests are performed for best model selection.

5.2.6 Estimation Issues

As already discussed, gravity models are often transformed into log-normal specification for analysis of international trade among countries. This adjustment, however, might cause estimation issues, such as violation of homoskedasticity assumption and problem of zero observations (Burger et al., 2009).

The issue of heteroscedasticity is already discussed in subchapter 5.2.3, so the second point to be considered is analysis of zero trade flows. Generally, the logics behind the Newtonian gravity law and international trade gravity equations is similar, but there is one crucial distinction: gravitational force never equals zero although it might be of a comparatively low value. Trade, on the contrary, can take zero values as there might be no trade between a pair of countries for a certain period of time.

The case of zero observations is common for trade data and poses no threat for dealing with multiplicative form of gravity equations, but estimation of a log-linear form becomes problematic because the logarithm of zero is not defined (Silva and Tenreyro, 2006). Also, Linders and de Groot (2006) state that gravity models always assume trade flow between countries to be positive in both directions even if it is relatively small.

Several research papers provide solutions for zero observation problem, thus, Burger et al. (2009) suggests replacing missing observations with a small constant value (might be equal to 0.1, 0.5 or 1). Silva and Tenreyro (2006) discuss two more methods: using Poisson Pseudo Maximum Likelihood estimator instead of the OLS regression excluding zero observations from the analysis. Thus, the constructed dataset includes several small values but no zero or missing values for trade flows.

6 Estimation Results

The following chapter includes discussion of the empirical results obtained from the main panel dataset estimations. As discussed in the "Methodology" chapter, the gravity equations are analysed via the common panel data techniques. Also, the realized volatility values, obtained from the historical exchange rate time series data, are introduced into the panel dataset as the explanatory variable. Realized volatility values are included separately in the "Appendix C".

6.1 Gravity Model Estimation

As already discussed in the chapter "Data", panel dataset is constructed for 53 countries for the period 2005-2016 and contains no missing observations. The initial step before discussing regression results is to obtain descriptive statistics for variables included into analysis, excluding the dummy ones. The variables are transformed into logarithmic form and their descriptive statistic is provided in table 3.

Table 3: Descriptive statistics of variables in panel dataset

Variable	*Mean*	*Median*	*Std. Dev.*	*Minimum*	*Maximum*
$\boldsymbol{ln(WDIST_{ij})}$	1.91	1.88	2.28	-2.56	7.89
$\boldsymbol{ln(GDP_{it})}$	25.6	25.9	2.15	20.9	30.6
$\boldsymbol{ln(POP_{it})}$	16.5	16.6	1.55	11.3	19.6
$\boldsymbol{ln(TB_{ijt})}$	0.736	0.429	1.48	-3.43	9.99
$\boldsymbol{ln(GDPCZ_{jt})}$	26.0	26.1	0.148	25.6	26.2
$\boldsymbol{ln(POPCZ_{jt})}$	16.2	16.2	0.0113	16.1	16.2
$\boldsymbol{ln(RV_{ijt})}$	-2.62	-2.50	0.750	-5.56	-0.565

Source: author's computations.

Generally, under the international trade gravity theory certain assumptions exist on the expected impact of explanatory variables on foreign trade. In the analysis, weighted distance between a pair of countries is supposed to have a negative effect on trade balance, whereas GDP of a trading partner as well as GDP of the Czech Republic are assumed to influence trade balance positively. Then, population of both a trading partner and the Czech Republic are expected to be positively correlated with trade balance, while negative relation is assumed to exist between realized volatility and trade balance. Moreover, dummy variables included in the panel dataset (contiguity, EU and OECD membership) are supposed to have a positive impact on trade balance except for the variable defining whether a country is landlocked or not. Thus, all expected signs of the included explanatory variables are summarized in table 4.

Table 4: Expected signs of explanatory variables

Variable	Sign
$\boldsymbol{ln(WDIST_{ij})}$	-
$\boldsymbol{ln(GDP_{it})}$	+
$\boldsymbol{ln(POP_{it})}$	+
$\boldsymbol{ln(GDPCZ_{jt})}$	+
$\boldsymbol{ln(POPCZ_{jt})}$	+
$\boldsymbol{ln(RV_{ijt})}$	-
$\boldsymbol{CONTIG_i}$	+
$\boldsymbol{LANDL_i}$	-
$\boldsymbol{EU_{it}}$	+
$\boldsymbol{OECD_{it}}$	+

Source: author's computations.

Another essential step before proceeding to estimation of the models is to check for presence of heteroscedasticity. As previously discussed, panel data might suffer from non-constant variance of the error term that might lead to biased results, i.e. heteroscedasticity. Thus, the augmented gravity model is checked with White's test for pooled OLS and the distribution free Wald test for the fixed effects estimation technique. The hypotheses for the above-mentioned tests are the following:

H_0: heteroscedasticity is not present: variance of the error term is constant

H_a: the model suffers from heteroscedasticity: variance of the error term is not constant

The obtained results from both tests are provided below:

White's test for heteroscedasticity:

Test statistic: TR^2 = 189.054283,

with p-value = P(Chi-square(58) > 189.054283) = 0.000000

Distribution free **Wald test** for heteroscedasticity:

Chi-square(53) = 381338, with p-value = 0

According to the obtained results, p-value in White's test as well as in Wald test equal zero, so the null hypotheses are rejected for both tests and that implies presence of heteroscedasticity in the analysed models. Consequently, robust standard errors, or the method of Huber-White, is applied in further estimations as a possible solution to overcome the issue of bias in standard errors.

6.1.1 Basic gravity model estimation

The constructed panel dataset is analysed by the proposed estimation techniques: pooled OLS, fixed effects, random effects models and the estimations are performed in the GRETL software. Also, before discussing the obtained results, it should be stated that in all models "***" means significance at 1% level, "**" stands for significance at 5% level and "*" implies significance at 10% level. Moreover, robust standard errors are included into all regression.

Initially, a reduced gravity model, specified in equation (17), is estimated to test for the impact of weighted distance, GDP of a trading partner and GDP of the Czech Republic on trade balance of the country:

$$ln(TB_{ijt}) = ln\,\beta_0 + \beta_1\,ln(GDP_{it}) + \beta_2\,ln(GDPCZ_{jt}) + \beta_3\,ln(WDIST_{ij}) + ln\,u_{ijt} \quad (17)$$

The first estimation technique applied to the basic gravity model is pooled OLS and the obtained coefficients together with the model statistics are provided in table 9 and in table 10 in Appendix D. According to the regression results, GDP of a trading partner and GDP of the Czech Republic are significant at 5% and at 1% levels respectively. Also, the effect of the GDP of the Czech Republic is positive that is in line with the initial assumptions. Still, weighted distance and GDP of a trading partner have the signs opposite the expected ones: weighted distance positively impacts trade balance, whereas the effect of trading partner's GDP is negative. Moreover, from the pooled OLS model statistics (table 10) it is visible that R-squared together with the adjusted R-squared values are considerably low and only around 17% of the data might be explained by the model.

