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Automotive fuel taxes and cross-border shopping

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Declaration of Authorship

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Abstract

This thesis investigates the presence of the cross-border shopping for automotive fuel between the Czech Republic and neighbouring countries over the time period from January 2005 to December 2012. Tax rates on fuels were described as one of the main source of price difference between countries that induces cross-border shopping. Using monthly data for diesel and petrol we used error correction model and estimated both long-term and short-term relationships between consumption of fuel in the Czech Republic and prices in Czech Republic and neighbouring countries. We found the evidence of a negative relationship between prices of petrol in the Czech Republic and its consumption as well as a positive relationship between relative price of petrol in Germany upon the consumption of petrol in the Czech Republic, which indicates presence of the cross-border shopping from Germany to Czech Republic.

Keywords cross-border shopping, automotive fuel, fuel taxes, fuel consumption, error correction model

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Abstrakt

Táto práca je zameraná na ukázanie existencie cezhraničného nakupovania pohonných hmôt medzi Českou Republikou a susediacimi štátmi v období od Januára 2005 do Decembra 2012. Ako jednu z hlavných príčin cezhraničného nakupovania sme uviedli rozdiely v zdanení pohonných hmôt v rozličných štátoch, ktoré následne spôsobujú rozdiely v cenách pohonných hmôt. S použitím mesačných dát na naftu a benzín sme skonštruovali model korekcie chyby a odhadli dlhodobé aj krátkodobé vzťahy medzi spotrebou pohonných hmôt a jednotlivými cenami za pohonné hmoty v Česku a susediacich štátoch. Zistili sme negatívny dopad zvýšenia cien benzínu v Česku na jeho spotrebu a pozitívny dopad zvýšenia relatívnej ceny benzínu v Nemecku na spotrebu benzínu v Česku, čo dokazuje existenciu cezhraničného nakupovania medzi Nemeckom a Českou Republikou.

Kľúčové slová cezhraničné nakupovanie, pohonné hmoty, dane na pohonné hmoty, spotreba pohonných hmôt, model korekcie chyby

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TEZE BAKALÁŘSKÉ PRÁCE

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Garant studijního programu Vám dle zákona č. 111/1998 Sb. o vysokých školách a Studijního a zkušebního řádu UK v Praze určuje následující bakalářskou práci

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Charakteristika tématu, současný stav poznání, případné zvláštní metody zpracování tématu:

In my thesis, I decided to focus on the topic of automotive fuel taxes and their impact on the cross-border shopping phenomenon. I will try to determine how the differences in the fuel prices among the neighbouring countries can influence the decisions of vehicle users to purchase fuel in those countries. Specifically, I will focus on the situation in the Czech Republic (CR).

The questions of my interest are following: If the excise tax on fuel in the Czech Republic is reduced, how would be affected the fuel purchases in the CR? Would it significantly increase the amount that foreign vehicle owners purchase in the CR? And most importantly, how would be affected the government revenues from fuel taxes collection?

In order to answer on these questions, I will attempt to estimate the purchases of fuel using panel data on the purchases of fuel in CR, prices of fuel in CR, prices of fuel in neighbouring countries and number of motor vehicles registered in CR.

I will apply the aforementioned method to estimate impact of lowered price of fuel caused by lower excise tax on fuel on the purchases of fuel in CR and in the neighbouring countries. Then I will use these results to estimate the effect on the government revenues collected from fuel taxes.

Preliminary outline:

1. Introduction
2. Cross-border shopping
3. Characteristics of the fuel taxation in Czech Republic
4. Methodology
5. Empirical analysis
6. Discussion of the results
7. Conclusion

Seznam základních pramenů a odborné literatury:

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V Praze dne

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Jozef Kubovič Petr Janský, M.Sc.

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Acronyms

CR Czech Republic

CZSO Czech Statistical Office

ECM Error Correction Model

EEP Europe’s Energy Portal

MICZ Ministry of Interior of Czech Republic

OLS Ordinary least squares

VAT Value added tax

Introduction

In the last few decades, globalization and the economic integration gained a momentum that forced most of the developed countries to restrict the various barriers to trade and open up their borders. The best example of this integration is the European Union. As a common market with four basic freedoms of movement (of goods, services, labour and capital) was being developed, people started to enjoy benefits of the integration – opportunity to purchase goods in foreign countries for possible lower prices than at home. Thus, this phenomenon known as cross-border shopping arose as a significant feature of economic integration for governments.

The objective of this thesis is to look into the cross-border shopping for fuels and its effect on demand for fuel in Czech Republic. Purchase of fuel is important part of cross-border shopping, as the consumers willing to purchase goods in foreign country usually need vehicles to do so. Therefore, one of their decisions is where to purchase fuel. If the price difference of the fuel between their home country and their destination is significant for them, they fill their vehicle in country where the price is lower, simply because they are rational. These differences among countries in prices are mainly caused by different level of taxation on goods. The most famous study of the effect of tax difference on cross-border shopping is the paper published by Kanbur and Keen (1993), which was expanded in the following years in the works of many researchers.

The basic framework of this thesis follows the study of Leal et al. (2009). We will use their method on the data for the Czech Republic to find out empirical relationship between quantity of fuel consumed in CR and prices of fuel in CR and neighbouring countries. We will try to show that there is positive relationship between these variables and confirm the negative relationship between price of automotive fuel in CR and quantity of fuel consumed in CR. The models we are going to use in this study are OLS and Error Correction Model (ECM).

The thesis is structured as follows. Chapter 1 consists of the literature survey on topic of cross-border shopping and impact of taxation on it. Then, in the Chapter 2 we talk about cross-border shopping in the context of our work and introduce some basic notions about taxation of the fuel. After that we study the structure of fuel taxes in CR and neighbouring countries, the effect of EU membership on the level of these taxes and current tax rates on fuel in those countries. The methodology and the econometric model used in the empirical part are discussed in the Chapter 3. Moreover, variables used in the models are introduced there. In Chapter 4, we discuss the dataset used for the empirical part, sources of data and then analyse few of the key variables in more details. The penultimate Chapter 5 explains the results obtained in both stages of the regression and various tests performed to ensure the clarity of the results and then discuss the significance of the results and possible improvements. Finally, the last chapter provides the summary of the whole thesis and draws conclusion from the results.

1 Literature review

This chapter's purpose is to look at the literature covering the topic of cross-border shopping. We start with the theoretical works capturing the effect of cross-border shopping on the countries. Then we introduce few empirical works on this topic.

As it was already mentioned, the best-known study of cross-border shopping is by Kanbur and Keen (1993). They developed a simple model that captures the interaction between national tax systems in economically integrated region. Assumptions of the model are that there are two countries, home and foreign, that differs in population size and one type of taxed good. People have certain reservation price for that good, and this reservation price[1] is common within one country but differs from one in other country. Population is distributed uniformly within both countries. Price of producing good is the same for all producers in both countries, and government is trying to maximise revenue from taxes it collect from good sold in the country. Therefore, correspondent taxes are determinants of price in the countries. Moreover, consumers incur costs by traveling to the border of the country. If the economies are closed, and there is no movement across borders, the tax is set at the reservation price of consumers in the country and there is no cross-border shopping. If the economy is open, consumers in home country have option to purchase the good in the foreign country. They do so only if their surplus from purchasing good abroad is greater than costs incurred from traveling to border.

Kanbur and Keen (1993) arrived to several conclusions about the situation when governments in open borders compete in taxes. In Nash equilibrium, smaller country sets lower tax rates than larger one. This induces the cross-border shopping toward the smaller country. This reduces the revenue from taxes in larger country and

[1] I tis a maximum price that consumer is willing to pay for the good. In other words, consumer will purchase good only if its price is below or equal to reservation price

increase revenue in smaller due to cross-border shopping. Total revenue is still higher in larger country, but revenue per capita is higher in smaller country.

Other authors expanded the work of Kanbur and Keen (1993) with similar results. Oshawa (1999) and Nielsen (2001) assume that two countries in the model differ in geographic size rather than population size. Oshawa (1999) constructed the model where are more than 2 countries and tried to show that the differences in taxes are caused by their relative positions as well. The governments in those countries face the trade-off between market share gained by cross-border shopping, and change in revenue from their original market area. The results of his model for two countries correspond with Kanbur and Keen (1993). In case of more than 2 countries, in Nash equilibrium the interior country (one that is bordering only with other countries) have lower tax rate than peripheral countries. This difference in tax rates generates the cross-border shopping. On the other hand, Nielsen (2001) stayed with the two-country model, but he included costs of transportation and border inspections in the model. The results coincide with the results of Kanbur and Keen (1993), and show that higher transportation costs lower the extent of cross-border shopping and in addition cause higher Nash equilibrium tax rates. Nevertheless, Nielsen (2001) concluded that technological development and integration are lowering the transportation costs.

Another author that included additional costs into basic model is Scharf (1999). She took into account transactional, storage and transport costs. Her results are that smaller transactions occurring more frequently should be taxed more than larger transactions. With the optimal taxation in the presence of cross-border shopping are also concerned studies of Christiansen (1994, 2003). Christiansen (1994) studied the impact of market structure on the cross-border shopping. The conclusion is that if the effect of price increase abroad make domestic elasticity of demand less elastic, home government should increase the taxes and monopolies raise the market prices. Christiansen (2003) considered the implications of cross-border shopping on the tax structure of larger country and proposed that tax rate should undercut Pigouvian taxes.[2]

Empirical studies mainly work with panel data and according to Leal et al. (2010), most general form of demand function representing cross-border shopping is following:

$$S_r = S(P_r, P_{\bar{r}}, T_r, T_{\bar{r}}, Y_r, C_r, X) \qquad (1.1)$$

where S_r are sales in territory *r* (can be country, region, etc.) of the studied commodity (alternatively it can be consumption of given commodity), P_r and $P_{\bar{r}}$ are price of that given commodity in region *r* and in bordering regions respectively, T_r and $T_{\bar{r}}$ are taxes on the commodity in region *r* and bordering regions respectively, Y_r is an income in *r*, C_r are costs of traveling to borders and *X* is set of additional control variables, such as dummies. The specification of equations is usually in the logarithmic form for all variables, as this allows examining elasticities between variables.

We will now focus on the studies dealing with cross-border shopping of automotive fuel. The paper of Leal et al. (2009), which is the main source of inspiration for this thesis, studied the effect of a cross-border shopping on consumption of diesel in Aragon. The authors were mainly interested on the impact of new regional taxes on the consumption. They used the monthly data from January 2001 to March 2007 for Aragon and neighbouring Autonomous Communities[3] and used number of new vehicle registrations as the only other variable. They applied two-stage procedure of ECM estimation to obtain the results. They found out that the prices of diesel in neighbouring Communities have positive both long-term and short-term impact on the consumption of diesel in Aragon. They also confirmed negative relationship between price of diesel in Aragon and its consumption there in the long-term. In the short-term, this effect was found to be positive, but authors contributed it to increasing number of vehicle registrations.

[2] Tax imposed on goods producing negative externalities
[3] Political-administrative regions in Spain

Other studies implemented panel data techniques. Banfi et al. (2005) used panel data set for three Switzerland's regions that borders with France, Germany and Italy with period from 1985 to 1997. Beside usual variables used in estimation of cross-border shopping they also included population, vehicle stock and number of daily commuters in the regions. The generalised least square method for pooled times series was used to estimate their equation. They arrived at the conclusion that there is important cross-border effect on demand for fuel – namely, 10% reduction in price of fuel in Switzerland cause 17,5% increase in demand for fuel in Switzerland. They also showed in simulations that cross-border shopping for fuel accounted for 9% of all demand for fuel in Switzerland at given time period and that introduction of new CO2 tax would significantly decrease the fuel tourism.

Rietveld et al. (2001) studied the cross-border shopping for automotive fuel in Netherlands. They used logit model to assess the decisions of Dutch consumer near the borders to purchase fuel in bordering country - Germany, respectively Belgium. The results were that in case of 5 eurocents lower price per litre in neighbouring country, 30% of consumers living near border would decide to purchase fuel abroad. Moreover, they uncovered low implicit value of time needed to travel across border for fuel, as it is often combined with other reasons to travel abroad.

Evers et al. (2004) tested the presence of tax competition in diesel excise among EU countries using panel data from 15 EU countries plus Norway and Switzerland over time period 1978-2001 using fixed effect and first difference estimations. They concluded that the competition exists and that higher- tax countries compete more intensively than lower-tax countries. On the other hand, they did not find an evidence that country size is important in tax competition. Other empirical studies concerned with cross-border shopping can be found in the survey of Leal et al. (2010).

This thesis will try to verify the assumptions about the tax rates mentioned in the theoretical works and then test empirically the presence of the cross-border shopping in the CR using the techniques mentioned in Leal et al. (2009).

