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The Trade Effect of Euro Adoption: An Estimation of the Rose Effect for the Czech Republic

MASTER THESIS

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Declaration of Authorship

I declare that I prepared the submitted work independently, citing all sources of information in accordance with the ethical principles for the preparation of university theses. I also declare that this thesis has not been used to obtain a different or the same degree. I acknowledge that I used AI tools, specifically DeepL Write and ChatGPT, to improve the quality of the text.

Prague, June 27, 2025 ....

Vítek Petržílka

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List of abbreviations

BoP = Balance of Payments

CA = Current Account

CEE = Central and Eastern Europe

CES = Constant Elasticity of Substitution

CPI = Consumer Price Index

CU = Currency Union

ECB = European Central Bank

EMU = The Economic and Monetary Union

EU = European Union

ER = Exchange Rate

ESCB = European System of Central Banks

FE = Fixed Effects

FDI = Foreign Direct Investment

FOB = Free on Board

FPE = Factor-Price Equalisation

FR = Forward Rate

FTA = Free Trade Agreement

FX = Foreign Exchange

GDP = Gross Domestic Product

GE = General Equilibrium (Model)

GEPPML = General Equilibrium Poisson Pseudo-Maximum Likelihood

GU = Gravity for Undergrads

HO = Heckscher-Ohlin (Model)

IMR = Inward Multilateral Resistance

ISIC = International Standard Industrial Classification

ITPD-S = International Trade and Production Database for Simulation

MU = Monetary Union

OCA = Optimum Currency Area

OLS = Ordinary Least Squares

OMR = Outward Multilateral Resistance

OTC = Over-The-Counter (market)

PML = Pseudo-Maximum Likelihood (Estimator)

PPML = Poisson Pseudo-Maximum Likelihood (Estimator)

RoW = Rest of the World

RTA = Regional Trade Agreement

SEPA = Single European Payment Area

UN = United Nations

US = United States

Introduction

When the Czech Republic joined the European Union in 2004, it took on the obligation to join the monetary union – the euro area – and thus adopt the euro as its currency instead of the koruna. When this commitment was made, no specific date was set for its fulfilment. Two decades later, the Czech Republic still has not adopted the euro, and the issue remains subject to political debate. As of now, the Czech Republic is not actively pursuing euro adoption, nor has it announced any specific timeline.

One of the arguments in favour of adopting the euro is that it promotes international trade by eliminating exchange rate risk and transaction costs. This thesis aims to evaluate this argument through data analysis. More specifically, the aim is to answer the following question: How would Czech exports change if the Czech Republic had adopted the euro?

The magnitude of the trade effect arising from currency sharing has been estimated numerous times in scholarly literature. At the beginning of the 21st century, it was estimated that joining the monetary union would increase international trade between union members by tens or even hundreds of percent (Rose & Stanley, 2005). Over the time, methodological improvements led to lower estimated trade effects, with recent literature suggesting that the impact of currency sharing on international trade is modest, if statistically significant at all (Polák, 2019).

The motivation for conducting this analysis is the lack of publications with a specific focus on the Czech Republic and the euro area.

By contrast, the thesis does not aspire to offer a comprehensive recommendation on whether the Czech Republic should adopt the euro or when it should do so, simply because the issue is too large and complex to be adequately addressed in a work of this extent.

The econometric gravity model of international trade, the primary analytical tool for modelling trade flows, integrated within a structural general equilibrium framework, is the analytical tool employed to estimate the impact of the euro on Czech trade flows. This framework is a closed system of countries in the panel that assumes constant total production and accommodates trade diversion effects. The trade effect estimate is derived from a counterfactual simulation modelling changes in relative trade costs. It captures the impact of the Czech Republic's hypothetical entry into the euro area in 2004, using multilateral resistance terms.

The dataset used for the analysis was created from the International Trade and Production Database for Simulation, which was compiled by Borchert et al. (2024). It includes the 48 largest trading partners of the Czech Republic (accounting for 98% of exports and 98% of imports), as well as the Czech Republic and the Rest of the World aggregate. It covers a total of 2,500 trading partner pairs (including both intra- and inter-national trade), spans 26 years (from 1994 to 2019), and comprises 65,000 observations in total.

Data preparation and basic analysis were performed in R. General equilibrium simulation was performed in Stata. The codes and data used are available in the online appendices of this thesis for replication purposes (accessible at https://github.com/vitekpetrzilka/MT).

Chapter 1 introduces readers to gravity models (1.1) and their foundations in international trade theory (1.2). Chapter 2 then moves on to the specifics of econometric application. It begins by clarifying the choice of Poisson Pseudo-Maximum Likelihood estimation over the more commonly used Ordinary Least Squares method (2.1). It then describes the within transformation of panel data, and the properties of fixed effects (2.2), which play a key role in general equilibrium analysis, and the method used in this thesis (2.3).

Readers will find the information on how estimates are produced helpful before reading the literature review in chapter 5.3, which might otherwise seem insufficiently explained from a technical point of view. Chapters 1 and 2 are placed at the very beginning of the thesis to avoid disrupting the flow of reasoning in chapter 5.

Chapter 3 focuses on the microeconomic aspects of international trade. It describes how trading in different currencies affects trade costs, primarily through exchange rate risk (3.1) and transaction costs (3.3). Chapter 4 shifts the focus to the macroeconomic impact of currencies on entire economies. It mainly considers the effects in the context of internal and external stability, and the adjustment mechanisms of the balance of payments (4.2).

Chapter 5 summarises the fundamental characteristics of different exchange rate regimes, including their advantages and disadvantages. It then assesses the suitability of territories for forming a monetary union from the perspective of the Optimum Currency Area theory (5.1), before discussing the costs and benefits of joining a monetary union (5.2). Chapter 5.3 provides an overview of the literature examining the effects of monetary unions on trade.

Chapter 6 presents the data used in the analysis (6.1), along with the results of estimating the impact of adopting the euro on Czech trade flows (6.3). The results suggest that it is reasonable to expect a modest effect that is economically significant only for a small number of trading partners.

Chapter 7 uses these results to make a policy recommendation.

1. Gravity model of international trade

1.1. Gravity equation

The gravity model of international trade in its basic form has been used to estimate international trade flows since Tinbergen (1962) even before its formal theoretical foundations were laid. It was used as an empirical tool for quantitative data analysis due to its intuitive nature and exceptionally strong predictive capability. Although for some time it had been perceived by many economists as a naive reduction of reality based on intuition, its popularity has led to successful efforts to explain theoretically why the gravity equation works, and the model has established itself in policy and counterfactual analysis related to the determinants of international trade flows (Yotov, 2024).

In its basic form, the model is analogous to the physical calculation of gravity (1) below. The volume of trade flows between two areas is therefore assumed to be directly proportional to their economic mass and inversely proportional to the distance between them, like calculating the strength of the gravitational field between two objects. Or to be more precise in economic terms, directly proportional to the exporter's production capacity and the importer's consumption capacity (both of which can be approximated by Gross Domestic Product (GDP), as discussed in chapter 1.2) and indirectly proportional to the trade-restricting factors that raise the transport and transaction costs of international trade between the partner countries.

Table 1: Analogy between gravity in trade and gravity in physics

Gravity in physics	Gravity in trade
$$F_{ij} = G\frac{M_i M_j}{D_{ij}^2} \quad (1)$$	$$X_{ij} = \tilde{G}\frac{Y_i E_j}{T_{ij}^{\sigma-1}}\eta_{ij} \quad (2)$$
Deterministic equation, where:	**Stochastic equation, where:**
$\boldsymbol{F_{ij}}$ is the gravitational force between objects *i* and *j*;	$\boldsymbol{X_{ij}}$ is the value of trade flows between countries *i* (exporter) and *j* (importer);
$\boldsymbol{G}$ is the gravitational constant in physics;	$\boldsymbol{\tilde{G}}$ is the gravitational constant in trade;
$\boldsymbol{M_i}$ denotes the mass of object *i*;	$\boldsymbol{Y_i}$ denotes the value of output in country *i*;
$\boldsymbol{M_j}$ denotes the mass of object *j*;	$\boldsymbol{E_j}$ denotes the value of expenditure in country *j*;
$\boldsymbol{D_{ij}}$ is the bilateral distance between objects *i* and *j*.	$\boldsymbol{T_{ij}}$ denotes the total bilateral trade frictions between *i* and *j*;
	$\boldsymbol{\sigma}$ is the elasticity of substitution across goods from different origins in CES utility frameworks;
	$\boldsymbol{\eta_{ij}}$ is a multiplicative error term.

Source: Adapted from Yotov (2024)

This equation (2) allows for econometric modelling and, it fits the data so well that *"students of trade theory who have characterised international trade with systems of simultaneous equations may find the empirical success of this hyper-simple relationship to be somewhat disconcerting"* (Baldwin and Taglioni 2007, p. 783).

In the econometric analysis, the model is extended with variables of interest (e.g., economic, cultural, political or geographical proximity of areas, free trade agreements, trade-promoting policies or tariffs) that either hinder or facilitate international trade flows. Although even in this naive form the models provide coefficient estimates for the variables that determine international trade flows with plausible magnitude and direction, today's application is not limited to this simple form of model estimation. More detailed information on the specifics of econometric application is provided in chapter 2.

1.2. Theoretical foundations of the gravity equation

As mentioned above, the application of the model started without any theoretical justification. This has created a stigma that has taken a great deal of time and academic research to overcome. To make the gravity model an analytical tool suitable for making predictions or policy recommendations, many authors have made efforts to place the model in the context of generally accepted theories of international trade. Linking the theoretical basis with the application in practice is essential to eliminate errors and missteps in its use (as described in chapter 5.3) and for the relevance of the interpretation of the results.

The first to make such an effort was Anderson (1979), who argued that the gravity equation can be derived from the properties of the expenditure system under the assumption of identical homogeneous preferences across regions, constant elasticity of substitution (CES), and an Armington specification of product differentiation by the country of origin. He concludes that the usage of the gravity equation for modelling international trade is valid, but its accuracy depends on the degree of homogeneity of preferences of traded products and the similarity of taxes, tariffs and transport costs between partner countries. Remarkably, the gravity model introduced by Anderson (1979) is consistent with today's modern gravity-model application (Yotov, 2024).

Bergstrand (1985) laid the microeconomic foundations of the gravity model by placing it in a general equilibrium framework. In his paper, he shows that the gravity equation can be derived as a reduced form of the general equilibrium world trade model, but only under certain assumptions, one of which is perfect substitutability of products produced in different countries. But he also points out that if this assumption is violated and trade flows are differentiated by place of origin, the gravity model in its typical form is mis-specified, and it is necessary to include variables capturing real exchange rates and their changes, since significant deviations of the exchange rate from purchasing power parity can be expected to persist even in the absence of tariffs and transport costs (Bergstrand 1985, p. 477).

Bergstrand (1989) shows that the gravity model is consistent with the Heckscher-Ohlin-Chamberlin-Linder model and extends it further to include the effects of factor proportions and consumer preferences. Considering an arbitrary number of two-factor economies with two sectors, the GDP and GDP per capita of the exporting country can be interpreted as proxy variables for the national product expressed in units of capital, as well as for the capital-labour endowment ratio of the country. Similarly, GDP and GDP per capita of the importer can serve as proxy variables for purchasing power and consumer preferences in the importing country (Bergstrand 1989, p. 152). Bergstrand (1990) builds on this approach and further extends the model to explain the share of intra-industry trade using gravity equation variables.

Whether or not the gravity equation is theoretically consistent with the Heckscher-Ohlin (HO) model was also examined by Deardorff (1997), who showed the basic mechanisms of the gravity equation derived from Cobb-Douglas and CES consumption functions, as well as from non-homothetical functions. The example provided was given in the context of the HO model and its two extreme cases: frictionless trade and complete specialisation. Deardorff concluded that *"it is not that difficult to justify even simple forms of the gravity equation from standard trade theories"* (Deardorff 1997, p. 21).

Deardorff (1997) further points out the limitations of the HO model and the problem of the factor-price equalisation (FPE) effect of international trade. He argues that in the presence of non-zero trade barriers (e.g., transport costs), FPE does not occur, and individual countries maintain different relative factor prices – otherwise foreign producers would not be able to compete with domestic producers on price, which would lead to the absence of trade.

An important contribution to the theoretical anchoring of gravity models was made by Eaton and Kortum (2002), who derive the gravity equation from the supply-side function in an extended Ricardian framework with heterogeneous technologies and randomly distributed productivity.

A seminal input was made by Anderson and van Wincoop (2003), who introduced the concept of multilateral resistance to international trade in response to the "border puzzle" posed by McCallum (1995). Multilateral trade resistance shows that trade between two countries is defined not only by the trade barriers between them, but also by the relative size of each country's trade barriers with all other third parties that represent alternative trading partners with alternative markets. The cost of trade between two countries must therefore be considered in relation to the alternatives that exist. For example, if the cost of trade between countries A and B remains the same, but other trade costs fall, trade between A and B may decline. Anderson and van Wincoop (2003) found a solution that correctly captures multilateral resistance in cross-sectional data – the inclusion of exporter and importer fixed effects.

In summary, the gravity equation can be derived from basic trade theories, including the Heckscher-Ohlin model, the Ricardian model, the Monopolistic Competition model or the Specific Factors model (Arkolakis et al., 2012). For a comprehensive overview of the derivation of gravity models from various demand-side and supply-side functions, see Head and Mayer (2014, chap. 2.3). All in all, *"the equation has… gone from an embarrassing poverty of theoretical foundations to an embarrassment of riches!"* (Frankel et al., 1997, p. 53, cited in Head & Mayer, 2014) and currently there is a wide range of applications in quantitative analysis, such as estimating the impact of Brexit, trade sanctions against Russia following its invasion of Ukraine, the United States (US) tariffs imposed by the Trump administration in early 2025 (Yotov, 2025), or the impact of joining a monetary union on trade, which is the aim of this paper.

2. Econometric application of the gravity model

2.1. OLS vs. PPML

The gravity equation is in its simple form (2) multiplicative, and in order to be estimated with the linear Ordinary Least Squares (OLS) estimator, it must be log-linearised by a logarithmic transformation, resulting in (3). Note that the multiplicative error term $\eta = \exp(\varepsilon)$ becomes additive in the log-linearised form.

$$X_{ij} = \tilde{G} \frac{Y_i E_j}{T_{ij}^{\sigma-1}} \eta_{ij} \quad \Rightarrow \quad \log X_{ij} = \log \tilde{G} + \beta_1 \log Y_i + \beta_2 \log E_j - (\sigma - 1) \log T_{ij} + \varepsilon_{ij} \tag{3}$$

The logarithmic transformation of all variables in the model (except the dummies) can reduce variance and often improves model fit. It changes only the interpretation of the coefficients – from the isolated absolute value of the effect of the marginal increase in the regressor on the dependent variable to the relative (percentage) effect of the percentage increase in the regressor on the dependent variable – the elasticity.

However, this approach holds only under certain assumptions, primarily homoskedasticity (4) – if the random component of the model has a constant finite variance independent of the values of the regressors. Let x_{ij} denote the vector of explanatory variables for the country-pair *i* and *j*.

$$Var\left(\varepsilon_{ij} \middle| x_{ij}\right) = \sigma^2 \tag{4}$$

The interpretation of OLS coefficients of log-linearised equations in the presence of heteroskedasticity is highly inappropriate due to Jensen's inequality (5). Since the expected value of the logarithm of a random variable depends on higher-order moments of its distribution (instead of being equal to the logarithm of its expected value), the heteroskedastic errors of the log-linearised (or otherwise non-linearly transformed) model (3) will be correlated with the regressors, leading to systematically biased OLS estimates (Silva & Tenreyro, 2006, p. 653). The fact that gravity models commonly suffer from heteroskedasticity is consistent with the findings of Petržílka (2025).

$$\mathbb{E}[\log(X_{ij})] \neq \log \mathbb{E}[X_{ij}] \tag{5}$$

The second major log-linearisation problem addressed by Silva & Tenreyro (2006) is zero trade flows. As the natural logarithm of zero is not defined, the log-linearized gravity equation excludes all zero trade flows, which are very frequent in trade data. Yet it is not implausible that there are pairs of countries whose subjects did not undertake any trade transactions during the period under review. This leads to a sample selection bias and estimates based only on country pairs with non-zero trade.

Silva & Tenreyro (2006) went further and proposed an alternative estimation method – the Poisson Pseudo-Maximum Likelihood Estimator (PPML). PPML allows estimating the model in its original multiplicative form (6), while remaining robust to heteroskedasticity. PPML also performed best against OLS, Gamma PML and Non-Linear Least Squares in terms of bias, consistency and efficiency on simulated data.

$$X_{ij} = \exp(\log \tilde{G} + \beta_1 \log Y_i + \beta_2 \log E_j - (\sigma - 1) \log T_{ij}) \cdot \eta_{ij} \quad (6)$$

Before PPML became widely used, some studies have resorted to adding a small non-zero number to all the values so that the dataset does not lose observations, but this generally leads to inconsistent estimates of the parameters of interest (Silva & Tenreyro, 2006, p. 643). Another possible solution is (inverse) hyperbolic (sine) transformation, which removes the multiplicative form from the equation while preserving zero trade flows. However, due to the ability of PPML to estimate the gravity model in multiplicative form and the specific properties described in chapter 2.3, hyperbolic transformation has not become widespread in applied analysis.

Unlike OLS, which is tasked with minimising the squares of the residuals, PPML algorithmically searches for values of β that maximise the value of the log-likelihood function (7), which is derived from the probability density function of the Poisson distribution. However, the dependent variable does not have to be Poisson nor an integer for the estimator based on (7) to be consistent (Silva & Tenreyro, 2006, p. 645).

$$\sum_{i,j} [X_{ij} \log(\mu_{ij}) - \mu_{ij}], \quad (7)$$

where:

$$\mu_{ij} = \exp\,(x_{ij}^T \beta) \quad (8)$$

In equation (8), x_{ij}^T is a transposed vector of regressors and β is a vector of parameters.

The classical Poisson Maximum Likelihood estimator implicitly assumes that the expected conditional value of the dependent variable is the same as its conditional variance (9), which is not feasible when heteroskedasticity of the residuals is present. This equality holds under the classical Poisson distributional assumption, but not in the more flexible PPML framework.

$$\mathbb{E}(y_i|x_i) = Var(y_i|x_i) \tag{9}$$

As shown by Gourieroux et al. (1984), the estimates of the Pseudo-ML (PML) estimator can be consistent, even if this equality does not hold and the variance is arbitrary, provided that the conditional mean is specified correctly. This is because PML uses a robust estimate of the variance matrix and can account for heteroskedasticity retrospectively. Therefore, the strength of the PML estimator is that it is sufficient to correctly define the first moment of the dependent variable, and even if the second moment is different from the Poisson distribution, the parameter estimates remain consistent and interpretable.

At the same time, since the dependent variable does not enter the estimation after the logarithmic transformation, but PPML models directly the exponential equation (6) – that is, the trade is modelled in levels, not logarithms – the estimator naturally includes the zero values of the dependent variable, which would be excluded in log-linearised models such as OLS. The log-likelihood contribution for $X_{ij} = 0$ is well-defined and continuous (10):

$$X_{ij} \log(\mu_{ij}) - \mu_{ij} = 0 \cdot log(\mu_{ij}) - \mu_{ij} = -\mu_{ij} \tag{10}$$

Consequently, these zero-valued observations, which may reflect trade barriers or prohibitively high costs and often carry information that is endogenous to the explanatory variables, contribute to the PPML estimation.

For these reasons, PPML is widely regarded as the preferred estimator in the current application of gravity models and, in combination with the fixed effects described in chapter 2.2, is considered to be the best practice. Taken together, the ability to model zeros and to provide valid inference under heteroskedasticity gives PPML a clear edge in applied work.

2.2. Fixed-effects

Fixed-effects (FE) allow us to separate the effect of observed variables from the effect of unobserved variables when using panel data, thus eliminating omitted variable bias. Although the use of FE estimators is a simple econometric procedure, it is useful to provide readers with a brief recap of the basics, given that FEs play a crucial role in the general equilibrium (GE) analysis in this paper. For illustrative purposes, the individual fixed-effects estimator is described first. However, time and other FEs work in a similar way, but with different dimensions of the data.

This estimation method is based on a fixed-effects transformation, called de-meaning, which consists of subtracting from the variables their own individual average over time of each of the cross-sectional units and then modelling only the deviations from these individual means in each period. This transformation yields the so-called within estimator, a model adjusted for any effects originating from individual heterogeneity, i.e., time-constant differences specific to each cross-sectional unit. These can include both observed variables (included in the model) and unobserved or unobservable factors.

