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Analysis of gasoline and diesel prices in the Czech Republic

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Declaration of Authorship

The author hereby declares that he compiled this thesis independently, using only the listed resources and literature. This thesis was not used to obtain another academic degree.

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Prague, July 31, 2012

Signature

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Abstract

This thesis investigates relationship between fuel (gasoline and diesel) prices in the Czech Republic and world crude oil prices over the period from 2004 to 2011. Using daily data we estimate an asymmetric error correction model and we find that in the short-run fuel prices are adjusted upwards to the long-run equilibrium faster than they are adjusted downwards to the equilibrium. However, the difference in responses is found to be not statistically significant.

Keywords crude oil price, gasoline price, diesel price, price adjustment, asymmetric ECM

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Abstrakt

Tato práce zkoumá vztah mezi cenami pohonných hmot (benzinu a nafty) v České republice a cenami surové ropy na mezinárodním trhu v období od roku 2004 do roku 2011. S použitím denních dat odhadujeme model asymetrické korekce chyby a zjišťujeme, že v krátkém období jsou ceny pohonných hmot přizpůsobovány vzhůru k dlouhodobému rovnovážnému stavu rychleji, než jsou přizpůsobovány dolu. Rozdíl v reakcích je avšak shledán jako statisticky nesignifikantní.

Klíčová slova cena ropy, cena benzínu, cena nafty, cenové přizpůsobení, asymetrický model korekce chyb

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Analysis of gasoline and diesel prices in the Czech Republic

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

The main goal of this bachelor's thesis is to analyze gasoline and diesel prices in the Czech Republic. Using an asymmetric error correction model, I would like to focus especially on how these prices respond to changes in the international price of crude oil. It will ask questions such as whether gas station operators adjust fuel prices upwards at the same pace as they bring them down or whether petrol prices adjust in the same manner as diesel prices. A proof of faster reaction during the upward movement of prices could indicate the need for closer monitoring or more direct government intervention in the fuel market.

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Acronyms

ADF test Augmented Dickey–Fuller test

AIC Akaike's Information Criterion

a.s. Akciová společnost (joint stock company)

CNB Czech National Bank

CZK Czech koruna

CZSO Czech Statistical Office

ECM Error correction model

EIA U.S. Energy Information Administration

FOB Free-on-board

IEA International Energy Agency

IKL Ingolstadt-Kralupy nad Vltavou-Litvínov pipeline

KPSS test Kwiatkowski-Phillips-Schmidt-Shin test

MICZ Ministry of the Interior of the Czech Republic

MITCZ Ministry of Industry and Trade of the Czech Republic

mt million tons

OLS Ordinary Least Squares

OPECCZ Office for the Protection of Economic Competition of the Czech Republic

PKN ORLEN S.A. Polski Koncern Naftowy Orlen Spółka Akcyjna

TAR Threshold autoregressive model

UK United Kingdom

US/USA United States of America

USD United States Dollar

VAT Value added tax

WTI West Texas Intermediate

Chapter 1

Introduction

Over the past 8 years, the world crude oil prices have been extremely volatile and have fluctuated in a wide range in comparison with the previous years. To prove this statement we can mention the time period from 2007 to the first half of 2008, over which the Brent crude oil prices have more than doubled and have risen to peak of 143.95 USD per barrel followed by a rapid fall to a low value of 33.73 USD per barrel at the end of 2008 and subsequent repeated growth to a value of 126.64 USD per barrel in May 2011. Thus, over the period from 2007 to 2011 there was a maximum range between recorded prices larger than 100 USD per barrel while the difference between maximum and minimum price was only 32 USD barrel in the whole period between the years of 1988 and 2004. The observed changes in crude oil price behavior are primarily the results of late, until then unprecedented, enormous price increases of crude oil. The crude oil price rises on the various grounds. In the last few years it is talked more and more about an uncertainty in supply and reserved availability and growing world energy demand given by high consumption and population growth. The extremely high crude oil prices involved a fast and extensive increase of fuel prices in the first half of 2008 and later in the first half of 2011.

Consumers in the Czech Republic, where the number of passenger cars grew to 4 576 574 from 3 706 012 between 2004 and 2011 (MICZ, 2004 and 2011) and where the average car to person ratio was approximately 0,44 at the end of 2011 (CZSO, 2011), are strongly sensitive to any increase in fuel prices. There is a common belief supported by recent considerable growth of fuel prices that the prices are raised too often and too much and that they decline rarely or rather follow increasing crude oil prices completely and faster than they follow crude oil price decreases. This behavioral pattern was endorsed by the Czech Office for the Protection of Competition which in 2004 rendered a decision of breaking the law by cartel behavior of six filling station operators and imposed until then the largest fine amounting in total 313 million CZK on them. The companies Agip Praha, a.s. (20 mil.), Aral ČR, a.s. (40 mil.), BENZINA a.s. (98 mil.), ConocoPhillips Czech Republic s.r.o. (22 mil.), OMV Česká republika, s.r.o. (68 mil.) and Shell Czech Republic a.s. (65 mil.)[1] were accused of using concerted practices which entail the fixing of high retail gasoline prices in the period from the end of May 2001 until the end of November 2001 despite the decreasing cost prices (OPECCZ, 2004). Companies participating in proceeding have lodged an appeal against the decision and the case was recommitted several times until 2010. Bacon (1991) called an activity, when company enriches oneself by maintaining high fuel prices in period of decreasing cost prices and when it adjust almost immediately to cost increases, the “rockets and feathers” behavior. To follow this pattern means to shoot up like a rocket and to fall down slowly like a feather.

Many authors focus on a price setting behavior and a downward price stickiness in the fuel market and offer several explanations of this behavior, if they find an asymmetry. The sooner reaction to crude oil rise than to crude oil fall is ascribed to market power of some retailers, costly production adjustment and high menu cost and some authors explain the asymmetric behavior by oligopolistic coordination theory or theory of costly search (Borenstein (1997), Radchenko (2005a)).

The goal of this thesis is to investigate whether an asymmetric price setting of fuel is only a public opinion or it can be corroborated by empirical results. There are a lot of possible determinants of fuel prices such as refinery capacity utilization, inventory levels, and future price expectations. We decided to employ the crude oil prices as the main input in production of fuel. We estimate a long-run equilibrium and a short-run dynamics between prices of crude oil and fuel (gasoline and diesel)

[1]Numbers in brackets denote the fine in million CZK imposed on the company.

using an Error Correction Model (ECM) for the period from 2004 to 2011 and then we make tests of an asymmetric behavior. We come to the conclusion that there is not any statistically significant difference in responses of fuel prices to crude oil price increases and decreases.

The thesis is organized as follows. Chapter 2 provides a overview of the literature on investigation of fuel price transmission mechanism. In Chapter 3 we describe the Czech fuel market. Chapter 4 discusses the data set that we use in our analysis. Basic data analysis and the econometric model is introduced in Chapter 5. Chapter 6 presents empirical results and concluding remarks are in Chapter 7.