2 Cross-border shopping and taxation of fuels

Having reviewed literature concerning our topic, we can now clarify the basic notions of the cross-border shopping and taxation of fuels. As a first thing in this chapter, we define the cross-border shopping and its main causes, and then we examine the tax rates on the fuel from theoretical point of view and finally, we will look into the actual taxation of automotive fuel in the EU and CR.

2.1 Cross-border shopping

In this place we would like to formally define the term cross-border shopping. According to OECD Glossary of Statistical Terms, *"Cross border shopping is the name given to the activity wherein private individuals buy goods abroad because of lower taxes and import them for their own consumption, without declaring them in full in order to avoid paying import duties."* In the EU, however, the consumers do not need to declare most of the goods because of the origin principle that will be mentioned later. For the case of automotive fuels, it is legal to purchase fuel in any country and pay the tax for it only in that country.

As it was mentioned in the definition, cross-border shopping occurs mainly due to differences in taxes. It is highly probable that the producers in the neighbouring countries in the region such as central Europe have similar production costs therefore the prices before taxes are almost at the same level. Nevertheless, taxes are not the only reason for the cross-border shopping. Price of the good is not affected only by taxes, and final prices are important for consumers. The volatility of the exchange rates is one of the reasons – when currency of neighbouring country depreciate considerably, the purchasing power of consumer's own currency is higher and they can buy more of the goods in the foreign country. This is incentive to shop in that country. Furthermore, it is worth mentioning that cross-border shopping may occur in connection with other activities, such as business trip or social visit to foreign country.

To return cross-border shopping for fuel, we know that most of the vehicle drivers are rational, and as the fuel is a product that is the same at any filling station, consumers have no reason to prefer any station to other. Therefore, they will purchase the fuel in foreign country if the price difference is enough to outweigh the costs of travelling to border. Rietveld et al. (2001) propose a solution on this matter. Countries suffering from cross-border shopping can impose spatial graduation of fuel taxes – near the border the taxes would be at the same level as in neighbouring country. Moving from border to inland, taxes would be linearly increasing until they reach the level of taxes of the home country. A good example of this is the smart card system in Italy. It allows the people living near border with Slovenia purchase fuel at Italian filling stations for lower taxes using the cards containing information about the owner and his distance from borders. Shorter this distance is lower tax is owner paying for fuel. This effectively dissuades cross-border fuelling.

From the theoretical point of view, researchers mentioned in previous chapter concludes that smaller countries, be it geographically or by population, should have lower taxes than its larger neighbours. This should draw the foreign consumers to cross-border shop in smaller country, and its revenues from taxes are increased. This is, for example, the case of Luxembourg. The case of CR is a little more complicated. If we look at the population size of the neighbouring countries to CR, Germany and Poland are more populated and Austria and Slovakia are less populated. The populations of Germany and Poland is, however, much bigger than population of CR and populations of Austria and Slovakia are in comparison more close to the population of CR. Similar situation is with geographical sizes. Germany and Poland are several times larger than CR, whereas Slovakia and Austria ale similarly large than CR, with Austria being slightly larger than CR and Slovakia smaller. From the mentioned theoretical works we would say that CR should have lower taxes than Germany and Poland, and thus there should be cross-border shopping in direction from Germany and Poland towards CR. At the same time, taxes should be higher than in Slovakia, which would induce outgoing cross-border shopping toward Slovakia.

With Austria, it is less clear. The taxes could be higher or lower in CR than in Austria, but roughly, they should be almost at the same level. We will see whether these predictions are right in the Chapter 4. In the next section the taxes on fuels are discussed in greater length to help understand the difference in tax rates between countries.

2.2 Taxation of fuel in the European Union and CR

Here we examine what are the tax rates in the EU and CR specifically. But first, we begin by describing the process that leads to final price of fuel. It can be described by the following equation:

$$P_F = (P_O + t_E) \times (1 + t_{VAT}) \qquad (1.1)$$

Final price of fuel is P_F, price of fuel before taxes is P_O, excise tax is t_E and t_{VAT} is value added tax. To explain these taxes, we use glossary of statistical terms by OECD (2013):

- **Value added tax (VAT)**

It is general ad valorem tax imposed by government collected from producer of goods and services. They pay the difference between amounts of VAT from sales and purchases. Therefore, full amount of VAT is transferred from producers on consumers.

- **Excise tax**

Tax imposed only on specific goods, usually on those producing negative externalities. It can be ad valorem or specific; fuel excise tax is specific.

- **Ad Valorem tax**

Tax is charged as fixed percentage of base price of a product. VAT is Ad Valorem tax.

- **Specific tax**

Tax levied on the quantity of goods, it do not depend on its price.

Both VAT and excise tax are indirect taxes, it means that the full amount of tax is not paid by taxpayer (in our case, fuel station owner), but its part is rather shifted on another person, consumer. To put it simply, we add the amount of excise duty to the price of fuel before taxes, and then we add VAT and get the final price of fuel. Excise tax of fuel is levied per litre of fuel and is used as means of correcting the externality produced by vehicle pollution and as a source of money for construction and maintenance of roads.

The important fact is that from 1 January 1993 the origin principle of taxation is applied in EU. This means, as Lockwood and Migali (2009) explained, that taxes must be paid in the country where the goods are purchased, and can be imported into home country if they are not for sale. This opened up possibility for cross-border shopping. Also the minimum tax harmonization in the EU means that there is possible for countries to compete with tax rates. Nowadays, only minimum tax rates are imposed by the EU. According to The VAT Directive 2006/112/EC, minimal basic rate of VAT is 15%. The minimal excise duty on petrol is 359 EUR per 1000 litre and on diesel it is 330 EUR per 1000 litre, as proposed in Council directive 2003/96/EEC.

The impact of the minimum tax rates on countries with the presence of cross-border shopping is positive according to Kanbur and Keen (1993). Larger countries benefits from minimum tax rate with increased revenue because volume of cross-border shopping decreases, as smaller country sets its tax rates to minimum rate (it is supposed to have lower tax rate than minimum before minimum rate is agreed in economic union). Evers et al. (2004) found evidence that the minimum tax rates contributed to increased average diesel prices and decreased the tax competition in the EU.

We now focus on the development of the excise taxes on fuel in CR for the last ten years. The excise duty on petrol rose from 10840 CZK per 1000 litres in 2003 to 11840 CZK per litres in 2006 and finally to 12840 CZK per 1000 litres since 2010.

The excise duty on diesel changed in similar fashion, from 8150 CZK per 1000 litres in 2003 to 9950 CZK per 1000 litres in 2006 and to 10950 CZK per 1000 litres since 2010. This increase in excise duties can be explained by inflation, so rates needed to be adjusted to catch up with it. Development of excise taxes in neighbouring countries is shown in Figure 1. As we can see, excise taxes in CR are relatively low, at the almost same level as Slovak excise taxes. Polish and Austrian rates are below Czech rates, and German excise tax rates are the highest.

If we look at the development of VAT rates, they have been changed only little. They decreased from 22% in 2004 to 19% and then they slightly rose to 20% since 2010. The development of VAT rates in CR and all neighbouring countries is shown in Figure 2. We can see that Czech VAT rates are one of the lower rates in the region. Higher are Polish and Austrian tax rates, lower only German rates.

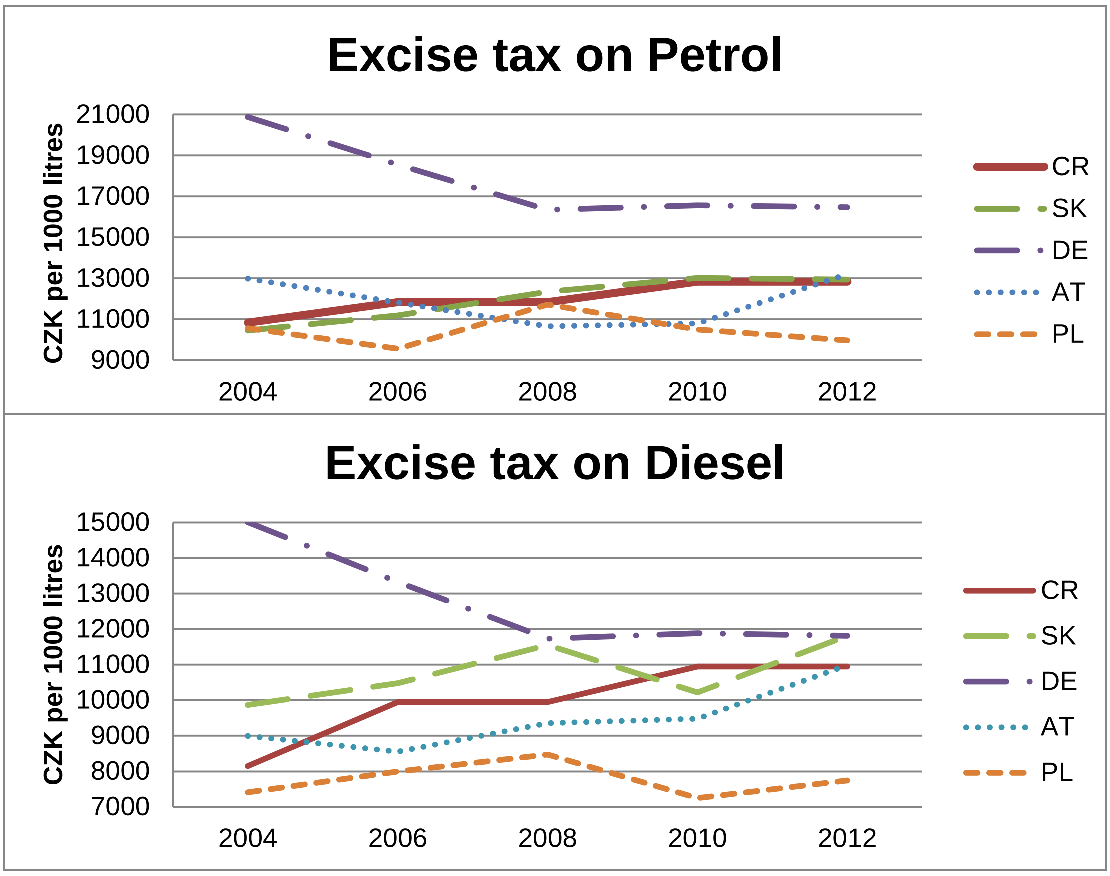

Figure 1: Development of excise taxes in CR and neighbouring regions
Source: OECD (2012) and author's caclulations

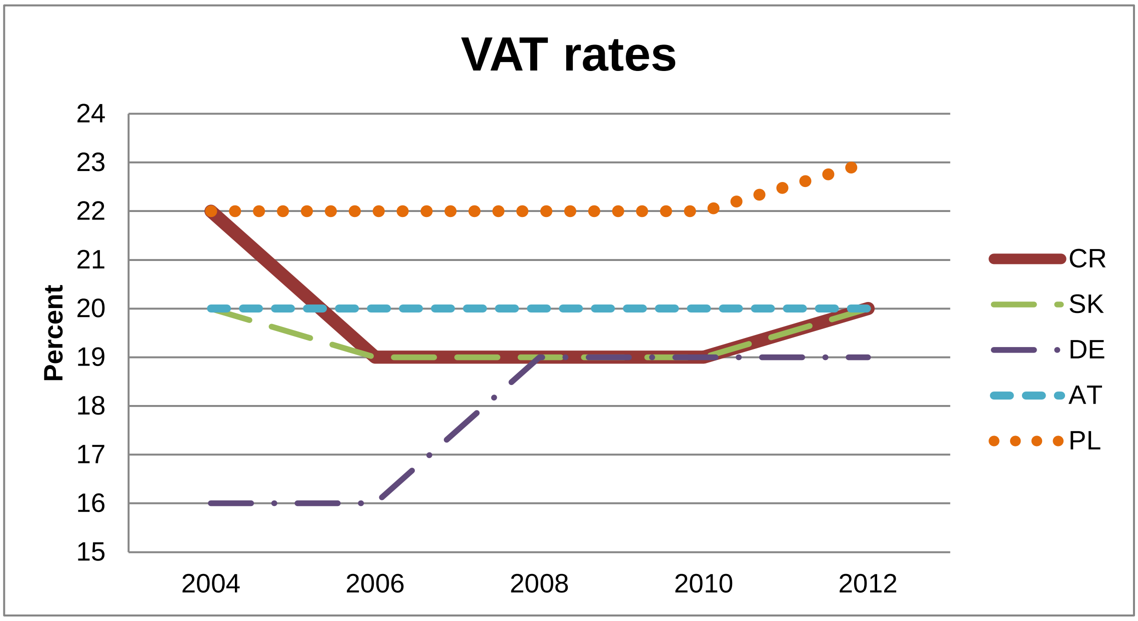

Figure 2: Development of VAT rates in CR and neighbouring regions
Source: OECD (2012) and author's caclulations

3 Methodology

In this chapter we explain the variables and methods we use in our empirical part. As it was mentioned earlier, this thesis follows the study of Leal et al. (2009). We use the econometric model proposed by them and apply it on the data for CR and countries bordering with it, namely Slovakia, Germany, Austria and Poland. In following sections, we introduce variables for the model and then the model itself.