Consider a simple model with dependent variable (y_{it}), only one regressor (x_{it}), error (u_{it}) and with each cross-sectional unit (denoted by i) having individual-specific effects that are constant over time (a_i):

$$y_{it} = \beta_1 x_{it} + a_i + u_{it} \tag{11}$$

If we average equation (11) over time (denoted by t) for each i, we get (12):

$$\bar{y}_i = \beta_1 \bar{x}_i + a_i + \bar{u}_i \tag{12}$$

Since a_i is time-constant, it appears unchanged in both equations. When we subtract equation (12) from equation (11), a_i is removed and the model can be estimated using time-demeaned data, which removes individual-specific effects, as shown in Wooldridge (2016, p. 435):

$$y_{it} - \bar{y}_i = \beta_1 (x_{it} - \bar{x}_i) + u_{it} - \bar{u}_i \quad \Rightarrow \quad \ddot{y}_{it} = \beta_1 \ddot{x}_{it} + \ddot{u}_{it} \tag{13}$$

This results in an estimation without omitted variable bias, but one that does not allow estimating the effects of any individual-level variables that do not vary over time, since these are eliminated by the transformation (Wooldridge 2016, Chapter 14).

The very same estimates can be obtained using Dummy-Variable Regression (Wooldridge, 2016, chap. 14–1a). By including a set of dummy variables in the model that indicate each of the cross-sectional units, except for one reference category to avoid perfect multicollinearity, we create an individual fixed-effects estimator. All other coefficient estimates for remaining dummies then capture the individual heterogeneity of cross-sectional units relative to the one omitted dummy variable (reference category).

Similarly, if we include dummies indicating periods in the dataset, we create a time FE estimator. Such dummy variables then absorb the effect of all (observed and unobserved) time-specific effects that affected all cross-sectional units equally in each period. By including a dummy for each pair of cross-sectional units, we estimate the pair FE and eliminate the effects of all time-constant pair-specifics on the dependent variable, such as distance, shared language or borders. On the one hand, such a model cannot identify the effects of time-invariant bilateral trade costs. On the other hand, as long as the variable of interest is time-varying, the inclusion of pair dummies is generally recommended, as it helps mitigate bias from many potentially omitted variables (Yotov, 2025).

An econometric application of the gravity model that is consistent with theory and correctly captures the effect of multilateral resistance on international trade flows is a fixed-effects estimator combining time-varying country (individual) dummies and time-invariant country-pair dummies. The alternative use of time-varying pair dummies is not suitable because it prevents the estimation of time-varying pair-specific variables — such as currency sharing between trading partners — which is central to this analysis.

For large datasets, such estimation can involve thousands of dummies and can reach computational limits (see Head & Mayer (2014) for suggestions on how to reduce the number of estimated coefficients). The problem arises when analysing in Stata, since it includes each fixed effect as an explicit parameter in the regression model. This significantly increases the size of the dataset and the computational requirements. The R package Fixest performs estimation in a more streamlined way.

2.3. From naive gravity to general equilibrium

Gravity models appear in the literature in several forms, each reflecting a different stage in the evolution of empirical and theoretical estimation. This chapter summarises the basic features of the naive gravity equation, structural gravity equation, and structural general equilibrium endowment system, which is the main analytical framework used in this work. This section does not cover more advanced frameworks, such as dynamic general equilibrium models or those nested within more complex structures.

The naive gravity equation resembles equation (2) from chapter 1.1, but it does not distinguish between the output of exporters (Y_i) and the expenditure of importers (E_j) and approximates them using GDP as a measure of economic size:

$$X_{ij} = \tilde{G}\frac{GDP_i GDP_j}{T_{ij}^{\sigma-1}} \tag{14}$$

This equation, augmented with variables of interest and control variables, was usually estimated using cross-sectional data or pooled OLS. These results were systematically biased due to the omission of multilateral resistance terms.

The structural gravity model in equation (15), introduced by Anderson & van Wincoop (2003), differs from the naive specification in three key ways (Yotov, 2025):

$$X_{ij} = \tilde{G}\frac{Y_i E_j}{\mathrm{Y}}\left(\frac{t_{ij}}{T_i T_j}\right)^{1-\sigma} \tag{15}$$

First, it distinguishes between output, representing the production capacity of the exporting country, and expenditure, representing the absorption (consumption) capacity of the importing country. This distinction is especially important in sector-level analysis, where trade imbalances can be substantial due to specialization. Second, it implies that bilateral trade flows are proportional to the product of each country's share in total world income (Y). Third, the trade cost term (T_{ij}) is decomposed into bilateral trade frictions (t_{ij}), such as distance or Regional Trade Agreements (RTAs), and multilateral resistance terms (T_i) and (T_j), which reflect average trade barriers faced by exporter i and importer j, respectively.

This makes it possible to control for multilateral resistance, i.e., the fact that trade is not only determined by trade costs between the two partners in question, but also by trade costs between all other potential trading partners. The naive gravity equation incorrectly assumes that such multilateral trade costs are irrelevant.

The exposition of the structural general equilibrium gravity model in this section closely follows the framework developed by Yotov et al. (2016, Chapter 2), which serves as the main reference for both the theoretical system and its empirical implementation.

The structural GE framework is a closed system of countries that assumes constant total production ($Q_{i,t}$) and accommodates trade diversion effects. It builds on the structural gravity equation (16), allowing changes in bilateral trade costs to transmit through the entire system as relative trade costs through outward multilateral resistance (OMR) and inward multilateral resistance (IMR) terms. When a policy shock replaces one of the trade cost variables in the vector $t_{ij,t}$ with a counterfactual variable, the GE framework allows for an endogenous response of output (Y_i) and expenditure (E_j) of each country in the panel.

$$X_{ij,t} = \tilde{G}\frac{Y_{i,t}E_{j,t}}{Y_t}\left(\frac{t_{ij,t}}{\Pi_{i,t}P_{j,t}}\right)^{1-\sigma} \tag{16}$$

$$\Pi_{i,t}^{1-\sigma} = \sum_j \left(\frac{t_{ij,t}}{P_{j,t}}\right)^{1-\sigma}\frac{E_{j,t}}{Y_t} \tag{17}$$

$$P_{j,t}^{1-\sigma} = \sum_i \left(\frac{t_{ij,t}}{\Pi_{i,t}}\right)^{1-\sigma}\frac{Y_{i,t}}{Y_t} \tag{18}$$

$$p_{i,t} = \left(\frac{Y_{i,t}}{Y_t}\right)^{\frac{1}{1-\sigma}}\frac{1}{\alpha_i\Pi_{i,t}} \tag{19}$$

$$E_{i,t} = \varphi_i Y_{i,t} = \varphi_i p_{i,t} Q_{i,t} \tag{20}$$

The system is defined by equations (16) through (20). As before, *i* and *j* index exporting and importing countries, respectively. The variables $X_{ij,t}$, $Y_{i,t}$, $E_{j,t}$ and $t_{ij,t}$ follow the definitions from the previous chapters, now indexed by time *t* to reflect the panel structure.

The following variables are introduced in the structural GE gravity model:

Table 2: Variables introduced in the structural GE model

$\boldsymbol{\Pi_{i,j}}$	Outward multilateral resistance of exporter *i*; a CES-weighted average of trade costs faced when exporting to all destinations
$\boldsymbol{P_{j,t}}$	Inward multilateral resistance of importer *j*; a CES-weighted average of trade costs faced when importing from all origins
$\boldsymbol{p_{i,t}}$	The factory-gate price for goods produced in country *i* in period *t*
$\boldsymbol{\alpha_i}$	Constant Elasticity of Substitution parameter
$\boldsymbol{\varphi_i}$	An exogeneous share parameter relating nominal income to total expenditure
$\boldsymbol{Q_{i,t}}$	Constant real output (endowment) of country *i*

Source: Adapted from Yotov et al. (2016)

Multilateral resistance captures how trade costs affect both producers and consumers in a general equilibrium setting, by decomposing their aggregate incidence across countries. Outward multilateral resistance can be understood as the weighted average of all bilateral trade costs faced by exporters from a given country – as if all producers sold their goods on a single global market with identical costs on the supply side. In contrast, inward multilateral resistance reflects the weighted average of trade costs affecting imports from the perspective of consumers, as if each country was purchasing on the global market at identical import costs. This construct allows policy modelling to separate the impacts of trade changes on producers and consumers in individual countries.

If OMR and IMR decrease between two partners – for instance, by entering an RTA – multilateral resistance with third countries rises in relative terms, reflecting the higher cost of trading outside the agreement.

Policy-induced changes in factory-gate prices stem from shifts in demand resulting from market reallocation. Producers in liberalising countries will experience increased demand for their products in a larger market and will raise their prices in response. In contrast, producers in non-member countries suffer declining demand due to trade diversion toward RTA members, which may lead them to lower prices in response.

The following subsection briefly outlines how this structural general equilibrium system is estimated in practice. This description is based on the General Equilibrium Poisson Pseudo-Maximum Likelihood (GEPPML) methodology developed by Yotov et al. (2016) and summarised in Anderson et al. (2018). It leverages the fact that exporter and importer fixed effects in the PPML estimator correspond to multilateral resistance terms under the structural model (Fally, 2015).

For simplicity, we group all trade policy variables into vector $\boldsymbol{T}_{ij,t}$, to which corresponds vector $\boldsymbol{\beta}$ of estimated coefficients. The estimation proceeds in the following steps:

1. Estimate the baseline structural gravity model (21) using PPML, controlling for exporter-time ($\pi_{i,t}$), importer-time ($\chi_{j,t}$), and pair fixed effects (δ_{ij}).

$$X_{ij,t} = \exp(\pi_{i,t} + \chi_{j,t} + \delta_{ij} + \boldsymbol{T}_{ij,t}\boldsymbol{\beta}) \cdot \eta_{ij,t} \tag{21}$$

2. Construct baseline OMR (22) and IMR (23) using the estimated fixed-effects, where $E_{R,t}$ represents the expenditure of the reference country in period *t*.

$$\exp(\hat{\pi}_{i,t}) = \frac{Y_{i,t}}{\widehat{\Pi}_{i,t}^{1-\sigma}} \cdot E_{R,t} \tag{22}$$

$$\exp(\hat{\chi}_{j,t}) = \frac{E_{j,t}}{\widehat{\mathrm{P}}_{j,t}^{1-\sigma}} \cdot \frac{1}{E_{R,t}} \tag{23}$$

3. Introduce a counterfactual trade cost scenario (e.g., remove tariffs, simulate an RTA) by modifying the trade cost vector ($t_{ij,t}$).
4. Re-estimate the conditional gravity model, holding output and expenditure fixed, to obtain counterfactual trade flows ($X_{ij,t}^{c}$).
5. Compute conditional multilateral resistance terms based on the new estimates.
6. Obtain full general equilibrium effects by iteratively updating output and expenditure according to equilibrium conditions.
7. Re-estimate the model using the updated variables of $Y_{i,t}$ and $E_{j,t}$ from step 6 to reflect endogenous changes in general equilibrium.
8. Construct full-endowment GE indexes for IMR, OMR, prices, output, and welfare measures as a percentage difference between baseline indexes and indexes after full GE adjustment.

This approach enables comparative statics analysis under a fully structural framework, while retaining the estimation advantages of PPML. By incorporating multilateral resistance and allowing for endogenous responses in output and expenditure, the GEPPML method provides internally consistent counterfactual predictions that respect general equilibrium constraints and trade diversion.

In the chapter 6, this method is applied to evaluate the effects of the adoption of euro by the Czech Republic. The counterfactual scenario uses a dummy variable to indicate the currency-sharing of the euro area, as if the Czech Republic had joined the eurozone in 2004 when it entered the European Union (EU). The elasticity of substitution across goods of different origins (σ) is taken from the literature (Head & Mayer, 2014) and set at 7. Germany is the reference country used to calculate OMR and IMR ($E_{R,t} = E_{DEU,t}$). The Stata code for GEPPML estimation provided by Yotov et al. (2016, Chapter 2, Exercise 2) was used for this analysis with only minor modifications. I gratefully acknowledge the authors for making their replication code publicly available, which greatly facilitated the implementation.

3. Currencies and International Trade

Information on the basics of international economics in chapters 3 and 4 was sourced from Neumann et al. (2010) and Krugman et al. (2018).

In general, currency sharing affects the microeconomic trading environment and trade costs in four ways. The first two – exchange rate (ER) risks and transaction costs – are more tangible and easier to measure. The other two – price transparency and economic sentiment – are rather soft and difficult to measure. This chapter summarises the main information about each of the four channels, providing an answer to the question of how currencies affect trade and how big an impact that is. It is important to take these findings into account to develop a reasonable expectation of the estimated trade effect of currency sharing.

When entering a business relationship with a counterpart from a country that uses a different currency, it does not matter whether the transaction is denominated in the exporter's or importer's currency – in each case, one of the parties takes on a payable or receivable in a currency other than their domestic. At the same time, the value of payables or receivables denominated in one's own domestic currency is more important for each of the counterparts, as exporters bear costs and importers generate revenues in their domestic currencies. Currency conversion must occur to pay the exporter's domestic costs (e.g., material input, rent, transport or wages) from export revenue, or to pay the importer's liabilities to foreign parties.

Currency exchange takes place through the foreign exchange market, which is a decentralised over-the-counter (OTC) market involving always two counterparties, one selling a currency and the other buying it. Currency exchange is usually conducted electronically through intermediaries, such as banks, brokers and online trading platforms. These intermediaries settle with each other only the net differences between their clients' supply and demand of given currency pairs.

The price of a currency is always related to a specific currency pair and is reflected in an exchange rate, which states (following direct quotation) the amount of domestic currency needed to purchase one unit of foreign currency. The second commonly used standard in exchange rate quotation is to express the price of the more widely used or internationally dominant currency in units of the (smaller or younger) less-established currency. The direction of quotation may vary depending on market convention and the home country of the trader. In the context of Czech international trade, the most important exchange rate – EUR/CZK – specifies how many Czech crowns (CZK) are needed to purchase one euro (EUR).

Let us consider, for example, a Czech company trading with a partner in the eurozone. The more CZK that a euro costs, the weaker or cheaper the CZK is against the euro. A cheap or depreciating domestic currency is favourable for exporters, as it means that they receive more CZK for the same amount of euros on the foreign exchange market, which makes them more competitive in terms of price. Conversely, the fewer CZK that a euro costs, the stronger or more expensive the CZK is. An expensive or appreciating domestic currency is favourable for importers, as it means that the same liability denominated in euros costs them fewer CZK, making foreign production relatively cheaper.

According to theory, the exchange rate should tend towards parity in the long term, reflecting the relative price levels in the respective markets. Theoretically, the exchange rate should be such that the price of a basket of goods abroad is equal to the exchange-rate-multiple of the price of the same basket on the domestic market. The interest rate parity theory states that the exchange rate of currencies with different interest rates tends to change in such a way that the return on holding each currency is equal. In other words, a currency with higher interest rates is likely to depreciate against a currency with lower interest rates, effectively eliminating the room for arbitrage (and vice versa). Expectations about future exchange rate movements may be also based on inflation differentials. For example, currencies of countries with high inflation tend to depreciate against currencies with lower inflation.

In a floating exchange rate regime, the price of a currency is determined by market dynamics – supply and demand in the foreign exchange market. Such a regime allows for a constant correction of the currency price in cases where the currency is overvalued or undervalued against others due to changes in the economic environment. In this way, the price of the currency reflects fundamental economic factors such as differences in inflation, interest rates and imbalances in countries' balances of payments (more information concerning fixed rates and central bank interventions can be found chapter 4).

This makes it reasonable to assume that the floating exchange rate tends to converge in the long run to an exchange rate at parity equal to the ratio of domestic and foreign price levels. However, the law of one price is usually not fulfilled in the short run and exchange rates thus do not perfectly capture purchasing power, price levels and interest rates in areas with different currencies. This can lead to situations in which currencies have higher either internal or external purchasing power.

3.1. Exchange rate risk

As mentioned above, currency prices can move freely under a floating exchange rate regime and respond to actual supply and demand in each currency pair. Exchange rates levels and developments can be reasonably predicted in the long run based on economic fundamentals. However, exchange rates deviate significantly from long-term trends and theoretical levels in the short term, and short-term volatility is rather unpredictable.

This unpredictability creates uncertainty regarding the future value of the exchange rate. More specifically, it creates uncertainty regarding the value of a receivable or payable from an international trade transaction at the time of maturity. This means that the domestic currency may appreciate or depreciate contrary to expectations. An appreciation would mean a decrease in the value of liabilities and receivables in foreign currency expressed in domestic currency, while a depreciation would mean an increase in the value of liabilities and receivables in foreign currency expressed in domestic currency. Whether such development is favourable or unfavourable depends on the position of the trading subject — whether the company has a net liability or net receivable towards all foreign partners with this currency.

Exchange rate movements may seem insignificant at first glance, yet even such minor percentage movements can cause material financial losses in business transactions. Let us consider a Czech merchant with a receivable (or a liability) in euros as an illustrative example. This receivable (or liability) is maturing in 30 days and was contracted in 2023 or 2024. During this period, the largest observed 30-day exchange rate movements included an appreciation of the CZK by 2.8% and a depreciation by 3% (ČNB, 2025). These represent the maximum 30-day fluctuations that would have occurred between the contracting and maturity dates of hypothetical one-month transactions with different start dates.

The value of an unhedged liability denominated in euros contracted on 10 June 2024 with a maturity of one month could thus increase by up to CZK 0.74 per euro. Similarly, the value of an unhedged receivable contracted on 16 March 2023 with the same maturity could fall by up to CZK 0.67 per euro. In the case of low-value contracts, the amounts involved are negligible in absolute terms. However, in the case of a contract worth a hundred thousand euros, the potential exchange rate loss exceeds the average monthly wage in the Czech Republic, and in the case of a contract worth one million euros, it is comparable to the value of a new car Škoda Octavia.

As the maturity period increases, the uncertainty of future exchange rates naturally rises, which means that receivables (or liabilities) with longer maturities may be subject to greater fluctuations. In our example, the EUR/CZK exchange rate fluctuated from -3.2% to +4% over 60-day periods, and from -3.1% to 4.4% over 90-day periods. This emphasises the need to consider not only the nominal value of the transaction but also its time horizon when assessing exchange rate risk.

The risk of adverse exchange rate development, which reduces receivables or increases liabilities, is called exchange rate risk. As economically rational participants are generally risk-averse, those involved in international trade typically seek to minimise their exposure to it.

3.2. Hedging strategies

The simplest strategy for eliminating exchange rate risk is called natural hedging and involves managing liabilities and receivables so that currency conversion can be avoided as much as possible. As a result, costs in foreign currency are covered by revenues in foreign currency, and costs in domestic currency are covered by revenues in domestic currency. To achieve natural hedging, the cost structure can also be adjusted to enable it, e.g., by relocating production or targeting new export markets. While natural hedging avoids financial costs, it may lead to less efficient operational choices. Unfortunately, for natural hedging to work perfectly, receivables and payables in different currencies must match both in volume and maturity, which is rarely the case.

When managing exchange rate risk, it is common to enter relationships with third parties who, in exchange for a fee, assume part or all of the exchange rate risk. Such arrangements, usually at the cost of reducing potential gains, ensure stability in expected cash flows and reduce or fully eliminate the risk arising from exchange rate volatility. On the other side of this relationship there is usually a financial institution (a bank), and the hedging is achieved through financial derivatives.

As for the Czech Republic, the most common instrument used by international traders is the Foreign Exchange (FX) Forward, which consists of a fixed contract to exchange a predetermined volume of foreign currency at a predetermined exchange rate (forward rate) at a set date. A forward is a binding agreement and represents an obligation of the seller to sell the currency at the forward rate (FR) and of the buyer to buy the currency at the FR. FX Forwards are non-standardised OTC contracts typically offered by banks, where the forward rate is derived from the interest rate differential between the two currencies. The main advantage of a Forward is a fixed exchange rate in the future. The main disadvantage is low flexibility and the inability to take advantage of a favourable exchange rate development. In other words, even if the exchange rate shifts in a favourable direction between the closing of the contract and the maturity date, both parties of the FX Forward must carry out the agreed currency conversion.

An alternative to FX forwards is the option, a financial derivative that offers greater flexibility. Unlike FX forwards, options are not symmetrical, and the option buyer has the right, but not the obligation, to exchange the specified amount at a predetermined price (strike price). In contrast, the option seller undertakes the obligation to exchange the currencies at the strike price upon the option buyer's request in exchange for a premium. The premium amount reflects the agreed strike price, the volatility of the currency pair and the time to maturity.

In this way, the trader can take advantage of positive exchange rate developments (although reduced by the premium) and at the same time choose the maximum acceptable loss in the event of unfavourable exchange rate developments through the strike price.

There are two basic types of options – put options and call options. A Czech trader can hedge their receivable in euros by purchasing a put option, i.e., the right to sell the underlying asset (euro) at the strike price. Similarly, they can hedge their liability in euros by purchasing a call option, i.e., the right to buy the underlying asset (euro) at the strike price.