Chapter 2

Literature review

This section reviews the relevant literature dealing with a testing of asymmetric price adjustment in the fuel market. The existing papers are based on partially or completely different specifications such as country under scrutiny, type of model employed in the empirical analysis, time period and frequency of the dataset, and price series used in the model.[1] It is therefore not surprising that findings vary across these specifications. A large part of the literature analyzes fuel markets in the United States and the United Kingdom, another one studies markets in Canada, New Zealand and in some European countries, namely Sweden, Germany, France, Spain, Italy and the Netherlands. To the best of our knowledge, similar analysis has not yet been done for the Czech Republic.

Bacon (1991) tests asymmetric price behavior in the UK as a response to the Monopolies and Mergers Commission inquiry, in which the UK petrol market is examined for the evidence that retail petrol prices adjust faster to upward cost changes than to their decreases. For purposes of the empirical investigation the author uses Rotterdam price of gasoline, because he considers the price at which refineries sell gasoline as the most relevant input cost for a retail price and the major market for petroleum products in northern Europe is in Rotterdam, and the retail price of gasoline observed in London, which is the determining price for an important part of the UK market. He employs the fortnightly data from 1982 to

[1] Price series used in the model can be retail fuel prices and crude oil or wholesale fuel prices related to the stage of distribution at which the price transmission is analyzed.

1989. At first, the long-run relationship is estimated and tested for full passing on of the costs. The null hypothesis of a full long-run pass through cannot be rejected, therefore he uses the restricted equation for the further analysis. Subsequently, the asymmetric speed of adjustment in the short run is tested using a Quadratic Quantity Adjustment Model. Since the null hypothesis of symmetric adjustment is rejected he states that an asymmetry was detected and the adjustments to cost increases are faster than to cost decreases. Finally, he compares mean adjustment lags for cost increases and decreases and concludes that the adjustment is about one week shorter for the cost rise.

Kirschgässner and Kübler (1992) study the adjustment of wholesale and retail gasoline prices in Germany to spot prices of the Rotterdam market for gasoline. The sampling period is from 1972 to 1989 with monthly frequency of observations. To test for any asymmetry the data is divided into two sub-periods, the 1970s and the 1980s. Using ECMs they find considerable asymmetry in the short-run adjustment process for the 1970s, however, the adjustment is found to be rapid, symmetric and full for the 1980s. Unlike other studies, the asymmetry detected in the former period is caused by faster responses of German gasoline prices to reductions in the Rotterdam prices than to their increases. The authors summarize these results by explanation that the gasoline market has become more competitive during the observed period and it might be seen as contestable market in sense of Baumol for the second decade.

Borenstein et al. (1997) investigate the US gasoline market employing reconfigured ECM model, which allows the short-run adjustment. They analyze the price transmission at different points in the distribution chain using semimonthly prices for retail gasoline and weekly prices for terminal and spot market unleaded gasoline, and spot West Texas Intermediate (WTI) crude oil over the sample period from 1986 to 1992.[2] Their findings confirm the existence of asymmetry at each level of distri-

[2]Borenstein (1997) describe the production and distribution of gasoline in the US using WTI crude oil price at which crude oil is sold to refineries, spot market price of gasoline at which refineries sell gasoline to city terminals, terminal market price of gasoline at which gasoline is sold to filling station and retail price of gasoline at which filling station sell gasoline to drivers.

bution, however, the asymmetry in adjustment of terminal prices to spot gasoline price changes is not statistically significant. The study also gives three possible explanations of asymmetry. The first, the oligopolistic coordination theory, attributes downward price stickiness to the existence of a natural focal point for oligopolistic coordination during decreases of input prices. This hypothesis could describe asymmetric transmission from changes in terminal prices to changes in retail prices. According to the inventories theory which might explain asymmetric adjustment speed in responses of terminal and spot prices, production lags and finite inventories lead to quicker adaptation of negative shocks to the future optimal consumption than positive shocks. Briefly stated, sellers cannot react immediately to decreases of cost prices because they have to sell more expensive inventories and conversely, they maximize profit by fast increase of output prices when cost prices are rising. The last one, the theory of costly search, rationalizes less competitive retail markets by behavior of consumers, who expect low payoff from search for cheaper gasoline when crude oil prices are known to be volatile. For this reason, sellers can increase prices or keep higher prices of gasoline without worries about a loss of customers. Again the terminal-retail asymmetry can be described by this hypothesis.

In the study of Reilly and Witt (1998), an unrestricted ECM is used to examine gasoline market in the UK. They revisit the evidence of Bacon (1991) employing monthly series for the crude oil price and the dollar/sterling exchange rate as explanatory variables and monthly series for the net UK retail gasoline price as an explained variable. The data cover a period from January 1982 to June 1995. They find an evidence of short term asymmetry in responses to the crude oil price as well as to the exchange rate. Results suggest that it takes more time to pass on to crude oil changes to changes in gasoline prices when crude oil prices are falling than in case of their increases. The short term asymmetry found in responses to the exchange rate means that devaluation leads to a petrol price increase comparable to the rate of increase in the long term but revaluation does not lead to a gasoline price decrease at all. In other words, devaluation is reflected in increased prices of petrol because of higher costs of purchasing crude oil and in the case of revaluation, sellers keep high gasoline prices and pocket the extra profit obtained due to strengthening of domestic currency, in the short term. As a final point, they look at the stability of asymmetric responses using recursive OLS estimation techniques. The asymmetric effect is assessed to be relatively stable in terms of crude oil and asymmetry increasing over time yields little evidence of stability for the exchange rate.

Asplund et al. (2000) use the data from 1980 to 1996 to investigate price responses in the Swedish gasoline market to changes in input costs and taxes. As a starting point, the data with monthly frequency is employed to estimate the long run relationship between petrol prices and independent variables, which are Rotterdam spot market price expressed in US dollars multiplied by SEK/USD exchange rate, quantity tax and nominal wage. The result of this is that there is nearly full adjustment of petrol to cost prices in the long run. Further, they analyze daily price changes by fitting an Ordered Probit Sample Selection Model and find a short run asymmetry in sense that retail prices react faster to changes in exchange rate than to changes in spot market price. Finally, they estimate a restricted ECM on monthly price changes to find evidence of a downward petrol price stickiness for spot market price decreases in the short-run and remind that the short run is only a few months for the Swedish gasoline market.

According to Godby et al. (2000), there is not any strong evidence of asymmetric behaviour in the Canadian retail gasoline market over the period from 1990 to 1996. The asymmetry is tested employing weekly prices of premium and regular gasoline in thirteen Canadian cities. Unlike previous studies this paper applies a Threshold Autoregressive model (TAR) within an error correction framework, which is considered to be more suitable for their analysis. The TAR ECM allows positive as well as negative threshold, at which an asymmetry occurs, while the ECM forces the zero threshold. The application of different model as well as different retail market structure in Canada and a dataset of different frequency, periodicity, and level of aggregation might contribute to the not so frequent finding of symmetry.