3.1 Variables

We use the similar set of variables and couple of our variables that may be useful in our model. All variables are monthly time series.

- **Quantity of automotive fuel demanded**

The variable that is to be explained by the model, it measures the amount of fuel purchased by consumers.

- **Price of automotive fuel in CR**

The traditional variable that has the greatest influence on quantity of fuel demanded. In basic economic theory, there is negative price elasticity of demand. That means higher price of fuel should lead to lower quantity of fuel purchased. Nowadays, as most of the people in mentioned countries use vehicles on the daily basis, fuel is regarded as necessary good, and thus is expected to be relatively less elastic; changes in quantity demanded are less than proportional to changes in price.

- **Prices of automotive fuel in neighbouring countries**

We have explanatory variable for price for each of the country that borders with CR. These are to be used to deduce the effect of the cross-border shopping on amount of fuel purchased in CR. The relationship is apparent: higher the price of fuel in one of the bordering countries, the higher quantity of fuel purchased in CR. The cross-price elasticity of demand is positive.

- **Number of new vehicle registrations in CR**

This acts as a proxy variable to income that is traditionally used in studies of cross-border shopping. The effect of this variable on quantity of fuel demanded should be positive, as more vehicles that are registered mean higher demand for fuel.

- **Exchange rate**

This variable serves to control for movements in prices of fuel in neighbouring countries caused by fluctuations in the exchange rates of their currencies. This is addition to the model because the countries in our work have different currencies.

- **Dummy variables**

Quantity of fuel demanded is the monthly time series. We expect it to show a seasonal pattern[4], so the full set of monthly variables is included to control for this seasonal effect.

The price variables can be regarded as exogenous, as fuel market is competitive and thus producers and consumers are price-takers. Vehicle registrations and exchange rates are exogenous as well, because the exchange rates are determined at the forex market.

[4] For example, during the summer months, more people drive longer distances for vacation and they choose where to stop for fuelling. Typical example: people from Germany travel to Croatia and they stop in CR to purchase fuel.

3.2 Model

The model that will be tested is based on following demand equation suggested by Leal et al. (2009):

$$Q_r = Q_r(P_r^G, P_{\bar{r}}^G, X_r) \tag{1.1}$$

which tells us that demand for fuel in region *r* is a function of price of fuel in the region *r* (P_r^G), price of fuel in other regions ($P_{\bar{r}}^G$) and other factors affecting demand for fuel in that region (X_r). This function differs from the one used by other authors in fact that Leal et al. (2009) do not include in the model consumer *i*'s disutility from distance to region *r* because the consumers that purchase fuel in that region are going to make the trip anyway.[5]

Next, we can extend this basic demand function into one that we use in our model:

$$Q_{CR}^f = Q_{CR}^f(P_{CR}^f, \frac{P_{SK}^f}{P_{CR}^f}, \frac{P_{DE}^f}{P_{CR}^f}, \frac{P_{AT}^f}{P_{CR}^f}, \frac{P_{PL}^f}{P_{CR}^f}, VehReg_{CR}, ExR_{\frac{CZK}{EUR}}, ExR_{\frac{CZK}{PLN}}) \tag{1.2}$$

where $Q_{CR}^f$is monthly amount of fuel f purchased (*f* can be petrol or diesel), P_{CR}^f is monthly price of fuel *f* in CR, P_{SK}^f, P_{DE}^f, P_{AT}^f and P_{PL}^f are prices of fuel in Slovakia, Germany, Austria and Poland respectively, $VehReg_{CR}$ number of new vehicle registrations in CR, $ExR_{\frac{CZK}{EUR}}$ and $ExR_{\frac{CZK}{PLN}}$ monthly average exchange rates of czech crowns to euro and polish zloty respectively. This is slightly expanded demand function as the one proposed by Leal et al. (2009). The demand for fuel *f* depends on its price in CR, and relative prices of fuel *f* comparing to prices in the neighbouring countries. Other variables serve as controls. This way we can separate the domestic substitution effect of price change and substitution of fuel consumption between bordering countries when their relative prices of fuel change.

[5]For example business trip, travel to vacation or to visit someone

Having defined our demand function for automotive fuel, we would like to find out the effects of cross-border shopping on the demand for fuel. We will do this by estimating the following equation:

$$(Q_{CR}^{f})_t = \alpha_0 + \alpha_1 (P_{CR}^{f})_t + \alpha_2 \left(\frac{P_{SK}^{f}}{P_{CR}^{f}}\right)_t + \alpha_3 \left(\frac{P_{DE}^{f}}{P_{CR}^{f}}\right)_t + \alpha_4 \left(\frac{P_{AT}^{f}}{P_{CR}^{f}}\right)_t + \alpha_5 \left(\frac{P_{PL}^{f}}{P_{CR}^{f}}\right)_t + \alpha_6 (VehReg_{CR})_t + \alpha_7 \left(ExR_{\frac{CZK}{EUR}}\right)_t + \alpha_8 (ExR_{\frac{CZK}{PLN}})_t + u_t \qquad (1.3)$$

We will estimate this equation firstly by OLS, and then by two-stage estimation procedure of Engle and Granger (1987) - ECM method.

- **Error correction model**

We assume that our variables are strongly dependend. Weak dependence is required property in the time series, as it is one of the OLS assumptions, and its violation causes invalid inference. We are concerned that our variables follows unit roots processes, such as:

$$y_t = \beta_0 + y_{t-1} + \varepsilon_t \qquad (1.4)$$

Such series are also called integrated of the order 1, I(1). According to Granger and Newbold (1974), this may cause spurious regression problem, where OLS can show relationship between variables, even though time series are independent of each other. Nevertheless, we can still use OLS for estimation of the long-term relationship, if the variables are cointegrated. They are cointegrated if there exists their linear combination that is I(0), which is stationary and weakly dependent process. The variables are cointegrated with parameters α (from equation (1.5)).Then we can construct ECM that allows us to study the short-term relationships between the variables. Our ECM follows Wooldridge (2002):

$$\Delta y_t = \beta_0 + \sum_{i=1}^{n} \beta_i \, \Delta x_{i,t} + \gamma(y_{t-1} - \sum_{i=1}^{n} \alpha_i x_{i,t-1}) + e_t \tag{1.5}$$

where term $\gamma(y_{t-1} - \sum_{i=1}^{n} \alpha_i x_{i,t-1})$ is the linear combination of cointegrated variables called error correction term and it is estimated from OLS equation as lagged residual $\hat{u}_{t-1}$ with $\gamma < 0$, letter Δ means the first difference of the variable and *n* is the number of explanatory variables in equation. Now differenced variables are I(0) (as differencing decrease the order of the integration) and error correction term, as the variables are cointegrated, is I(0) as well. Therefore, all of the variables used in this model are stationary and weakly dependent, and can be used in OLS regression with consistent results. The error correction term corrects the deviations from long-term equilibrium using short-term dynamics. The two-stage estimation suggested by Engle and Granger (1987) includes firstly estimating long-term equilibrium using OLS on equation 1.5 to obtain long-term equilibrium and estimates of cointegration parameters α, and secondly, using OLS on ECM equation (1.7) to obtain short-term relationships.

4 Data analysis

This chapter provides the analysis of the dataset we are going to use in our empirical part of the thesis. Firstly, we mention here the source of the data used in the empirical part. The data for the variable of our interest, monthly quantity of automotive fuel consumed, were gained from the monthly journals of Czech Statistical Office (CZSO) *“Ropa, ropné produkty a zemný plyn”*. These data are in 1000 tons.

Monthly average price of the automotive fuel in all five countries were obtained from dataset of historical fuel prices from Europe’s Energy Portal. The data on this portal are received from its registered responded and are analysed and weighted to build accurate average monthly price of fuel. The prices are in both euro and local currency. In order to be consistent, we obtained the average monthly exchange rates from Czech National Bank (CNB) and calculated all prices in CZK.

Number of new vehicles registrations is available at the Ministry of the Interior of the Czech Republic (MICZ), section Central Vehicle registration. It is the total number of all new registrations in the given month, including new and used vehicles.

All of the variables are observed monthly from January 2005 to December 2012, thus making it time series with 96 observations for each variable, which is relatively large number to make good conclusion from regression. Moreover, we took the natural logarithms of all variables as it is usual in all empirical works concerning the cross-border shopping. This allows us to interpret the results of regression as elasticities and it deals with possible outliers in the dataset. Descriptive statistics are in the Appendix B.

- **Quantity of automotive fuel demanded in CR**

Here we will look how the consumption of fuel in CR developed over the observed period of time. Both petrol and diesel quantity are plotted in Figure 3. As we can see, there is more demand for diesel in CR. Among the personal vehicles, number of petrol and diesel ones is roughly the same. What makes the difference is usage of diesel motors in truck. Both petrol and diesel are therefore important part of cross-border fuelling. Another information we see from this figure is that there is seasonality in fuel consumption. The peaks in consumption are in the summer months, and troughs are in the winter months. This can be explained by movement to holidays during the summer and larger volume of foreigners travelling through CR.

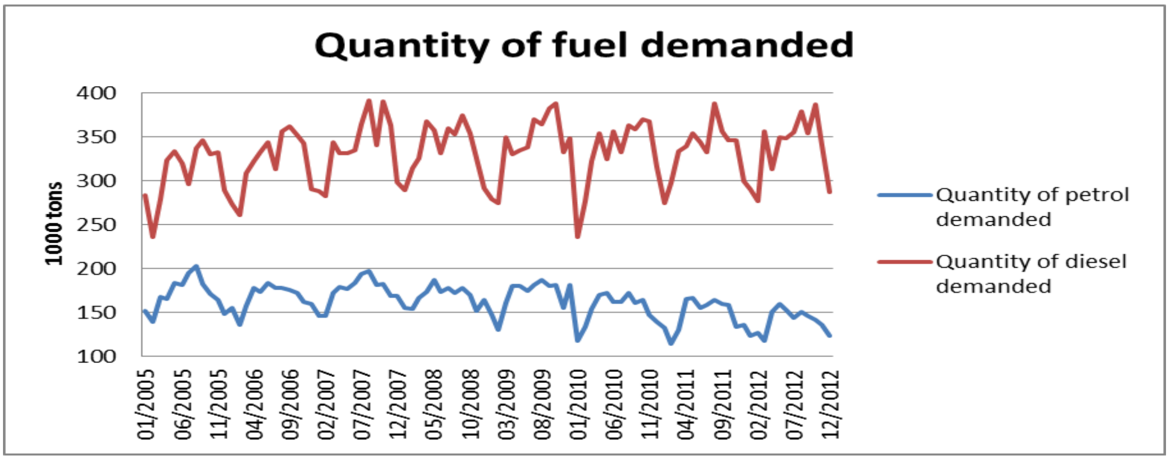

Figure 3: Quantity of automotive fuel demanded in CR
Source: CZSO (2013) and author's calculations

- **Number of new vehicle registrations**

Figure 4 shows the development of new vehicle registrations. As we can see, here are some seasonal trends as well. Peaks are in the May, and troughs are in January.

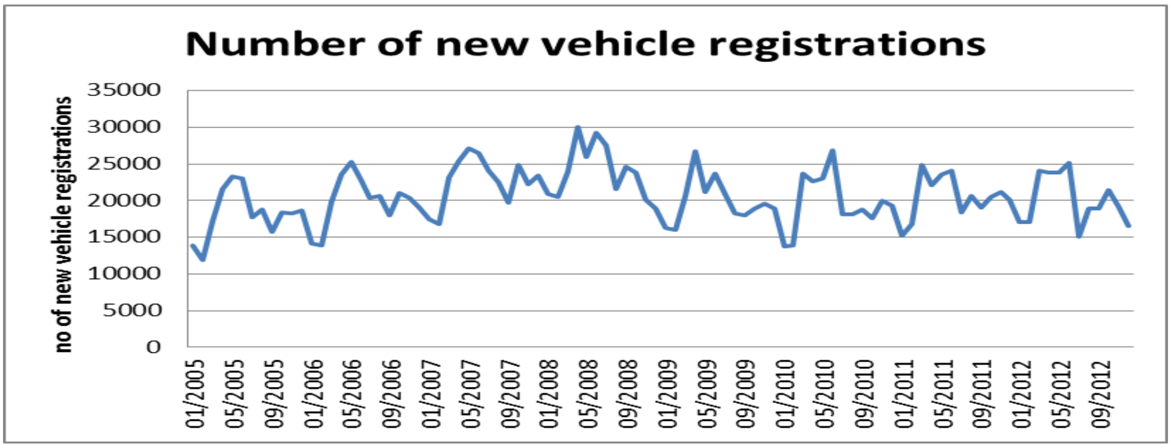

Figure 4: Number of new vehicle registrations in CR
Source: MICZ (2013) and author's calculations

- **Price of automotive fuel in CR**

We will look at the composition of fuel prices in CR. Using equation 1.2 we calculated base price of fuels and the amount of VAT to show the importance of taxes on the fuel price. As it can be seen in the Figure 3, taxes on petrol make up more than 50% of the final price of petrol. In December 2012, price of petrol was 37.81 CZK per litre, and total taxation was 19.14. Price of diesel was at that time 36.88 and total tax was worth 17.10 CZK, which is slightly less than a half (See Appendix C). Therefore, taxes are indeed the significant part of the fuel prices. In addition, we can see in Figure 3 that VAT part of the tax is getting larger, as the base price of fuel increases. Overall, prices of fuel follows upward trend, with slump at the start of the crisis in fall 2008.