The next estimation technique applied to the basic gravity model is the fixed effects approach. According to the regression output (table 5), significance of the explanatory variables decreased in comparison to the pooled OLS model. Also, the signs of both GDP variables changed. Thus, the impact of trading partner's GDP is now positive and that is in line with the initial assumption. Still, the effect of the Czech Republic's GDP is negative, so the variable has the sign opposite than is expected. Also, similarly to the pooled OLS regression results, the effect of weighted distance on trade balance is positive and that contradicts the theoretical background.

Table 5: Fixed effects basic gravity model results

	Coefficient	*Std. Error*	*t-ratio*	*p-value*
const	−8.69613	9.90772	−0.8777	0.3841
l_WDIST	0.292672	0.792564	0.3693	0.7134
l_GDP	0.441583	0.744346	0.5933	0.5556
l_GDPCZ	−0.0930665	0.433726	−0.2146	0.8309

Source: author's computations.

Table 6: Fixed effects basic gravity model statistics

Mean dependent var	0.736398	S.D. dependent var	1.484232
Sum squared resid	254.2421	S.E. of regression	0.662079
LSDV R-squared	0.818252	Within R-squared	0.065017
Log-likelihood	−610.8670	Akaike criterion	1333.734
Schwarz criterion	1583.225	Hannan-Quinn	1430.601
rho	0.271469	Durbin-Watson	1.286471

Source: author's computations.

According to the fixed effects model statistics (table 6), the LSDV R-squared value is comparatively high so that 81% of the data might be explained by the fixed effects model.

Finally, the basic gravity equation is estimated with the random effects model by the GLS estimation method. As visible from regression output in table 11, the signs of variables are in line with the initial assumptions: both the GDP of a trading partner and of the GDP of the Czech Republic positively impact trade balance, whereas weighted distance has a negative impact. Also, the GDP of the Czech Republic is significant at 5% level.

To sum up, the basic gravity model is estimated by techniques relevant for gravity panel data analysis. From economic theory perspective, random effects model provides the most adequate results. Still, relying solely on economic theory is insufficient and most appropriate model is to be chosen based on the formal tests.

Thus, the Breusch-Pagan LM test is carried out to select between the pooled OLS and random effects models. According to the test statistics (equation 18), p-value equals zero, so the null hypothesis in favour of the pooled OLS is rejected. Consequently, random effects model is preferred over the pooled OLS model.

$$\textit{Chi-square}(1) = 1893.04 \textit{ with p-value} = 0 \tag{18}$$

Secondly, the F-test that enables to compare pooled OLS and fixed effects models is carried out. Based on the test statistics (equation 19), the null hypothesis might be rejected. Consequently, fixed effects model is to be chosen instead of the pooled OLS.

$$F(3,\ 52) = 7.240757 \textit{ with P-value}(F) = 0.000378 \tag{19}$$

Finally, it is required to decide between the fixed effects and random effects models. Thus, the Hausman test is performed and as per the test statistics (equation 20), p-value is significantly small, so the null hypothesis is rejected. Consequently, the fixed effects model is chosen instead of the random effects model.

$$\textit{Chi-square}(2) = 18.6295 \textit{ with p-value} = 9.00851\text{e-}005 \tag{20}$$

To sum up, the fixed effects model is considered as the most efficient based on the obtained results from all the three formal tests. However, the regression results of the model are not in line with the economic intuition as compared to the random effects models that provides most sensible results.

6.1.2 Augmented model estimation

The next step of analysis after discussing the results from basic gravity model estimation is testing the augmented model as defined in equation (21):

$$ln(TB_{ijt}) = ln\,\beta_0 + \beta_1\,ln(GDP_{it}) + \beta_2\,ln(GDPCZ_{jt}) + \beta_3\,ln(WDIST_{ij}) + \beta_4 ln(\,RV_{ijt}) + \beta_5 ln(\,POP_{it}) + \beta_6 ln(\,POPCZ_{jt}) + CONTIG_i + LANDL_i + EU_{it} + OECD_{it} + ln\,u_{ijt} \quad (21)$$

Thus, the augmented gravity model is firstly analysed with the pooled OLS technique and the regression output together with the model statistics are provided below in table 13 and table 14 in Appendix E. According to the regression results, population of the Czech Republic, realized volatility and the GDP of the Czech Republic are significant at 1%, 5% and 10% levels respectively. Based on the obtained coefficients, the effect of realized volatility might be interpreted in the following way: 1% increase in realized volatility leads to improvement of trade balance by 0.31%.

Also, the signs of variables denoting population of the Czech Republic and EU membership are positive that is in line with the theory. Moreover, the variable for weighted distance has the expected negative sign, but it is insignificant. Then, according to the model statistics (table 12), the R-squared and adjusted R-squared values are comparatively low and are equal to approximately 20%. Consequently, nearly 20% of the analysed data might be explained by the pooled OLS model.

The next technique applied for the analysis of panel dataset is the fixed effects model. As already stated, robust standard errors are included into the regression. While estimating the fixed effects model, the dummy variables are omitted as a result of collinearity. Among all the included explanatory variables, population of the Czech Republic is of the highest significance, at 5% level. Also, the signs are in line with the initial assumptions for the following variables: population and GDP of the Czech Republic, population of a trading partner.

Table 7: Fixed effects augmented gravity model results

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	−198.864	81.8302	−2.430	0.0186	**
l_WDIST	1.81091	1.09751	1.650	0.1050	
l_GDP	−1.17863	0.996443	−1.183	0.2423	
l_POP	0.499665	1.53223	0.3261	0.7457	
l_GDPCZ	0.0569509	0.500691	0.1137	0.9099	
l_POPCZ	13.4045	6.35990	2.108	0.0399	**
l_RV	0.0272427	0.0447001	0.6095	0.5449	

Source: author’s computations.

Table 8: Fixed effects augmented gravity model statistics

Mean dependent var	0.736398	S.D. dependent var	1.484232
Sum squared resid	251.6796	S.E. of regression	0.660444
LSDV R-squared	0.820084	Within R-squared	0.074441
Log-likelihood	−607.6456	Akaike criterion	1333.291
Schwarz criterion	1596.148	Hannan-Quinn	1435.348
rho	0.278679	Durbin-Watson	1.270360

Source: author's computations.