The advantages arising from the flexibility of options are partly offset by their price. However, various option strategies can be chosen to reduce or eliminate the price. For example, a zero-cost option strategy consists of buying a put option and simultaneously selling a call option (or vice versa), with the strike price of both set in such a way that the premiums are equal. This effectively creates a range of exchange rates within which the currency conversion can be carried out on the FX market at the spot price, which is however limited from below by the strike price of the put option (below which the holder of the put option exercises their right) and from above by the strike price of the call option (above which the holder of the call option exercises their right to exchange).

For the cases when one of the counterparties delays payment or there is a lack of liquidity in cross-currency transactions (e.g., for the execution of FX Forwards agreed in advance), there is another important OTC financial derivative – FX Swap. The FX Swap consists of a spot transaction and a simultaneous forward contract in the opposite direction, typically used to manage short-term liquidity.

3.3. Transaction costs

Another channel through which currencies influence trade costs is represented by transaction costs, i.e., costs connected to the actual execution of a transaction in foreign currency.

Primarily, these are currency conversion fees charged by foreign exchange market intermediaries for the currency exchange itself. These fees often take the form of a spread, i.e., the difference between the buying and selling exchange rates. For commercial banks, these can be as high as 3% from the exchange rates reported by the central bank: for example, according to the exchange rate list of the Czech bank Fio Banka a. s. dated June 22, 2025 (Fio Banka, 2025). The exchange of 100 CZK to euros and then back to CZK results in 94.2 CZK.

Spreads offered by brokers specializing in the foreign exchange market or online trading platforms tend to be considerably lower. However, there are often fees for withdrawing funds from a trading account to a bank account, minimum volumes or fixed transaction sizes, and even then, the spreads are never zero. These are costs of currency conversion that cannot be easily avoided. The fees are generally higher for consumers and small businesses, who typically lack bargaining power or access to institutional FX Services, and it is the larger clients who can reach better terms from exchange service providers.

In addition to spreads, foreign currency payments may also be subject to bank charges for foreign transfers. This is not relevant within the Single European Payment Area (SEPA) and therefore does not apply to payments in euros. However, this cost should still be considered for other currencies.

Apart from the fees paid to the financial service providers, international trade also incurs costs within companies themselves. These mainly include the costs of accounting in multiple currencies, recording exchange rate differences, valuing receivables and payables, recalculations at the end of the financial year, and adjusting the company's pricing policy in response to exchange rate developments. Moreover, it is particularly common in the Czech context for corporate teams serving the Czech and Slovak markets to operate jointly, as if Czechoslovakia still existed. As Slovakia uses the euro, companies operating in both the Czech and Slovak markets typically have no option but to maintain a two-currency accounting framework.

3.4. Economic sentiment, price transparency and competition

Soft arguments also appear in the discussion on the effects of sharing a currency. One of these arguments, which also appeared in the official argumentation supporting the creation of the European Economic and Monetary Union (EMU), is the improvement of economic sentiment (Directorate-General for Economic and Financial Affairs, 1990). The idea behind this is that currency sharing is a sign of deeper economic integration, which can lead to greater trust between partners and more long-term strategic cooperation instead of shallow and fragile trade relations. This newly acquired confidence in foreign markets with the same currency may also encourage foreign direct investment across the euro area.

Another common argument used to be that having the same currency would mean greater price transparency and lead to increased competition from foreign entities, as the need to convert foreign prices in order to put them in the context of domestic alternatives would be eliminated. This argument undoubtedly carried more weight at the beginning of the eurozone project, but it seems less relevant in today's environment. Firstly, the increased use of cashless payments has substantially reduced the need for foreign valuta and cash exchange. Secondly, technology provides us with continuous access to live updates from the foreign exchange market. Sellers and service providers set their price lists in the currencies of their target markets, and if they do not, accurate price conversion poses no problem.

Overall, these arguments should be viewed with a fair amount of scepticism, as they are difficult to grasp theoretically and measure empirically.

4. Internal and External Stability

First, the terms internal and external stability of a country must be defined, as they appear frequently throughout the rest of this work.

Internal stability of a country refers to a situation where the economy is stable in domestic terms. Such an economy has stable and predictable inflation (i.e., in line with the central bank's target), low and stable unemployment, close to the natural rate, and sustainable GDP growth. In other words, such an economy grows at a steady pace without overheating or experiencing recession.

External stability refers to an economy that has stable international economic relations. Such an economy has a sustainable external position (i.e., a balanced current account or the ability to finance current account deficits through stable capital inflows), a stable exchange rate (without significant, sudden fluctuations), and it maintains the confidence of credit rating agencies and foreign investors regarding fulfilling its foreign obligations.

The pursuit of internal and external stability is a common objective for governments and non-governmental institutions, but the tools used to achieve each component may be mutually conflicting. This contradiction forms the basis of the economic trilemma: it is impossible to have a fixed exchange rate, free movement of capital and an independent monetary policy simultaneously.

4.1. Fiscal and monetary policy

Achieving internal and external stability of a country falls within the jurisdiction of two separate institutions – the state and the central bank. It is important to note that these are two distinct, though partly cooperating, institutions with different objectives, which is crucial for understanding the arguments in the following chapters.

The state government, namely the ministry of finance, conducts fiscal policy and manages the public finance in terms of both revenue (taxes) and expenditure. Fiscal policy refers to all actions taken by governments to influence the domestic economy through the state budget. The main objectives of fiscal policy are to maintain economic stability at both the macroeconomic and social welfare level. At the social level, this is achieved through income redistribution and the provision of social security. At the economic level, it is achieved by mitigating the impact of crises and increasing employment through fiscal expansion or restriction, depending on the economic cycle. At the same time, however, it is essential not to allow excessive spending to lead to unsustainable public debt.

Monetary policy is conducted by the central bank and aims to control inflation and currency stability by managing the money supply and interest rates. The most common task of the central bank is to target inflation by setting short-term interest rates, which influences credit terms and investments, slowing down or stimulating the supply of liquidity in the economic system. Another common regime is exchange rate targeting, typically involving foreign exchange interventions – buying or selling currencies to influence the exchange rate.

One central bank is usually responsible for managing one national currency. In the case of the eurozone, monetary policy is conducted at the union level by the European Central Bank (ECB), while the national central banks of euro area countries continue to exist and cooperate with the ECB within the European System of Central Banks (ESCB). They no longer conduct independent monetary policy but implement the ECB's decisions and contribute to currency management and financial stability.

4.2. Balance of payments and its adjustment

The balance of payments (BoP) is closely related to the external balance of an economy, as it tracks the movement of goods, services, and capital across borders.

The current account (CA) records international transactions related to trade in goods and services, income from abroad (such as wages and investment returns), and current transfers (such as remittances or foreign aid). If the sum of the inflows and outflows in these accounts is not equal, the country has an unbalanced current account, which means that it either earns more than it spends (surplus) or vice versa (deficit).

The capital account captures unilateral capital transfers such as international grants and investments, debt relief, or transfers of non-financial assets, and this item is usually small.

The financial account records the movement of financial capital, i.e., the purchase and sale of assets between domestic and foreign parties. Examples include foreign direct investments (FDIs), portfolio investments (i.e., shares and bonds), loans, and changes in central bank foreign exchange reserves. It shows how a country finances its current account deficit, for example through the sale of bonds or through direct investments.

Economists generally distinguish five mechanisms through which the balance of payments adjusts (Neumann et al., 2010). These mechanisms are key to understanding how a country maintains both internal and external stability.

The most autonomous mechanism, which works without institutional intervention, is the exchange rate adjustment mechanism in a freely floating exchange rate regime. Since both domestic and foreign currencies are needed to carry out international trade transactions, CA imbalances manifest themselves as imbalances in the foreign exchange market, creating pressures to change the price of domestic currency expressed in units of foreign currency.

If a country operates with a CA surplus, there is an excess supply of foreign currency on the foreign exchange market, which is caused by increased demand for the domestic currency when converting foreign currency revenues. This causes the domestic currency to appreciate, leading to a decrease in domestic price competitiveness and a decline in exports. At the same time, it increases the external purchasing power of the domestic currency, which leads to an increase in imports and effectively eliminate the current account surplus. Similarly, a CA deficit is accompanied by an excess supply of domestic currency and a demand for foreign currency. Consequently, this leads to a decline in imports and an increase in exports.

However, the balance of payments is also adjusted in situations where the exchange rate mechanism (or parity changes in fixed exchange rate regimes) cannot be applied. In addition to changes in exchange rates, Friedman (1953) defines three other adjustment mechanisms and notes that *„The ‚real' adjustment must be made in one way or another, the question is only how,“* (p. 182).

The first adjustment mechanism he proposes – the monetary mechanism – assumes that excess demand or supply in the foreign exchange market is absorbed by the central bank. In a fixed exchange rate system, the central bank satisfies excess demand for the domestic currency by purchasing foreign currency, while absorbing excess supply by selling foreign currency. However, the limited nature of central bank foreign currency reserves makes this mechanism effective only in the short term and unsuitable for lasting adjustments. Moreover, changes in the money supply affect internal economic stability – an increase may cause inflation, while a decrease may slow GDP growth.

The second option involves adjustment through changes in domestic prices (i.e., adjusting the price of domestic production on foreign markets) and incomes (i.e., adjusting the price of foreign production on the domestic market). This is commonly referred to as two separate mechanisms – "price" and "income". As prices and incomes are generally not flexible, it is more likely that unemployment will rise rather than wages decline. Similarly, GDP growth may slow down, as the adjustment takes place through quantities rather than prices. Consequently, Friedman (1953) concludes that the general focus on internal stability and the policies adopted to maintain it, together with low price and income flexibility, will prevent this mechanism from functioning as a fast and effective adjustment tool.

The last mechanism that prevailed during the dollar gold standard era and substantially hindered the emergence of global trade links and the world economy, is direct control over transactions involving the exchange of currencies. This control had the form of either barriers to trade or policy tools aimed at encouraging exports and discouraging imports, typically through tariff policy, with the aim of achieving a balanced current account. From a liberal economic perspective, Friedman considers this mechanism to be the least desirable of all and believes that the loosening of currency regimes and the global transition to floating is *„…the fundamental prerequisite for the economic integration of the free world through multilateral trade,“* (Friedman, 1953, p. 203).

For illustration, let us consider a situation in which two territories (A and B) are under a fixed exchange rate regime and there is a reduction in demand for output from territory B in favour of output from territory A. This implies a need for real wage adjustments in both territories (growing in A and declining in B). This will create a pressure for an increase in the price level in territory A, and a pressure for a rise in unemployment in territory B. The subsequent anti-inflationary policy in territory A would have a restrictive impact on both territories (Mundell, 1961).

By removing international trade barriers and joining the monetary union, the countries in the euro area have effectively lost four out of five BoP adjustment mechanisms and are left with real wage adjustment as the only remaining tool, at the cost of internal stability, which is actively countered by policies to maintain employment, stable price level and to support the economy. As a result, imbalances in trade flows persist for a longer period, and the countries form a so-called international disequilibrium system (Friedman, 1953). Within the euro area, this creates export areas that have low inflation thanks to the euro (e.g., Germany) and import areas that are forced to achieve a reduction in real wages through rising unemployment (e. g., Spain) and that would need a higher inflation target for GDP growth.

A change in the exchange rate can cause a change in real income of the same amount and achieve the external economic equilibrium of the country through a change in the internal and external purchasing power of the currency (change in the relative prices of exports and imports) without disrupting the internal stability (Mundell, 1961).

5. Currency regimes and monetary union

A country that issues its own currency is free to choose the exchange rate regime it wants to operate under. There are two standard currency regimes to choose from – floating and fixed exchange rate regimes – or the country can leave its own currency altogether and join a currency union by adopting a foreign currency.

Most countries opt for managed floating (or dirty floating) instead of free (clean) floating. The difference is that central banks reserve the right to enter the currency market to manipulate the exchange rate and thus exercise an autonomous monetary policy.

The main disadvantage of the floating regime is the exchange rate risk that companies face, as discussed in chapter 3.1. Another common argument against floating regimes is that they can create an environment for destabilising speculation in the currency market. It should be noted, though, that for speculation to be destabilising, speculators must support a decline in the currency's price by selling more of it and support a rise in the currency's price by buying more of it, until the exchange rate ceases to be stable. In other words, this would be a situation in which speculators' trades, on average, result in losses (Friedman, 1953).

A fixed exchange rate regime addresses some of the shortcomings of a floating regime, in which a central parity is set and the value of the exchange rate against the selected currency is then maintained by central bank intervention within a defined fluctuation band. Such a system eliminates exchange rate volatility against the selected currencies and thus creates an environment of stable currency prices with trading partners whose currencies are pegged or stable in relation to the domestic currency.

However, this system is not without flaws either and there are several disadvantages associated with this system as well. The most important drawback seems to be the loss of the exchange rate BoP adjustment mechanism, as discussed in chapter 4.2. Other disadvantages include the loss of autonomous monetary policy and control over the domestic money supply, and the considerable requirements on central banks' foreign exchange reserves. Central banks can reduce the value of the domestic currency by issuing additional currency, subject to monetary policy goals, but they can strengthen the currency only through the sale of foreign currency reserves, which are inherently limited.

Moreover, the pressure to change the value of the exchange rate regularly reaches a level requiring occasional changes in the central parity, that are usually delayed until the direction of the adjustment is absolutely certain, leading to a speculation in such an extent that every change in the central parity is an opportunity for an economic crisis (Friedman 1953, p. 163).

There is another option: joining a monetary union (CU). A CU has many features in common with the system of fixed exchange rates. By contrast, a country in a monetary union loses its own central bank, making adjustments to the exchange rate impossible, as the national currency no longer exists. Another difference is the complete loss of autonomous monetary policy: inflation targeting, interest rate setting and reserve requirements are set at the level of the entire monetary union. However, monetary union provides deep integration and the effect of monetary unions on international trade between members is estimated to be higher than the mere absence of exchange rate volatility, i.e., a fixed ER peg (Rose, 2000), suggesting that currency unions may foster trade not only through exchange rate stability, but also through institutional credibility and economic integration.

5.1. Optimum Currency Area theory and EMU

Just like the Bretton Woods system of fixed exchange rates, a currency union is not universally suitable. However, under certain conditions, it may be beneficial for two or more regions to share a currency. In simple terms, if the chosen monetary regime allows the maintenance of an external balance in traded goods without distorting the internal stability, such a currency regime is optimal (Kenen, 1969).

Mundell (1961) was among the first to attempt to answer the question of what such areas should look like and thus provide a definition of an optimum currency area (OCA). He suggests that OCA is a territory that is coherent in terms of production factors (labour and capital) mobility. The production factors in such a region must be therefore highly mobile for internal adjustment through geographical reallocation in response to an asymmetric shock to be achieved. At the same time, mobility must be relatively low in relation to neighbouring regions. In general, greater emphasis is placed on mobility of labour as it is significantly lower than in the case of capital, making it more difficult for labour to meet the condition of mobility of production factors.

However, as McKinnon (1963) or Kenen (1969) pointed out, mere geographical mobility of labour is not sufficient, and perfect occupational-mobility between sectors, i.e., homogeneous labour, combined with very specific demand and production conditions (such that the marginal product of relocated labour is just high enough to absorb the market imbalance) would be necessary. In this case, then, it should be single-product regions or regions producing close substitutes, with similar capital and labour requirements, that can share a currency more easily. Kenen (1969) draws a similar conclusion as Mundell (1961), stating that it is not possible for each single-product region to issue its own currency. Indeed, such an arrangement would lead to economic subjects being deprived of a stable-valued liquid currency that would function as an effective means of exchange, as pointed out by McKinnon (1963).

According to Kenen (1969), optimum currency areas consist of countries whose production and exports are highly diversified and have a similar structure (also known as the Kenen’s criterion). This is because such economies don't have to undergo changes in the terms of trade so often, and benefit from more stable employment, as no single export sector dominates. Diversified economies are less dependent on a single industry and thus less prone to asymmetric shocks. Nevertheless, the risk cannot be eliminated entirely, and it is essential that regions sharing a currency are part of a broader fiscal union. This would constitute a system of risk sharing and the dissolution of asymmetric economic shocks between regions. It would also enable transfer payments to cushion the impact of regional recessions.

Two additional conditions for the OCA have been proposed in the literature: sufficiently large trade linkages between territories (also known as the McKinnon's criterion) and synchronisation of business cycles (and thus economic shocks), which ensures that regions experience economic expansions and recessions at similar times.

In general, international trade may lead to different macroeconomic effects. If countries specialize in different sectors, it may cause a desynchronization of business cycles. Conversely, if they specialize in different stages of the same value chain, it may promote synchronization of business cycles. Since the effect of monetary union in this question is theoretically ambiguous, Frankel and Rose (1998) have turned to empirical analysis and questioned the validity of both conditions due to their endogenous nature. An increase in trade flows between members of the pre-EMU monetary unions resulted in a synchronisation of business cycles. Assuming that the increase in trade is caused by entry into a currency union, *„a country is more likely to satisfy the criteria for entry into a currency union ex post than ex ante,"* (Frankel & Rose, 1998, p. 1024). This finding supports the idea that countries may become more suitable for currency union membership after joining the union – not before.

The first two OCA criteria remain relevant, however, and according to Krugman (2013), the OCA theory proved to be true, it only underestimated the consequences of non-fulfilment of the conditions for regions to share a currency and it was not taken seriously enough in the creation of the euro area. He identifies, for example, the Euro-crisis as a direct consequence of the absence of the exchange rate as a balance of payments adjustment mechanism.

The core problem was the structural inability of eurozone member states to adjust to asymmetric shocks in the absence of national monetary policy and without mechanisms such as fiscal transfers and without the lender of last resort. This vulnerability was further amplified by the fact that investors priced sovereign bonds across the eurozone almost uniformly, disregarding the actual solvency and external balance of individual member states. This mispricing enabled large current account deficits to persist and contributed to the accumulation of macroeconomic imbalances. As Krugman (2013) notes, this systemic vulnerability turned into a full-blown crisis once capital inflows reversed, leaving peripheral economies exposed and unable to recover through traditional exchange rate adjustment.

It is clear that EMU does not meet the criteria of the OCA, and when compared to e.g., the USA, that are generally considered a successful monetary union project (although it meets the conditions rather relatively), EMU has *„...limited labour mobility and virtually no fiscal integration,"* (Krugman, 2013, p. 443).

Nevertheless, Krugman (2013) outlines the conditions under which the euro area could function successfully in the long run. The first measure should be the introduction of bank support throughout the euro area, that would be set up in such a way that the aid provided to the banks does not undermine their solvency (i.e., aid other than loans). Secondly, he proposes that the ECB should begin to act as the lender of last resort, following the example of sovereign central banks. The final measure he proposes to maintain the stability of the euro area is to raise the inflation target so that areas that need to reduce real wages can do so by slowing nominal wage and price growth relative to the rest of the euro area, rather than increasing unemployment.

5.2. Costs and benefits of entering a monetary union

This chapter summarises the arguments presented in chapters 3 and 4, supplementing them with additional points from Krugman et al. (2018) to provide a comprehensive overview.

When a country joins a monetary union, the costs associated with managing exchange rate risk and executing foreign currency transactions disappear in trade with other members (see chapters 3.1 and 3.3). This simplifies the calculation of expected revenues, costs and prices. A decline in trade costs is expected to lead to increased international trade and greater capital mobility. Another argument is that a higher trading volume of the shared currency compared to a smaller national currency leads to a more stable exchange rate against third-country currencies and a more stable domestic (union) price level. At the same time, a larger central bank may have a stronger capacity to maintain exchange rate stability.

A country joining a currency union faces costs including the loss of an autonomous monetary policy. This leads to inflation targeting being set at the level of the entire currency union, which may not always be ideal. The country loses the ability to respond to asymmetric shocks via monetary policy. The second significant cost is the loss of the balance of payments exchange rate adjustment mechanism (see chapter 4.2). At the same time, the autonomy of the fiscal policy will also be reduced, as it will have to comply with union rules on public finance sustainability. Finally, if the monetary union project ultimately fails, member countries may face the high costs of its disintegration.

Although it is difficult to clearly separate microeconomic and macroeconomic effects due to the complex interconnections within the economy, initial benefits from monetary integration are often observed at the micro level, whereas the initial costs tend to manifest at the macroeconomic level. However, despite the economic arguments, public support remains a decisive factor. Interestingly, the reluctance to adopt the euro in the Czech Republic appears to stem not only from institutional concerns, but also from public scepticism. If public backing were stronger, the government would likely be more willing to proceed with adoption.

5.3. Trade effect of a monetary union in the literature

Irrespective of the theory of optimum currency areas and the suitability of territories for the formation of a currency union, the arguments about the elimination of exchange rate risk and the decrease in transaction costs leading to an increase in trade interdependence with other members of the currency union are valid.

This is what Rose (2000) concludes in his paper, whose primary objective is to estimate the effect of exchange rate volatility and currency union on trade separately. He is one of the first authors who work with the effect of a currency union instead of estimating the effect of reducing exchange rate volatility to zero. He concludes that the effect of sharing a currency is many times larger than simply eliminating volatility (in a fixed exchange rate regime). According to his panel data analysis, countries sharing a currency trade more than 3 times as much with each other (ceteris paribus) than if they did not share a currency. However, a major weakness of this analysis is that it was conducted before the euro area was formed, and the currency unions in his dataset are typically territories that are significantly different from EMU countries – small, poor, or both (Rose 2000, p. 37). The results cannot thus be reasonably extrapolated to EMU countries.