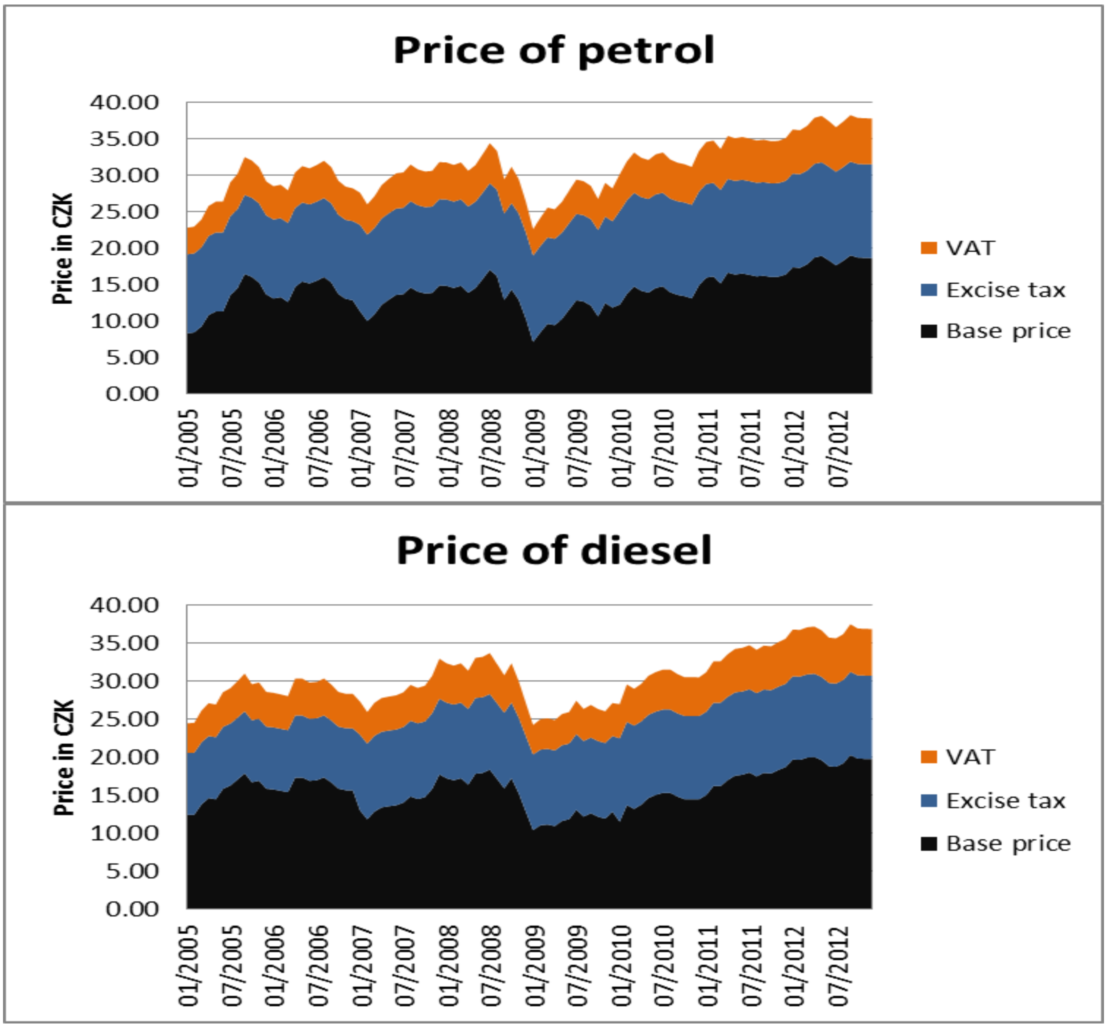

Figure 5: Composition of price of automotive fuel in CR
Source: OECD (2012), EEP (2013), CNB (2013) and author's calculations

- **Comparison of total amount of taxation of CR with neighbouring countries**

Now we will compare the total amount of tax per litre of fuel in CR with the other countries. As we can see, for both petrol and diesel the highest taxes are in Germany. This is not surprising, as Germany is much larger and more populated than other countries. This confirms the theoretical assumption about the level of taxation. Slovakia is, in case of petrol taxes, almost at the same level than CR and in diesel it is also similar. We noted that theoretically, Slovakia should have lower tax rates. This similarity can be attributed to the fact that Slovakia and CR were one republic few years earlier and they keep similar rates since then. Austria have lower tax rates than CR, which partially confirms the theory. On the other hand, Poland, as much larger and more populated country, have lower rates. This is contradictory to the theory. Explanation can be that Poland keeps lower taxes to compete with other countries to improve their economic situation.

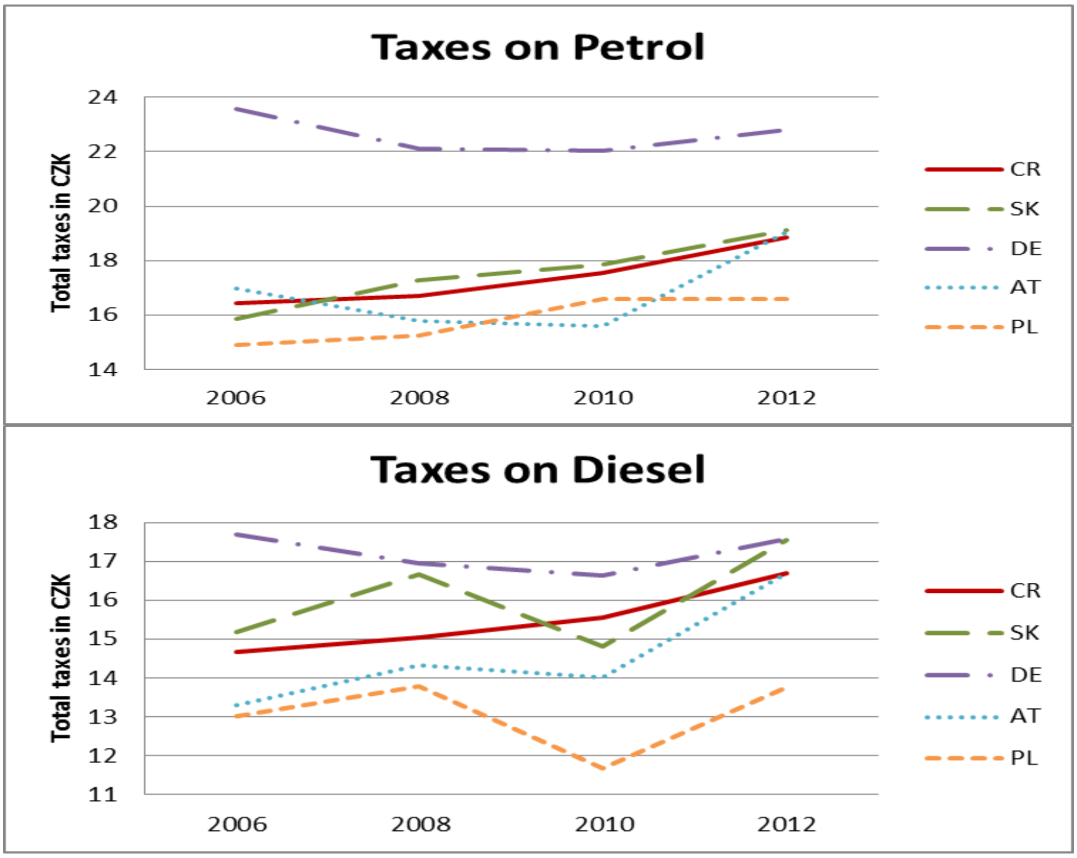

Figure 6: Total amount of fuel taxes in CR in comparison with neighbouring countries.
Source: OECD (2012), EEP (2013), CNB (2013) and author's calculations

5 Empirical analysis

In this chapter, we will use the models introduced in Chapter 3.2 on the data described in the previous chapter. First, we will use the OLS model and show the results of the regression, and then we perform the necessary tests to determine whether OLS is satisfying. After that, we move on ECM model and the results of it. OLS model can be used as a static model showing long-term equilibrium, and ECM shows us short-term adjustments of the model. This is basically the two-stage estimation procedure suggested by Engle and Granger (1987). We will use the models separately for the petrol and for the diesel. Last part will be dedicated to the discussion of the results.

Before we look at the actual results, let us state our expectations. Firstly, we would like to show inverse relationship between price of automotive fuel in CR and quantity of fuel demanded in CR. The relative prices of neighbouring countries should have positive impact on quantity of fuel demanded in CR. The number of new vehicle registered should have positive impact as well. Exchange rates should have also positive impact, as the more Czech crowns foreigners get for euro (or zloty), more fuel they are able to buy in the CR. Finally, we will look whether we can confirm these hypotheses.

5.1 OLS and long-term equilibrium

In this section, we use the OLS estimation to obtain preliminary results. First of all, we check the variables for multicollinearity. Multicollinearity occurs when there is correlation between couple of variables higher than 0.8 and it causes the instability of the results. Perfect collinearity is violation of one of the OLS assumption. From the correlation matrix (in Appendix D) we see that data for diesel do not contain any multicollineared variables. The data for petrol, on the other hand, reveal few couples with correlation higher than 0.8, namely between $\frac{P_{DE}^{p}}{P_{CR}^{p}}$ and $\frac{P_{AT}^{p}}{P_{CR}^{p}}$. It can be possible that Germany and Austria had similar development of fuel prices, hence the high correlation. Another highly correlated couple of variables are P_{CR}^{p} and $\frac{P_{DE}^{p}}{P_{CR}^{p}}$. Moreover, exchange rates are correlated to relative prices. This is expected, as it is possible that changes in relative price can be caused by exchange rates fluctuations. Therefore, the models for diesel can be regarded safe from multicollinearity, and models for petrol not, which can cause instability of the results. Nevertheless, no variable is perfectly correlated with another, so OLS assumption is not violated. We will test for significance of exchange rates and construct the model without these two variables.

We performed OLS regression with 96 observations on the following equation:

$$\begin{aligned}\ln\left(Q_{CR}^{f}\right)_t = {} & \alpha_0 + \alpha_1 \ln\left(P_{CR}^{f}\right)_t + \alpha_2 ln\left(\frac{P_{SK}^{f}}{P_{CR}^{f}}\right)_t + \alpha_3 ln\left(\frac{P_{DE}^{f}}{P_{CR}^{f}}\right)_t \\ & + \alpha_4 ln\left(\frac{P_{AT}^{f}}{P_{CR}^{f}}\right)_t + \alpha_5 ln\left(\frac{P_{PL}^{f}}{P_{CR}^{f}}\right)_t + \alpha_6 \ln(VehReg_{CR})_t \\ & + \alpha_7 \ln\left(ExR_{\frac{CZK}{EUR}}\right)_t + \alpha_8 \ln(ExR_{\frac{CZK}{PLN}})_t + \delta_0 t \\ & + \delta_i \sum_{i=1}^{11} D_i + u_t\end{aligned} \qquad (\ 3.1\ )$$

where $\alpha_0,\ \alpha_1, \dots, \alpha_8$ are parameters to be estimated, *t* is variable for time trend, D_i is the set of the monthly dummy variables and u_t is the sequence of disturbance terms. First of all, we performed the regression of this equation and tested the joint significance of month dummies. They were jointly significant (Appendix E) and also most of them were significant individually. Therefore, we “deseasonalized” the variables and then performed the regression without dummies.

The results of this regression are presented in the Table 1, under headings OLS 1.1 and OLS 2.1 for petrol and diesel respectively. Before commenting the results, we need to look on OLS assumptions if they are satisfied. We assume that the equation (3.1) is the true model, and that the disturbance term is uncorrelated with explanatory variables at the time *t*. We then performed Breusch-Pagan test for heteroscedasticty and correlogram in STATA and have found out that for petrol, we have both homoscedasticity and no serial correlation assumptions satisfied. For diesel estimation, heteroscedasticity and serial correlation is present. Additionally, we performed Shapiro-Wilk tests for normality of residuals, and they are normaly distributed in both cases. The estimations for diesel are therefore likely to be biased and inefficient. The test results are in Appendix E.