What is more, LSDV R-squared equals 0.82 that means that 82% of the data might be explained by the fixed effects model. Thus, the R-squared value is considerably higher compared to the pooled OLS augmented gravity model.

Finally, the extended model is estimated with random effects technique by the general least squares. Generally, the GLS enables to solve the issue of autocorrelation, so the dummy variables excluded from the fixed effects model are now included into the regression. Also, robust standard errors are used in the model. The results of regression are presented in table 15 and test statistics is included in table 16.

Compared to the results from pooled OLS and fixed effects models, it is clearly visible that significance of included variables has increased. Population of a trading country that is insignificant in previous estimations is now significant at 1% level. Also, population of the Czech Republic as well as realized volatility are significant at 5% level and at 10% level respectively. Among the significant variables are also the two dummies: OECD membership of a country and the variable depicting access to a coastline of a trading partner.

As visible from the regression coefficients (table 15), the signs of independent variables are mostly different from the expected ones. The signs are in line with the initial assumptions only for EU membership, GDP of a trading partner and population of the Czech Republic that are all positive.

After discussing the results from pooled OLS, fixed effects and random effects, the most efficient model among them is to be selected based on the formal tests. Firstly, the Breusch-Pagan LM test is performed to select between the pooled OLS and random effects models. As visible from the test statistics (equation 22), p-value equals zero, so the null hypothesis, under which pooled OLS is more efficient than random effects model, is rejected. Thus, the choice is made in favour of the random effects model.

$$\textit{Chi-square(1) = 1894.22 with p-value = 0} \tag{22}$$

Secondly, the comparison between the pooled OLS and fixed effects models is done with the help of the F-test. According to the test statistics (equation 23), the null hypothesis might be rejected, so the fixed effects model is preferred over the pooled OLS.

$$\textit{F(10, 52) = 3.595154 with P-value(F) = 0.001114} \tag{23}$$

Finally, the fixed effects and random effects models are to be contrasted by the Hausman test. Based on the test statistics (equation 24), p-value is comparatively small, so the null hypothesis is rejected. Thus, the choice is made in favour of the fixed effects model.

$$\textit{Chi-square(4) = 13.7777 with p-value = 0.00803943} \tag{24}$$

Consequently, according to the formal test results, the fixed effects model appears to be the most efficient for analysing the augmented trade gravity equation.

To sum up, the basic as well as the augmented gravity models are analysed by the proposed panel data estimation techniques: pooled OLS, fixed effects, random effects. Among all estimated models the highest R-squared and adjusted R-squared values are achieved for fixed effects estimation of the augmented gravity model and it implies that 82% of the data is explained by this model. Also, based on the formal tests carried out to choose among the estimation techniques, fixed effects appears to be most efficient for both the basic and the augmented trade gravity models.

As for the realized volatility, that is the variable of interest and is included in the extended model, it has the highest significance (5% level) in pooled OLS model and it is also significant in the random effects model at 10% level. Also, the estimation outcomes of augmented models for both pooled OLS, fixed and random effects reveal that the impact of realized volatility on trade balance is significant positive. The obtained results do not correspond with the initial assumption on the negative sign. Still, as already discussed in “Literature Review” chapter, empirical studies admit existence of positive exchange rate volatility impact on trade balance.

7 Conclusion

Following the issues discussed in the thesis, it can be concluded that foreign trade is crucial for economic performance of any state and the Czech Republic as a country with open trade regime is nowadays highly involved in international trade. Foreign trade of the Czech Republic is currently extending, the leading sector of tradable goods are machinery and transport equipment. Key trading partners of the Czech Republic are determined by its geographical position and include the neighbouring states. Also, due to EU membership, trade within the group accounts for almost 80% of the total national trade turnover. Foreign trade of the Czech Republic is characterized by an increasing ratio of international trade to GDP over the last couple of years. Also, the trade balance of the Czech Republic is characterized by growth especially over the reviewed period of 2005-2016.

As already discussed, international trade is frequently held in local currencies, thus, exchange rate volatility may not be neglected in foreign trade review. In the analysis realized volatility is calculated from historical exchange rate data for 43 Czech koruna pairs against the local currencies. As already stated, the thesis contributes to the existing literature on the topic by the applied methodological techniques. Thus, realized volatility as a non-parametric approach is implemented and this technique is proved to be favourable for historical time series data analysis. This model-free estimator is advantageous for estimating volatility over a discrete time interval because it treats ex-post volatility as an observable rather than a latent variable.

In order to evaluate the impact of exchange rate volatility on trade balance gravity models for foreign trade are used. Initially the basic model is tested, after that the augmented model is estimated. Trade balance, the explained variable, is defined as a ratio of exports from the Czech Republic to a trading partner over the amount of exports from a trading partner to the Czech Republic. The explanatory variables included into the extended gravity model are GDP and population of the Czech Republic and its trading partners, realized volatility, weighted distance. Also, the model contains the dummy variables: EU and OECD membership, common border and direct access of a country to the sea.

The core methodological approaches applied for gravity models estimation are the panel data techniques: pooled OLS, fixed effects and random effects. Also, the estimated models are compared by the formal tests, and the most efficient among them is the fixed effects. Also, advantageous in gravity models estimation is the included weighted distance variable, the values for which are calculated not solely as a geographical distance between capital cities but also based on the GDP values of trading partners. Introducing weighted distance, that serves as an indicator of transportation costs, in the analysis instead of the common geographical measures allows to turn distance into a time-varying variable so that its effect is not omitted in the fixed effects model.

The initially stated research hypotheses are answered in the thesis. Thus, the key question is to reveal if exchange rate volatility effects trade balance of the Czech Republic and the results of the estimated augmented model confirm the significant positive impact. As discussed in the “Literature Review” chapter, current empirical studies on the topic provide heterogeneous results. Positive relationship between exchange rate volatility and trade balance is reasoned by the presence of opportunity for generating profit from increased currency risk. Also, rise of exchange rate volatility allows for greater trade gains as the value of exports to the global market increases.

Positive relationship between changes in exchange rate and trade balance is also justified in the discussed theoretical approaches on the topic. For instance, under the J-Curve theory, trade balance of a country decreases in the short term, right after depreciation of a national currency, and later increases in the long term. Another aspect under the J-Curve theory is that domestic production is stimulated, and it substitutes imports. The positive relationship between change in exchange rate and trade balance is also justified by the monetary approach, according to which, depreciation improves trade balance by increasing home prices that leads to decrease in the real money supply.