Bachmeier and Griffin (2003) conduct an analysis for US daily spot gasoline and crude oil price data from 1985 to 1998. They estimate an ECM and, in contrast with

Borenstein et al. (1997), find no evidence of asymmetric price behaviour in the US wholesale gasoline market. The authors provide two explanations of this difference in results. In this paper a standard Engle-Granger two-step estimation procedure is employed on daily data while Borenstein et al. (1997) apply a nonstandard one-step estimation procedure on weekly data. They attach more weight to the difference in data frequency than to the type of estimation method since they used an one-step method individually on daily and weekly data and in case of a daily as opposed to a weekly frequency they found a little evidence of asymmetry. Supported by these findings they criticize a low frequency of observation when model is not able to capture almost instantaneous responses of gasoline prices to crude oil prices.

Responses of the unleaded gasoline retail price in the Netherlands to the Rotterdam spot price for premium unleaded gasoline are studied by Bettendorf et al. (2003). Using daily data for years 1996-2001 they estimate an asymmetric ECM on weekly price changes. For this analysis five datasets are constructed, one for each working day, and estimation results differ over these subsets. The hypothesis of symmetry cannot be rejected for Tuesday and Wednesday datasets nevertheless findings imply faster pass-through to spot price increases than to decreases for Monday, Thursday and Friday datasets. Based on these results, the authors attach weight to the choice of the day whose prices will be used in the empirical analysis. As a final point, they analyze effect of price asymmetry on consumer costs and determine it as negligible.

Galeotti et al. (2003) focus on potential price asymmetries in gasoline markets in five European countries, namely Germany, France, Spain, Italy and the UK. As they attempt to describe price transmission at different stages of the transmission chain they use three price series. Adjustment is described by the relation between crude oil price and retail petrol price in the single stage, by the relation between crude oil and spot petrol price in the first (refinery) stage, and by the relation between spot and retail petrol price in the second (distribution) stage.[3] The monthly data from 1985 to 2000 and the asymmetric ECM are employed to find that output prices

[3]Spot gasoline price is the gasoline spot price f.o.b. Rotterdam for the European countries and crude oil price is the Crude Oil Import Costs.

adjust quicker to input price increases than to its decreases at all stages and nearly in all five countries.

Grasso and Manera (2005) examine gasoline markets in the same five European countries as Galeotti et al. (2003) study in the previous paper. As they state, the study provides a detailed comparison of the three most popular models applied to describe an asymmetry in the price behaviour. The models mentioned above are the asymmetric ECM, the threshold autoregressive ECM (TAR ECM) and the ECM with threshold cointegration. They also measure price transmission at the single, the first and the second stage of distribution chain. Therefore, they estimate three equations for each model and country. All estimations are based on monthly data between January 1985 and March 2003. They conclude that all models are able to identify temporal lags in responses of petrol prices to changes in spot petrol and crude oil prices, and a certain part of asymmetry in these responses. More precisely, long run asymmetries are detected by the asymmetric ECM and by the ECM with threshold cointegration, and the asymmetric ECM is able to recognize a larger percentage of these asymmetries. Again the asymmetric ECM and also the TAR-ECM identify short run asymmetries and the second model identifies more of these asymmetries.

Again the US retail petrol market is analyzed even in two studies of Radschenko (2005). In the first one, special attention is paid to the existence of long term and short term cost shocks to the gasoline prices, and to different responses of retail prices to these two types of shocks. The author estimates reconfigured ECMs on weekly data for the period from March 1991 to February 2003(?) to analyze how gasoline prices react on cost price changes. Further, he investigates the impact of crude oil shocks and shocks in spot prices on retail gasoline prices using a Markov-switching model. By comparison of cumulative adjustment functions of gasoline prices to long-term and short-term shocks it is concluded that when the crude oil shocks are considered by market as long term, the retail gasoline prices respond faster than when the shocks are short term.

The second study of Radschenko (2005) examines an oil price volatility and its influence on the degree of gasoline price asymmetry. He also discusses to what extent the oligopolistic coordination theory, the search theory, and the search theory with Bayesian updating explain the relationship between volatility and asymmetry. He employs weekly data from March 1991 to February 2003 and the reconfigured ECM to test for any asymmetry and then he employs the Vector Autoregressive Model to analyze the impact of the oil price volatility on this asymmetry. His results indicate a strong negative relation between volatility and asymmetry and suggest the oligopolistic coordination theory as most fitting explanation of the detected asymmetry.

Adilov and Samavati (2008) conduct an analysis on weekly prices of retail gasoline and crude oil in nine US states from January 2000 to June 2007. They estimate separate Asymmetric Price Response Model for each of nine states and for the United States. A potential asymmetric behavior is tested by comparison of cumulative adjustment functions for the crude oil increases and decreases. As the price adjustment of gasoline to crude oil is found to be faster in case of crude oil increases in three states, faster in case of crude oil decreases in other three states, and the result is ambiguous in remaining three states, they state that the hypothesis about faster responses to the crude oil increases could not be confirmed.

Finally, Liu et al. (2010) investigate how pre-tax gasoline and diesel prices in New Zealand respond to changes in Dubai crude oil prices also using the asymmetric ECM. The weekly data from April 2004 to February 2009 confirm the evidence of statistically significant asymmetric response of diesel prices and cannot reject the hypothesis of symmetric response of gasoline prices. Thus, it is concluded that companies adjust diesel prices considerable faster when the crude oil prices are rising than in case of their reduction and that the gasoline prices respond without noticeable (appreciable) asymmetries. These results together with higher importer margin for diesel indicate that the gasoline market is more competitive than the diesel market in New Zealand.

Chapter 3

Czech fuel market

In the previous section we have discussed several papers dealing with an analysis of fuel price adjustment. Now we attempt to conduct our own analysis for the Czech Republic. We start by describing the Czech gasoline and diesel production and distribution process.

In the Czech Republic, annual deliveries of gasoline to the market maintained at the same level around 2 million tons (mt) from 2004 to 2009 and then decreased down to 1,787 mt in 2011. In 2004, 3,258 mt of diesel has been delivered and the volume gradually grown up to 4 mt per year in 2007 and stabilized at this level until 2011 (MITCZ, 2011). More than half of the total gasoline and diesel consumption is produced by Czech refineries and the rest is made up by fuel imported (MITCZ, 2011).