Nevertheless, such a high robust estimate of the effect of currency union on international trade caused a general stir, triggering a stream of follow-up research that has been referred to as "Rosean" literature, and the effect of monetary union on international trade has been named the Rose-effect. The main analytical tool used in the Rosean literature is the gravity model of international trade.

Since Rose (2000), a number of other authors have used the gravity model to estimate the Rose-effect themselves, and their results have generally differed significantly. For example, Pakko and Wall (2001) estimated that sharing a currency has a trade-reducing effect of up to -69%. They also pointed out that different methods lead to significantly different results and advised caution in drawing broad generalisations due to the lack of longer time series data. In contrast, one of the estimates by Alesina et al. (2002, p. 341) was as large as +476%.

Apart from dependence on the number of cross-sectional units, periods and focus on different currency unions, one possible explanation for the large variability in estimates is that some were derived from naive gravity models, some from structural gravity models, some from general equilibrium models and some from many variations of specifications between them, which may have differed from study to study. The first estimates were mostly naive gravity estimates based on cross-sectional data or pooled OLS.

After only a few years, it was possible to perform one of the first meta-analyses of the 34 studies published at that time. A full 92% of the point estimates were positive, 43% exceeded a number that implies that currency union doubles trade and 29% of the estimates implied that currency union triples trade (Rose and Stanley 2005).

Rose & Stanley (2005) found publication bias of two types in the literature at the time. The first type of publication bias is due to a preference for papers whose Rose-effect estimate is in the expected direction (i.e., an increase in international trade). The second type of bias is associated with the publication of papers whose results are statistically significant. Nonetheless, they confirmed the presence of a true positive trade effect of the currency union, adjusted for publication bias, between 20 and 80% (with a point estimate of 47%). They thus robustly rejected the hypothesis of no effect of the currency union on trade.

Interestingly, when combining results from multiple studies, the authors did not weight the estimates by their precision (i.e., the inverse of the standard errors), as recommended by Havránek (2010), who considers it standard meta-analytic practice. Rose and Stanley (2005, p. 350) instead summarize that *"while we have strong views about the quality of some of these estimates, each estimate is weighted equally; alternative weighting schemes might be regarded as suspect."*

This meta-analysis has two shortcomings, that have been pointed out by the authors themselves. The first is that their meta-regression models have remaining excess variation in the CU estimates which is still to be explained. The second is that the meta-analysis performed fails to distinguish systematic bias across the entire literature from the true effect, and if the results from the literature tend to be all biased in the same direction due to a common misspecification, the pooled results from the meta-analysis also contain this bias (Rose and Stanley 2005, p. 362).

This turned out to be the case when Baldwin and Taglioni (2007) identified three medal errors (Gold, Silver and Bronze) of misspecification of the estimated gravity model that were so common in the Rosean literature that they may have appeared to be standard practice. They showed in their paper what researchers estimate instead of the true gravity equation when committing each of the errors and demonstrated that all three errors lead to a systematic overestimation of the effect of currency union on international trade flows.

The least serious of the errors (Bronze Medal) commonly made by researchers was the use of an incorrect deflator to convert the observed variables from current prices to real prices. In fact, it was common practice in the analyses to convert data on trade flows and the size of each country's GDP measured in current USD to real values using the American Consumer Price Index (CPI) instead of the locally corresponding CPIs, ignoring local differences in price level developments. This practice then creates spurious correlation in the model and leads to false positive estimates. As shown in the paper, this bias can be eliminated by including time dummies. The inclusion of time dummies not only corrects the bias, but their inclusion also removes the need to work with real data, as they absorb all year-specific idiosyncratic shocks, and any deflators thus would not be clearly identifiable from them (Baldwin and Taglioni 2007, p. 811).

The Silver Medal Mistake is related to incorrect transformation of the dependent variable. International trade flows are typically captured in several statistics – once by the exporting country as exports, once by the trading partner as imports. Many authors have chosen to work with the dependent variable averaged bilaterally – the average of exports and imports from both statistics – instead of with direction-specific trade as the theory would suggest. Averaging should lead to the same estimates if done correctly. Since the OLS-estimated equation is log-transformed in multiplicative form, the average should be geometric (i.e., the sum of the logs) and not arithmetic (log of the sum), which is chosen by most authors (Baldwin and Taglioni 2007, p. 807). Such a transformation causes less bias for countries with similar export and import volumes and more bias for countries with unbalanced trade. Correcting for this bias reduces the coefficient estimates for CU significantly.

The Golden Medal Mistake with the most severe implications is ignoring multilateral trade resistance or treating it by including time-invariant exporter and importer dummies in panel data analysis, as suggested by Anderson & van Wincoop (2003) for cross-sectional data, and thus to assume that all multilateral resistance factors are time-constant, which is not correct.

Incorrect treatment of multilateral resistance causes that variables capturing trade costs are strongly correlated with omitted variables included in residuals, leading to an endogenous upward bias. The bias caused by the golden error may account for several hundreds of percent and has been committed, for example, by Rose (2000) (Baldwin and Taglioni 2007, p. 793). Baldwin and Taglioni (2007, p. 811) offer a solution to the Golden Mistake by including time-varying individual country dummies that capture multilateral trade resistance that varies over time, combined with time-invariant country-pair dummies that remove the bias stemming from the correlation between the included determinants of trade flows and unobserved variables.

While Anderson and van Wincoop (2003) and Baldwin and Taglioni (2007) focused mainly on the inconsistency of the application of the gravity model in published studies with its theoretical foundations, Havránek (2010) analysed the systematic dependencies of the magnitude of Rose-effect estimates on study design using a meta-regression approach. In his meta-analysis, he concludes that it is crucial to distinguish between studies on the euro and on other currency unions because the two subsamples tell very different stories and only studies focusing on the EMU should be used for policy recommendations within the EU.

Glick and Rose (2016) reached similar findings when they replicated their estimates using available data for EMU. Specifically, they argue that different currency unions have different effects on international trade, that the choice of period and countries included in the dataset clearly affects the results of the econometric analysis, and that estimates of the effect of EMU must be modelled differently than estimates of the effect of currency unions in general. In doing so, Rose confirmed his own doubts about the possibility of extrapolating the results of his original paper (2000) to the countries of the European Union.

The second important outcome of Havránek's meta-analysis is the detection of a strong publication bias of both types, as reported by Rose and Stanley (2005). Therefore, articles with statistically insignificant or negative Rose-effect estimates were not published between 2000 and 2008 in favour of those with significant estimates and with estimates with the expected direction. Havránek (2010) goes on to estimate the true Rose-effect corrected for publication bias and concludes that *"...beyond publication bias, there is a significant and huge Rose-effect of the currency unions other than the euro, more than 60%; but no effect at all for the euro area,* " (Havránek 2010, p. 254). The literature on Rose-effect estimates for non-EMU countries suffered from significantly less publication bias.

According to this meta-analysis, a higher Rose-effect was reported in papers using panel data for analysis (it could be due to improper treatment of multilateral resistance) and in papers where one of the authors was Rose. Conversely, lower estimates were reported in articles where one of the authors was Baldwin, articles focusing on EMU, articles with a high number of cross-sectional units, articles focusing on longer time periods and covering more periods, and articles published in journals with higher impact factors (Havránek, 2010). Havránek (2010) also points out that Rose-effect estimates may vary across countries and sectors, and it is thus not appropriate to apply the estimates universally.

Havránek's meta-analysis works only with those estimates that were preferred by the authors of the analysed papers. In a way, Polák (2019) goes one step further by including all estimates contained in the articles in the meta-analysis, in addition to expanding the sample of estimates with the results of new studies.

A positive finding is that publication bias began to decrease over time after the publication of the meta-analysis by Havránek (2010) and it is currently not nearly as large. However, even Polák (2019) finds the difference in estimates between the so-called "working papers" and published articles consistent with the expected publication bias of the first type. At the same time, articles in high-quality journals contain lower estimates than articles in lower-quality journals. In contrast, articles with higher estimates tend to be more cited because of their higher attractiveness.

Adjusting for publication bias (including only the estimates preferred by the authors of the analysed papers) leads to a similar result as in Havránek (2010): the average reported increase in trade due to the euro adoption is 3%, but the estimate is not statistically significantly different from zero. If we consider only studies published after Havránek's meta-analysis, or select only the preferred estimates, we will find no effect of the euro on international trade. Including all published estimates leads to the conclusion that the Rose-effect of the euro can be expected to be between 2 and 6%.

According to Polák’s (2019) meta-analysis, lower estimates of the Rose-effect can be obtained by using disaggregated (e.g., sectoral) data, including many observations in the sample, or using dummy variables capturing Free Trade Agreements (FTAs). His results are thus consistent with the previous important meta-analysis.

The potential Rose-effect specifically for the Czech Republic was estimated, for example, by Festoc et al. (2017) using sectoral data. But their gravity model works with an inappropriate sample both in terms of cross-sectional units (21 rich industrialised countries, 11 of which are eurozone countries and 10 non-eurozone countries) and time periods (years between 1993 and 2008), and the method of calculating the Rose-effect assumes insignificant differences in the economic structures of the countries in the sample and in the whole Central and Eastern European (CEE) region.

6. Trade effect of Czech euro adoption

6.1. Data used in analysis

This thesis uses two main data sources. The first source is the Gravity for Undergrads (GU) dataset, compiled by Yotov (2025) and based on the United Nations (UN) Comtrade Database. This dataset contains trade data and basic gravity variables for the world's 100 largest exporters (for a full list of countries, see Appendix D) between 1990 and 2023, covering 98.9% of world exports, 97.7% of world imports and 98.3% of world GDP. If data were available for all countries and years, the dataset would comprise 336,600 observations. However, the GU dataset is imbalanced, with missing data mainly from the early 1990s for countries that were disintegrating or merging, such as countries of the former Soviet Union. This leads to a total of 320,920 observations.

The GU dataset has one key limitation. It does not include data on intra-national trade flows, which are essential for general equilibrium analysis because they form part of countries' total expenditure and output and are used to benchmark international trade flows.

The second data source is the International Trade and Production Database for Simulation (ITPD-S), compiled by Borchert et al. (2024). This dataset contains disaggregated sectoral data on both international and intra-national trade flows for 265 countries covering 170 industries between 1986 and 2019 (for a full list of countries, see Appendix E)

The dataset is therefore very extensive and contains almost 300 million observations, most of them from administrative data sources, and missing data are imputed by various methods to make the dataset fully balanced. See the ITPD-S Technical Documentation (Borchert et al., 2024b) for full details on data sources and imputation methods.

Note that intra-national trade flows or domestic market absorption cannot be calculated by subtracting total exports from GDP. This is because GDP statistics are based on value added, which only contains the value of final products, whereas trade statistics are based on absolute value, which also contains intermediate products and repeated exports. Therefore, such calculation would systematically underestimate domestic trade flows. To ensure consistency between the variables, domestic trade must be calculated as gross industry production minus industry exports.

6.1.1. Dependent variable

The dependent variable in the models is the aggregate value of bilateral exports supplemented by domestic trade flows.

For this analysis, export statistics used in ITPD-S are preferred to import statistics because export reporting determines the value and place of payment of value-added tax within the European Union. Therefore, it can be assumed that export data will be more accurately documented in the sample countries than import data, which tends to be more accurate in cases where international trade involves customs procedures or import barriers.

The trade is treated as paired directional variable – it depends on where to a where from the volume of exports moved from each year and the value of exports is thus information related to organized (exporter, importer) pairs. Working with directional trade data is consistent with theory. However, since the gravity equation should apply to all expenditure, averaging the data yields the same results, as demonstrated by Baldwin and Taglioni (2007).

ITPD-S trade data is recorded at free on board (FOB) delivery parity. This means that the value of the goods is captured when they leave the exporting country, excluding the cost of transportation and insurance to the destination. The trade is in millions of current (nominal) US dollars. The conversion to real values is replaced by the inclusion of time-varying country dummies to capture the varying price level developments.

6.1.2. Explanatory variables

Since the underlying estimated model includes both time-invariant pair fixed effects and time-varying individual fixed effects, many potentially relevant explanatory variables are implicitly accounted for by these controls.

For example, variables indicating whether a pair of trading partners shares a border, language, or religion are time-invariant and thus absorbed by the pair fixed effects. Similarly, variables like GDP or population, which vary over time at the individual level, are captured by the individual time-varying fixed effects and therefore cannot be separately identified.

What remains relevant, though, are pair variables indicating trade preferences, FTAs, and the sharing of currency, as these have variation over time.

Therefore, a dummy variable was created, which takes the value 1 when both trading partners are EU members in each period, and another analogous variable for cases when they are members of the eurozone. The establishment of the euro area was defined as the year of launch of the cashless euro (i.e., 1999). In further analysis, the use of the year of launch of the cash euro (2002) could be considered.

One of the steps in GE analysis involves estimating a reduced model with distances between partners without paired FE. In this step, the population-weighted distance in kilometres from the Dynamic Gravity Dataset (Gurevich & Herman, 2018) was used. All pair observations that include the RoW aggregate were assigned the average distance of the areas outside the scope from the areas belonging to the top 48 CZE partners + CZE. For intra-national trade flows, a distance of 100 km was used, following common practice in the literature when more precise spatial data are not used.

6.1.1. Panel sample and aggregation

As GE analysis in Stata is highly computationally demanding, the dataset had to be reduced to a manageable size. This was done in two steps.

In the first step, the ITPD-S dataset was limited to 100 countries from the GU dataset that sufficiently cover total world trade and GDP. The excluded territories caused inconsistent estimates when aggregated on different sample sizes from the ITPD-S.

In the second step, the TOP 48 trading partners of the Czech Republic were defined based on the GU dataset, covering 97.7% of total Czech exports and 98.1% of total Czech imports. All EU countries except Cyprus, Estonia, Latvia, Luxembourg and Malta and all G20 countries except Argentina passed this filter (for a complete list of countries in sample, see Appendix F). The Czech Republic was added, and the remaining countries were aggregated into a single Rest of the World (RoW) item, resulting in a panel with 50 cross-sectional units, 2,500 pairs (both inter- and intra-national trade), 26 years (from 1994 to 2019) and total of 65,000 observations. The dataset took on a structure that is presented in simplified form in Table 3 for two periods and four countries.

All industries corresponding to services were removed from the ITPD-S dataset prior to industry aggregation, so that the total trade data covered industries falling under Agriculture, Manufacturing, and Mining and Energy, making it consistent with the UN Comtrade Database. See Appendix B for a comparison of the GU and ITPD-S datasets, as well as a comparison of the reduced-form estimates based on each of them. For a list of International Standard Industrial Classification (ISIC) codes for individual industries included in each sector, see Appendix G.

Table 3: Dataset structure

year	exporter	importer	trade	EU	Euro	Euro_c	DIST	pair_id
2018	AUT	AUT	156,175	0	0	0	100	100
2018	AUT	CZE	5,432	1	0	1	248	108
2018	AUT	DEU	44,603	1	1	1	584	109
2018	AUT	POL	4,555	1	0	0	525	132
2018	CZE	AUT	7,921	1	0	1	248	108
2018	CZE	CZE	174,454	0	0	0	100	438
2018	CZE	DEU	52,077	1	0	1	505	439
2018	CZE	POL	9,060	1	0	0	376	462
2018	DEU	AUT	65,586	1	1	1	584	109
2018	DEU	CZE	46,520	1	0	1	505	439
2018	DEU	DEU	1,836,740	0	0	0	100	480
2018	DEU	POL	60,028	1	0	0	712	503
2018	POL	AUT	4,922	1	0	0	525	132
2018	POL	CZE	14,165	1	0	0	376	462
2018	POL	DEU	59,535	1	0	0	712	503
2018	POL	POL	397,011	0	0	0	100	1140
2019	AUT	AUT	147,548	0	0	0	100	100
2019	AUT	CZE	5,027	1	0	1	248	108
2019	AUT	DEU	41,920	1	1	1	584	109
2019	AUT	POL	4,061	1	0	0	525	132
2019	CZE	AUT	7,331	1	0	1	248	108
2019	CZE	CZE	182,551	0	0	0	100	438
2019	CZE	DEU	49,589	1	0	1	505	439
2019	CZE	POL	8,264	1	0	0	376	462
2019	DEU	AUT	61,557	1	1	1	584	109
2019	DEU	CZE	44,145	1	0	1	505	439
2019	DEU	DEU	1,790,116	0	0	0	100	480
2019	DEU	POL	52,774	1	0	0	712	503
2019	POL	AUT	5,204	1	0	0	525	132
2019	POL	CZE	13,728	1	0	0	376	462
2019	POL	DEU	59,289	1	0	0	712	503
2019	POL	POL	401,815	0	0	0	100	1140

Source: Author's own processing

6.2. Reduced-form estimates

This section summarises the results of the reduced form of the gravity model, which was used as the basis for the GE analysis. This model corresponds to the general notation (15) and its econometric estimation form (21). The reason for including it is that the results based only on a reduced-form model differ not only in the size of the estimate but even in the direction, which highlights the importance of the methods used for estimation.

Based on the reduced model, the point estimates of the effects of EU and eurozone membership on international trade flows are +10.5% and -4.2%, respectively. These estimates are statistically significant at the 5% significance level.

Table 4: Reduced-form gravity model

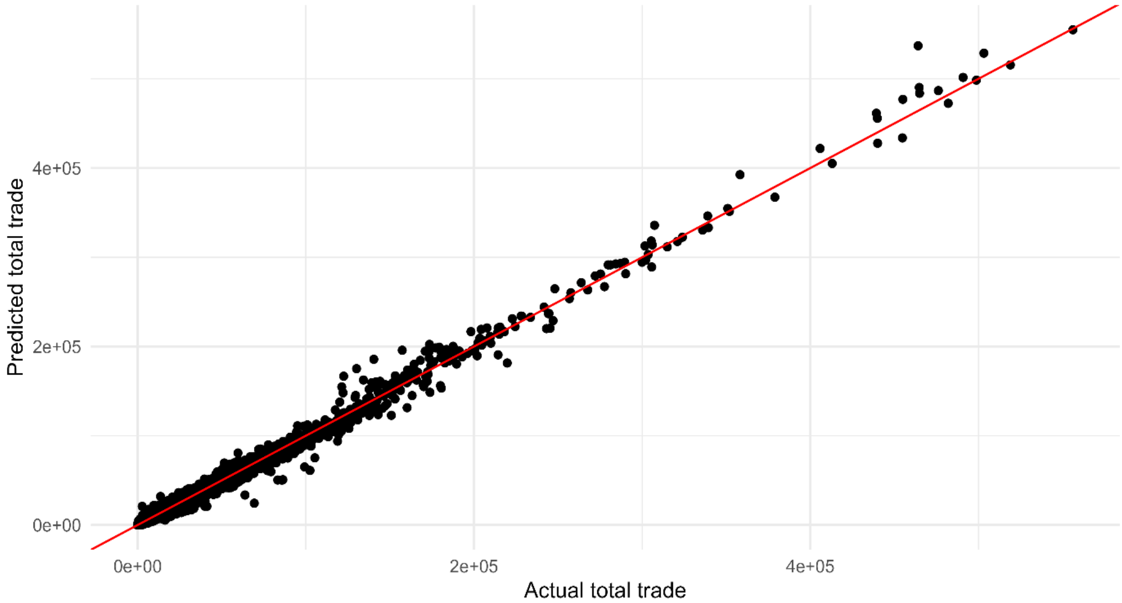
Dependent Var.:	trade
EU	0.1000*** (0.0172)
Euro	-0.0430* (0.0168)
Fixed-Effects:	
exporter_year	Yes
importer_year	Yes
exporter_importer	Yes
S.E. type	Heteroskedas.-rob.
Observations	63,700
Squared Cor.	0.99233
Pseudo R2	0.99140
BIC	8,083,337.7
RMSE	1,432.4
AIC	8,037,574.9

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Source: Author's own processing

As shown in the following figure, which compares actual values with those predicted by the model, this model shows a very good fit to the observed data, with predicted values closely tracking actual trade flows. The red line passes through points where the values on the x-axis are equal to the values on the y-axis.