The next investigated assumption is to discover if the augmented gravity model provides a clearer picture of the relationship between exchange rate volatility and trade balance. According to the estimation results, 82% of the data is explained by the fixed effects estimation of the augmented gravity model, that is the largest value as compared to other regression results. Also, the augmented model includes more explanatory variables that contribute to the output. Thus, the results from the extended gravity model are preferable over the simple gravity model outcome.

The following research hypotheses refer to the significance of included variables in the estimated models. Thus, in the simple gravity model weighted distance and GDP of trading partners are mostly insignificant except for the pooled OLS regression where GDP is statistically relevant at 5% level and this variable also has the expected positive sign in the random effects and fixed effects models. In the simple model the variable of highest significance is GDP of the Czech Republic and it has the expected positive sign that corresponds with the economic assumptions.

Considering the estimation results of the augmented model, they are mixed. Common border and EU membership are insignificant, as initially assumed. On the contrary, population as well as population of the Czech Republic are significant. The obtained estimation results differ according to the types of estimated models. In the basic model the signs of variables that are in line with the economic assumptions are GDP of the Czech Republic and GDP of trading partners that have the significant positive impact on trade balance. Also, variables of population in the Czech Republic and EU membership in the augmented model match the economic logics in their positive sign.

To sum up, the broad field of international trade is currently widely investigated, and currency risk should not be neglected. The thesis contributes to the investigated topic, but current research is subject to certain limitations because of data availability and possible statistical discrepancies. Also, this work might be applicable for explaining trade policies and making predictions on future behaviour of international trade of the Czech Republic.

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Appendix A: Countries and Local Currencies Included into the Analysis

Country (trading partner)	Local Currency	Import share (2016)	Export share (2016)
1. Afghanistan	AFN	0	0
2. Albania	ALL	0,01	0,03
3. Andorra	EUR	0	0
4. Argentina	ARS	0,08	0,06
5. Armenia	AMD	0	0,01
6. Australia	AUD	0,11	0,26
7. Austria	EUR	2,9	4,23
8. Bangladesh	BDT	0,29	0,03
9. Bosnia and Herzegovina	BAM	0,05	0,09
10. Brazil	BRL	0,16	0,16
11. Canada	CAD	0,13	0,15
12. Colombia	COP	0,02	0,02
13. Denmark	DKK	0,57	1
14. Finland	EUR	0,28	0,53
15. France	EUR	3,18	5,18
16. Georgia	GEL	0,02	0,05
17. Germany	EUR	26,54	32,39
18. Greece	EUR	0,16	0,21
19. Hungary	HUF	2,34	2,88
20. Ireland	EUR	0,88	0,41
21. Italy	EUR	4,33	4,24
22. Japan	JPY	1,74	0,57
23. Jordan	JOD	0	0,04
24. Kyrgyz Republic	KGS	0	0

25. North Macedonia	MKD	0,36	0,07
26. Maldives	MVR	0	0
27. Moldova	MDL	0,02	0,03
28. Mongolia	MNT	0	0,01
29. Morocco	MAD	0,11	0,16
30. Nepal	NPR	0	0
31. Netherlands	EUR	2,86	2,87
32. Norway	NOK	0,16	0,45
33. Pakistan	PKR	0,1	0,04
34. Paraguay	PYG	0	0
35. Peru	PEN	0,01	0,02
36. Poland	PLN	8,27	5,77
37. Portugal	EUR	0,29	0,33
38. Saudi Arabia	SAR	0,05	0,27
39. Slovak Republic	SKK, EUR	5,1	8,36
40. Spain	EUR	1,86	2,82
41. Sweden	SEK	0,78	1,5
42. Switzerland	CHF	0,99	1,46
43. Tajikistan	TJS	0	0
44. Tunisia	TND	0,1	0,08
45. Turkey	TRY	1,01	1,35
46. Uganda	UGX	0	0,02
47. Ukraine	UAH	0,54	0,55
48. United Kingdom	GBP	2,68	5,26
49. USA	USD	2,3	2,15
50. Uruguay	UYU	0,01	0
51. Uzbekistan	UZS	0	0,04
52. Vietnam	VND	0,54	0,06
53. Yemen	YER	0	0

Appendix B: Quadratic Variation Theory

The quadratic variation theory introduced by Andersen et. al. (2003) serves as a foundation for the concept of realized volatility and their work is reviewed in the chapter. The authors begin with specifying appropriate setting: logarithmic price vector process $p = \big(p(t)\big)_{t\in[0,T]}$ that is "defined on a complete probability space, $(\Omega, \mathcal{F}, P)$, evolving in continuous time over the interval $[0, T]$" with T being a positive integer. Then, it is assumed that an information filtration, or "an increasing family of σ-fields, $(\mathcal{F}_t)_{t\in[0,T]} \subseteq \mathcal{F}$, satisfies the usual conditions of P-completeness and right continuity". Finally, it is settled that the information set $\mathcal{F}_t$ includes asset prices through time t, also containing the related state variables.

Proposition 1:

"For any n-dimensional arbitrage-free vector price process with finite mean, the logarithmic vector price process, p, may be written uniquely as the sum of a finite variation and predictable mean component, $A = (A_1, \dots, A_n)$, and a local martingale, $M = (M_1, \dots, M_n)$. These may each be decomposed into a continuous sample-path and jump part,

$$p(t) = p(0) + A(t) + M(t) = p(0) + A^c(t) + \Delta A(t) + M^c(t) + \Delta M(t), \tag{25}$$

where the finite-variation predictable components, A^c and ΔA, are respectively continuous and pure jump processes, while the local martingales, M^c and ΔM, are respectively continuous sample-path and compensated jump processes, and by definition $M(0) \equiv A(0) \equiv 0$. Moreover, the predictable jumps are associated with genuine jump risk, in the sense that if $\Delta A(t) \neq 0$, then

$$P\,[sgn(\,\Delta A(t)\,) = -\,sgn(\,\Delta A(t) + \Delta M(t)\,)] \;>\; 0\,, \tag{26}$$

where $sgn(x) \equiv 1$ for $x \geq 0$ and $sgn(x) \equiv -1$ for $x < 0$."

According to the first proposition, price process might be uniquely separated into components with a finite variation and predictable mean as well as into a local martingale,

assuming that components include both continuous and jump parts. Then, equation (26) represents the no-arbitrage condition meaning that no extra gain might be forecasted. In case there is expected jump in price, or if $\Delta A(t) \neq 0$, an arbitrage opportunity arises; consequently, jump in the other component should appear:
$\Delta M(t) \neq 0$.