3.1 Production and transport of fuel

There are three refineries in the Czech Republic: in Litvínov, Kralupy nad Vltavou and Pardubice. First two are operated by the company Česká rafinérská a.s. and the last one by the company Paramo a.s.. The indigenous production of crude oil is low and the Czech Republic is therefore almost completely dependent on imports. In 2011, the crude oil imported from abroad made up 98% of crude oil refined here. The remaining 2% represent oil drilled from reservoirs in the Czech Republic (MITCZ, 2011). Russian Federation is the most significant importer of crude oil with more than half of the total volume imported in the country. Other suppliers are Azerbaijan (29,4%), Kazakhstan (8,6%), Iran (2,4%), Algeria (0,3%) and Poland (0,1%)[1] (MITCZ, 2011). Transport of crude oil is realized by (the) oil pipelines Družba and IKL (Ingolstadt-Kralupy nad Vltavou-Litvínov). They are independent in the sense that they are not interconnected. While the Družba pipeline transports crude oil from Russia and from domestic reservoirs in the South Moravian Region, crude oil from the Caspian Sea, North Africa and the Arabian Peninsula is transported by the IKL pipeline (Zaplatílek, 2007). Nevertheless, both pipelines empty into the same Central Crude Oil Tank Farm Nelahozeves and are owned by the company MERO ČR, a.s.. Since Ministry of Finance of the Czech Republic is its sole shareholder (MERO, 2010), the crude oil transmission constitutes a state monopoly. Fuel produced at Czech refineries is often distributed through the pipeline system of the joint stock company Čepro also fully owned by the state (Čepro, 2010). The rest of fuel consumption is imported by foreign companies such as OMV or Shell.

3.2 Fuel market

The Czech fuel market is characterized by the large number of filling stations per capita in comparison with other European countries. There are also a lot of operators running small amount of stations. In 2011, there were 1133 operators who ran only one station (MITCZ, 2011). Filling stations in the Czech Republic are divided into three types. At public stations, anyone can buy fuel. Stations with restricted access and sale are only for definite customers and private stations are operated by owners only for their own use. Number of public stations is approximately the same as a sum of remaining two types. In 2011, 3717 public filling stations were run there by 1422 operators (MITCZ, 2012). This number have gradually increased from 2004 when there were counted 1887 public filling stations. In 2004, however, there was not any legislation about an operator's registration obligation. For that reason and also because not all operators gave necessary information, it was not possible to count all filling station. The actual number was assessed approximately at 2220 (MITCZ,

[1] Values in brackets denote proportions of total imports in 2011 (MITCZ, 2011)

2004). In 2011, the Czech company Benzina was the market leader with 338 filling stations (Unipetrol, 2011). The next large operator is OMV (220), followed by EuroOil (192), Shell (172), PapOil (127) and Agip (124).[2] The largest operators who run more than hundred filling stations have substantial market share nearly 50 percents in the sale of gasoline and diesel. Even thought the quantity of their branded filling stations comprises only around 31 percents of the total sum, these stations are advantageously located along frequented primary and secondary state highways and urban communications where run on the fuel is.

Benzina, the largest operator of filling stations in the Czech fuel market, is a subsidiary of Unipetrol a.s.. Unipetrol is the incumbent company of the joint stock company Paramo, one of two companies running refinery in the Czech Republic (Unipetrol, 2011). Second of them, Česká rafinérská, is a joint venture of three shareholders, namely Unipetrol a.s. (51,22%), Eni International B.V. (32,445%) and Shell Overseas Investments B.V (16,335%)(Česká rafinérská, 2010), and acts as a processing refinery. It means that the company does not carry out financial activities such as a purchase of raw material or a sale of products but only process crude oil delivered by shareholders. Production quantity is also defined and taken over by shareholders. Thus, shareholders represent suppliers as well as customers. Since Unipetrol Group is the majority shareholder of refineries Česká rafinérská and even the sole shareholder of the Paramo refinery, Unipetrol directly controls oil processing in all three Czech refineries. Since 2004, Unipetrol is the subsidiary of the company Polski Koncern Naftowy Orlen Spółka Akcyjna (PKN ORLEN S.A.) which ranks among largest processors of crude oil in the Central Europe (Unipetrol, 2011).

To sum up, the vertically integrated company Unipetrol represents the largest market player since it controls crude oil refining in all three Czech refineries and retail sales of gasoline and diesel in the Czech Republic's largest network of filling stations.

[2]Numbers in brackets represent number of filling stations ran by the company in the Czech Republic in 2011.

Chapter 4

Data description

The data sample used in this thesis consists of crude oil prices and retail prices of gasoline (Natural 95) and diesel in the Czech Republic. We employ daily prices for time period from January 2, 2004 to December 15, 2011.[1]

As a crude oil price we select the Brent spot price FOB for Europe which is most closely watched by the Czech National Bank (CNB) and Ministry of Industry and Trade of the Czech Republic (MITCZ) as a benchmark price for crude oil in the Czech Republic. The data was obtained from the U.S. Energy Information Administration.[2] For purposes of our analysis oil prices expressed in terms of U.S. dollars per barrel were converted to Czech crowns (CZK) per liter using exchange rates provided by the CNB[3] for a given day and the equality: 1 barrel = 158,987 liter.

The retail fuel prices reported by CCS were taken from the website www.finance.cz.[4] These prices are calculated as an average of the fuel prices at filling stations in the acceptance network of CCS cards. CCS is the Czech company issuing fuel cards which are accepted by most of branded filling stations nationwide. As stated in the

[1] Since prices are not quoted on weekends and holidays, we have 1845 observations.

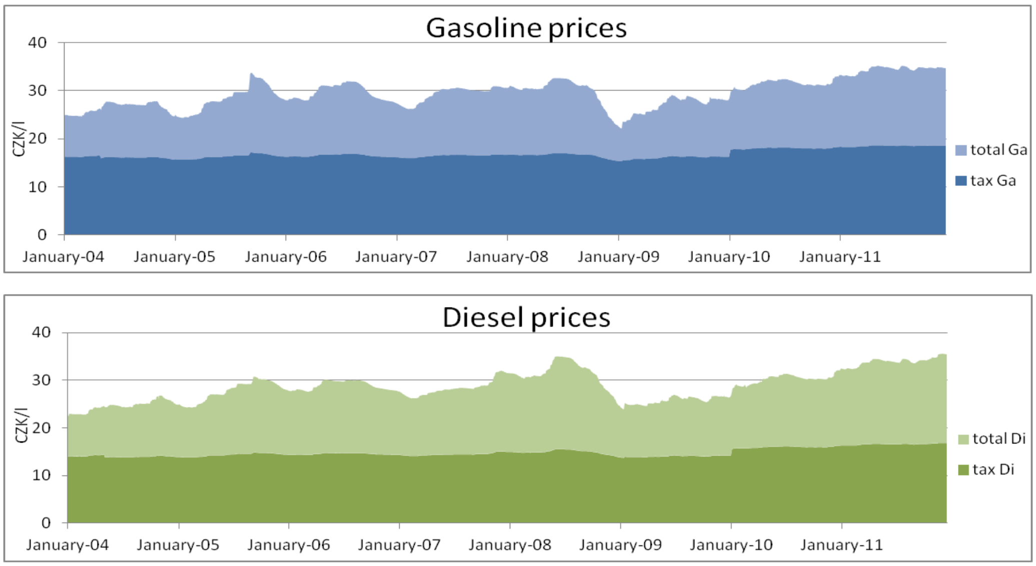
[2] The data can be accessed online via the link `http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=RBRTE&f=D`

[3] Exchange rates can be accessed online via the link `http://www.cnb.cz/cs/financni_trhy/devizovy_trh/kurzy_devizoveho_trhu/vybrane_form.jsp`

[4] The data can be accessed online via the link `www.finance.cz/makrodata-eu/pohonne-hmoty/`

previous section, these largest operators have substantial market share and other small operators follow them in fuel pricing. Thus, we have a representative data set of fuel prices.