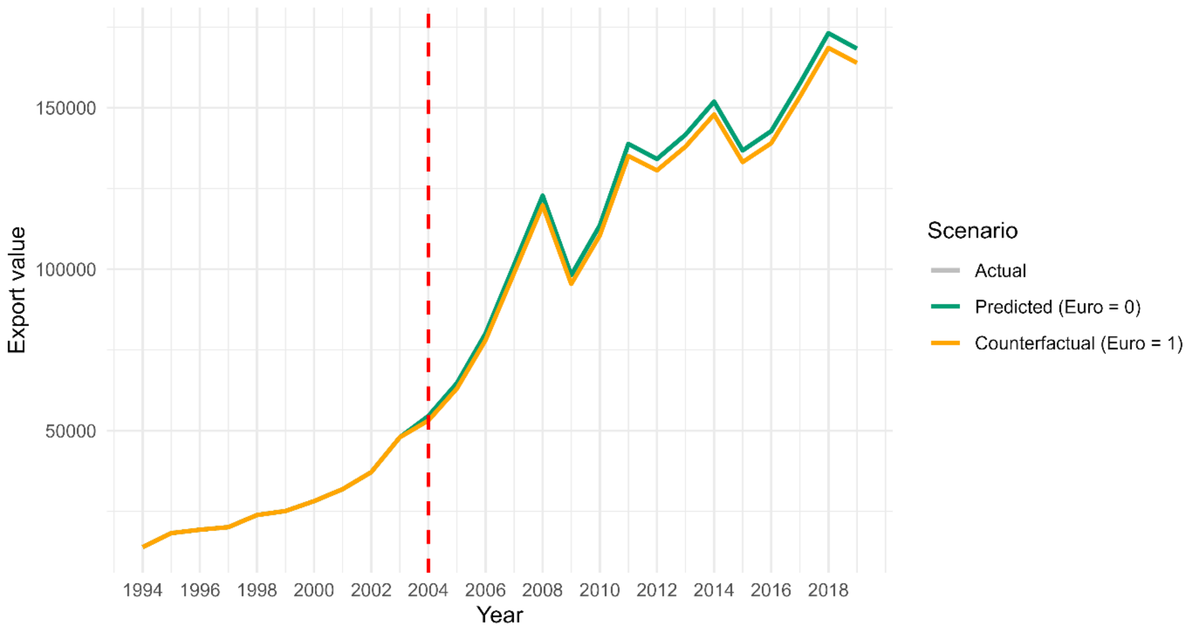
Figure 1: Actual trade vs. predicted trade by the reduced model



Source: Author's own processing

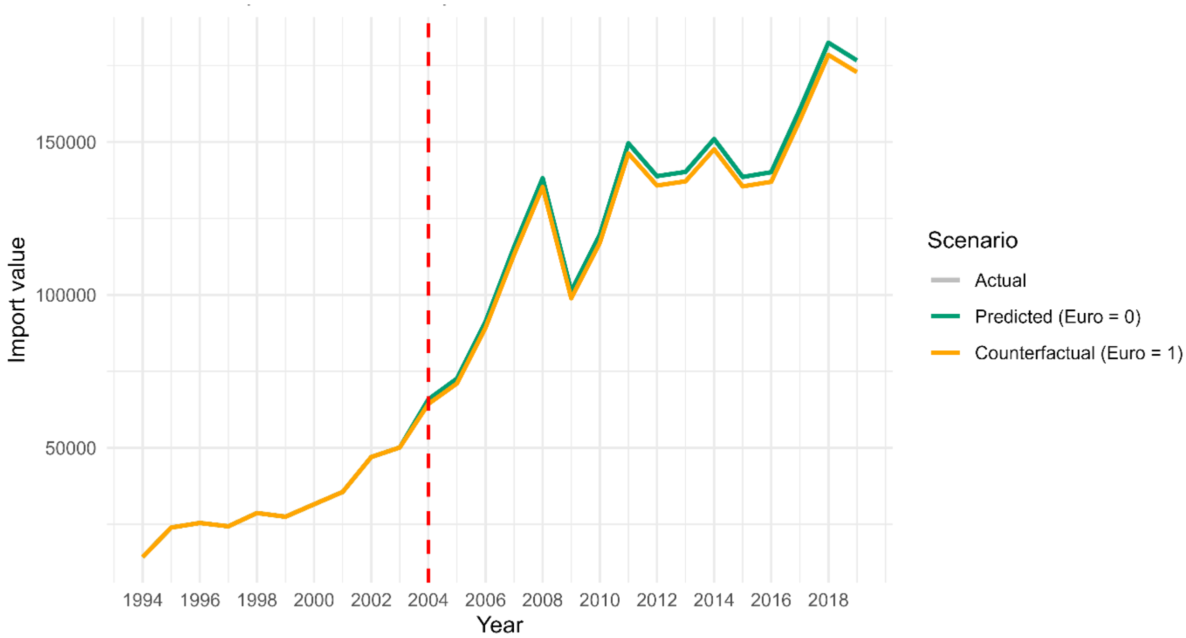
When we compare the model's predictions for two scenarios – one actual, in which the Czech Republic is not in the eurozone, and one counterfactual, in which it joined the eurozone in 2004 – eurozone membership is predicted to reduce exports and imports by an average of 2.6% and 2.2%, respectively. Note that the model predictions in Figure 2 and Figure 3 for the non-euro scenario (green line) overlap with the actual values (grey line), effectively covering them in the figure. The yellow line represents the predictions of the Czech exports and imports for the counterfactual scenario.

Figure 2: Czech exports predicted by the reduced model



Source: Author's own processing

Figure 3: Czech imports predicted by the reduced model



Source: Author's own processing

However, these estimates have two major shortcomings and do not necessarily imply that euro area membership would have a negative impact on Czech trade flows.

The first limitation is that they capture the average overall effect of euro area membership for all countries across all periods and do not consider differences in the effects on individual member states. The prediction for the scenario in which the Czech Republic is in the eurozone is also based on this effect.

The second (more important) limitation is that while this model includes high-dimensional fixed effects (pair, exporter-time and importer-time) to control for multilateral resistance, it does not permit endogenous IMR and OMR changes in response to policy shocks. In addition, the model does not allow for reallocation effects (trade diversion) and adjustments in income and expenditure.

As a result, estimates based on GEPPML are positive, as shown in the chapter 6.3.

6.3. GEPPML: Counterfactual simulation of Czech euro adoption

The results below are based on a counterfactual simulation in which the Czech Republic is assumed to have adopted the euro in 2004, with an elasticity of substitution (σ) set to 7, following Head & Mayer (2014).

Table 5 shows the estimated general equilibrium effects of the Czech Republic's membership in the euro area on countries with an expected increase in their total exports under the counterfactual. For clarity, countries with an estimated negative impact on exports are presented in Table 6. Both tables are sorted by the absolute value of the estimated percentage change in exports. In Table 5 and Table 6, the 10 largest trading partners of the Czech Republic are highlighted in bold.

Table 5: Estimated positive GE effects of Czech euro adoption

Country	Eurozone	Percentage change in:				
		Exports	Real GDP	IMR	OMR	Prices
CZE	Yes*	5.14	0.98	-0.57	-0.48	0.41
AUT	**Yes**	**0.23**	**0.03**	**-0.01**	**-0.03**	**0.03**
DEU	**Yes**	**0.21**	**0.02**	**0.00**	**-0.03**	**0.02**
ITA	**Yes**	**0.10**	**0.01**	**0.00**	**-0.01**	**0.01**
ESP	Yes	0.08	0.00	0.00	-0.01	0.01
GRC	Yes	0.07	0.00	0.00	-0.01	0.01
FRA	**Yes**	**0.07**	**0.01**	**0.00**	**-0.01**	**0.01**
FIN	Yes	0.06	0.01	0.01	-0.01	0.01
NLD	**Yes**	**0.06**	**0.01**	**0.00**	**-0.02**	**0.01**
BEL	Yes	0.05	0.01	0.00	-0.01	0.01
PRT	Yes	0.04	0.00	0.00	-0.01	0.01
IRL	Yes	0.02	0.01	0.01	-0.01	0.01
CAN	No	0.01	0.00	0.01	-0.01	0.01
IDN	No	0.01	0.00	0.01	-0.01	0.01
SGP	No	0.01	0.00	0.01	-0.01	0.01
SAU	No	0.00	0.00	0.01	-0.01	0.01
MEX	No	0.00	0.00	0.01	-0.01	0.01
ARE	No	0.00	0.00	0.01	-0.01	0.01
AUS	No	0.00	0.00	0.01	-0.01	0.01
MYS	No	0.00	0.00	0.01	-0.01	0.01
IND	No	0.00	0.00	0.01	-0.01	0.01
PHL	No	0.00	0.00	0.01	-0.01	0.01

Table 5: Estimated positive GE effects of Czech euro adoption (continued)

Country	Eurozone	Percentage change in:				
		Exports	Real GDP	IMR	OMR	Prices
VNM	No	0.00	0.00	0.01	-0.01	0.01
THA	No	0.00	0.00	0.01	-0.01	0.01
JPN	No	0.00	0.00	0.01	-0.01	0.01
BRA	No	0.00	0.00	0.01	-0.01	0.01
KOR	No	0.00	0.00	0.01	-0.01	0.01

* “Yes” in a counterfactual scenario from 2004 onwards.

Source: Author's own processing

According to the model, membership in the euro area would reduce international trade costs for Czech firms and consumers by approximately 0.5%. Interestingly, the model predicts a slightly larger decline in IMR (-0.6%), with an expected positive impact on imports, than in OMR (-0.5%), with an expected positive impact on Czech exports.

The 0.5% decline in the weighted average of all outbound multilateral trade costs faced by Czech exporters (OMR) would lead to a 5.1% increase in exports from the Czech Republic and Czech producers would respond to the higher demand for Czech products in a larger market with lower trade costs by increasing their factory-gate prices by 0.4%. Overall, the Czech real GDP, which is often used as a proxy for welfare, would grow by almost 1%. However, such increases in exports do not always translate into welfare gains if accompanied by deterioration in terms of trade – that is, when import prices rise more than export prices.

The Czech Republic's membership in the eurozone would have the greatest simulated positive effect on trading partners with whom it would share the currency. Austria ranks first, with exports set to increase by 0.2%, followed by Germany (+0.2%) and Italy (+0.1%). The next eight countries are also eurozone members.

However, it is important to note that while the estimated increases in exports by Czech trading partners may reflect increased Czech demand for their goods, they cannot be simply interpreted as an increase in exports into the Czech Republic. The trade flows in the simulation are redirected, and the table thus captures the overall net effects.

Take, as an example, German exporters who, thanks to reduced trade costs, will focus more on trade with Czech partners, but will do so at the expense of, for example, exports to the USA, which have become relatively less attractive. The percentage change in German exports thus represents the net effect on exports, combining increased demand from the Czech Republic with reduced exports to other destinations. At the same time, the change may increase exports in value terms due to improved terms of trade, even if the destination shifts away from the Czech Republic.

Similarly, this type of analysis does not specify the exact distribution of the additional 5% increase in Czech exports across destination countries, but it is safe to assume that the countries in the euro area would enjoy most of the positive, trade-promoting effect. However, a partial reduction in trade costs may also occur with many countries (particularly smaller or emerging markets) whose currencies are not directly traded against the Czech koruna on the foreign exchange market. Instead, these conversions require an intermediary (vehicle) currency, such as the euro or US dollar. This two-step exchange process involving cross-exchange rates leads to higher transaction costs and greater exchange rate volatility, both of which could be mitigated by adopting the euro. This effect is more relevant for currencies that are not directly traded against CZK, such as the Indonesian rupiah, Malaysian ringgit or Singapore dollar, but less so for regional currencies like Polish zloty.

Table 6: Estimated negative GE effects of Czech euro adoption

Country	Eurozone	Percentage change in:				
		Exports	Real GDP	IMR	OMR	Prices
SVK	**Yes**	**-0.17**	**-0.05**	**0.03**	**0.03**	**-0.02**
POL	**No**	**-0.10**	**-0.01**	**0.01**	**0.00**	**0.00**
HUN	No	-0.06	-0.01	0.01	0.00	0.00
AZE	No	-0.06	-0.01	0.01	0.00	0.00
HRV	No*	-0.06	0.00	0.01	-0.01	0.01
ROU	No	-0.05	0.00	0.01	-0.01	0.01
SVN	Yes	-0.04	-0.01	0.01	0.00	0.00
BGR	No	-0.03	0.00	0.01	-0.01	0.00
GBR	**No**	**-0.02**	**0.00**	**0.01**	**-0.01**	**0.01**
UKR	No	-0.02	0.00	0.01	0.00	0.00
DNK	No	-0.02	0.00	0.01	-0.01	0.01
TUR	No	-0.02	0.00	0.01	-0.01	0.01
RUS	**No**	**-0.02**	**0.00**	**0.00**	**0.00**	**0.00**
LTU	Yes	-0.01	-0.01	0.01	0.00	0.00
CHE	No	-0.01	-0.01	0.01	-0.01	0.01

Table 6: Estimated negative GE effects of Czech euro adoption (continued)

Country	Eurozone	Percentage change in:				
		Exports	**Real GDP**	**IMR**	**OMR**	**Prices**
SWE	No	-0.01	0.00	0.01	-0.01	0.01
KAZ	No	-0.01	0.00	0.01	0.00	0.00
NOR	No	0.00	0.00	0.01	-0.01	0.01
ISR	No	0.00	0.00	0.01	-0.01	0.01
CHN	**No**	**0.00**	**0.00**	**0.01**	**-0.01**	**0.01**
ZAF	No	0.00	0.00	0.01	-0.01	0.01
RoW	No	0.00	0.00	0.01	-0.01	0.01
USA	No	0.00	0.00	0.01	-0.01	0.01

* “No”, since the panel ends with 2019 data.

Source: Author's own processing

The country with the largest estimated decline in exports (-0.2%) is Slovakia, which despite also being a eurozone member, could experience a small GDP loss due to trade diversion in favour of the Czech Republic. The decline is likely because the trade-promoting effect between the Czech Republic and Slovakia stemming from the shared currency was outweighed by a diversion of western eurozone imports away from Slovakia and towards the geographically closer Czech Republic. Other countries with estimated negative export effects include Poland, Hungary, Azerbaijan, Croatia, and Romania. These declines may stem from reduced exports to the Czech Republic itself, as well as from the intensified competition for exports to western eurozone countries, partially redirected towards the Czech Republic.

Although the estimated effects expressed as a percentage have higher informative value in this type of analysis, Table 7 provides a framework of reference containing the five largest positive absolute changes and the five largest negative absolute changes. The changes are in millions of current USD and were calculated from export values in 2019, the last year in the analysed dataset. Note that the ranking has changed due to the different sizes of economies.

Table 7: Top export changes in absolute value

Country	%Δ in Exports	2019 values in mil. of current USD	
		Exports	Absolute change
CZE	5.14	199,470	10,262
DEU	0.21	1,493,267	3,147
ITA	0.10	537,748	513
AUT	0.23	171,532	403
FRA	0.07	556,364	390
RUS	-0.02	426,720	-69
HUN	-0.06	122,181	-78
GBR	-0.02	468,322	-110
SVK	-0.17	89,920	-155
POL	-0.10	251,865	-244

Source: UN Comtrade, Author's own processing

Taking 2019 as an example, the change in exports resulting from the Czech Republic's membership in the eurozone would reach the highest absolute values in the Czech Republic and Germany, its largest trading partner. For many countries in the panel, absolute changes would reach tens to hundreds of millions of USD, depending on the baseline export volume.

Given the total volume of international trade, the presented effects are economically significant only for the Czech Republic and a handful of the most affected partner and competitor countries. However, for most of the world, the impact is not dramatic, both because of the small size of the Czech economy in the global context and because of the modest trade-promoting effect of currency sharing.

These estimates (5.1%) are broadly consistent with findings reported in the literature. The recent meta-analysis carried out by Polák (2019) reported an average trade effect of 3% from euro adoption (but not statistically significantly different from zero), and that the effect can be expected to be between 2% and 6% (see chapter 5.3). In this analysis, unfortunately, standard errors and confidence intervals could not be reported due to the computational demands of implementing a full bootstrap procedure in a general equilibrium framework, which would require recalculating the entire model solution for each resample (each takes around 90 minutes). The results presented should therefore be interpreted as deterministic simulations rather than inferentially tested effects. They reflect equilibrium responses to a policy change, rather than empirical forecasts based on observed variation.

6.4. Differences between sectors

Even though sectoral analysis is not the aim of this paper, it should be noted that trade liberalisation, in whatever form, has different impacts on different sectors of the economy. Different responses to currency sharing across sectors may arise from varying price elasticities, the importance of fixed costs or sensitivity to exchange rate volatility.

Since gravity holds at every level of aggregation (Yotov, 2025), the GE simulation was also performed at the level of broad sectors (agriculture, manufacturing, mining and energy) to demonstrate the heterogeneity of sectoral impacts. The largest effect was observed in agriculture, where Czech exports are estimated to increase by 17%. The other two sectors exhibited smaller gains and are not shown here for brevity.

Table 8: Top agriculture export changes

Country	Eurozone	Percentage change in: Exports	Percentage change in: Real industry output
CZE	Yes*	16.78	0.27
AUT	Yes	1.45	0.03
DEU	Yes	0.49	0.06
GRC	Yes	0.20	0.03
ITA	Yes	0.20	0.02
PRT	Yes	0.12	0.02
ESP	Yes	0.11	0.03
NLD	Yes	0.08	0.03
ROU	No	-0.02	0.01
TUR	No	-0.02	0.01
CHE	No	-0.04	0.02
HUN	No	-0.08	-0.01
HRV	No**	-0.10	0.01
SVN	Yes	-0.11	0.00
POL	No	-0.19	0.00
SVK	Yes	-0.75	-0.14

* “Yes” in a counterfactual scenario from 2004 onwards.

** “No”, since the panel ends with 2019 data.

Source: Author's own processing

Although Czech agricultural exports are estimated to grow strongly, real output in the sector would rise by only 0.3%, notably less than the 1% real GDP growth observed in the total-level simulation. The difference between the change of exports and output may partly reflect a substitution of domestic consumption by imports from partner countries, limiting the expansion of domestic production. This would effectively enhance the interconnectedness of agricultural markets, which are often subject to protective policies in order to ensure supply-side stability.

It is therefore important to be aware that the effect of trade policy and changes in trade costs is not uniform across sectors, and different responses can be expected in each industry. Although euro adoption does not reduce trade costs as dramatically as tariff elimination or major regulatory harmonization, a reduction in transaction costs would still likely create groups of winners in industries that would benefit most and losers that would be negatively affected by the change, in line with, for example, the specific factors model, which predicts that returns to sector-specific capital may rise or fall depending on the sector's trade exposure. This underlines the need to complement aggregate analysis with sector-level insights when assessing the economic consequences of trade integration.

7. Policy recommendation

This thesis does not attempt to comprehensively assess whether the Czech Republic is ready to adopt the euro, nor does it aim to recommend when or whether it should do so. However, based on the analysis presented, it is possible to draw a few observations relevant to that decision.

The estimated trade effect of adopting the euro is positive but modest. According to the general equilibrium simulation, real GDP would increase by around 1%, driven by a reduction in trade costs and stronger trade integration with eurozone partners. The effect is economically significant for a small number of countries, including the Czech Republic, but marginal for most of the others.

At the same time, the Czech Republic is already highly integrated into international trade. Trade amounts to almost 150% of Czech GDP (World Bank, 2025), and the EU absorbs around 80% of Czech exports (Eurostat, 2025). The country manages this level of openness with its own currency and without euro membership. It is therefore not clear whether joining the euro would substantially change the country's trade position. Furthermore, recent global shocks have shifted attention toward economic resilience and the risks of overdependence on tightly internationally integrated supply chains.

It is not possible to conclude whether the benefits of euro adoption outweigh the broader economic costs based on this analysis. That depends on priorities beyond the scope of this paper. If the Czech government perceives euro adoption as part of a broader strategy to deepen the country's integration with the EU, then it would make sense to proceed. If, on the other hand, monetary independence and internal stability is a priority, there is no urgent trade-related reason to adopt the euro.

The results suggest that from the trade perspective, euro adoption would help but is not essential. The main question is a political one: to what extent should the Czech Republic aim to align itself with the eurozone?

Conclusion

This thesis aimed to evaluate the argument that joining a monetary union has a trade-promoting effect, using data analysis to estimate the impact of euro adoption on Czech exports.

The model suggests that joining the euro area would reduce international trade costs by approximately 0.5% and lead to a 5.1% increase in Czech exports. As a result, real GDP would rise by nearly 1%. The Czech Republic's eurozone membership would have the strongest simulated positive effect on trade with countries using the euro.

The largest estimated export decline (-0.2%) was found for Slovakia. Other countries with negative effects included Poland, Hungary, Azerbaijan, Croatia, and Romania – possibly due to the reduced exports to the Czech Republic, as well as from the intensified competition for exports to western eurozone countries, partially redirected towards the Czech Republic.

These effects are economically significant for only a few countries both because of the small size of the Czech economy in the global context and because of the modest trade-promoting effect of currency unions. At the same time, the Czech Republic manages very high level of openness with its own currency, and it is not clear whether joining the euro would substantially change the country's trade position.

The findings suggest that there is no urgent trade-related reason to adopt the euro.

Beyond the quantitative findings, the thesis also reviewed key mechanisms of currency sharing and exchange rate regimes, both at micro- and macroeconomic levels, thus providing a broader economic context for interpreting the results.