As we can see for petrol equation and OLS estimation in Table 1, the inverse relationship between price of petrol in CR and quantity demanded in CR is indeed negative and highly statistically significant at 1% level. Specifically, 1% increase in price of petrol in CR causes 0.23% decrease in petrol demand in the long-term, holing other variables constant. This confirms our hypothesis and elasticity is indeed relatively inelastic. In addition, the amount of vehicles registered is positively related to quantity of petrol demanded and highly statistically significant at 1% level. Unfortunately, other variables are insignificant, only the relative price of petrol in Slovakia is significant at 10% level, but the direction is opposite of what we have expected. The adjusted R-squared tells us that 68% of variations in the quantity of fuel demanded is explained by explanatory variables, which is relatively good number. The results for diesel, in column OLS 2.1, are worse. The only statistically highly significant variable is amount of new vehicle registrations, which have the desired effect on the quantity of diesel demanded in CR. The R-squared for this model is only 37%. This may be caused by the heteroscedasticity and serial correlation problem mentioned earlier.

We then tested the joint significance of the exchange rates variables, and found out that they are jointly insignificant. We then performed OLS estimation on the model without them, with results in Table 1, columns OLS 1.2 and OLS 2.2 for petrol and diesel respectively. After performing tests for heteroscedasticity and serial correlation, we arrived to similar results as in previous models. Model for petrol satisfies homoscedasticity and no serial correlation assumptions, whereas model for diesel have serially correlated disturbances, but this time we could not reject homoscedasticity. Again, normality assumption was in both cases confirmed (see

Appendix E). This change of the model brought only minor changes in the results. Results for petrol are similar, with variables P_{CR}^{p} and $VehReg_{CR}$ as highly statistically significant at 1% level. The effect of petrol price in CR is now less, only 0.02% decrease of demand with 1% increase in this price. Relative price of petrol in Slovakia, $\frac{P_{SK}^{p}}{P_{CR}^{p}}$, now became more significant- at 5% level, but still at the opposite direction than expected. Moreover, Adjusted R-squared remained at 68% level. Results for diesel variables are similar to OLS 2.1 that all variables are statistically insignificant besides new vehicle registrations.

As we mentioned in the theoretical part, it is likely that our time series have unit roots, meaning they are strongly dependent. Then the results of OLS regression are inconsistent, because we need weak dependence for the estimates to be consistent. Now we need to test for unit roots in variables, and then find out whether the dependent variable, quantity of automotive fuel demanded in CR, is cointegrated with the linear combination of explanatory variables. After we verify the cointegration, we can use ECM to estimate better results. The OLS estimation then serves us as the first stage in this estimation.

- **Unit root & cointegration**

We firstly plotted the variables against time variable to see possible trends in the time series. Figures are in Appendix F. Then we used Augumented Dickey-Fuller test to determine whether the variables have unit roots. We use 11 lags as we are using monthly data. Null hypothesis of the test is unit root in variable. In case of petrol, we cannot reject unit root at 5% in almost all variables. Only exception is variable $\frac{P_{SK}^{p}}{P_{CR}^{p}}$, where we reject unit root at this level of confidence. In case of the diesel, we cannot reject unit roots at 5% level in almost every variable beside $\frac{P_{DE}^{d}}{P_{CR}^{d}}$. All of these results are in Appendix F.

$\log(Q^p_{CR})$	OLS 1.1	OLS 1.2	$log(Q^d_{CR})$	OLS 2.1	OLS 2.2
$\ln(P^p_{CR})$	-0.40113932*** (-0.22717233)	-0.42627179*** (-0.02301591)	$\ln(P^d_{CR})$	-0.12730003 (0.30109705)	-0.11883308 (0.18774639)
$\ln(\frac{P^p_{SK}}{P^p_{CR}})$	-0.43996184*	-0.43906907**	$\ln(\frac{P^d_{SK}}{P^d_{CR}})$	-0.02904548	-0.05794274
$\ln(\frac{P^p_{DE}}{P^p_{CR}})$	0.43546088	0.27863348	$\ln(\frac{P^d_{DE}}{P^d_{CR}})$	-0.24754561	-0.14819484
$\ln(\frac{P^p_{AT}}{P^p_{CR}})$	-0.27599342	-0.30813519	$\ln(\frac{P^d_{AT}}{P^d_{CR}})$	0.16153195	0.04747508
$\ln(\frac{P^p_{PL}}{P^p_{CR}})$	0.10652739	0.0653149	$\ln(\frac{P^d_{PL}}{P^d_{CR}})$	-0.31333794*	-0.14791697
$\ln(VehReg_{CR})$	0.14900733***	0.17266805***	$\ln(VehReg_{CR})$	0.23646109***	0.26414267***
$\ln\left(ExR_{\frac{CZK}{EUR}}\right)$	-0.22140902	-	$\ln\left(ExR_{\frac{CZK}{EUR}}\right)$	0.06066639	-
$\ln(ExR_{\frac{CZK}{PLN}})$	0.10652739	-	$\ln(ExR_{\frac{CZK}{PLN}})$	0.29735721	-
t	-0.00100245	-0.00094398*	t	0.0013944**	0.00058742*
$\bar{R}^2$	0.6805	0.6842	$\bar{R}^2$	0.3740	0.3705

Table 1: Econometric results for OLS estimation of petrol and diesel demand.
Source: Output from Stata, Data source: EEP (2013), CZSO (2013), CNB (2013), MICZ (2013)
Legend: * p-value < 10%, ** p-value < 5%, *** p-value < 1%, $\bar{\boldsymbol{R}}^{\boldsymbol{2}}$ is adjusted R squared. The brackets () means that this is the elasticity of variable as calculated by differentiating eq. (3.1)

In order to use ECM successfully, we need also show that variables are cointegrated. For this, we used the Engle-Granger test in Stata developed by Schaffer (2010). Null hypothesis of this test is that there is no cointegration. For petrol variables, we rejected the null, therefore the variables are indeed cointegrated and we can proceed to ECM. On the other side, test results for diesel variables showed that they are not cointegrated (see Appendix F). We, therefore, estimate ECM only for petrol.

5.2 Error correction model

The model we will estimate have following equation:

$$\Delta\ln\left(Q_{CR}^{f}\right)_t = \alpha_0 + \alpha_1\,\Delta\ln\left(P_{CR}^{f}\right)_t + \alpha_2\Delta ln\left(\frac{P_{SK}^{f}}{P_{CR}^{f}}\right)_t + \alpha_3\Delta ln\left(\frac{P_{DE}^{f}}{P_{CR}^{f}}\right)_t + \alpha_4\Delta ln\left(\frac{P_{AT}^{f}}{P_{CR}^{f}}\right)_t + \alpha_5\Delta ln\left(\frac{P_{PL}^{f}}{P_{CR}^{f}}\right)_t + \alpha_6\Delta\ln(VehReg_{CR})_t + \delta_0 t + \gamma\hat{u}_{t-1} + e_t \quad (3.2)$$

where Δ means that the variable is first-differenced, $\hat{u}_{t-1}$ are the lagged residuals from first stage – OLS regression, γ is the coefficient measuring the speed of the adjustment of the model to the long-term equilibrium and e_t is the disturbance term, independent and identically distributed. The number of the observations used in this regression is now just 95, as one observation cannot be used due to presence of the lagged variable. The OLS estimation is applied on this equation and subsequent results of the regression are presented in the Table 2. The tests for serial correlations confirmed that we have no serial correlation in the disturbance term and Breusch-Pagan test indicates that we have the presence of the heteroscedasticity. This can be corrected by using heteroscedasticity-robust standard errors. This, nevertheless, only change the significance of the variables, estimates remains the same. Finally, we confirmed the normality of residuals by Shapiro-Wilk test.

From the Table 2 we can see that we obtained some interesting results. The results now show short-term elasticities. Variable price of petrol in CR, P_{CR}^{p}, is statistically significant at 5% level, and tells us that 1% increase in price cause 0.36% decrease in petrol demand in CR, which is according to our hypothesis. We also obtained statistically significant elasticity on variable relative price of petrol in Germany, $\frac{P_{DE}^{p}}{P_{CR}^{p}}$, at 5% level. If relative price in Germany increases by 1%, demand for petrol in CR increases by 0.51%, which confirms our theory. Another statistically significant variable, relative price in Austria $\frac{P_{AT}^{p}}{P_{CR}^{p}}$, have negative coefficient, which is not according to our hypothesis. The statistical insignificance of the relative price of petrol in Slovakia, $\frac{P_{SK}^{p}}{P_{CR}^{p}}$, can be explained by the fact that Slovakia's prices of petrol developed similarly to prices in CR, and so the amount of cross-border shopping for petrol is likely to be low. Other variables are not statistically significant. Coefficient on lagged residuals of the first-stage estimation is negative and highly statistically significant. This tells us that the model adjust to its long-term equilibrium almost immediately. The adjusted R-squared of the model is 52%, which is relatively good for the economics.

$\Delta\log(Q_{CR}^{p})_t$	**ECM**
$\Delta\ln(P_{CR}^{p})_t$	-0.45555854** (-0.35699912)
$\Delta\ln(\frac{P_{SK}^{p}}{P_{CR}^{p}})_t$	-0.36851173
$\Delta\ln(\frac{P_{DE}^{p}}{P_{CR}^{p}})_t$	0.50956298**
$\Delta\ln(\frac{P_{AT}^{p}}{P_{CR}^{p}})_t$	-0.61694025**
$\Delta\ln(\frac{P_{PL}^{p}}{P_{CR}^{p}})_t$	0.00881785
$\Delta\ln(VehReg_{CR})_t$	0.0643532
u_{t-1}	-0.97097824***
t	-0.00001699
$\bar{R}^2$	0.5263

Table 2: Econometric results for ECM estimation of petrol demand.
Source: Output from Stata, Data source: EEP (2013), CZSO (2013), CNB (2013), MICZ (2013)
Legend: * p-value < 10%, ** p-value < 5%, *** p-value < 1%, $\bar{\boldsymbol{R}}^{\boldsymbol{2}}$ is adjusted R squared. The brackets () means that this is the elasticity of variable as calculated by differentiating eq. (3.2)

5.3 Discussion of the results

Our models provided us with a few interesting results. We start with the discussion on the result of the diesel variables. We managed to find out in both models OLS 2.1 and OLS 2.2 that in the long-term, there is positive relationship between new vehicle registrations in CR and demand of diesel in CR. The lack of significance of the other estimated coefficients may be caused by heteroscedasticity and serial correlation problems, which cause invalid standard errors and we cannot test hypothesis validly. Results from the petrol variables OLS regression look a lot better. There is neither heteroscedasticity nor serial correlation present, so we have consistent estimates, although many of them statistically insignificant. On the other hand, we moved on to estimate ECM where we obtained some good results. Only problem occurred with the heteroscedasticity. As it was mentioned, however, we can correct the estimates using heteroscedasticity-robust standard errors, or using feasible generalized least squares estimation, which would make the model more complicated. We applied ECM because we proved that petrol variables are cointegrated. On the other hand, we disregarded the fact that in one of the variables we rejected the unit root, because we felt that another form of strong dependence was present in that variable. On the diesel variables, we did not applied ECM model as we did not find the evidence on cointegration, which is one of the assumption of the model.

When we compare our results with the results of study by Leal et al. (2009), we see that they get more statistically significant results. They confirmed positive long-term and short-term relationship between price of diesel in Aragorn and the diesel consumption there and also they managed to confirm the inverse short-term relationship between price of diesel in neighbouring regions and diesel consumption in Aragon in most of the regions. One source of the problems in our data can be the fact that the relative price levels of neighbouring countries are heavily affected by the fluctuations of the exchange rates. This causes that our model, which is originally set to find out evidence of the cross-border shopping between the regions with the same currency, is not able to cope well with these different currencies. In our case is cross-border shopping affected not only by differences in prices due to different taxation (which is our hypothesis) but also by depreciation or appreciation of currency. In case of the study by Leal et al. (2009), they did not have to deal with the different currencies, as all of the Spanish regions use the same currency. Another complication in our data in comparison to Spanish data is that the production costs of providing filling stations can differ across countries due to different labour costs. This causes the differences in prices of fuels as well, so taxes probably play smaller role in relative prices than we thought.

One of the improvements would be to include some variables that could cope with these changes in exchange rate. We tried by including the exchange rates in the model, but they proved insignificant and did not affect the result much, possibly because we were using the prices already converted to CZK. Another possible improvement would be to use more sophisticated models that can be used for both I(0) and I(1) variables. Moreover, the model’s explanatory power might increase if we would be able to include income per capita variable, as it is better control explanatory variable than number of new vehicle registrations, which acts only as proxy to income.