Figure 4.1: Fuel tax components



Source: Data: CCS; author's computations

Gasoline and diesel prices are reported including value added tax (VAT) and excise duty. Taxes play an important role in the Czech fuel market. The tax component has ranged from 51% to 69% of the final cost of (in) gasoline prices and from 44% to 62% of (in) diesel prices over the observed period. The VAT has been changed twice in this period. Its rate was 22% until April 2004, 19 % from May 2004 to December 2009, and since January 2010 it has been 20%.[5] The excise duty increased from 9.95 CZK per liter for diesel and 11.84 CZK per liter for gasoline to 10.95 CZK per liter for diesel and 12.84 CZK per liter for gasoline on January 1, 2011. As we can see on Figure 4.1, changes in tax rates can affect retail fuel prices. Especially at the beginning of 2010, gasoline and diesel prices increased mainly due to the rise both in VAT and excise duty. Therefore, we remove taxes from the total amount and use the net of tax prices in our regressions.

[5]The excise duty is included in the VAT tax base.

Chapter 5

Methodology

The vast majority of the aforesaid literature applies an error correction framework in the empirical analysis. Only Bacon (1991) who employs a Quadratic Quantity Adjustment Model and Adilov and Samavati (2008) who employ an Asymmetric Price Response Model do not use the ECM at all. In all remaining studies the ECM or some of its specifications is used in at least a certain part of investigation. Thus, it can be concluded that an error correction approach as the most common method for exploration of downward price stickiness of fuel and it is appropriate to use it. Prior to applying this approach in our own analysis we describe its basic framework.

5.1 Introduction to ECM

The error correction estimation method uses relation between explained and explanatory variable called cointegration. Two variables are said to be cointegrated (C(1,1)) if both are I(1) and if there exist a linear combination of these two variables that is I(0) (Engle and Granger, 1987). I(1) indicates a unit root process integrated of order one and means that process is stationary after first differencing. Process integrated of order zero (I(0)) is a stationary, weakly dependent process which means that it has "constant mean, constant variance, autocorrelations that depend only on the time distance between any two variables in the series, and it is asymptotically uncorrelated."[1] From economic point of view, if two variables x and y are cointegrated, there is a long-term equilibrium relationship between them represented by equation

$$x_t = \phi_0 + \phi_1 y_t + \varepsilon_t \tag{5.1}$$

where ϕ_0 and ϕ_1 are model parameters. A change in one of variables can be explained by past equilibrium errors and past changes in both variables as in following Error Correction Model:

$$\Delta x_t = \alpha(x_{t-1} - \hat{\phi}_0 - \hat{\phi}_1 y_{t-1}) + \sum_{i=0}^{n} \beta_i \Delta y_{t-i} + \sum_{i=1}^{p} \gamma_i \Delta x_{t-i} + u_t \tag{5.2}$$

where Δ indicates the first difference operator, thus $\Delta X_t = X_t - X_{t-1}$, α, β and γ are the model parameters and n, p indicate length of adjustment lag. We know that if x_t and y_t are cointegrated then $(x_{t-1} - \hat{\phi}_0 - \hat{\phi}_1 y_{t-1}) = \hat{\varepsilon}_{t-1}$ is I(0) and hence stationary.[2] and Δx_t and Δy_t are stationary since x_t and y_t are I(1). Then all variables used in equation (5.2) are stationary and the regression can be consistently estimated by Ordinary Least Squares (OLS) method. In some models only the disequilibrium in the previous period and past change in y_t are used as explanatory variables. Whether to incorporate past change in x_t in regression as well as to what extent lag variables in regression is individual and depend on purposes of analysis (Wooldridge (2002)). Term $\alpha(x_{t-1} - \hat{\phi}_0 - \hat{\phi}_1 y_{t-1})$ is called error correction term and, as its appellation suggests, it corrects past deviations from the long-run equilibrium in the short-run adjustment. In other words, if the long-run equilibrium is steady there exists a tendency, represented by error correction term, pushing any deviation from the equilibrium backward. For that reason, the coefficient α which measures the error correction speed is expected to be negative. The coefficients β_i capture the short-run adjustment of changes in x to changes in y and its lagged values and coefficients γ_i capture the autoregressive relation of x.

[1](Wooldridge (2002), p. 586)

[2]Moreover, α has to be nonzero. Failing that there is no adjustment back to long-run equilibrium and then the residuals are non-stationary.

5.2 Asymmetric ECM

Model (5.2) can be reconfigured to include the possibility of asymmetric price adjustment and allow short-run responses to differ for increases and decreases. The asymmetric short-run adjustment model is, therefore, specified as follows:

$$\Delta x_t = \alpha^{(+)}\hat{\varepsilon}_{t-1}^{(+)} + \alpha^{(-)}\hat{\varepsilon}_{t-1}^{(-)} + \sum_{i=0}^{n}\beta_i^{(+)}\Delta y_{t-i}^{(+)} + \sum_{i=0}^{n}\beta_i^{(-)}\Delta y_{t-i}^{(-)} + \sum_{i=1}^{p}\gamma_i^{(+)}\Delta x_{t-i}^{(+)} + \sum_{i=1}^{p}\gamma_i^{(-)}\Delta x_{t-i}^{(-)} + \nu_t$$

Superscripts (+) or (-) on first differences of variables and on their lagged values indicate whether these differences are positive or negative. The superscript on lagged residuals (error correction term) indicates whether the explained variable was on the previous day above or below their long run equilibrium level. At this instant it should be noticed that as Granger and Lee (1989) state if $\hat{\varepsilon}_{t-1}$ is I(0), then $\hat{\varepsilon}_{t-1}^{(+)}$ and $\hat{\varepsilon}_{t-1}^{(-)}$ are I(0) too but both coefficient, $\alpha^{(+)}$ and $\alpha^{(-)}$, should be non-zero.

After the estimation of asymmetric ECM coefficients, we can investigate whether there is a presence or absence of asymmetries in fuel price responses. It lies in formally testing the null hypotheses about equality of coefficients with opposite superscripts, $H_0:\ \alpha^{(+)}=\alpha^{(-)}, \beta_i^{(+)}=\beta_i^{(-)}, \gamma_i^{(+)}=\gamma_i^{(-)}$, against the alternatives about their inequality, $H_1: \alpha^{(+)}\neq\alpha^{(-)}, \beta_i^{(+)}\neq\beta_i^{(-)}, \gamma_i^{(+)}\neq\gamma_i^{(-)}$. If we cannot reject the null hypothesis at some level of significance we are unable to find any evidence of asymmetric adjustment behavior. Failing that, we can say that there is an asymmetry in transmission mechanism. If the negative coefficient on lagged positive residuals is significantly lower in absolute value than this on negative residual it will be qualified to say that the adjustment to the long-run equilibrium is faster when the values of the explanatory variable are below this equilibrium level. Thus, the lower fuel prices are adjusted significantly faster upwards to the equilibrium than the higher prices are adjusted downwards. We find that explained variable adjust faster to increases in explanatory variable than to its decreases in case of higher coefficient with positive superscript. For our analysis this would mean faster responses of fuel prices to rising crude oil prices and slower responses of fuel prices to falling crude oil prices. It is also possible to find an asymmetry in the opposite direction which means fast adjustment to decreasing crude oil prices and slow adjustment to increasing crude oil prices and which would be detected in case of higher coefficient with negative superscript.