Also, proposition 1 describes the asset return process and the authors define returns in the following way: "We denote the (continuously compounded) return over $[t-h, t]$ by $r(t,h) = p(t) - p(t-h)$. The cumulative return process from $t = 0$ onward, $r = \left(r(t)\right)_{t\in[0,T]}$, is then $r(t) \equiv r(t,t) = p(t) - p(0) = A(t) + M(t)$." According to the definition, the return process acquires the properties of the price process and may be decomposed uniquely into the predictable and integrable mean component, A, and into M that is the local martingale.

Proposition 2:
"For any n-dimensional arbitrage-free price process with finite mean, the quadratic variation *nxn* matrix process of the associated return process, $[r,r] = \{ [r,r]_t \}_{t\in[0,T]}$, is well-defined. The i'th diagonal element is called the quadratic variation process of the *i*'th asset return while the *ij*'th off-diagonal element, $[r_i, r_j]$, is called the quadratic covariation process between asset returns *i* and *j*. The quadratic variation and covariation processes have the following properties:

(i) For an increasing sequence of random partitions of $[0,T]$, $0 = \tau_{m,0} \leq \tau_{m,1} \leq \ldots$, such that $sup_{j\geq 1}(\tau_{m,j+1} - \tau_{m,j}) \to 0$ and $sup_{j\geq 1}\tau_{m,j} \to T$
for $m \to \infty$ with probability one, we have that
$$\lim_{m\to\infty}\{\textstyle\sum_{j\geq 1}[r(t\wedge\tau_{m,j}) - r(t\wedge\tau_{m,j-1})][r(t\wedge\tau_{m,j}) - r(t\wedge\tau_{m,j-1})]'\} \to [r,r]_t \quad (27)$$
where $t\wedge\tau \equiv min(t,\tau), t \in [0,T]$, and the convergence is uniform on $[0,T]$ in probability.
(ii) If the finite variation component, A, in the canonical return decomposition in Proposition 1 is continuous, then
$$[r_i, r_j]_t = [M_i, M_j]_t = [M_i^c, M_j^c]_t + \textstyle\sum_{0\leq s\leq t} \Delta M_i(s)\,\Delta M_j(s). \quad (28)"$$

The second proposition is essential as it reveals some of the important features of quadratic return variation process. Thus, the quadratic covariation achieved by this method, is a unique and model free measure of realized volatility. Also, the (ii) property justifies the fact that the mean component might be considered insignificant for the quadratic variation, whereas the squared jump size is crucial for it.

Theorem 1:

"Consider an n-dimensional square-integrable arbitrage-free logarithmic price process with a continuous mean return, as in property (ii) of Proposition 2. The conditional return covariance matrix at time t over $[t, t+h]$, where $0 \leq t \leq t+h \leq T$, is then given by

$$Cov(r(t+h,h)|\mathcal{F}_t) =$$

$$E([r,r]_{t+h} - [r,r]_t|\mathcal{F}_t) + \Gamma_A(t+h,h) + \Gamma_{AM}(t+h,h) + \Gamma_{AM}{}'(t+h,h), \quad (29)$$

where $\Gamma_A(t+h,h) = Cov(A(t+h) - A(t)|\mathcal{F}_t)$ and

$\Gamma_{AM}(t+h,h) = E(A(t+h)[M(t+h) - M(t)]'|\mathcal{F}_t)$."

Corollary 1:

"Consider an n-dimensional square-integrable arbitrage-free logarithmic price process, as described in Theorem 1. If the mean process, $\{A(s) - A(t)\}_{s\in[t,t+h]}$, conditional on information at time *t* is independent of the return innovation process, $\{M(u)\}_{u\in[t,t+h]}$, then the conditional return covariance matrix reduces to the conditional expectation of the quadratic return variation plus the conditional variance of the mean component, i.e., for $0 \leq t \leq t+h \leq T$,

$Cov(r(t+h,h)|\mathcal{F}_t) = E([r,r]_{t+h} - [r,r]_t|\mathcal{F}_t) + \Gamma_A(t+h,h)$.

If the mean process, $\{A(s) - A(t)\}_{s\in[t,t+h]}$, conditional on information at time t is a predetermined function over $[t, t+h]$, then the conditional return covariance matrix equals the conditional expectation of the quadratic return variation process, i.e., for $0 \leq t \leq t+h \leq T$,

$$Cov(r(t+h,h)|\mathcal{F}_t) = E([r,r]_{t+h} - [r,r]_t|\mathcal{F}_t). \quad (30)"$$

Thus, theorem 1 together with corollary 1 prove that under assumptions related to equation (30), the quadratic variation is a crucial component for volatility estimation and forecasting. Another essential implication is "that the time $t+h$ ex-post realized quadratic variation is an unbiased estimator for the return covariance matrix conditional on information at time *t*.” Also, the general case described in theorem 1 implies that interaction may appear between the return innovations and the instantaneous mean within the period, especially in case of asymmetry or a leverage effect, under that volatility influences the contemporaneous mean drift.

The next aspect under discussion is the martingale representation theorem, described in proposition 3. The theorem is relevant for return generating process that is based on realized volatility measures. It serves as a benchmark for setting conditions, such as assuming a continuous price process, or absence of jumps ($\Delta M(t) = 0$).

Proposition 3:

“For any n-dimensional square-integrable arbitrage-free logarithmic price process, p, with continuous sample path and a full rank of the associated *nxn* quadratic variation process, $[r,r]_t$ we have a.s. (P) for all $0 \leq t \leq T$,

$$r(t+h,h) \;=\; p(t+h) - p(t) \;=\; \int_0^h \mu_{t+s} ds + \int_0^h \sigma_{t+s} dW(s), \tag{31}$$

where μ_s denotes an integrable predictable *nx1* dimensional vector,$\sigma_s = \left(\sigma_{(i,j),s}\right)_{i,j=1,\dots,n}$ is a *nxn* matrix, $W(s)$ is a *nx1* dimensional standard Brownian motion, integration of a matrix or vector w.r.t. a scalar denotes component-wise integration, so that

$$\int_0^h \mu_{t+s} ds = \left(\int_0^h \mu_{1,t+s} ds\,, \dots, \int_0^h \mu_{n,t+s} ds\right)',$$

and integration of a matrix w.r.t. a vector denotes component-wise integration of the associated vector, so that

$$\int_0^h \sigma_{t+s} dW(s) = \left(\int_0^h \sum_{j=1,\dots,n} \sigma_{(1,j),t+s} dW_j(s), \dots, \int_0^h \sum_{j=1,\dots,n} \sigma_{(n,j),t+s} dW_j(s)\right)'. \tag{32}$$