Finally, two promising directions for further research emerged during the thesis project. These were not given sufficient attention due to either not fitting within the scope of the thesis or limitations in the author's capacity. Firstly, fully transposing the GEPPML analysis from Stata to R would enable estimation using larger datasets, as R provides more optimised functions that would substantially reduce the computational demands of the analysis (e.g., without the need for RoW aggregation or on disaggregated sectoral data). Secondly, a sectoral analysis would provide insight into the heterogeneous effects of currency unions across industries.

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Appendices

For illustrative purposes only, these appendices include a significantly shortened selection of the code that captures its key parts. The complete R Markdown files, Stata Do-files and their results (including logs), which enable full replication, are available as online appendices at https://github.com/vitekpetrzilka/MT. The repository is archived and will remain publicly accessible for verification and replication purposes.

Appendix A: Data preparation in R

For clarity, only abbreviated code snippets are provided in this paper. The complete replicable code and data files are available as an online appendix.

Download and data processing

ECB

Downloading data from the ECB website on EU and Eurozone members:

```
ECB_URL <- "https://www.ecb.europa.eu/euro/intro/html/index.en.html"

ECB_website <- read_html(ECB_URL) %>%
  html_nodes("table") %>%
  html_table(fill = TRUE)
```

Creating a dummy variable (Euro) indicating Eurozone members.

```
Euro <- ECB_website[[1]] %>%
  rename(Adopted_Euro = `Adopted the euro`) %>%
  mutate(Adopted_Euro = str_replace(Adopted_Euro,
                                    "1999 \\(cash since 2002\\)", "1999"),
         Adopted_Euro = str_replace(Adopted_Euro,
                                    "2001 \\(cash since 2002\\)", "2001"),
         Adopted_Euro = as.numeric(Adopted_Euro),
         iso3c = countrycode(Country,
                             origin = "country.name",
                             destination = "iso3c")) %>%
  select(-Country, -"Joined the EU") %>%
  expand_grid(year = 1994:2019) %>%
  mutate(Euro = ifelse(year >= Adopted_Euro, 1, 0)) %>%
  select(-Adopted_Euro)
```

Constructing a counterfactual dummy variable (Euro_c) indicating the euro area including the Czech Republic from 2004 onwards:

```
Euro_c <- ECB_website[[1]] %>%
  rename(Adopted_Euro = `Adopted the euro`) %>%
  mutate(Adopted_Euro = str_replace(Adopted_Euro, "1999 \\(cash since 2002\\)", "1999"),
         Adopted_Euro = str_replace(Adopted_Euro, "2001 \\(cash since 2002\\)", "2001"),
         Adopted_Euro = as.numeric(Adopted_Euro),
         iso3c = countrycode(Country, origin = "country.name", destination = "iso3c")) %>%
  select(-Country, -"Joined the EU") %>%
  add_row(Adopted_Euro = 2004, iso3c = "CZE") %>%
  expand_grid(year = 1994:2019) %>%
  mutate(Euro = ifelse(year >= Adopted_Euro, 1, 0)) %>%
  select(-Adopted_Euro)
```

Constructing EU dummy:

```
euro_info <- ECB_website[[1]] %>%
  rename(Joined_EU = `Joined the EU`,
         Adopted_Euro = `Adopted the euro`) %>%
  mutate(Left_EU = as.numeric(""),
         iso3c = countrycode(Country, origin = "country.name", destination = "iso3c")) %>%
  select(-Country, -Adopted_Euro)

non_euro_info <- ECB_website[[2]] %>%
  rename(Joined_EU = `Joined the EU`) %>%
```

```r
  mutate(Left_EU = as.numeric(""),
         iso3c = countrycode(Country, origin = "country.name", destination = "iso3c")) %>%
  select(-Country) %>%
  bind_rows(tibble(iso3c = "GBR",
                   Joined_EU = c(1973),
                   Left_EU = c(2020)))

europe_info <- bind_rows(euro_info, non_euro_info)

EU <- europe_info %>%
  expand_grid(year = 1994:2019) %>%
  mutate(EU = ifelse(!is.na(Joined_EU) &
                       year >= Joined_EU &
                       (is.na(Left_EU) | year <= Left_EU), 1, 0)) %>%
  select(-Joined_EU, -Left_EU)
```

GU

```r
tmp <- tempfile(fileext = ".zip")
download.file("https://yotoyotov.com/Data__Code__R.zip", tmp)

unzipped <- unzip(tmp, exdir = tempdir())

Gravity_Undergrads_Data.rds <-
  unzipped[grepl("\\.rds$", unzipped) & !grepl("__MACOSX", unzipped)]

GU <- readRDS(Gravity_Undergrads_Data.rds)
```

TOP49 Scope

Defining TOP trading partners.

```r
cz_trade <- GU %>%
  filter(exporter == "CZE" | importer == "CZE") %>%
  mutate(partner = if_else(exporter == "CZE", importer, exporter)) %>%
  group_by(partner) %>%
  summarise(total_trade = sum(trade, na.rm = TRUE)) %>%
  arrange(desc(total_trade)) %>%
  slice_head(n = 49)

cz_top49 <- cz_trade$partner

# SRB do not exist in all periods

cz_top48 <- setdiff(cz_top49, "SRB")

scope <- c(cz_top48, "CZE", "RoW")
```

ITPD-S

Downloading the data.

```r
zip_url <- "https://www.usitc.gov/data/gravity/itpd_s/itpd_s_r1.1_no_names.zip"
zip_path <- "Data/itpd_s_r1.1_no_names.zip"

GET(zip_url, write_disk(zip_path, overwrite = TRUE), progress())

unzip(zip_path, exdir = "Data")
```

Mapping the 14GB dataset without fully loading it:

```r
dataset_path <- "Data/ITPD_S_R1.1_no_names.csv"

ds <- open_dataset(dataset_path, format = "csv")
```

Filtering the scope, aggregating the trade by summing across industries and creating a RoW aggregate:

```r
ITPD_S <- ds %>%
  filter(broad_sector != "Services") %>%
  rename(exporter = exporter_iso3,
         importer = importer_iso3) %>%
  group_by(year, exporter, importer) %>%
  summarise(trade = sum(as.numeric(trade), na.rm = TRUE), .groups = "drop") %>%
  collect()
```

Creating ITPD-S50

Define the scope of the GU dataset.

```r
GU_scope <- union(unique(GU$exporter),
                  unique(GU$importer))
```

Filter the ITPD-S and create consistent RoW aggregate.

```r
ITPD_S50 <- ITPD_S %>%
  filter(exporter %in% GU_scope,
         importer %in% GU_scope) %>%
  filter(year >= 1994, year <= 2019) %>%
  mutate(
    exporter = if_else(!(exporter %in% scope), "RoW", exporter),
    importer = if_else(!(importer %in% scope), "RoW", importer)
  ) %>%
  group_by(year, exporter, importer) %>%
  summarise(trade = sum(as.numeric(trade), na.rm = TRUE), .groups = "drop")
```

Joining with EU and Euro

```r
# Joining with EU

ITPD_S50 <- ITPD_S50 %>%
  left_join(EU %>%
              rename(EU_x = EU),
            by = c("exporter" = "iso3c", "year")) %>%
  left_join(EU %>%
              rename(EU_m = EU),
            by = c("importer" = "iso3c", "year")) %>%
  mutate(EU_x = replace_na(EU_x, 0),
         EU_m = replace_na(EU_m, 0),
         EU = ifelse(exporter == importer, 0, EU_x * EU_m)) %>%
  select(-EU_x, -EU_m)

# Joining with Euro

ITPD_S50 <- ITPD_S50 %>%
  left_join(Euro %>%
              rename(Euro_x = Euro),
            by = c("exporter" = "iso3c", "year")) %>%
  left_join(Euro %>%
              rename(Euro_m = Euro),
            by = c("importer" = "iso3c", "year")) %>%
  mutate(Euro_x = replace_na(Euro_x, 0),
         Euro_m = replace_na(Euro_m, 0),
         Euro = ifelse(exporter == importer, 0, Euro_x * Euro_m)) %>%
  select(-Euro_x, -Euro_m)
```

Adding Euro_c and DIST

Adding counterfactual Euro_c and distance (DIST) to ITPD-S50.

```
ITPD_S50 <- ITPD_S50 %>%
  left_join(Euro_c %>%
              rename(Euro_c_x = Euro),
            by = c("exporter" = "iso3c", "year")) %>%
  left_join(Euro_c %>%
              rename(Euro_c_m = Euro),
            by = c("importer" = "iso3c", "year")) %>%
  mutate(Euro_c_x = replace_na(Euro_c_x, 0),
         Euro_c_m = replace_na(Euro_c_m, 0),
         Euro_c = ifelse(exporter == importer, 0, Euro_c_x * Euro_c_m)) %>%
  select(-Euro_c_x, -Euro_c_m)
```

Adding distance from GU dataset to ITPD-s50.

```
GU_DIST <- GU %>%
  select("exporter", "importer", "year", "DIST")

ITPD_S50 <- ITPD_S50 %>%
  left_join(GU_DIST, by = c("exporter", "importer", "year"))
```

Appendix B: Dataset comparison in R

For clarity, only abbreviated code snippets are provided in this paper. The complete replicable code and data files are available as an online appendix.

Reduced-form estimates

GU and ITPD-S contain all available data. GU50 and ITPD-50 are comparable and contain RoW aggregate. GU50a and ITPD-S50a are comparable and do not contain RoW aggregate.

```
e_GU <- fepois(
  trade ~  0 + EU + Euro
  | exporter_year + importer_year + exporter_importer,
  data = GU,
  fixef.rm = "none")

e_GU50 <- fepois(
  trade ~  0 + EU + Euro
  | exporter_year + importer_year + exporter_importer,
  data = GU50,
  fixef.rm = "none")

e_GU50a <- fepois(
  trade ~  0 + EU + Euro
  | exporter_year + importer_year + exporter_importer,
  data = GU50a,
  fixef.rm = "none")

e_ITPD_S <- fepois(
  trade ~  0 + EU + Euro
  | exporter_year + importer_year + exporter_importer,
  data = ITPD_S,
  fixef.rm = "none")

e_ITPD_S50 <- fepois(
  trade ~  0 + EU + Euro
  | exporter_year + importer_year + exporter_importer,
  data = ITPD_S50,
  fixef.rm = "none")

e_ITPD_S50a <- fepois(
  trade ~  0 + EU + Euro
  | exporter_year + importer_year + exporter_importer,
  data = ITPD_S50a,
  fixef.rm = "none")

GU_estimates <- etable(e_GU, e_GU50, e_GU50a,
                       fitstat = ~. +rmse + AIC + BIC,
                       vcov = "HC1")

print(GU_estimates)
```

```
##                                e_GU              e_GU50              e_GU50a
## Dependent Var.:               trade              trade                trade
##
## EU                  0.0924*** (0.0182) 0.1244*** (0.0167)  0.1472*** (0.0170)
## Euro               -0.1217*** (0.0148)  -0.0405* (0.0167) -0.0544*** (0.0163)
## Fixed-Effects:     ------------------- ------------------ -------------------
## exporter_year                      Yes                Yes                 Yes
## importer_year                      Yes                Yes                 Yes
## exporter_importer                  Yes                Yes                 Yes
## _________________ ___________________ __________________ ___________________
## S.E. type         Heteroskedast.-rob. Heteroskedas.-rob. Heteroskedast.-rob.
## Observations                   320,920             63,016              60,482
## Squared Cor.                   0.98491            0.99249             0.99354
## Pseudo R2                      0.98829            0.99213             0.99199
## BIC                           2.33e+13           7.52e+12            6.44e+12
## RMSE                   1,012,105,874.0    1,462,600,037.0     1,207,444,690.9
## AIC                           2.33e+13           7.52e+12            6.44e+12
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

ITPD_S_estimates <- etable(e_ITPD_S, e_ITPD_S50, e_ITPD_S50a,
                           fitstat = ~. +rmse + AIC + BIC,
                           vcov = "HC1")

print(ITPD_S_estimates)

##                             e_ITPD_S         e_ITPD_S50         e_ITPD_S50a
## Dependent Var.:                trade              trade               trade
##
## EU                0.3048*** (0.0250) 0.1000*** (0.0172)  0.1187*** (0.0175)
## Euro                -0.0098 (0.0224)  -0.0430* (0.0168) -0.0569*** (0.0164)
## Fixed-Effects:    ------------------ ------------------ -------------------
## exporter_year                    Yes                Yes                 Yes
## importer_year                    Yes                Yes                 Yes
## exporter_importer                Yes                Yes                 Yes
## _________________ __________________ __________________ ___________________
## S.E. type         Heteroskedas.-rob. Heteroskedas.-rob. Heteroskedast.-rob.
## Observations               1,940,681             63,700              61,152
## Squared Cor.                 0.99963            0.99233             0.99355
## Pseudo R2                    0.99704            0.99140             0.99116
## BIC                     45,931,637.1        8,083,337.7         6,970,516.8
## RMSE                          864.41            1,432.4             1,163.6
## AIC                     44,915,883.2        8,037,574.9         6,926,313.3
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

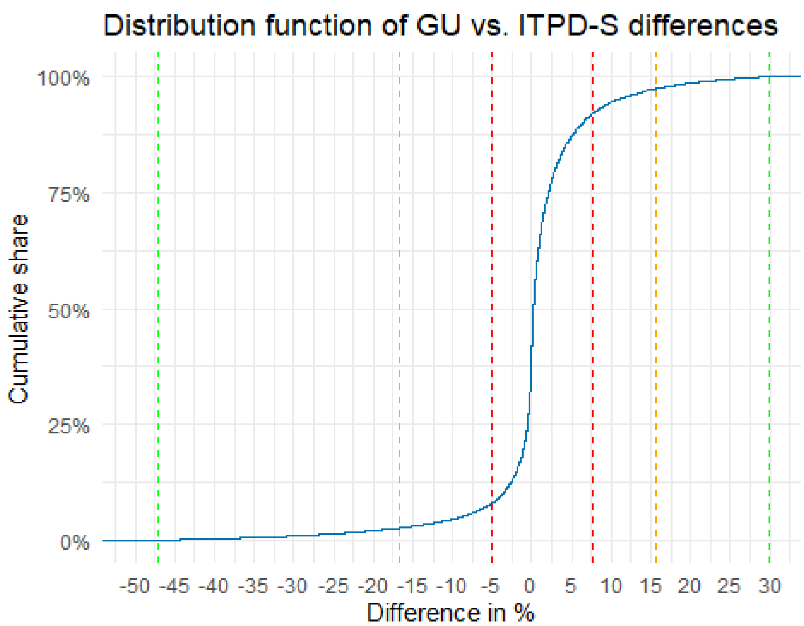
Merging in one dataframe

```
dataset_comparison <- GU50 %>%
  select(exporter, importer, year, trade_gu = trade) %>%
  inner_join(
    ITPD_S50 %>% select(exporter, importer, year, trade_itpd = trade),
    by = c("exporter", "importer", "year")) %>%
  mutate(trade_itpd = trade_itpd*1000000,
         pct_diff = (trade_gu - trade_itpd) / trade_gu * 100)
```

Showing differences of 95 % of the data (green lines), 90 % of the data (orange), and 80 % of the data (red).

```r
ggplot(dataset_comparison, aes(x = pct_diff)) +
  stat_ecdf(geom = "step", color = "#0072B2") +
  scale_x_continuous(limits = c(-50, 30),
                     breaks = seq(-50, 30, by = 5)) +
  scale_y_continuous(labels = percent_format(accuracy = 1)) +
  geom_vline(xintercept = quantile(dataset_comparison$pct_diff,
                                   probs = c(0.025, 0.975), na.rm = TRUE),
             linetype = "dashed", color = "green") +
  geom_vline(xintercept = quantile(dataset_comparison$pct_diff,
                                   probs = c(0.05, 0.95), na.rm = TRUE),
             linetype = "dashed", color = "orange") +
  geom_vline(xintercept = quantile(dataset_comparison$pct_diff,
                                   probs = c(0.10, 0.90), na.rm = TRUE),
             linetype = "dashed", color = "red") +
  labs(
    title = "Distribution function of GU vs. ITPD-S differences",
    x = "Difference in %",
    y = "Cumulative share"
  ) +
  theme_minimal()
```

Figure 4: Distribution function of GU vs. ITPD-S differences



Source: Author’s own processing

Appendix C: Reduced-form analysis

For clarity, only abbreviated code snippets are provided in this paper. The complete replicable code and data files are available as an online appendix.

Reduced-form estimates

Estimating the model for total trade and separate sectors:

```
library(fixest)

total <- fepois(
  trade ~  0 + EU + Euro
  | exporter_year + importer_year + exporter_importer,
  data = ITPD_S50,
  fixef.rm = "none")

agriculture <- fepois(
  trade ~  0 + EU + Euro
  | exporter_year + importer_year + exporter_importer,
  data = ITPD_S50ag,
  fixef.rm = "none")

manufacturing <- fepois(
  trade ~  0 + EU + Euro
  | exporter_year + importer_year + exporter_importer,
  data = ITPD_S50ma,
  fixef.rm = "none")

mining_energy <- fepois(
  trade ~  0 + EU + Euro
  | exporter_year + importer_year + exporter_importer,
  data = ITPD_S50me,
  fixef.rm = "none")

estimates <- etable(total, agriculture, manufacturing, mining_energy,
                    fitstat = ~. +rmse + AIC + BIC,
                    vcov = "HC1")

print(estimates)

##                                 total       agriculture       manufacturing
## Dependent Var.:                 trade             trade               trade
##
## EU                0.1000*** (0.0172) 0.8826*** (0.0362)     0.0157 (0.0174)
## Euro               -0.0430* (0.0168) 0.1301*** (0.0314) -0.0610*** (0.0173)
## Fixed-Effects:    ------------------ ------------------ -------------------
## exporter_year                    Yes                Yes                 Yes
## importer_year                    Yes                Yes                 Yes
## exporter_importer                Yes                Yes                 Yes
## _________________ __________________ __________________ ___________________
## S.E. type         Heteroskedas.-rob. Heteroskedas.-rob. Heteroskedast.-rob.
## Observations                  63,700             63,700              63,700
## Squared Cor.                 0.99233            0.98101             0.99342
## Pseudo R2                    0.99140            0.97719             0.99208
## BIC                      8,083,337.7          962,811.3         6,569,064.9
## RMSE                         1,432.4             97.130             1,199.6
## AIC                      8,037,574.9          917,048.5         6,523,302.1
##
```

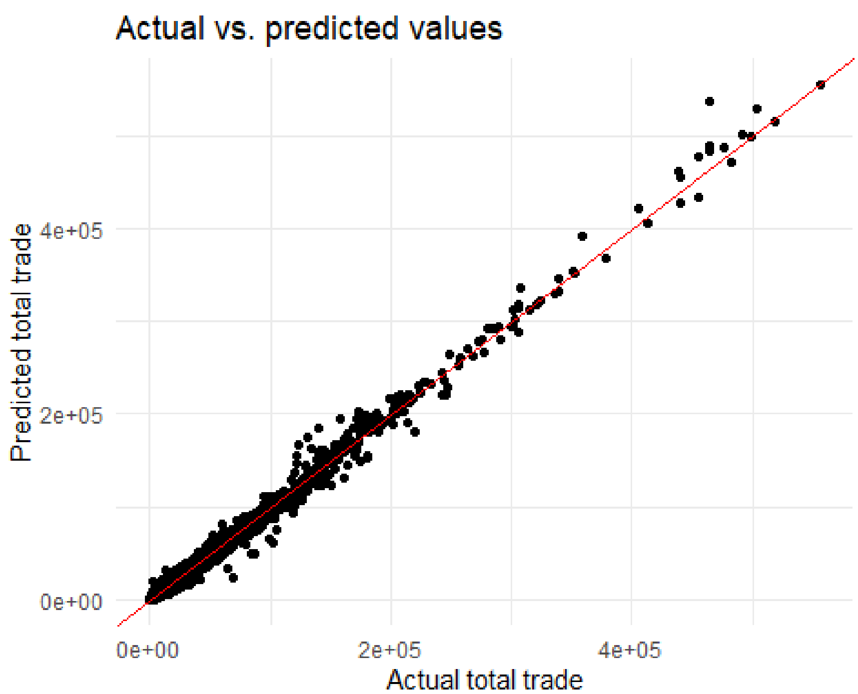
```
##                          mining_energy
## Dependent Var.:                  trade
##
## EU                 0.5452*** (0.0912)
## Euro                 -0.1217 (0.1269)
## Fixed-Effects:     ------------------
## exporter_year                     Yes
## importer_year                     Yes
## exporter_importer                 Yes
## _________________  __________________
## S.E. type          Heteroskedas.-rob.
## Observations                   63,700
## Squared Cor.                  0.98815
## Pseudo R2                     0.98120
## BIC                       3,430,992.4
## RMSE                           384.68
## AIC                       3,385,229.6
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Actual vs. predicted data

```r
ITPD_S50$total_pred <- predict(total, newdata = ITPD_S50)

total_pred <- ggplot(ITPD_S50, aes(x = trade, y = total_pred)) +
  geom_point(aes(
    text = paste(
      "Exporter:", exporter,
      "<br>Importer:", importer,
      "<br>Year:", year
      ))) +
  geom_abline(slope = 1, intercept = 0, color = "red") +
  labs(title = "Actual vs. predicted values",
       x = "Actual total trade",
       y = "Predicted total trade") +
  theme_minimal()

print(total_pred)
```



```r
# ggplotly(total_pred, tooltip = "text")

ggsave("Reduced-form PPML/Results/Actual vs. predicted.png",
       plot = total_pred, width = 8, height = 4.5, units = "in", dpi = 600)

)
```