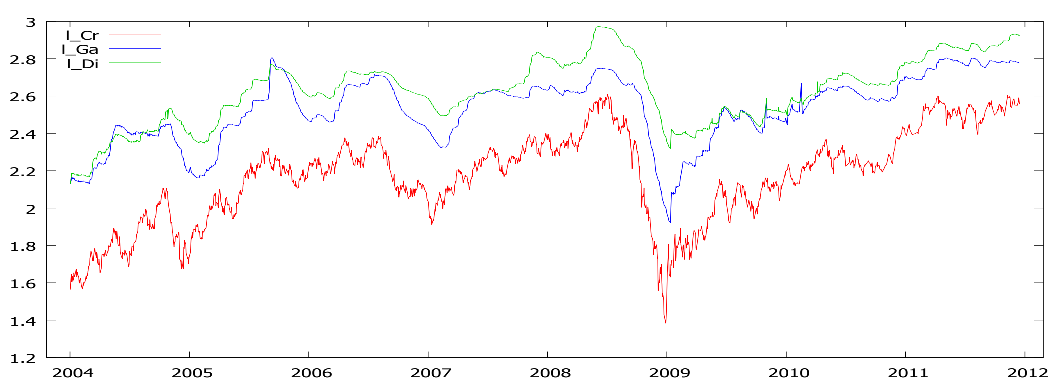
Chapter 6

Empirical results

We start our empirical investigation by basic data analysis. Then, we follow the majority of discussed studies and employ an asymmetric error correction model. We estimate the long-run relationship between the crude oil price and the retail price of fuel. After that we compute a short-run adjustment model and use the results of asymmetric ECM to testing whether there are some differences in the adjustment to the crude oil price increases and decreases.

6.1 Data analysis

Figure 6.1: Time series



Notes: All prices are in ln CZK per liter, fuel prices exclusive of taxes.

Source: Data: EIA, CCS; author's computations

Time plots of all three series used in analysis are illustrated on Figure 6.1.As we can observe, the crude oil price is more volatile than fuel prices. One possible explanation for this is a much larger number of factors affecting this price. Table 6.1 shows the summary statistics of series. Higher values of both the median and the mean for diesel prices implies that diesel is more expensive than gasoline despite the lower excise tax. It can be explained, as Liu et al. (2010) state, by the international market condition when "diesel is more expensive than petrol due to strong demand from emerging economies such as India and China."[1] Further explanation of increasing demand for diesel provide the International Energy Agency (IEA): "The accession to the European Union in 2004 is also seen as a significant contributing factor to the increase in diesel demand, as this has led to a greater number of heavy goods vehicles transiting the country."[2] The maximum price of gasoline was recorded on May 5, 2011. Remaining two variables reached their maximum in 2008, however, diesel about one month earlier (June 4th and July 3rd). Although this finding does not support a fact that fuel prices rise and fall primarily in response to changes in the crude oil price too much, we can consider it to be true after looking at graphs on Figure 6.1. We may also notice that diesel follows crude oil price more precisely than gasoline.

Table 6.1: Summary statistics

	Mean	Median	Minimum	Maximum	SD
ln Cr	2.1551	2.1960	1.3827	2.6082	0.24337
ln Ga	2.5189	2.5526	1.9229	2.8045	0.18229
ln Di	2.6161	2.6263	2.1314	2.9732	0.17861

Source: Data: EIA, CCS; author's computations

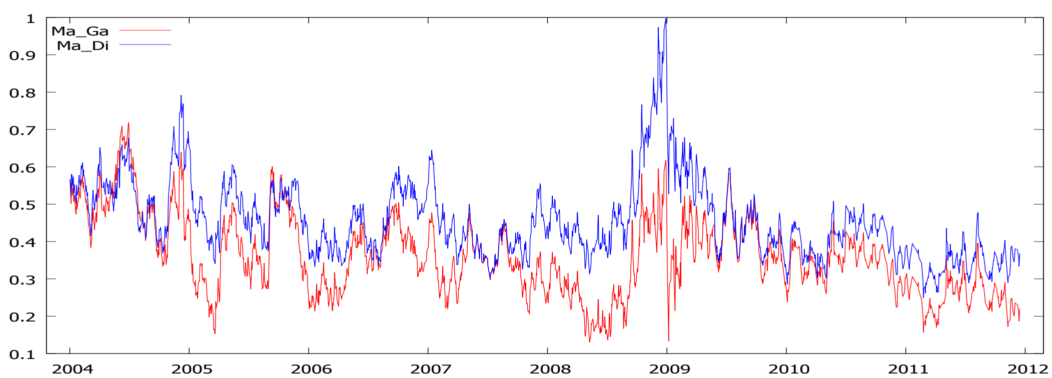
To provide a closer study of the relation between fuel and crude oil prices we

[1] Liu et al. (2010), p. 928

[2] IEA (2010), p.5

define a variable called margin[3] as the difference between the crude oil price and the fuel prices and look at its behavior. Figure 6.2 shows the time plots of the daily margins for gasoline and diesel over our sample period. Both variables seem to be relatively stable over time, however, diesel margin shows the extraordinary growth at the end of 2008. Thus, at the end of 2008 the diesel prices did not fully and immediately adjust to the fall in the crude oil price and remained at high values for a longer time. Except for this, both margins have downward trend and give evidence of increasing level of competitiveness in the Czech fuel market.