Moreover, we have

$$P\left[\int_0^h \left(\sigma_{(i,j),t+s}\right)^2 ds < \infty\right] = 1, \quad 1 \leq i,j \leq n. \tag{33}$$

Finally, letting $\Omega_s = \sigma_s {\sigma_s}'$, the increments to the quadratic return variation process take the form $[r,r]_{t+h} - [r,r]_t = \int_0^h \Omega_{t+s} ds$.” (34)

Theorem 2:

"For any n-dimensional square-integrable arbitrage-free price process with continuous sample paths satisfying Proposition 3, and thus representation (31), with conditional mean and volatility processes μ_s and σ_s independent of the innovation process $W(s)$ over $[t, t+h]$,

we have $r(t+h, h)|\sigma\{\mu_{t+s}, \sigma_{t+s}\}_{s\in[0,h]} \sim N\left(\int_0^h \mu_{t+s} ds, \int_0^h \Omega_{t+s} ds\right)$, (35)

where $\sigma\{\mu_{t+s}, \sigma_{t+s}\}_{s\in[0,h]}$ denotes the σ-field generated by $(\mu_{t+s}, \sigma_{t+s})_{s\in[0,h]}$."

Thus, theorem 2 states that distributional characterization depends on the ex-post sample path realization of $(\mu_s, \sigma_s)_{s\in[t,t+h]}$. Also, the key results from the theorem is that returns are normally distributed, and the realized quadratic return variation is determining the distribution.

Generally, key aspects from the discussed quadratic variation theory are the following. Due to no-arbitrage setting, semi-martingale structure is set and represented in proposition 1, whereas quadratic variation is specified by proposition 2 and this proposition serves as a tool to approach the quadratic variation. Theorem 1 together with corollary 1 demonstrate the relation between quadratic variation and the return volatility process. In equation (31) representation for continuous sample path case is presented. Also, the quadratic variation is transformed by equation (34) into $\int_0^h \Omega_{t+s} ds$ and is identified as the integrated volatility.

Appendix C: Realized Volatility Values

Currency	AFN	ALL	ARS	AMD	BDT
2005	-2.639531642	-2.688888809	-2.32693332	-1.976972322	-2.360601145
2006	-1.981334549	-3.355950918	-2.499566746	-2.391195129	-2.013057724
2007	-2.349477454	-2.816686577	-2.319765739	-2.425317745	-2.394548749
2008	-1.717901571	-2.213634181	-1.984372846	-1.815681943	-1.729617693
2009	-2.001384065	-2.545216174	-1.75368653	-1.230705288	-1.977407111
2010	-1.940465995	-3.065731222	-1.780249365	-1.630930737	-1.739302322
2011	-1.879908293	-2.823463578	-1.87747554	-1.872496968	-2.029055699
2012	-1.730609433	-2.795593392	-2.110054988	-2.240077069	-2.220169511
2013	-2.492687321	-2.796137266	-2.144553667	-2.46835542	-2.446141887
2014	-2.57811227	-3.707405608	-2.964619921	-2.240056403	-2.718341778
2015	-2.031143689	-3.811780464	-1.10876172	-2.262728044	-2.383542577
2016	-2.768528337	-3.909188526	-1.939970424	-3.133986343	-2.844577735
Currency	**BAM**	**COP**	**GEL**	**JOD**	**KGS**
2005	-3.217333265	-2.679310278	-2.588147946	-2.630488507	-2.560922885
2006	-3.547545878	-1.860995727	-2.601698117	-2.490900256	-2.607193477
2007	-2.985629677	-1.660135595	-2.423443076	-2.373987544	-2.733494786
2008	-2.262183347	-1.529929193	-1.72435562	-1.768840526	-1.711113559
2009	-2.571130773	-1.931906066	-2.08965674	-1.992745081	-1.82499159
2010	-3.065182249	-1.971105298	-1.737441753	-1.751897039	-1.729478996
2011	-3.094596823	-2.486692203	-2.027687394	-1.880395948	-1.88582007
2012	-3.112259124	-2.231747391	-2.086172141	-2.148327847	-2.169555326
2013	-2.746483956	-2.640837633	-2.464428604	-2.456302167	-2.404956746
2014	-4.08164534	-2.183818541	-2.517393231	-2.670140154	-2.131965066
2015	-3.982802293	-1.698805335	-1.950660715	-2.397751853	-1.786203731
2016	-5.113936432	-1.962394777	-2.12875028	-2.75105113	-2.772658325
Currency	**MKD**	**MVR**	**MDL**	**MNT**	**MAD**
2005	-2.418056216	-2.558891503	-2.623162327	-2.485286682	-3.133786106
2006	-3.344657042	-2.466174006	-2.430098402	-2.377632937	-3.37561999

2007	-3.118876882	-2.393438459	-2.450665932	-2.380941523	-2.870052852
2008	-2.210507405	-1.769117348	-1.881695555	-1.591524323	-2.300335625
2009	-2.37178545	-1.98816202	-1.807669363	-1.900901794	-2.482974518
2010	-2.986739827	-1.747554085	-2.171945503	-1.615731677	-2.768130356
2011	-3.09073814	-1.662453215	-2.289049119	-1.857573043	-2.76992619
2012	-2.65704378	-2.145668527	-2.383777578	-2.05583674	-2.848616394
2013	-2.756657894	-2.405213012	-2.663217572	-1.923353083	-2.662008811
2014	-3.556955453	-2.702015298	-2.498125515	-2.461429839	-3.637082766
2015	-4.099678161	-2.432371393	-1.891640359	-2.2540683	-3.338891539
2016	-3.930799689	-2.74429332	-2.92811157	-2.173817278	-3.653367919
Currency	**NPR**	**PKR**	**PYG**	**PEN**	**SAR**
2005	-2.302883738	-2.598001398	-2.409606431	-2.613014468	-2.638947876
2006	-2.248065658	-2.436770299	-2.275859427	-2.455248629	-2.481806859
2007	-2.30853697	-2.330281523	-2.953228877	-2.577398062	-2.450799411
2008	-1.935261547	-1.84316856	-1.933405065	-1.816723494	-1.763545843
2009	-2.056600398	-1.929860831	-1.988739052	-2.193821275	-1.987707202
2010	-2.069808885	-1.766677859	-1.587555097	-1.775300071	-1.7463923
2011	-2.197705393	-2.038682781	-1.877310168	-1.885691539	-1.879177256
2012	-2.267695863	-2.286762926	-2.198409779	-2.346461957	-2.144054306
2013	-2.019299672	-2.38861913	-1.943403394	-2.495465357	-2.458141026
2014	-2.55188642	-2.326372278	-2.613725097	-2.878851156	-2.672976102
2015	-2.298325179	-2.342638945	-1.954487832	-2.28658872	-2.388321211
2016	-3.536147723	-2.762807594	-2.647322996	-2.653898578	-2.758984718
Currency	**TJS**	**TND**	**UGX**	**UAH**	**UYU**
2005	-1.955350267	-2.961059772	-2.401124812	-2.361870874	-2.170716833
2006	-2.411292314	-3.069433713	-2.386265442	-2.505886925	-2.350003903
2007	-2.371417834	-2.775755812	-1.809399137	-2.329202104	-2.51845454
2008	-1.743345947	-2.382848525	-2.054656055	-1.377298545	-1.955944727
2009	-1.461526226	-2.556801055	-1.621400176	-1.859304746	-1.804776626
2010	-1.757229355	-2.549012241	-1.941232805	-1.740882341	-1.708241638
2011	-1.888016217	-2.589438043	-1.542265831	-1.881698838	-2.282728546
2012	-2.14276054	-2.720358235	-1.88686343	-2.200433821	-2.045382589
2013	-2.410603471	-2.703134453	-2.353807022	-2.472688121	-1.89304231