Conclusion

The objective of this thesis was to study the extent of the cross-border shopping for automotive fuel in the CR. In order to examine the extent of cross-border shopping on the quantity of fuel demanded we used the approach proposed by Leal et al. (2009) and applied their model on the data from the CR.

In the first part of the thesis, we introduced the topic of cross-border shopping and various factors affecting its extent. We introduced the taxation in the CR and in the EU, and explained how the automotive fuel is taxed. The governments levy excise tax on fuels and of course, the VAT applies on the fuels, so in fact fuels are relatively heavily taxed. We showed that in the CR, the taxes form about 50% of the final price of fuel. Subsequently, we tried to state our expectation about the tax rates in CR in comparison to neighbouring countries according to theoretical works. These assumptions were that CR should have lower taxes than Germany and Poland, and greater that Slovakia and about the same as Austria. In fourth chapter, we showed that we were right about German and Austrian tax rates, but Polish and Slovak tax rates were not what we expected. Nevertheless, similar Slovak rates can be explained by the fact that Slovakia and CR were one country not long ago, and Polish lower rates can be explained by their weaker economy or lower fuel margins in the filling stations.

The most important part of this thesis was the empirical part where we tested the econometric models of the cross-border shopping for fuel. We tested separately models for petrol and diesel, and we tried to explain the quantity of fuel demanded in CR with variables price of fuel in CR, relative prices of fuel in neighbouring countries, and with control variables number of new vehicle registrations and exchange rates. Variables were taken as natural logarithms to allow us the elasticity interpretation. Monthly data were used from the period beginning in January 2005 and ending in December 2012. The sources and analysis of the data was provided in

Chapter 4. We then stated our hypothesis about the results of the model and for the estimation we used the two-stage Engle-Granger procedure.

As a first stage, we performed OLS regression of the model written in the equation (3.1). The results for the diesel were that almost all variables were statistically insignificant. We just managed to show at 1% level of significance that one per cent increase in number of new vehicle registrations causes 0.24% increase in diesel consumption, other thing equal. Second model for diesel without exchange rate variables was almost the same. The adjusted R-squared was about 37%, which was another sign that the models were not good enough. Moreover, the models suffered from heteroscedasticity and serial correlation, so results are likely to be inconsistent. On the other hand, the results for petrol models were much more persuasive. It not only confirmed the positive relationship of the number new vehicle registrations to quantity of petrol demanded, but also the inverse relationship between the price of petrol in CR and quantity of petrol demanded. At 1% significance level, the one per cent increase in petrol price in CR leads to 0.23% decrease in quantity of petrol demanded. This confirms that petrol is relatively inelastic normal commodity. Moreover, the adjusted R-squared of petrol models were 68%, and OLS assumption were all satisfied beside the weak dependence.

Nevertheless, that was only the long-run equilibrium as we showed that the variables have units roots and are I(0). After we confirmed the cointegration relationship between petrol variables, we performed the second stage of the Engle-Granger procedure – we estimated the ECM model. For the diesel variables we rejected the cointegration in the test, so we did not proceed to second stage. The ECM estimation brought us some results that were able to confirm partially our hypotheses. We were able to confirm at 5% significance level an inverse short-term relationship between price of petrol in CR and quantity of petrol demanded in CR and a positive relationship of relative price of petrol in Germany to fuel demand in CR. Specifically, we found out that 1% increase in price of petrol in CR causes short-term 0.36% decrease in petrol demand, and 1% increase in relative price of petrol in Germany causes 0.51% increase in petrol demand in CR. The new vehicle registrations were in short-term insignificant. Furthermore, the ECM showed that the transition from short-term to long-term equilibrium happens almost immediately. The R-squared from ECM model is 53%, which is still fairly good for social science. Some of the possible improvements of the used models are mentioned in the discussion of the results at the end of the empirical part.

To sum it up, in this thesis we tried to compare the tax rates in CR and neighbouring countries with the theoretical assumptions and showed that they hold for Germany and Austria. We also managed to confirm in the empirical part the relative price inelasticity of the petrol demand in CR, positive long-term and short-term relationship between number of new vehicle registrations and petrol consumption and, most importantly, confirmed the existence of the cross-border shopping for petrol from Germany to CR. Therefore, as a potential expansion of this work, it could be beneficial to analyse the effect of this cross-border shopping for petrol on the governmental tax collection revenues and find out how the change in tax rates could affect those tax revenues from cross-border shopping. In the case of the other countries, Slovakia, Austria and Poland, we did not find enough evidence about the cross-border shopping, mainly due to reasons mentioned in the discussion of the results.

Appendices

Appendix A – Dataset

Date	Q^p_{CR}	Q^d_{CR}	P^p_{CR}	P^p_{SK}	P^p_{DE}	P^p_{AT}	P^d_{CR}	P^d_{SK}	P^d_{DE}	P^d_{AT}	P^d_{PL}	P^p_{PL}	$VehReg$	CZK/EUR	CZK/PLN
01/2005	152	284	22.83	26.26	33.37	28.36	24.50	26.61	29.27	26.35	24.85	26.79	13865	7.43	30.31
02/2005	139	236	22.97	26.65	33.54	27.86	24.52	26.67	28.72	25.44	25.58	28.44	11951	7.51	29.96
03/2005	168	279	23.95	26.51	34.22	28.35	26.12	27.34	30.52	26.50	26.68	29.12	17241	7.41	29.78
04/2005	166	323	25.82	27.65	36.08	30.46	27.13	28.23	31.45	28.25	26.45	29.05	21528	7.25	30.13
05/2005	184	334	26.40	28.08	35.86	30.40	26.94	27.88	31.38	27.82	25.15	27.76	23358	7.23	30.21
06/2005	181	320	26.40	28.89	36.70	30.53	28.57	29.37	32.66	28.41	28.55	30.77	22988	7.39	30.03
07/2005	195	296	29.03	29.38	37.97	32.07	29.08	29.74	33.39	29.74	27.83	30.28	17764	7.35	30.19
08/2005	203	337	30.20	29.67	38.22	32.02	30.00	30.04	33.25	29.30	28.63	31.38	18767	7.31	29.59
09/2005	183	346	32.52	31.17	39.71	33.36	31.02	31.16	33.34	30.22	30.88	33.89	15705	7.48	29.30
10/2005	171	330	32.05	31.18	39.77	34.12	29.61	31.39	34.19	30.37	30.38	32.96	18439	7.57	29.67
11/2005	164	333	31.14	29.57	36.57	32.22	29.85	30.61	32.32	29.28	28.52	30.25	18317	7.37	29.26
12/2005	149	289	29.19	29.39	35.42	30.12	28.61	30.04	31.70	28.26	30.01	30.81	18653	7.52	28.97
01/2006	156	274	28.52	29.93	36.24	30.11	28.48	30.10	31.63	28.12	27.93	28.27	14136	7.51	28.72
02/2006	136	261	28.73	29.52	35.83	30.18	28.28	29.80	30.91	27.89	27.39	27.69	13949	7.48	28.40
03/2006	158	309	27.95	29.32	35.90	30.42	28.05	30.17	31.94	28.48	26.46	26.56	19891	7.37	28.65
04/2006	178	322	30.42	30.35	38.02	31.40	30.33	30.95	32.59	29.56	28.62	29.59	23532	7.27	28.50
05/2006	174	333	31.29	30.89	37.77	32.38	30.35	30.52	31.71	29.47	28.68	30.87	25300	7.25	28.27
06/2006	184	344	30.97	30.74	38.02	32.47	29.83	30.33	32.08	29.61	27.02	28.85	22734	7.05	28.38
07/2006	178	313	31.42	31.18	39.13	32.65	29.92	30.75	32.89	29.75	28.53	30.41	20382	7.12	28.44
08/2006	178	356	32.01	31.59	38.78	33.44	30.37	30.76	32.39	29.96	30.26	32.91	20697	7.22	28.19
09/2006	176	362	31.15	30.14	36.42	32.50	29.58	30.45	31.53	29.23	27.61	29.80	18020	7.15	28.38
10/2006	172	352	29.27	28.57	34.32	29.62	28.61	29.26	30.55	27.49	28.46	29.06	21025	7.25	28.29
11/2006	162	343	28.46	28.35	33.32	28.74	28.36	29.49	29.83	27.22	28.76	28.44	20437	7.32	28.03
12/2006	160	291	28.24	28.33	33.27	28.10	28.35	29.50	29.76	26.74	27.35	27.07	19024	7.28	27.77
01/2007	146	288	27.64	28.50	33.88	28.06	27.33	28.63	29.61	26.35	25.11	25.85	17509	7.17	27.84
02/2007	146	283	26.03	28.23	34.68	27.90	25.96	29.07	30.38	26.36	25.42	26.72	16758	7.24	28.23
03/2007	172	344	27.13	29.46	35.77	28.66	27.17	30.08	30.85	26.85	25.95	28.31	23108	7.22	28.05
04/2007	179	331	28.68	30.90	36.73	29.49	27.80	30.57	31.75	27.30	27.64	31.27	25434	7.34	28.01
05/2007	177	331	29.54	31.64	38.91	31.13	27.99	30.84	32.21	27.98	27.77	32.80	27072	7.46	28.23
06/2007	184	335	30.29	31.98	39.85	32.05	28.15	31.23	32.98	28.07	27.13	32.53	26413	7.49	28.54
07/2007	194	364	30.42	32.51	38.92	32.61	28.55	31.89	32.44	29.43	28.34	33.57	24130	7.51	28.33
08/2007	197	392	31.49	32.09	37.51	32.49	29.52	31.07	31.90	29.38	27.04	31.77	22531	7.31	27.85
09/2007	182	340	30.84	31.08	36.80	31.61	29.13	30.69	31.90	28.97	27.37	31.18	19680	7.27	27.57
10/2007	183	391	30.54	30.74	37.18	32.15	29.42	30.98	32.60	29.90	29.21	32.21	24876	7.37	27.33
11/2007	169	363	30.62	30.37	36.37	31.09	30.72	31.20	33.47	29.52	30.07	32.19	22257	7.30	26.73
12/2007	169	299	31.84	30.37	37.08	32.43	32.97	31.77	34.30	31.43	31.20	32.59	23391	7.30	26.3
01/2008	155	289	31.78	30.30	35.57	31.55	32.36	31.59	32.96	30.75	30.06	31.93	20939	7.21	26.05
02/2008	154	315	31.43	29.41	34.22	30.10	32.06	31.08	31.57	29.25	28.44	30.10	20523	7.09	25.37
03/2008	167	326	31.79	30.13	35.44	30.61	32.37	31.80	33.30	30.19	29.83	31.05	23929	7.13	25.22
04/2008	174	368	30.64	30.27	35.19	30.84	31.39	32.12	33.05	31.05	31.77	31.91	29996	7.28	25.06
05/2008	187	358	31.40	30.84	36.07	31.42	33.08	33.33	35.10	32.09	33.32	33.00	25940	7.37	25.09
06/2008	174	331	32.89	31.99	36.35	31.86	33.21	34.91	36.08	33.63	34.04	33.29	29266	7.20	24.31
07/2008	178	360	34.43	31.99	36.07	31.49	33.71	34.51	35.21	33.25	34.74	34.09	27526	7.22	23.52
08/2008	172	353	33.35	33.15	35.90	31.80	32.27	35.60	34.62	33.72	35.51	35.89	21521	7.37	24.28