Figure 6.2: Margins for gasoline and diesel



Source: Data: EIA, CCS; author's computations

Table 6.2 presents the summary statistics of both margins. The mean and median values are as well as the maximum and minimum values higher for diesel margins confirming the higher diesel margin which can be given by stronger demand for diesel or larger production cost. The standard deviations are almost identical for gasoline and diesel margins, even if it is not apparent from Figure 6.2. Both margins have the positive skewness value indicating more high values lying on the left of the mean value and longer tail on the right site of the probability density function. The bulk of the values lying on the left of the mean include the median and explain the lower value of the median. The probability density function of margin are depicted in Figure 6.3. The positive skew is visible in both plots, albeit in gasoline function only imperceptible. We can also observe that only a few numbers of large deviations

[3]Notice that it is not importer margin

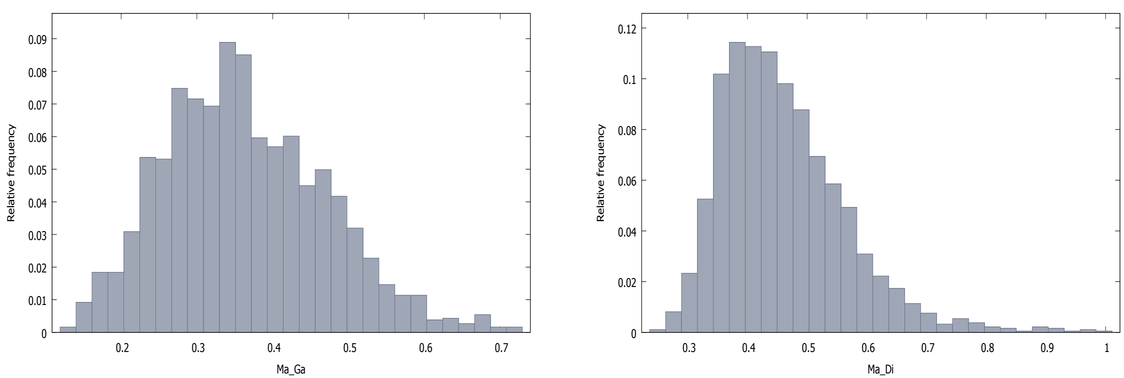
Table 6.2: Summary statistics of margins

	Mean	Median	Min	Max	SD	Skewness	Ex. kurtosis
Ma Ga	0.36361	0.35303	0.13002	0.71877	0.10642	0.4422	-0.0396
Ma Di	0.46097	0.44411	0.24941	0.99743	0.10472	1.1535	2.2563

Source: Data: EIA, CCS; author's computations

from the mean value of diesel margin affect the standard deviation. After looking at the graph of margin depicted in Figure 6.2 it is evident that these deviations are the values measured at the end of 2008. Positive excess kurtosis of diesel margin indicates that the distribution of diesel margin has fatter tails than a normal distribution and that the probability of large deviation is higher than a normal probability. We ascribe this fact again to the price development at the end of 2008.

Figure 6.3: Probability density functions of margins



(a) Gasoline margin

(b) Diesel margin

Source: Data: EIA, CCS; author's computations

6.2 Model estimation

6.2.1 Long-run equilibrium

The long-run relationship is expressed by a cointegrating equation:

$$\ln R_t = \phi_0 + \phi_1 \ln Cr_t + \varepsilon_t \tag{6.1}$$

where R_t is the retail fuel (gasoline or diesel) price in CZK per liter excluding VAT and excise duty, Cr_t denotes the crude oil price in CZK per liter, ε_t is a stationary error term, ϕ_0 and ϕ_1 are the model parameters, and ln indicates a natural logarithm. We decided to use the natural logarithm of prices since we would like to estimate the elasticity of the fuel price with respect to the crude oil price. Then, the parameter ϕ_0 measure the constant margin[4] and ϕ_1 represents the elasticity of the fuel price and measure the proportion of the crude oil which is passed through to the retail fuel price in the long run. If $\phi_1 = 1$, the pass through is complete. This case, however, almost never occurs since there are always some market imperfections such as asymmetric information, not fully competitiveness or high switching and menu costs, and moreover other expenses affecting fuel prices such as refining cost, international shipping or local transportation, and then $\phi_1 < 1$. If, in certain studies, the authors receive the complete pass through in the long run, it is always implication of the fact that the parameter is found to be not statistically different from one.

The results on the long-run relationship between gasoline and crude oil price are depicted in Table 6.3, the results corresponding to diesel prices are depicted in Table 6.4. The degree of pass through from crude oil to gasoline and diesel prices is incomplete as we expected and very similar for both cases, around 68%. The F statistics with p values lower than 0.05 reject the hypothesis of full long run pass through.[5] The higher intercept for diesel prices affirms the higher margin for diesel, the same conclusion to which we have came in the previous section. Plots of residuals

[4]Since we use such a model specification, we consider the margin to be constant. In some studies (Borenstein (1997)), the authors are convinced that the use of the data in log is not appropriate for the analysis. We ran regressions with the data in levels and we obtain results comparable with results that we present.

[5]P values are 2.72251e-295 and 0.

from the both long-run relationships are presented in Figures 6.4 and 6.5. From the Figures it is evident that both series of residuals suffer from autocorrelation, especially in the period from 2004 until 2009 when a large percentage of residuals deviated from zero is followed by deviation with the same sign.

Table 6.3: Long-term relationship between gasoline and crude oil price

OLS, Dependent variable: l_Ga

	Coefficient	Std. Error	t-ratio	p-value
const	1.04291	0.0153245	68.0552	0.0000 ***
l_Cr	0.684855	0.00706578	96.9257	0.0000 ***

Mean dependent var	2.518866	S.D. dependent var	0.182288
Sum squared resid	10.04911	S.E. of regression	0.073842
R^2	0.835997	Adjusted R^2	0.835908
$F(1, 1843)$	9394.588	P-value(F)	0.000000
Log-likelihood	2190.821	Akaike criterion	−4377.641
Schwarz criterion	−4366.601	Hannan–Quinn	−4373.571
$\hat{\rho}$	0.968066	Durbin–Watson	0.063873

*** Indicates significance at the 1% level.

Table 6.4: Long-term relationship between diesel and crude oil price

OLS, Dependent variable: l_Di

	Coefficient	Std. Error	t-ratio	p-value
const	1.15765	0.0143449	80.7012	0.0000 ***
l_Cr	0.676752	0.00661414	102.3189	0.0000 ***

Mean dependent var	2.616147	S.D. dependent var	0.178608
Sum squared resid	8.805514	S.E. of regression	0.069122
R^2	0.850311	Adjusted R^2	0.850229
$F(1, 1843)$	10469.16	P-value(F)	0.000000
Log-likelihood	2312.688	Akaike criterion	−4621.377
Schwarz criterion	−4610.337	Hannan–Quinn	−4617.307
$\hat{\rho}$	0.968941	Durbin–Watson	0.061436

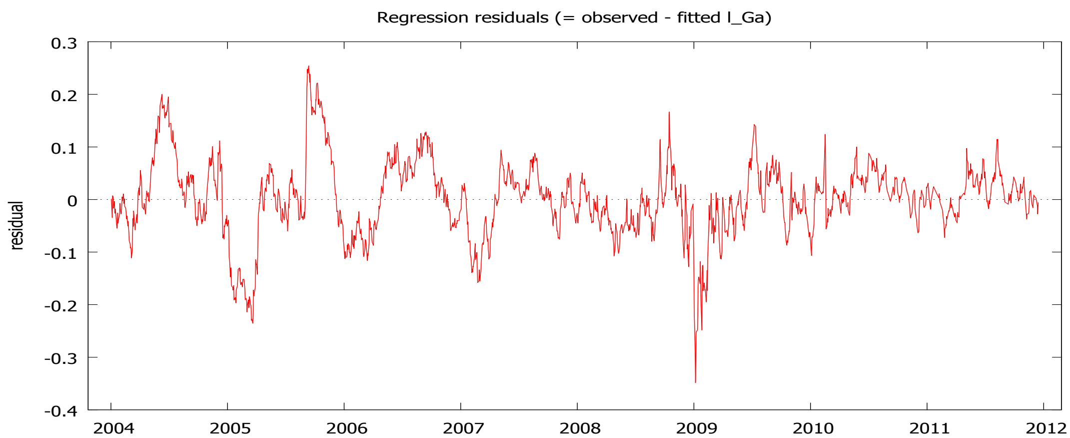
*** Indicates significance at the 1% level.