2014	-2.695456437	-3.091488613	-2.537649795	-1.309973895	-2.367032525
2015	-1.976767271	-2.910800858	-1.667387522	-0.564738135	-2.37768856
2016	-2.655762731	-2.920233227	-2.59070206	-2.211935758	-2.420589428
Currency	**UZS**	**VND**	**YER**	**AUD**	**BRL**
2005	-2.713714111	-2.658918952	-2.238307856	-2.527245669	-1.762821054
2006	-2.400179399	-2.481598966	-2.482185795	-2.536605711	-1.802567668
2007	-2.304896562	-2.413647165	-2.344560774	-2.114897128	-2.076793052
2008	-1.78111809	-1.628728281	-1.780870569	-1.916750067	-1.646644575
2009	-1.855442676	-1.895820829	-2.006064694	-2.355041379	-2.150162763
2010	-1.745416297	-1.745275963	-1.805811133	-2.43278843	-1.951038476
2011	-1.904110361	-1.778344849	-1.882964646	-2.387052617	-2.157865893
2012	-2.112247418	-2.157734381	-2.105022769	-2.28722664	-2.216932305
2013	-2.436846581	-2.499349893	-2.458576082	-2.162710983	-2.136317548
2014	-2.827347044	-2.667050158	-2.670489712	-2.515590089	-2.435584627
2015	-2.50027169	-2.319438517	-2.379079495	-2.342853699	-1.663456496
2016	-2.849646197	-2.879355204	-1.792893312	-2.833967909	-1.820975326
Currency	**CAD**	**DKK**	**CHF**	**HUF**	**JPY**
2005	-2.293053662	-3.103626886	-3.077106768	-2.944760111	-2.490251468
2006	-2.443187368	-3.821143079	-3.338369072	-2.29902145	-2.555900135
2007	-2.107202537	-2.973407927	-2.97150982	-2.545582815	-2.660470197
2008	-1.864479205	-2.232890201	-2.067224475	-2.033328482	-1.501710151
2009	-1.908370367	-2.568504108	-2.363608307	-2.42343292	-2.061991483
2010	-2.051291887	-3.054898584	-1.906386789	-2.632352319	-1.697618518
2011	-2.427303322	-3.114193114	-2.278884191	-2.480703416	-1.887611996
2012	-2.442368676	-3.186198589	-3.103459588	-2.507602299	-1.605262143
2013	-2.689888478	-2.795343581	-2.703326127	-2.78368057	-2.424334848
2014	-2.956270628	-3.971083227	-3.919371439	-3.011541991	-2.600845722
2015	-2.340608923	-4.09457899	-2.879063102	-2.961081796	-2.678573344
2016	-2.776623089	-5.493798087	-3.255894125	-3.605726511	-2.00134189
Currency	**NOK**	**PLN**	**SEK**	**TRY**	
2005	-2.750893299	-2.594516448	-2.804251458	-2.325037267	
2006	-2.724743309	-2.718919964	-3.26628352	-1.523983413	
2007	-2.312623005	-2.764948225	-2.544291498	-2.419836807	

2008	-2.214218967	-2.279458584	-2.376198157	-1.415848411	
2009	-2.380558635	-2.340106291	-2.330322647	-2.109184305	
2010	-2.626437772	-2.970684992	-2.57832924	-2.307552912	
2011	-2.928371613	-2.698573051	-2.609164874	-2.510491447	
2012	-3.084431693	-2.809660591	-2.908135035	-2.46083339	
2013	-2.840983887	-2.667969858	-2.80581067	-2.135558239	
2014	-2.522159521	-3.377426755	-3.590767022	-2.578290506	
2015	-2.50756179	-3.115742462	-3.01761946	-1.979787356	
2016	-2.979584749	-2.866077937	-3.075194183	-2.333726595	
Currency	**USD**	**GBP**	**EUR**	**SKK**	
2005	-2.452554858	-2.828947456	-3.060032743	-3.542989198	
2006	-2.621356124	-3.324007478	-3.797481663	-3.282280855	
2007	-2.420626224	-2.516758373	-2.996111145	-3.011254116	
2008	-1.755992598	-2.041065801	-2.23455642	-2.585999352	
2009	-1.992412832	-2.032824403	-2.562708939	-2.562708939	
2010	-1.732142414	-2.13387154	-3.050661222	-3.050661222	
2011	-1.933316582	-2.30851162	-3.133942021	-3.133942021	
2012	-2.09394704	-2.623064637	-3.114251205	-3.114251205	
2013	-2.434653784	-2.386816084	-2.792646134	-2.792646134	
2014	-2.659024922	-3.116477417	-3.968246327	-3.968246327	
2015	-2.421028484	-2.525282369	-4.289499232	-4.289499232	
2016	-2.64851582	-2.171569111	-5.558992498	-5.558992498	

Source: author's computations.

Appendix D: Basic Gravity Model Estimation Results

Table 9: Pooled OLS basic gravity model results

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	−14.7419	6.71420	−2.196	0.0326	**
l_WDIST	0.00140508	0.116080	0.01210	0.9904	
l_GDP	−0.285521	0.134480	−2.123	0.0385	**
l_GDPCZ	0.876200	0.298470	2.936	0.0049	***

Source: author's computations.