Trade-flow prediciton

```r
CZE_trade <- ITPD_S50 %>%
  filter(exporter == "CZE" | importer == "CZE") %>%
  select(-DIST, -pair_id) %>%
  rename(actual = trade)

pred <- predict(total, newdata = CZE_trade, type = "response")

pred_c <- predict(total, newdata = CZE_trade %>%
                    select(-Euro) %>%
                    rename(Euro = Euro_c),
                  type = "response")
```

Calculating the relative change (in %) on total level.

```r
CZE_trade_total <- CZE_trade %>%
  mutate(direction = if_else(exporter == "CZE", "export", "import")) %>%
  group_by(year, direction) %>%
  summarise(actual = sum(actual, na.rm = TRUE),
            pred = sum(pred, na.rm = TRUE),
            pred_c = sum(pred_c, na.rm = TRUE),
            .groups = "drop") %>%
  mutate(delta = pred_c - pred,
         rel_change = delta / pred *100)


export_change <- CZE_trade_total %>%
  filter(direction == "export",
         year >= 2004)

summary(export_change$rel_change)

##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##  -2.790  -2.631  -2.622  -2.612  -2.574  -2.444

import_change <- CZE_trade_total %>%
  filter(direction == "import",
         year >= 2004)

summary(import_change$rel_change)

##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##  -2.299  -2.222  -2.204  -2.201  -2.186  -2.065
```

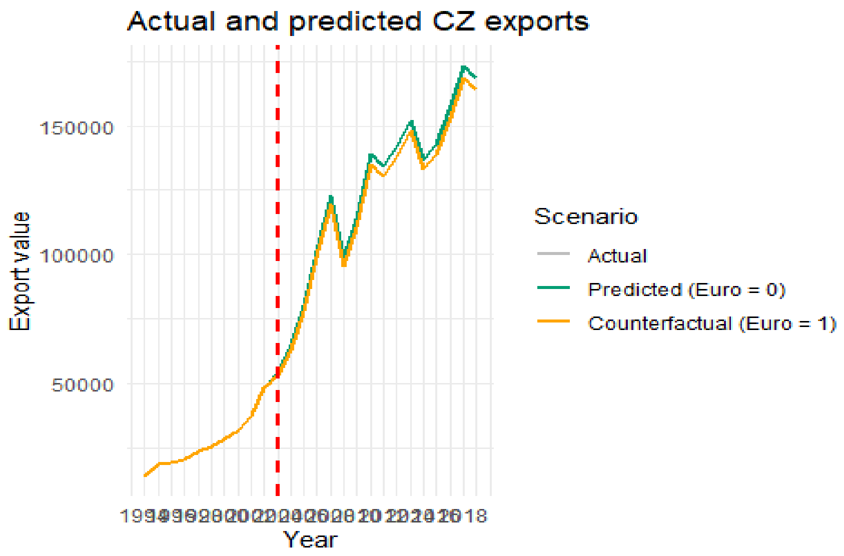
Visualising the prediction of CZE exports.

```r
CZE_exports <- CZE_trade_total %>%
  filter(direction == "export") %>%
  pivot_longer(cols = c(actual, pred, pred_c),
               names_to = "type",
               values_to = "value")

pred_exports <- ggplot(CZE_exports, aes(x = year, y = value, color = type)) +
  geom_line(linewidth = 1) +
  labs(
```

```
    title = "Actual and predicted CZ exports",
    x = "Year",
    y = "Export value",
    color = "Scenario"
  ) +
  scale_color_manual(
    values = c(actual = "grey", pred = "#009E73", pred_c = "orange"),
    labels = c(actual = "Actual",
               pred = "Predicted (Euro = 0)",
               pred_c = "Counterfactual (Euro = 1)")
  ) +
  scale_x_continuous(breaks = seq(1994, 2019, by = 2)) +
  geom_vline(xintercept = 2004,
             linetype = "dashed", color = "red", linewidth = 0.8) +
  theme_minimal()

print(pred_exports)
```




```
ggsave("Reduced-form PPML/Results/Predicted exports.png",
       plot = pred_exports, width = 8, height = 4.5, units = "in", dpi = 600)
```

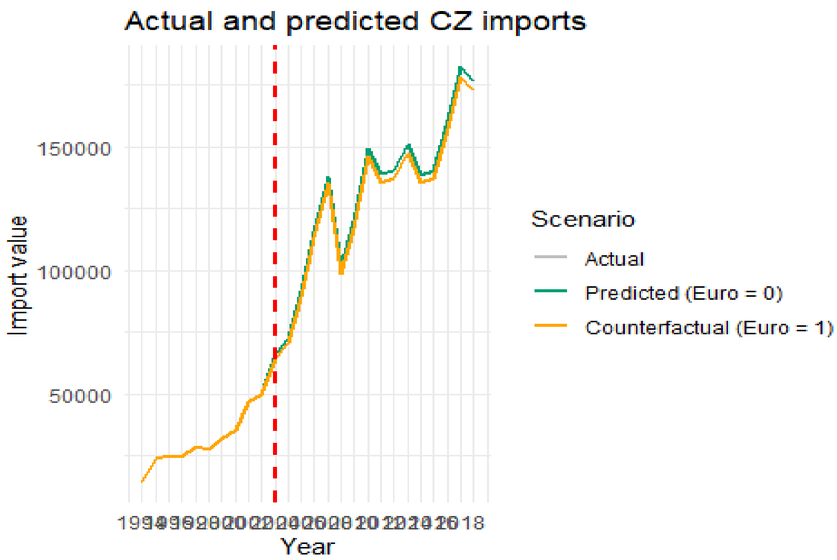
Visualising the prediction of CZE imports.

```
CZE_imports <- CZE_trade_total %>%
  filter(direction == "import") %>%
  pivot_longer(cols = c(actual, pred, pred_c),
               names_to = "type",
               values_to = "value")

pred_imports <- ggplot(CZE_imports, aes(x = year, y = value, color = type)) +
  geom_line(linewidth = 1) +
  labs(
    title = "Actual and predicted CZ imports",
    x = "Year",
    y = "Import value",
    color = "Scenario"
  ) +
  scale_color_manual(
    values = c(actual = "grey", pred = "#009E73", pred_c = "orange"),
    labels = c(actual = "Actual",
               pred = "Predicted (Euro = 0)",
               pred_c = "Counterfactual (Euro = 1)")
  ) +
```

```
  scale_x_continuous(breaks = seq(1994, 2019, by = 2)) +
  geom_vline(xintercept = 2004,
             linetype = "dashed", color = "red", linewidth = 0.8) +
  theme_minimal()

print(pred_imports)
```




```
ggsave("Reduced-form PPML/Results/Predicted imports.png",
       plot = pred_imports, width = 8, height = 4.5, units = "in", dpi = 600)
```

Appendix D: GU Countries

Table 9: GU Countries

ISO 3 Code	Country	ISO 3 Code	Country	ISO 3 Code	Country
AGO	Angola	GIN	Guinea	NLD	Netherlands
ARE	United Arab Emirates	GRC	Greece	NOR	Norway
ARG	Argentina	GTM	Guatemala	NZL	New Zealand
AUS	Australia	GUY	Guyana	OMN	Oman
AUT	Austria	HKG	Hong Kong	PAK	Pakistan
AZE	Azerbaijan	HND	Honduras	PER	Peru
BEL	Belgium	HRV	Croatia	PHL	Philippines
BGD	Bangladesh	HUN	Hungary	PNG	Papua New Guinea
BGR	Bulgaria	IDN	Indonesia	POL	Poland
BHR	Bahrain	IND	India	PRT	Portugal
BOL	Bolivia	IRL	Ireland	PRY	Paraguay
BRA	Brazil	IRN	Iran	QAT	Qatar
CAN	Canada	IRQ	Iraq	ROU	Romania
CHE	Switzerland	ISR	Israel	RUS	Russia
CHL	Chile	ITA	Italy	SAU	Saudi Arabia
CHN	China	JOR	Jordan	SGP	Singapore
CIV	Côte d'Ivoire	JPN	Japan	SRB	Serbia
COD	Congo - Kinshasa	KAZ	Kazakhstan	SVK	Slovakia
COG	Congo - Brazzaville	KHM	Cambodia	SVN	Slovenia
COL	Colombia	KOR	South Korea	SWE	Sweden
CRI	Costa Rica	KWT	Kuwait	THA	Thailand
CZE	Czechia	LBY	Libya	TTO	Trinidad & Tobago
DEU	Germany	LKA	Sri Lanka	TUN	Tunisia
DNK	Denmark	LTU	Lithuania	TUR	Turkey
DOM	Dominican Republic	LUX	Luxembourg	TZA	Tanzania
DZA	Algeria	LVA	Latvia	UKR	Ukraine
ECU	Ecuador	MAR	Morocco	URY	Uruguay
EGY	Egypt	MEX	Mexico	USA	United States
ESP	Spain	MKD	North Macedonia	UZB	Uzbekistan
EST	Estonia	MMR	Myanmar (Burma)	VNM	Vietnam
FIN	Finland	MNG	Mongolia	ZAF	South Africa
FRA	France	MOZ	Mozambique	ZMB	Zambia
GBR	United Kingdom	MYS	Malaysia		
GHA	Ghana	NGA	Nigeria		

Source: Yotov (2025)

Appendix E: ITPD-S Countries

Table 10: ITPD-S Countries

ISO 3 Code	Country	ISO 3 Code	Country	ISO 3 Code	Country
ABW	Aruba	GEO	Georgia	NRU	Nauru
AFG	Afghanistan	GHA	Ghana	NTZ	Neutral Zone
AGO	Angola	GIB	Gibraltar	NZL	New Zealand
AIA	Anguilla	GIN	Guinea	OMN	Oman
ALB	Albania	GLP	Guadeloupe	PAK	Pakistan
AND	Andorra	GMB	Gambia	PAN	Panama
ANT	The Netherlands Antilles	GNB	Guinea-Bissau	PCN	Pitcairn Islands
ARE	United Arab Emirates	GNQ	Equatorial Guinea	PER	Peru
ARG	Argentina	GRC	Greece	PHL	Philippines
ARM	Armenia	GRD	Grenada	PLW	Palau
ASM	American Samoa	GRL	Greenland	PNG	Papua New Guinea
ATA	Antarctica	GTM	Guatemala	POL	Poland
ATF	French Southern Territories	GUF	French Guiana	PRI	Puerto Rico
ATG	Antigua & Barbuda	GUM	Guam	PRK	North Korea
AUS	Australia	GUY	Guyana	PRT	Portugal
AUT	Austria	HKG	Hong Kong SAR China	PRY	Paraguay
AZE	Azerbaijan	HMD	Heard & McDonald Islands	PSE	Palestinian Territories
BDI	Burundi	HND	Honduras	PYF	French Polynesia
BEL	Belgium	HRV	Croatia	QAT	Qatar
BEN	Benin	HTI	Haiti	REU	Réunion
BES	Caribbean Netherlands	HUN	Hungary	ROU	Romania
BFA	Burkina Faso	IDN	Indonesia	RUS	Russia
BGD	Bangladesh	IMN	Isle of Man	RWA	Rwanda
BGR	Bulgaria	IND	India	SAU	Saudi Arabia
BHR	Bahrain	IOT	British Indian Ocean Territory	SCG	Serbia and Montenegro
BHS	Bahamas	IRL	Ireland	SDN	Sudan
BIH	Bosnia & Herzegovina	IRN	Iran	SEN	Senegal
BLM	St. Barthélemy	IRQ	Iraq	SGP	Singapore
BLR	Belarus	ISL	Iceland	SGS	South Georgia & South Sandwich Islands
BLX	Belgium-Luxembourg	ISR	Israel	SHN	St. Helena
BLZ	Belize	ITA	Italy	SLB	Solomon Islands
BMU	Bermuda	JAM	Jamaica	SLE	Sierra Leone
BOL	Bolivia	JOR	Jordan	SLV	El Salvador
BRA	Brazil	JPN	Japan	SMR	San Marino
BRB	Barbados	KAZ	Kazakhstan	SOM	Somalia
BRN	Brunei	KEN	Kenya	SPM	St. Pierre & Miquelon

Table 10: ITPD-S Countries (continued)

ISO 3 Code	Country	ISO 3 Code	Country	ISO 3 Code	Country
BTN	Bhutan	KGZ	Kyrgyzstan	SRB	Serbia
BVT	Bouvet Island	KHM	Cambodia	SSD	South Sudan
BWA	Botswana	KIR	Kiribati	STP	São Tomé & Príncipe
CAF	Central African Republic	KNA	St. Kitts & Nevis	SUR	Suriname
CAN	Canada	KOR	South Korea	SVK	Slovakia
CCK	Cocos (Keeling) Islands	KWT	Kuwait	SVN	Slovenia
CHE	Switzerland	LAO	Laos	SVU	Soviet Union
CHL	Chile	LBN	Lebanon	SWE	Sweden
CHN	China	LBR	Liberia	SWZ	Eswatini
CIV	Côte d'Ivoire	LBY	Libya	SXM	Sint Maarten
CMR	Cameroon	LCA	St. Lucia	SYC	Seychelles
COD	Congo - Kinshasa	LIE	Liechtenstein	SYR	Syria
COG	Congo - Brazzaville	LKA	Sri Lanka	TCA	Turks & Caicos Islands
COK	Cook Islands	LSO	Lesotho	TCD	Chad
COL	Colombia	LTU	Lithuania	TGO	Togo
COM	Comoros	LUX	Luxembourg	THA	Thailand
CPV	Cape Verde	LVA	Latvia	TJK	Tajikistan
CRI	Costa Rica	MAC	Macao SAR China	TKL	Tokelau
CSK	Czechoslovakia	MAR	Morocco	TKM	Turkmenistan
CUB	Cuba	MCO	Monaco	TLS	Timor-Leste
CUW	Curaçao	MDA	Moldova	TON	Tonga
CXR	Christmas Island	MDG	Madagascar	TTO	Trinidad & Tobago
CYM	Cayman Islands	MDV	Maldives	TUN	Tunisia
CYP	Cyprus	MEX	Mexico	TUR	Turkey
CZE	Czechia	MHL	Marshall Islands	TUV	Tuvalu
DDR	German Democratic Republic	MKD	North Macedonia	TWN	Taiwan
DEU	Germany	MLI	Mali	TZA	Tanzania
DJI	Djibouti	MLT	Malta	UGA	Uganda
DMA	Dominica	MMR	Myanmar (Burma)	UKR	Ukraine
DNK	Denmark	MNE	Montenegro	UMI	United States Minor Outlying Islands (the)
DOM	Dominican Republic	MNG	Mongolia	URY	Uruguay
DZA	Algeria	MNP	Northern Mariana Islands	USA	United States
ECU	Ecuador	MOZ	Mozambique	UZB	Uzbekistan
EGY	Egypt	MRT	Mauritania	VAT	Vatican City
ERI	Eritrea	MSR	Montserrat	VCT	St. Vincent & Grenadines
ESH	Western Sahara	MTQ	Martinique	VEN	Venezuela
ESP	Spain	MUS	Mauritius	VGB	British Virgin Islands

Table 10: ITPD-S Countries (continued)

ISO 3 Code	Country	ISO 3 Code	Country	ISO 3 Code	Country
EST	Estonia	MWI	Malawi	VIR	U.S. Virgin Islands
ETF	Ethiopia (includes Eritrea)	MYS	Malaysia	VNM	Vietnam
ETH	Ethiopia (excludes Eritrea)	MYT	Mayotte	VUT	Vanuatu
FIN	Finland	NAM	Namibia	WLF	Wallis & Futuna
FJI	Fiji	NCL	New Caledonia	WSM	Samoa
FLK	Falkland Islands	NER	Niger	YEM	Yemen
FRA	France	NFK	Norfolk Island	YMD	Democratic Yemen
FRE	Free Zones	NGA	Nigeria	YUG	
FRO	Faroe Islands	NIC	Nicaragua	ZAF	South Africa
FSM	Micronesia (Federated States of)	NIU	Niue	ZMB	Zambia
GAB	Gabon	NLD	Netherlands	ZWE	Zimbabwe
GAZ	Gaza Strip	NOR	Norway		
GBR	United Kingdom	NPL	Nepal		

Source: Borchert et al. (2024a)

Appendix F: Panel scope

Table 11: Panel scope

ISO 3 Code	Country	ISO 3 Code	Country
ARE	United Arab Emirates	JPN	Japan
AUS	Australia	KAZ	Kazakhstan
AUT	Austria	KOR	South Korea
AZE	Azerbaijan	LTU	Lithuania
BEL	Belgium	MEX	Mexico
BGR	Bulgaria	MYS	Malaysia
BRA	Brazil	NLD	Netherlands
CAN	Canada	NOR	Norway
CZE	Czechia	PHL	Philippines
DEU	Germany	POL	Poland
DNK	Denmark	PRT	Portugal
ESP	Spain	ROU	Romania
FIN	Finland	RoW	Rest of the World
FRA	France	RUS	Russia
GBR	United Kingdom	SAU	Saudi Arabia
GRC	Greece	SGP	Singapore
HRV	Croatia	SVK	Slovakia
HUN	Hungary	SVN	Slovenia
CHE	Switzerland	SWE	Sweden
CHN	China	THA	Thailand
IDN	Indonesia	TUR	Turkey
IND	India	UKR	Ukraine
IRL	Ireland	USA	United States
ISR	Israel	VNM	Vietnam
ITA	Italy	ZAF	South Africa

Source: Author’s own processing

Appendix G: Aggregated industries

This table appendix is too extensive to be clearly presented on an A4 page. Please refer to the online appendices.