Date	Q^p_{CR}	Q^d_{CR}	P^p_{CR}	P^p_{SK}	P^p_{DE}	P^p_{AT}	P^d_{CR}	P^d_{SK}	P^d_{DE}	P^d_{AT}	P^d_{PL}	P^p_{PL}	$VehReg$	$CZK/_{EUR}$	$CZK/_{PLN}$
09/2008	178	375	29.47	32.77	35.87	31.34	30.79	35.15	33.46	32.20	32.29	33.34	24562	7.26	24.49
10/2008	170	354	31.19	32.79	35.51	31.31	32.39	35.13	33.03	31.22	31.67	32.41	23862	6.94	24.78
11/2008	152	326	29.50	31.68	33.47	29.55	30.02	33.04	31.51	29.51	28.28	29.62	20055	6.75	25.18
12/2008	165	292	26.36	29.63	31.41	28.18	27.10	32.25	30.24	29.08	24.77	26.00	18870	6.52	26.10
01/2009	147	279	22.63	26.90	29.80	23.80	24.25	30.62	27.63	24.51	21.30	21.38	16246	6.42	27.16
02/2009	131	275	24.18	27.86	33.07	26.78	25.01	30.65	29.65	26.95	21.35	21.87	15993	6.12	28.45
03/2009	161	350	25.59	27.45	31.50	25.73	25.13	28.73	27.15	25.11	21.14	22.58	20670	5.89	27.22
04/2009	180	330	25.36	27.43	32.30	25.58	24.88	28.10	27.67	24.78	21.32	23.55	26709	6.04	26.76
05/2009	180	335	26.39	28.13	32.29	27.01	25.70	28.26	28.56	25.00	21.20	24.05	21187	6.05	26.73
06/2009	175	338	27.92	29.20	34.78	27.93	25.95	28.35	27.88	24.87	21.05	25.22	23698	5.88	26.54
07/2009	181	370	29.42	30.17	34.08	28.42	27.44	29.19	28.40	26.15	23.33	27.69	20916	6.00	25.78
08/2009	187	364	29.21	29.91	34.18	28.62	26.36	28.39	28.46	25.06	23.38	27.95	18296	6.20	25.64
09/2009	180	383	28.57	29.99	33.00	27.30	26.89	28.16	28.35	25.12	22.93	26.73	18061	6.10	25.34
10/2009	182	388	26.77	30.49	33.85	27.70	26.35	28.68	28.96	26.46	22.56	26.56	18888	6.13	25.83
11/2009	156	333	28.99	29.68	33.06	28.69	26.05	28.64	28.51	26.11	22.56	26.06	19581	6.19	25.82
12/2009	181	348	28.22	30.87	35.10	28.63	27.14	29.54	29.91	27.17	24.12	27.18	18869	6.29	26.07
01/2010	118	236	30.14	30.87	33.95	29.72	27.00	29.74	31.62	28.23	26.60	28.91	13725	6.42	26.13
02/2010	134	277	31.92	30.55	37.17	30.68	29.59	29.61	31.87	29.33	25.61	28.01	13953	6.47	25.97
03/2010	154	322	33.14	30.04	36.52	31.29	29.01	28.17	31.26	28.94	27.30	29.87	23756	6.56	25.54
04/2010	170	354	32.43	31.03	35.87	30.96	29.67	28.53	31.21	28.48	27.21	29.93	22656	6.53	25.31
05/2010	172	325	32.12	32.26	36.73	31.06	30.73	28.75	30.65	28.31	26.90	28.79	23062	6.32	25.66
06/2010	162	357	32.89	32.97	35.73	30.63	31.21	29.21	31.01	28.80	26.82	28.68	26819	6.28	25.78
07/2010	162	333	33.15	32.04	35.40	30.32	31.54	28.65	30.16	28.19	27.40	29.11	18146	6.20	25.30
08/2010	172	363	32.19	31.63	34.08	29.52	31.55	27.91	30.02	27.56	27.37	29.14	18087	6.21	24.80
09/2010	161	359	31.76	31.26	33.48	29.01	30.96	27.73	30.72	27.73	26.77	28.43	18816	6.23	24.65
10/2010	165	370	31.54	30.66	34.41	29.19	30.53	27.91	31.22	28.92	26.46	27.76	17637	6.21	24.52
11/2010	148	368	31.17	30.97	35.65	30.67	30.54	28.31	32.25	30.80	27.02	28.36	20022	6.23	24.63
12/2010	140	316	33.35	31.91	37.17	32.56	30.52	31.38	33.72	31.83	27.19	28.47	19271	6.29	25.16
01/2011	133	275	34.58	31.07	35.26	31.44	31.19	31.42	34.50	32.88	30.28	31.58	15183	6.28	24.44
02/2011	115	297	34.79	33.31	36.68	32.87	32.62	31.61	34.59	32.68	29.17	29.82	16795	6.18	24.27
03/2011	131	334	33.63	34.37	38.10	33.22	32.63	32.86	33.42	32.61	28.74	29.17	24849	6.07	24.39
04/2011	166	339	35.42	33.93	37.63	34.10	33.57	33.30	33.28	32.79	30.18	30.66	22117	6.12	24.29
05/2011	167	354	35.10	36.09	37.06	35.11	34.25	33.26	32.92	33.40	31.17	31.75	23607	6.18	24.38
06/2011	156	344	35.28	35.48	37.45	35.31	34.40	32.64	33.88	32.93	30.46	31.20	24147	6.11	24.28
07/2011	159	333	35.05	35.10	38.02	34.64	34.75	32.42	34.66	32.67	30.38	31.53	18335	6.08	24.34
08/2011	165	388	34.80	35.54	36.77	33.50	34.13	32.65	33.52	31.85	29.59	30.35	20658	5.89	24.27
09/2011	160	357	34.90	35.53	37.94	33.54	34.70	32.69	34.67	32.93	29.14	29.44	19003	5.67	24.55
10/2011	159	346	34.70	36.38	39.11	34.46	34.60	33.42	36.03	34.36	30.49	30.54	20578	5.70	24.84
11/2011	134	346	34.74	37.29	39.83	35.66	35.15	34.49	36.47	35.89	32.28	32.05	21241	5.74	25.45
12/2011	136	300	35.10	37.23	39.40	35.77	35.60	35.62	35.82	36.26	31.92	30.67	20107	5.7	25.51
01/2012	124	291	36.30	37.58	40.01	35.54	36.80	36.08	36.79	35.77	33.32	32.21	17018	5.83	25.53
02/2012	127	277	36.20	37.69	40.89	34.83	36.75	35.76	37.81	35.13	34.24	33.52	17077	5.98	25.04
03/2012	118	357	36.80	37.95	41.06	35.66	37.10	35.90	37.63	34.82	34.24	33.88	24107	5.96	24.67
04/2012	151	313	37.90	39.06	41.76	36.60	37.20	36.48	38.09	34.62	34.02	34.74	23875	5.93	24.79
05/2012	160	350	38.17	39.76	42.24	36.84	36.70	36.62	38.39	34.62	33.58	35.05	23768	5.89	25.32
06/2012	153	349	37.45	39.74	41.33	36.49	35.75	36.44	36.74	35.54	33.84	34.50	25140	5.96	25.64
07/2012	144	355	36.61	39.22	41.84	35.91	35.65	35.51	37.26	34.69	33.77	33.95	15082	6.08	25.43
08/2012	151	379	37.38	38.86	43.16	35.90	36.20	35.53	38.63	35.03	34.72	34.97	18934	6.11	25.02
09/2012	146	354	38.27	39.50	42.98	36.18	37.50	35.91	37.89	35.27	34.09	34.74	18910	5.98	24.73
10/2012	142	387	37.90	39.45	41.75	36.71	36.95	36.33	38.11	35.49	34.61	35.16	21497	6.07	24.93
11/2012	136	341	37.84	39.21	41.83	36.60	36.90	36.83	38.81	35.82	34.81	34.81	19186	6.13	25.36
12/2012	124	287	37.81	38.20	40.30	35.88	36.88	35.35	37.37	35.28	34.60	34.54	16544	6.15	25.21

Table 3: Dataset

Source: EEA (2013), CZSO (2013), MICZ (2013), CNB (2013)

Appendix B – Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
Q_{CR}^{p}	161.9479	19.33329	115	203
Q_{CR}^{d}	331.2604	34.52177	236	392
P_{CR}^{p}	31.20812	3.777406	22.63495	38.27
P_{CR}^{d}	30.56094	3.538108	24.25205	37.5
P_{SK}^{p}	31.85329	3.48668	26.26377	39.75554
P_{SK}^{d}	31.27133	2.695494	26.61407	36.82998
P_{DE}^{p}	36.61245	2.77109	29.80439	43.1595
P_{DE}^{d}	32.59023	2.826252	27.14731	38.80845
P_{AT}^{p}	31.41844	2.856498	23.80004	36.84351
P_{AT}^{d}	29.98557	3.180891	24.50644	36.25682
P_{PL}^{p}	30.12212	3.08453	21.38234	35.88628
P_{PL}^{d}	28.54209	3.654435	21.04959	35.50712
$VehReg$	20632.01	3690.969	11951	29996
$ExR\,\frac{CZK}{EUR}$	26.53907	1.862976	23.529	30.31
$ExR\,\frac{CZK}{PLN}$	6.697208	.6229166	5.67	7.572

Table 4: Descriptive statistics
Source: EEA (2013), CZSO (2013), MICZ (2013), CNB (2013), STATA output

Appendix C – Composition of automotive fuel taxes in CR

- Tax on petrol

Date	P_{CR}^{p}	Base price	Excise tax (CZK/litre)	VAT (%)	VAT (CZK)	Total tax (CZK)	Total tax (%)
12/2005	29.19	13.69	10.84	0.19	4.66	15.50	53.11
12/2006	28.24	12.89	10.84	0.19	4.51	15.35	54.35
12/2007	31.84	14.91	11.84	0.19	5.08	16.92	53.16
12/2008	26.36	10.31	11.84	0.19	4.21	16.05	60.88
12/2009	28.22	11.88	11.84	0.19	4.51	16.35	57.92
12/2010	33.35	14.95	12.84	0.2	5.56	18.40	55.17
12/2011	35.10	16.41	12.84	0.2	5.85	18.69	53.25
12/2012	37.81	18.67	12.84	0.2	6.30	19.14	50.63

Table 5: Composition of taxes on petrol
Source: EEA (2013), European Commission (2013), author's calculations

- Tax on diesel

Date	P_{CR}^{d}	Base price	Excise tax (CZK/litre)	VAT (%)	VAT (CZK)	Total tax (CZK)	Total tax (%)
12/2005	28.61	15.89	8.15	0.19	4.57	12.72	44.46
12/2006	28.35	15.67	8.15	0.19	4.53	12.68	44.72
12/2007	32.97	17.76	9.95	0.19	5.26	15.21	46.14
12/2008	27.10	12.82	9.95	0.19	4.33	14.28	52.68
12/2009	27.14	12.85	9.95	0.19	4.33	14.28	52.63
12/2010	30.52	14.48	10.95	0.2	5.09	16.04	52.54
12/2011	35.60	18.72	10.95	0.2	5.93	16.88	47.43
12/2012	36.88	19.78	10.95	0.2	6.15	17.10	46.36

Table 6 Composition of taxes on diesel
Source: EEA (2013), European Commission (2013), author's calculations

Appendix D – Correlation matrix

Petrol	$\ln(Q^{p}_{CR})$	$\ln(P^{p}_{CR})$	$\ln(\frac{P^{p}_{SK}}{P^{p}_{CR}})$	$\ln(\frac{P^{p}_{DE}}{P^{p}_{CR}})$	$\ln(\frac{P^{p}_{AT}}{P^{p}_{CR}})$	$\ln(\frac{P^{p}_{PL}}{P^{p}_{CR}})$	$\ln(V_{CR})$	$\ln\left(E_{\frac{C}{E}}\right)$	$\ln\left(E_{\frac{C}{P}}\right)$
$\ln(Q^{p}_{CR})$	1								
$\ln(P^{p}_{CR})$	-0.288	1							
$\ln(\frac{P^{p}_{SK}}{P^{p}_{CR}})$	-0.044	-0.529	1						
$\ln(\frac{P^{p}_{DE}}{P^{p}_{CR}})$	0.286	-0.808	0.627	1					
$\ln(\frac{P^{p}_{AT}}{P^{p}_{CR}})$	0.228	-0.703	0.587	0.910	1				
$\ln(\frac{P^{p}_{PL}}{P^{p}_{CR}})$	0.414	-0.530	0.320	0.693	0.727	1			
$\ln(VehReg_{CR})$	0.461	0.209	-0.156	-0.160	-0.156	0.050	1		
$\ln\left(ExR_{\frac{CZK}{EUR}}\right)$	0.315	-0.649	0.287	0.854	0.817	0.620	-0.218	1	
$\ln(ExR_{\frac{CZK}{PLN}})$	0.439	-0.441	-0.097	0.531	0.553	0.801	0.063	0.667	1

Table 7: Correlation matrix of petrol variables
Source: EEA (2013), CZSO (2013), MICZ (2013), CNB (2013), STATA output

Diesel	$\ln(Q^{d}_{CR})$	$\ln(P^{d}_{CR})$	$\ln(\frac{P^{d}_{SK}}{P^{d}_{CR}})$	$\ln(\frac{P^{d}_{DE}}{P^{d}_{CR}})$	$\ln(\frac{P^{d}_{AT}}{P^{d}_{CR}})$	$\ln(\frac{P^{d}_{PL}}{P^{d}_{CR}})$	$\ln(V_{CR})$	$ln\left(E_{\frac{C}{E}}\right)$	$ln\left(E_{\frac{C}{P}}\right)$
$\ln(Q^{d}_{CR})$	1								
$\ln(P^{d}_{CR})$	0.326	1							
$\ln(\frac{P^{d}_{SK}}{P^{d}_{CR}})$	-0.242	-0.689	1						
$\ln(\frac{P^{d}_{DE}}{P^{d}_{CR}})$	-0.377	-0.699	0.741	1					
$\ln(\frac{P^{d}_{AT}}{P^{d}_{CR}})$	-0.335	-0.421	0.657	0.755	1				
$\ln(\frac{P^{d}_{PL}}{P^{d}_{CR}})$	-0.178	-0.088	0.225	0.420	0.394	1			
$\ln(VehReg_{CR})$	0.576	0.209	-0.054	-0.204	-0.161	0.040	1		
$\ln\left(ExR_{\frac{CZK}{EUR}}\right)$	-0.328	-0.649	0.433	0.718	0.376	0.365	-0.218	1	
$\ln(ExR_{\frac{CZK}{PLN}})$	-0.179	-0.441	0.312	0.531	0.279	0.750	0.063	0.667	1