Table 10: Pooled OLS basic gravity model statistics

Mean dependent var	0.736398	S.D. dependent var	1.484232
Sum squared resid	1158.139	S.E. of regression	1.353698
R-squared	0.172090	Adjusted R-squared	0.168160
F(3, 52)	7.240757	P-value(F)	0.000378
Log-likelihood	−1093.045	Akaike criterion	2194.090
Schwarz criterion	2211.910	Hannan-Quinn	2201.009
rho	0.837162	Durbin-Watson	0.287542

Source: author's computations.

Table 11: Random effects basic gravity model results

	Coefficient	*Std. Error*	*z*	*p-value*	
const	−14.4637	6.45608	−2.240	0.0251	**
l_WDIST	−0.0555079	0.143537	−0.3867	0.6990	
l_GDP	0.0288979	0.166816	0.1732	0.8625	
l_GDPCZ	0.560335	0.270592	2.071	0.0384	**

Source: author's computations.

Table 12: Random effects basic gravity model statistics

Mean dependent var	0.736398	S.D. dependent var	1.484232
Sum squared resid	1360.696	S.E. of regression	1.466151
Log-likelihood	−1144.301	Akaike criterion	2296.602
Schwarz criterion	2314.422	Hannan-Quinn	2303.521
rho	0.271469	Durbin-Watson	1.286471

Source: author's computations.

Appendix E: Augmented Gravity Model Estimation Results

Table 13: Pooled OLS augmented gravity model results

	Coefficient	*Std. Error*	*t-ratio*	*p-value*	
const	−346.227	98.0118	−3.533	0.0009	***
LANDL	0.164545	0.496182	0.3316	0.7415	
CONTIG	−0.0915731	0.360505	−0.2540	0.8005	
EU	0.170825	0.319908	0.5340	0.5956	
OECD	−0.379968	0.746354	−0.5091	0.6128	
l_WDIST	−0.0411312	0.167642	−0.2454	0.8072	
l_GDP	−0.0691211	0.343417	−0.2013	0.8413	
l_POP	−0.197976	0.248328	−0.7972	0.4289	
l_GDPCZ	−0.855063	0.483319	−1.769	0.0827	*
l_POPCZ	23.2178	6.44432	3.603	0.0007	***
l_RV	0.313792	0.124720	2.516	0.0150	**

Source: author's computations.

Table 14: Pooled OLS augmented gravity model statistics

Mean dependent var	0.736398	S.D. dependent var	1.484232
Sum squared resid	1118.443	S.E. of regression	1.337725
R-squared	0.200467	Adjusted R-squared	0.187674
F(10, 52)	3.595154	P-value(F)	0.001114
Log-likelihood	−1081.954	Akaike criterion	2185.908
Schwarz criterion	2234.915	Hannan-Quinn	2204.936
rho	0.834167	Durbin-Watson	0.294469

Source: author's computations.

Table 15: Random effects augmented gravity model results

	Coefficient	*Std. Error*	*z*	*p-value*	
const	−160.077	67.5084	−2.371	0.0177	**
LANDL	0.777946	0.461788	1.685	0.0921	*
CONTIG	−0.138100	0.402780	−0.3429	0.7317	
EU	0.360471	0.394235	0.9144	0.3605	
OECD	−1.93046	0.663545	−2.909	0.0036	***
l_WDIST	0.0146780	0.197986	0.07414	0.9409	
l_GDP	0.396364	0.260729	1.520	0.1285	
l_POP	−0.516435	0.171040	−3.019	0.0025	***
l_GDPCZ	−0.476553	0.371554	−1.283	0.1996	
l_POPCZ	10.6635	4.40412	2.421	0.0155	**
l_RV	0.0831987	0.0467177	1.781	0.0749	*

Source: author's computations.

Table 16: Random effects augmented gravity model statistics

Mean dependent var	0.736398	S.D. dependent var	1.484232
Sum squared resid	1221.082	S.E. of regression	1.396642
Log-likelihood	−1109.874	Akaike criterion	2241.749
Schwarz criterion	2290.756	Hannan-Quinn	2260.776
rho	0.278679	Durbin-Watson	1.270360

Source: author’s computations.

Appendix F: Script for Realized Volatility Calculations in RStudio

```
install.packages("readxl")

library("readxl")

setwd("C:/Users/Praha/Desktop/Ex-Rate data/Ukraine")


 rm(list = ls())

 my_data <- read_excel("2008.xls",sheet = 2)

 my_data_analysis <- t(my_data)

 c(my_data_analysis)

 Rate <-c(my_data_analysis)

 log_rate <- log(Rate)  #Natural logs of rates

 log_ret <- diff(log_rate)   #Calculating returns

 log_ret_squared <- log_ret^2 #Squared return

 realized_variance <- sum(log_ret_squared)  # Sum of squared return

 realized_volatility <- sqrt(realized_variance)

 realized_volatility
```

Appendix G: Script for Gravity Panel Data Models Estimation in GRETL

```
open C:_data_naletova_upd_2005-2016_RV.xlsx
setobs 12 1:1 --stacked-time-series
logs WDIST GDP POP TB GDPCZ POPCZ RV
summary l_WDIST l_GDP l_POP l_TB l_GDPCZ l_POPCZ l_RV --simple
# model 1
panel l_TB 0 l_GDPCZ l_POPCZ l_RV l_WDIST l_GDP l_POP LANDL CONTIG EU
\par  OECD --pooled
modtest --white
# model 2
panel l_TB 0 l_GDPCZ l_POPCZ l_RV l_WDIST l_GDP l_POP LANDL CONTIG EU
OECD
modtest --panel
# model 3
panel l_TB 0 l_WDIST l_GDPCZ l_GDP --pooled --robust
# model 4
panel l_TB 0 l_WDIST l_GDPCZ l_GDP --robust
# model 5
panel l_TB 0 l_WDIST l_GDPCZ l_GDP --robust --random-effects
# model 6
panel l_TB 0 l_GDPCZ l_POPCZ l_RV l_WDIST l_GDP l_POP LANDL CONTIG EU
\par  OECD --pooled --robust
# model 7
panel l_TB 0 l_GDPCZ l_POPCZ l_RV l_WDIST l_GDP l_POP LANDL CONTIG EU
\par  OECD --robust
# model 8
panel l_TB 0 l_GDPCZ l_POPCZ l_RV l_WDIST l_GDP l_POP LANDL CONTIG EU
\par  OECD --robust --random-effects
```