Appendix H: GEPPML analysis in Stata

The Stata code used for the GEPPML estimation in this analysis was provided by Yotov et al. (2016, Chapter 2, Exercise 2) and underwent only minor modifications to tailor the code to this thesis's research question and dataset. Main credit for its completion goes to these authors.

```
* This application applies the methods developed by Anderson et al. (2015) in
* order to investigate the potential effects of adopting euro on Czech exports.
*
* This code was taken from Exercise 2 of Chapter 2 of Yotov et al. (2016) and
* modified to make the counterfactual scenario correspond to the Czech Republic's
* entry into the euro area together with its entry into the EU in 2004.
*


******************************* PRELIMINARY STEP *******************************

* Clear memory and set parameters
    clear all
    set more off
    clear matrix
    *set memory 500m
    *set matsize 8000
    set maxvar 30000
    set type double, permanently

* Set directory path, where "$input" refers to the path of the main folder
* "Data Analysis"
    cd "C:\Users\vitek\iCloud Drive 2\Škola\Diplomová práce\Data Analysis"

* Close and create log
    capture log close
    log using "GEPPML\Results\GEPPML ITPD-S50.log", text replace

* Install or update the ppml command if necessary
    * ssc install ppml

* Install or update the esttab command if necessary
    * findit esttab


************************* OPEN AND MANAGE THE DATABASE *************************

* Open the database according to the Stata version you are using
    import delimited "Data\ITPD-S50.csv", clear case(preserve)

* Create the log of distance variable
        generate ln_DIST = ln(DIST)

* Create aggregate output
        bysort exporter year: egen Y = sum(trade)

* Create aggregate expenditure
        bysort importer year: egen E = sum(trade)

* Chose a country for reference group: GERMANY
* The country code of the reference country is set to "ZZZ" so that the exporter
* and exporter fixed effects of the reference country are always the last ones
* created
        gen E_R_BLN = E if importer == "DEU"
            replace exporter = "ZZZ" if exporter == "DEU"
            replace importer = "ZZZ" if importer == "DEU"
        bysort year: egen E_R = mean(E_R_BLN)
```

```
* Create exporter time fixed effects
        egen exp_time = group(exporter year)
        quietly tabulate exp_time, gen(EXPORTER_TIME_FE)

* Create importer time fixed effects
        egen imp_time = group(importer year)
        quietly tabulate imp_time, gen(IMPORTER_TIME_FE)

* Rearrange so that country pairs (e.g. NER-PAN, MWI-MAC, NPL-MWI, PAN-MWI,
* NPL-CMR), which will be dropped due to no trade, are last
        bysort pair_id: egen X = sum(trade)
        quietly summarize pair_id
        replace pair_id = pair_id + r(max) + 1 if X == 0 | X == .
        drop X

* Rearrange so that the last country pair is the one for internal trade
        quietly sum pair_id
        replace pair_id = r(max) + 1 if exporter == importer
        quietly tabulate pair_id, gen(PAIR_FE)

* Set additional exogenous parameters
        quietly ds EXPORTER_TIME_FE*
        global NT = `: word count `r(varlist)''

        quietly tabulate year, gen(TIME_FE)
        quietly ds TIME_FE*
        global Nyr = `: word count `r(varlist)''
        global NT_yr = $NT - $Nyr

        quietly ds PAIR_FE*
        global NTij = `: word count `r(varlist)''
        global NTij_1 = $NTij - 1

* Need to change by number of intra-national trade pairs.
* It's number of partners + CZE + RoW (= 50).
* Leaving the naming with an 8 so it fits in with the rest of the code
        global NTij_8 = $NTij - 50

* Save data
    save "GEPPML/Datasets/EuroImpact.dta", replace


****************************** EXERCISE 1 PART (i) *****************************

    * Estimate the gravity model with a specific variable for EU and Euro
        ppml trade PAIR_FE1-PAIR_FE$NTij_1 EXPORTER_TIME_FE* IMPORTER_TIME_FE1-
IMPORTER_TIME_FE$NT_yr EU Euro, iter(30) noconst
            * Save the estimation results to be used instead of re-estimating the
same equation three times
            estimate store gravity_panel


****************************** EXERCISE 1 PART (ii) *****************************

* Use the Euro-specific estimates from part (i) to obtain general equilibrium
* effects of the Euro.

************************* GENERAL EQUILIBRIUM ANALYSIS *************************

* Step I: Solve the baseline gravity model

    * Step I.a. Obtain estimates of trade costs and trade elasticities baseline
    *            indexes

        * Implementation of Anderson and Yotov (2016) two-stage procedure to
        * construct the full matrix of trade costs, including when there is no
        * trade or zero trade
```

```
            * Stage 1: Obtain the estimates of pair fixed effects and the effect of
Euro
            * Estimate the gravity model

        *ppml trade PAIR_FE1-PAIR_FE$NTij_1 EXPORTER_TIME_FE* IMPORTER_TIME_FE1-
IMPORTER_TIME_FE$NT_yr Euro, iter(30) noconst

            * Alternatively recall the results of the gravity model obtained above
                estimate restore gravity_panel

                scalar EU_est = _b[EU]
                scalar Euro_est = _b[Euro]

                * Construct the trade costs from the pair fixed effects
                    forvalues ijt = 1(1)$NTij_8{
                        qui replace PAIR_FE`ijt' = PAIR_FE`ijt' * _b[PAIR_FE`ijt']
                    }

                    egen gamma_ij = rowtotal(PAIR_FE1-PAIR_FE$NTij )
                        replace gamma_ij = . if gamma_ij == 1 & exporter !=
importer
                        replace gamma_ij = 0 if gamma_ij == 1 & exporter ==
importer
                    generate tij_bar = exp(gamma_ij)
                    generate tij_bln = exp(gamma_ij + EU_est*EU + Euro_est*Euro)

            * Stage 2: Regress the estimates of pair fixed effects on gravity
variables and country fixed effects
                * Perform the regression for the baseline year
                    keep if year == 2004

                * Specify the dependent variable as the estimates of pair fixed
                * effects
                    generate tij = exp(gamma_ij)

                * Create the exporters and importers fixed effects
                    quietly tabulate exporter, gen(EXPORTER_FE)
                    quietly tabulate importer, gen(IMPORTER_FE)

                * Estimate the standard gravity model
                ppml tij EXPORTER_FE* IMPORTER_FE* ln_DIST EU Euro if exporter !=
importer, cluster(pair_id)
                    estimates store gravity_est

                * Create the predicted values
                    predict tij_noRTA, mu
                        replace tij_noRTA = 1 if exporter == importer

                * Replace the missing trade costs with predictions from the
                * standard gravity regression
                    replace tij_bar = tij_noRTA if tij_bar == .
                    replace tij_bln = tij_bar * exp(EU_est*EU + Euro_est*Euro) if
tij_bln == .

                * Specify the complete set of bilateral trade costs in log to
                * be used as a constraint in the PPML estimation of the
                * structural gravity model
                    generate ln_tij_bln = log(tij_bln)

        * Set the number of exporter fixed effects variables
        quietly ds EXPORTER_FE*
        global N = `: word count `r(varlist)''
        global N_1 = $N - 1

        * Estimate the gravity model in the "baseline" scenario with the PPML
        * estimator constrained with the complete set of bilateral trade costs
```

```
        ppml trade EXPORTER_FE* IMPORTER_FE1-IMPORTER_FE$N_1 , iter(30) noconst
offset(ln_tij_bln)
            predict tradehat_BLN, mu


    * Step I.b. Construct baseline indexes
        * Based on the estimated exporter and importer fixed effects, create
        * the actual set of fixed effects
            forvalues i = 1 (1) $N_1 {
                quietly replace EXPORTER_FE`i' = EXPORTER_FE`i' *
exp(_b[EXPORTER_FE`i'])
                quietly replace IMPORTER_FE`i' = IMPORTER_FE`i' *
exp(_b[IMPORTER_FE`i'])
            }

        * Create the exporter and importer fixed effects for the country of
        * reference (Germany)
            quietly replace EXPORTER_FE$N = EXPORTER_FE$N * exp(_b[EXPORTER_FE$N ])
            quietly replace IMPORTER_FE$N = IMPORTER_FE$N * exp(0)

        * Create the variables stacking all the non-zero exporter and importer
        * fixed effects, respectively
            egen exp_pi_BLN = rowtotal(EXPORTER_FE1-EXPORTER_FE$N )
            egen exp_chi_BLN = rowtotal(IMPORTER_FE1-IMPORTER_FE$N )

        * Compute the variable of bilateral trade costs, i.e. the fitted trade
        * value by omitting the exporter and importer fixed effects
            generate tij_BLN = tij_bln

        * Compute the outward and inward multilateral resistances using the
        * additive property of the PPML estimator that links the exporter and
        * importer fixed effects with their respective multilateral resistances
        * taking into account the normalisation imposed
            generate OMR_BLN = Y * E_R / exp_pi_BLN
            generate IMR_BLN = E / (exp_chi_BLN * E_R)

        * Compute the estimated level of international trade in the baseline for
        * the given level of ouptput and expenditures
            generate tempXi_BLN = tradehat_BLN if exporter != importer
                bysort exporter: egen Xi_BLN = sum(tempXi_BLN)
                    drop tempXi_BLN
            generate Y_BLN = Y
            generate E_BLN = E


* Step II: Define a conterfactual scenario
    * The counterfactual scenario consists in re-specifying the Euro variable
    * as if the CZE was in euro area from 2004 on.

        * Constructing the counterfactual bilateral trade costs    by imposing the
        * constraints associated with the counterfactual scenario
        generate tij_CFL = tij_bar * exp(EU_est*EU + Euro_est*Euro_c)

* Step III: Solve the counterfactual model

    * Step III.a.: Obtain conditional general equilibrium effects

    * (i):    Estimate the gravity model by imposing the constraints associated
    *         with the counterfactual scenario. The constraint is defined
    *         separately by taking the log of the counterfactual bilateral trade
    *         costs. The parameter of this expression will be constrainted to be
    *        equal to 1 in the ppml estimator

        * Specify the constraint in log
            generate ln_tij_CFL = log(tij_CFL)

        * Re-create the exporters and imports fixed effects
                drop EXPORTER_FE* IMPORTER_FE*
```

```
            quietly tabulate exporter, generate(EXPORTER_FE)
            quietly tabulate importer, generate(IMPORTER_FE)

        * Estimate the constrained gravity model and generate predicted trade
        * value
        ppml trade EXPORTER_FE* IMPORTER_FE1-IMPORTER_FE$N_1 , iter(30) noconst
offset(ln_tij_CFL)
            predict tradehat_CDL, mu

    * (ii):    Construct conditional general equilibrium multilateral resistances

        * Based on the estimated exporter and importer fixed effects, create
        * the actual set of counterfactual fixed effects
            forvalues i = 1(1)$N_1 {
                quietly replace EXPORTER_FE`i' = EXPORTER_FE`i' *
exp(_b[EXPORTER_FE`i'])
                quietly replace IMPORTER_FE`i' = IMPORTER_FE`i' *
exp(_b[IMPORTER_FE`i'])
            }

        * Create the exporter and importer fixed effects for the country of
        * reference (Germany)
            quietly replace EXPORTER_FE$N = EXPORTER_FE$N * exp(_b[EXPORTER_FE$N ])
            quietly replace IMPORTER_FE$N = IMPORTER_FE$N * exp(0)

        * Create the variables stacking all the non-zero exporter and importer
        * fixed effects, respectively
            egen exp_pi_CDL = rowtotal( EXPORTER_FE1-EXPORTER_FE$N )
            egen exp_chi_CDL = rowtotal( IMPORTER_FE1-IMPORTER_FE$N )

        * Compute the outward and inward multilateral resistances
            generate OMR_CDL = Y * E_R / exp_pi_CDL
            generate IMR_CDL = E / (exp_chi_CDL * E_R)

        * Compute the estimated level of conditional general equilibrium
        * international trade for the given level of ouptput and expenditures
            generate tempXi_CDL = tradehat_CDL if exporter != importer
                bysort exporter: egen Xi_CDL = sum(tempXi_CDL)
                    drop tempXi_CDL


    * Step III.b: Obtain full endowment general equilibrium effects

        * Create the iterative procedure by specifying the initial variables,
        * where s = 0 stands for the baseline (BLN) value and s = 1 stands for
        * the conditional general equilibrium (CD) value

            * The constant elasticity of substitutin is taken from the literature
            scalar sigma = 7

            * The parameter phi links the value of output with expenditures
            bysort year: generate phi = E/Y if exporter == importer

            * Compute the change in bilateral trade costs resulting from the
            * counterfactual
            generate change_tij = tij_CFL / tij_BLN

            * Re-specify the variables in the baseline and conditional scenarios
                * Output
                generate Y_0 = Y
                generate Y_1 = Y

                * Expenditures, including with respect to the reference country
                generate E_0 = E
                generate E_R_0 = E_R
                generate E_1 = E
                generate E_R_1 = E_R
```

```
                * Predicted level of trade
                generate tradehat_1 = tradehat_CDL


        * (i)    Allow for endogenous factory-gate prices

            * Re-specify the factory-gate prices under the baseline and
            * conditional scenarios
            generate exp_pi_0 = exp_pi_BLN
            generate tempexp_pi_ii_0 = exp_pi_0 if exporter == importer
                bysort importer: egen exp_pi_j_0 = mean(tempexp_pi_ii_0)
            generate exp_pi_1 = exp_pi_CDL
            generate tempexp_pi_ii_1 = exp_pi_1 if exporter == importer
                bysort importer: egen exp_pi_j_1 = mean(tempexp_pi_ii_1)
                drop tempexp_pi_ii_*
            generate exp_chi_0 = exp_chi_BLN
            generate exp_chi_1 = exp_chi_CDL

            * Compute the first order change in factory-gate prices    in the
            * baseline and conditional scenarios
            generate change_pricei_0 = 0
            generate change_pricei_1 = ((exp_pi_1 / exp_pi_0) / (E_R_1 /
E_R_0))^(1/(1-sigma))
            generate change_pricej_1 = ((exp_pi_j_1 / exp_pi_j_0) / (E_R_1 /
E_R_0))^(1/(1-sigma))

            * Re-specify the outward and inward multilateral resistances in the
            * baseline and conditional scenarios
            generate OMR_FULL_0 = Y_0 * E_R_0 / exp_pi_0
            generate IMR_FULL_0 = E_0 / (exp_chi_0 * E_R_0)
            generate IMR_FULL_1 = E_1 / (exp_chi_1 * E_R_1)
            generate OMR_FULL_1 = Y_1 * E_R_1 / exp_pi_1

        * Compute initial change in outward and multilateral resitances, which
        * are set to zero
            generate change_IMR_FULL_1 = exp(0)
            generate change_OMR_FULL_1 = exp(0)


    ****************************************************************************
    ******************** Start of the Iterative Procedure  *********************

    * Set the criteria of convergence, namely that either the standard errors or
    * maximum of the difference between two iterations of the factory-gate
    * prices are smaller than 0.01, where s is the number of iterations
        local s = 3
        local sd_dif_change_pi = 1
        local max_dif_change_pi = 1
    while (`sd_dif_change_pi' > 0.01) | (`max_dif_change_pi' > 0.01) {
        local s_1 = `s' - 1
        local s_2 = `s' - 2
        local s_3 = `s' - 3

        * (ii)    Allow for endogenous income, expenditures and trade
        *    generate trade_`s_1' = change_tij * tradehat_`s_2' *
change_pricei_`s_2' * change_pricej_`s_2' /
(change_OMR_FULL_`s_2'*change_IMR_FULL_`s_2')
            generate trade_`s_1' =  tradehat_`s_2' * change_pricei_`s_2' *
change_pricej_`s_2' / (change_OMR_FULL_`s_2'*change_IMR_FULL_`s_2')


        * (iii)    Estimation of the structural gravity model
                drop EXPORTER_FE* IMPORTER_FE*
                quietly tabulate exporter, generate (EXPORTER_FE)
                quietly tabulate importer, generate (IMPORTER_FE)
            capture ppml trade_`s_1' EXPORTER_FE* IMPORTER_FE*, offset(ln_tij_CFL)
noconst iter(30)
                predict tradehat_`s_1', mu
```

```
            * Update output & expenditure
                bysort exporter: egen Y_`s_1' = total(tradehat_`s_1')
                quietly generate tempE_`s_1' = phi * Y_`s_1' if exporter ==
importer
                    bysort importer: egen E_`s_1' = mean(tempE_`s_1')
                quietly generate tempE_R_`s_1' = E_`s_1' if importer == "ZZZ"
                    egen E_R_`s_1' = mean(tempE_R_`s_1')

            * Update factory-gate prices
                forvalues i = 1(1)$N_1 {
                    quietly replace EXPORTER_FE`i' = EXPORTER_FE`i' *
exp(_b[EXPORTER_FE`i'])
                    quietly replace IMPORTER_FE`i' = IMPORTER_FE`i' *
exp(_b[IMPORTER_FE`i'])
                }
                quietly replace EXPORTER_FE$N = EXPORTER_FE$N *
exp(_b[EXPORTER_FE$N ])
                egen exp_pi_`s_1' = rowtotal(EXPORTER_FE1-EXPORTER_FE$N )
                quietly generate tempvar1 = exp_pi_`s_1' if exporter == importer
                    bysort importer: egen exp_pi_j_`s_1' = mean(tempvar1)

            * Update multilateral resistances
                generate change_pricei_`s_1' = ((exp_pi_`s_1' / exp_pi_`s_2') /
(E_R_`s_1' / E_R_`s_2'))^(1/(1-sigma))
                generate change_pricej_`s_1' = ((exp_pi_j_`s_1' / exp_pi_j_`s_2') /
(E_R_`s_1' / E_R_`s_2'))^(1/(1-sigma))
                generate OMR_FULL_`s_1' = (Y_`s_1' * E_R_`s_1') / exp_pi_`s_1'
                    generate change_OMR_FULL_`s_1' = OMR_FULL_`s_1' /
OMR_FULL_`s_2'
                egen exp_chi_`s_1' = rowtotal(IMPORTER_FE1-IMPORTER_FE$N )
                generate IMR_FULL_`s_1' = E_`s_1' / (exp_chi_`s_1' * E_R_`s_1')
                    generate change_IMR_FULL_`s_1' = IMR_FULL_`s_1' /
IMR_FULL_`s_2'

            * Iteration until the change in factory-gate prices converges to zero
                generate dif_change_pi_`s_1' = change_pricei_`s_2' -
change_pricei_`s_3'
                    display "************************* iteration number " `s_2' "
*************************"
                        summarize dif_change_pi_`s_1', format
                    display
"**************************************************************************"
                    display " "
                        local sd_dif_change_pi = r(sd)
                        local max_dif_change_pi = abs(r(max))

            local s = `s' + 1
            drop temp*
    }

    ********************* End of the Iterative Procedure  **********************
    ****************************************************************************

        * (iv)    Construction of the "full endowment general equilibrium"
        *        effects indexes
            * Use the result of the latest iteration S
            local S = `s' - 2
        *    forvalues i = 1 (1) $N_1 {
        *        quietly replace IMPORTER_FE`i' = IMPORTER_FE`i' *
exp(_b[IMPORTER_FE`i'])
        *    }
        * Compute the full endowment general equilibrium of factory-gate price
            generate change_pricei_FULL = ((exp_pi_`S' / exp_pi_0) / (E_R_`S' /
E_R_0))^(1/(1-sigma))

        * Compute the full endowment general equilibrium of the value output
            generate Y_FULL = change_pricei_FULL  * Y_BLN
```

```
        * Compute the full endowment general equilibrium of the value of
        * aggregate expenditures
          generate tempE_FULL = phi * Y_FULL if exporter == importer
              bysort importer: egen E_FULL = mean(tempE_FULL)
                  drop tempE_FULL

        * Compute the full endowment general equilibrium of the outward and
        * inward multilateral resistances
          generate OMR_FULL = Y_FULL * E_R_`S' / exp_pi_`S'
          generate IMR_FULL = E_`S' / (exp_chi_`S' * E_R_`S')

        * Compute the full endowment general equilibrium of the value of
        * bilateral trade
          generate X_FULL = (Y_FULL * E_FULL * tij_CFL) /(IMR_FULL * OMR_FULL)

        * Compute the full endowment general equilibrium of the value of
        * total international trade
          generate tempXi_FULL = X_FULL if exporter != importer
              bysort exporter: egen Xi_FULL = sum(tempXi_FULL)
                  drop tempXi_FULL

    * Save the conditional and general equilibrium effects results
    save "GEPPML/Results/FULLGE.dta", replace


* Step IV: Collect, construct, and report indexes of interest
    use "GEPPML/Results/FULLGE.dta", clear
        collapse(mean) OMR_FULL OMR_CDL OMR_BLN change_pricei_FULL Xi_* Y_BLN
Y_FULL, by(exporter)
          rename exporter country
          replace country = "DEU" if country == "ZZZ"
          sort country


* Percent change in full endowment general equilibrium of factory-gate prices
generate change_price_FULL = (change_pricei_FULL - 1) * 100

* Percent change in full endowment GE of outward multilateral resistances
generate change_OMR_CDL = (OMR_CDL^(1/(1-sigma)) - OMR_BLN^(1/(1-sigma))) /
OMR_BLN^(1/(1-sigma)) * 100
generate change_OMR_FULL = (OMR_FULL^(1/(1-sigma)) - OMR_BLN^(1/(1-sigma))) /
OMR_BLN^(1/(1-sigma)) * 100

* Percent change in conditional GE of bilateral trade
generate change_Xi_CDL  = (Xi_CDL - Xi_BLN) / Xi_BLN * 100

* Percent change in full endowment GE of bilateral trade
generate change_Xi_FULL = (Xi_FULL - Xi_BLN) / Xi_BLN * 100

save "GEPPML/Results/FULL_PROD.dta", replace

* Construct the percentage changes on import/consumption side
use "GEPPML/Results/FULLGE.dta", clear
collapse(mean) IMR_FULL IMR_CDL IMR_BLN, by(importer)
rename importer country
replace country = "DEU" if country == "ZZZ"
sort country

* Conditional GE of inward multilateral resistances
generate change_IMR_CDL = (IMR_CDL^(1/(1-sigma)) - IMR_BLN^(1/(1-sigma))) /
IMR_BLN^(1/(1-sigma)) * 100

* Full endowment GE of inward multilateral resistances
generate change_IMR_FULL = (IMR_FULL^(1/(1-sigma)) - IMR_BLN^(1/(1-sigma))) /
IMR_BLN^(1/(1-sigma)) * 100

save "GEPPML/Results/FULL_CONS.dta", replace
```

```
* Merge the GE results from production and consumption sides
use "GEPPML/Results/FULL_PROD.dta", clear
joinby country using "GEPPML/Results/FULL_CONS.dta"

* Full endowment general equilibrium of real GDP
generate rGDP_BLN  = Y_BLN  / (IMR_BLN  ^(1 / (1 - sigma)))
generate rGDP_FULL = Y_FULL / (IMR_FULL ^(1 / (1 - sigma)))
generate change_rGDP_FULL = (rGDP_FULL - rGDP_BLN) / rGDP_BLN * 100

* Keep indexes of interest
keep country change_Xi_CDL change_Xi_FULL change_price_FULL ///
     change_IMR_FULL change_OMR_FULL change_rGDP_FULL Y_BLN
order country change_Xi_CDL change_Xi_FULL change_price_FULL ///
     change_IMR_FULL change_OMR_FULL change_rGDP_FULL Y_BLN

* Export results to Excel
export excel using "GEPPML/Results/Result S50.xls", firstrow(variables) replace
```