Table 8: Correlation matrix of diesel variables
Source: EEA (2013), CZSO (2013), MICZ (2013), CNB (2013), STATA output

Appendix E – Significance & OLS assumptions tests

- Test for joint significance of monthly dummies:

$$H_0: Feb = Mar = Apr = May = Jun = Jul = Aug = Sep = Oct = Nov = Dec = 0 \quad (A.1)$$

Fuel type	$F\ statistics$	$p - value$
Petrol	16.54	0.0000
Diesel	19.19	0.0000

Table 9: joint significance of monthly dummies
Source: STATA output

- OLS assumptions tests:

Model	**B-P test**	**White test**	**S-W test**	**A.c. (1)**	**A.c. (2)**	**A.c. (3)**
OLS 1.1	0.3964	0.4946	0.37603	0.9798	0.6970	0.8675
OLS 2.1	0.1405	0.3014	0.57095	0.0316	0.0687	0.1379
OLS 1.2	0.4834	0.5425	0.38867	0.7809	0.5624	0.7622
OLS 2.2	0.1267	0.1383	0.36009	0.0268	0.0479	0.0888
ECM	0.0035		0.58171	0.9243	0.8409	0.8968

Table 10: OLS assumptions tests
Source: STATA output

- Test for the significance of Exchange rates variables:

$$H_0: ExR(\frac{CZK}{EUR}) = ExR(\frac{CZK}{PLN}) = 0$$

Fuel type	$F\ statistics$	$p - value$
Petrol	0.49	0.6143
Diesel	1.25	0.2912

Table 11: joint significance of Exchange rates
Source: STATA output

Appendix F – Unit roots & cointegration tests

- Plots:

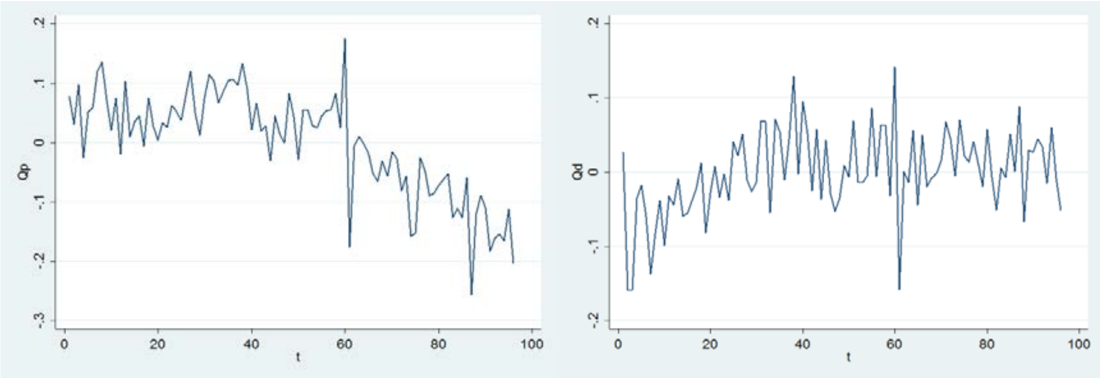

Figure 7: Quantity of petrol and diesel consumed
Source: STATA output
*Note: Qp – quantity of petrol consumed, Qd – quantity of diesel consumed

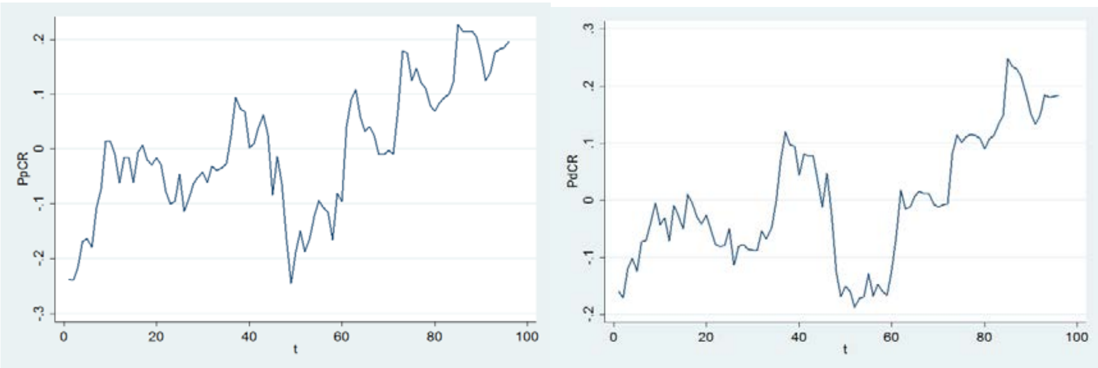

Figure 8: Price of petrol and diesel in CR
Source: STATA output
*Note: PpCR – Price of petrol in CR, PdCR – price of diesel in CR

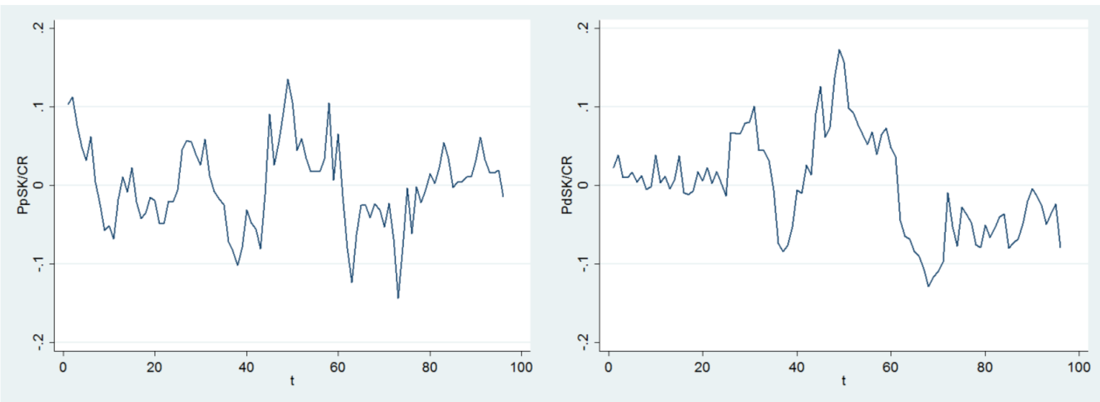

Figure 9: Relative price of petrol and diesel in Slovakia
Source: STATA output
*Note: PpSK/CR – Relative price of petrol in Slovakia, PdSK/CR – relative price of diesel in Slovakia

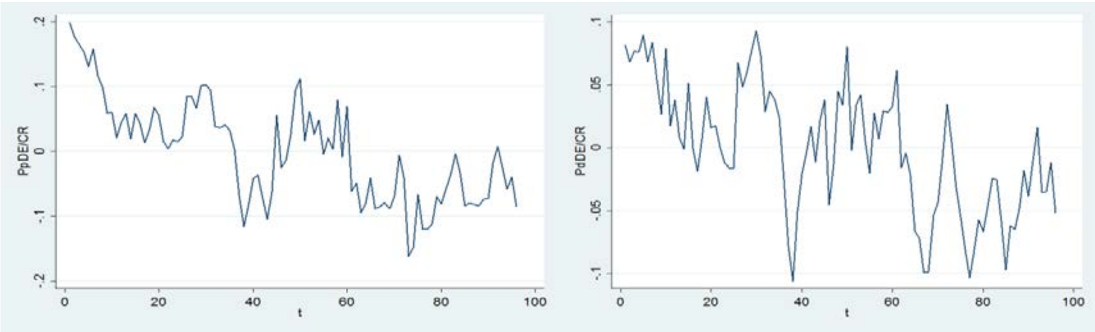

Figure 10: Relative price of petrol and diesel in Germany
Source: STATA output
*Note: PpDE/CR – Relative price of petrol in Germany, PdDE/CR – relative price of diesel in Germany

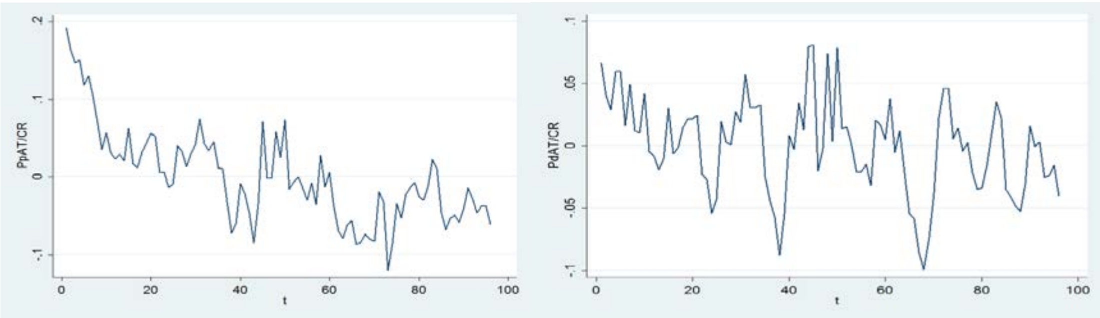

Figure 11: Relative price of petrol and diesel in Austria
Source: STATA output
*Note: PpAT/CR – Relative price of petrol in Austria, PdAT/CR – relative price of diesel in Austria

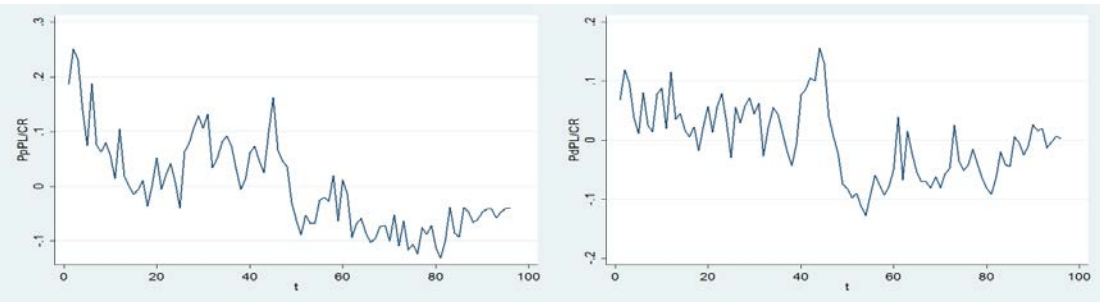

Figure 12: Relative price of petrol and diesel in Poland
Source: STATA output
*Note: PpPL/CR – Relative price of petrol in Poland, PdPL/CR – relative price of diesel in Poland

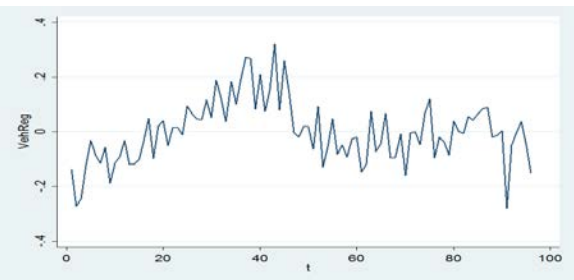

Figure 13: Number of new vehicle registrations in CR (VehReg)
Source: STATA output

- Tests for unit roots:

Variable	P-value	Variable	P-value
$\log(Q^p_{CR})$	0.8230	$log(Q^d_{CR})$	0.2895
$\ln(P^p_{CR})$	0.4166	$\ln(P^d_{CR})$	0.2049
$\ln(\frac{P^p_{SK}}{P^p_{CR}})$	0.0168	$\ln(\frac{P^d_{SK}}{P^d_{CR}})$	0.2546
$\ln(\frac{P^p_{DE}}{P^p_{CR}})$	0.0806	$\ln(\frac{P^d_{DE}}{P^d_{CR}})$	0.0392
$\ln(\frac{P^p_{AT}}{P^p_{CR}})$	0.2945	$\ln(\frac{P^d_{AT}}{P^d_{CR}})$	0.0966[n]
$\ln(\frac{P^p_{PL}}{P^p_{CR}})$	0.3982	$\ln(\frac{P^d_{PL}}{P^d_{CR}})$	0.2623[n]
$\ln(VehReg_{CR})$	0.4011[n]		

Table 12: Tests for unit roots
Source: STATA output

- Tests for cointegration:

	Petrol (0 lags)	**Diesel** (4 lags)*
t statistics	-9.924	-2.777
10% critical value	-6.131	-5.841
5% critical value	-5.482	-5.199
1% critical value	-5.152	-4.873

Table 13: Tests for cointegration
Source: Schaffer (2013), STATA output

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