Since we estimate the long-run relationship using OLS method, we should verify whether our model fulfils its assumptions. It is necessary if we want to declare the unbiased and consistent estimators of ϕ_0 and ϕ_1 and if we want to use the F statistic with approximated F distribution in the further analysis. We have already known that if Cr is cointegrated with R, the OLS estimators $\hat{\phi}_0$ and $\hat{\phi}_1$ are consistent for ϕ_0 and ϕ_1. Cointegration test are presented in the following section. We found out that both series (gasoline and diesel prices) are cointegrated with crude oil price series. Consistency of estimators means that the estimate converges in probability to the true value of estimated parameter. Further, although the assumptions of homoskedasticity and no autocorrelation of residuals are violated the estimators are unbiased. Heteroskedasticity of residuals have no impact on bias in OLS and we can assume uncorrelation between the crude oil price and the disturbance term since the variable representing the crude oil price can be treated as exogenous.[6] Very high

[6] Just as Liu (2010) did because the Czech fuel market as well as the fuel market in New Zealand are similar in sense that world crude oil price does not depend on Czech or New Zealand demand.

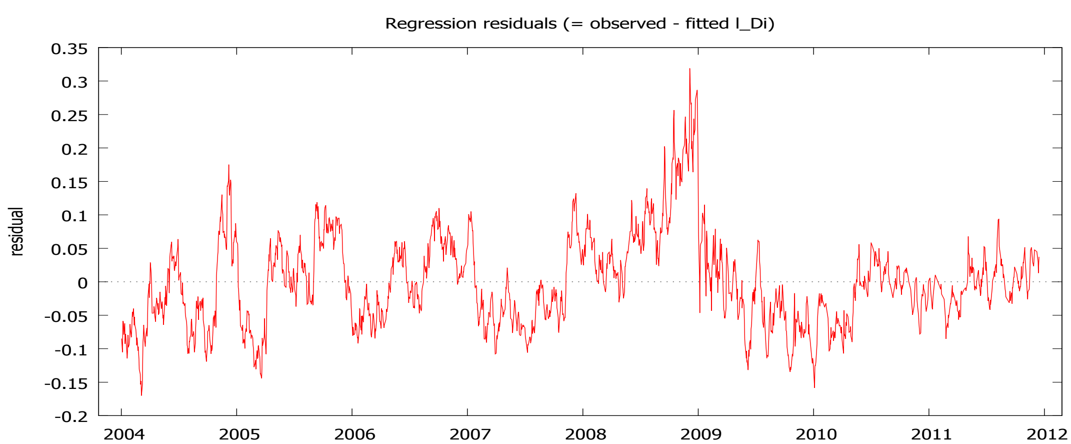
value of $\hat{\rho}$ in both models is not surprising since the error correction terms are highly autocorrelated. Problem of autocorrelation could be solved by using some more complicated method, such as Feasible generalized least squares, Cochrane–Orcutt or Prais–Winsten estimation. However, these estimation methods are not applied in the literature dealing with the same topic and it is out of the scope of our study.

Figure 6.4: Gasoline EC terms



Source: Data: EIA, CCS; author's computations

Figure 6.5: Diesel EC terms



Source: Data: EIA, CCS; author's computations

6.2.2 Cointegration tests

We test cointegration between crude oil and gasoline price series, and between crude oil and diesel price series using Engle-Granger cointegration test and Johansen cointegration test.

The Engle-Granger cointegration test consist in testing whether individual series are unit root processes using Augmented Dickey-Fuller test (ADF) and simultaneously whether residuals from cointegrating regression which is the same as our long-run equation are stationary again using the ADF test. If both conditions hold, there is an evidence for cointegrating relationship. The results from the Engle-Granger tests confirm cointegration between crude oil prices and gasoline prices and between crude oil prices and diesel prices. The null hypotheses of unit root process cannot be rejected on the 5% level of significance for all three time series and we reject the null hypotheses of unit root in residuals from cointegrating regressions (see Figures A.1 and A.2 in the Appendix). The ADF test, however, tests only a presence of unit roots in a process and an absence of unit roots does not necessarily imply a stationarity. Moreover, the Engle-Granger test verifies stationarity of residuals from the regression estimated by OLS and, as Wooldrigde (2002) state, "OLS which minimizes the sum of squared residuals, tends to produce residuals that look like an I(0) sequence even if y_t and x_t are not cointegrated."[7] Therefore, we employ also the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test for testing the stationarity of residuals to strengthen our conclusion. The null hypothesis of stationarity cannot be rejected on the 5% level of significance in terms of gasoline price (see Table B.1 in the Appendix). The results for diesel price are sensitive to the choice of lag length. For lags longer than 17, we cannot reject stationarity on the 5% level of significance concerning diesel price (see Table B.2 in the Appendix).[8]

The second test employed to test for cointegration is Johansen cointegration test. Both the trace and the maximum likelihood tests indicate 2 cointegrating relation between crude oil and gasoline or diesel prices on the 5% level of significance (see Tables A.1 and A.2 in Appendix).

[7] Wooldridge (2002), p.588

[8] The KPSS test statistic declines with additional lags.

As crude oil and fuel series are found to be cointegrated then residuals from the long-run relationship follow a stationary process (Engle and Granger, 1987).

6.2.3 Asymmetric ECM

Knowing the long-run equilibrium we are able to devise a model explaining the adjustment of fuel prices to crude oil price in the short-run. We employ the lagged residuals from the long-run relationship, $\hat{\varepsilon}_{t-1} = \ln R_{t-1} - \hat{\phi}_0 - \hat{\phi}_1 \ln Cr_{t-1}$, to estimate the following model

$$\Delta \ln R_t = \alpha^{(+)} \hat{\varepsilon}_{t-1}^{(+)} + \alpha^{(-)} \hat{\varepsilon}_{t-1}^{(-)} + \sum_{i=0}^{n} \beta_i^{(+)} \Delta \ln Cr_{t-i}^{(+)} + \sum_{i=0}^{n} \beta_i^{(-)} \Delta \ln Cr_{t-i}^{(-)} + \nu_t \quad (6.2)$$

where $\hat{\varepsilon}_{t-1}^{(+)} = \max\{\hat{\varepsilon}_{t-1}, 0\}$, $\hat{\varepsilon}_{t-1}^{(-)} = \min\{\hat{\varepsilon}_{t-1}, 0\}$, $\Delta \ln Cr_{t-i}^{(+)} = \max\{\Delta \ln Cr_{t-i}, 0\}$, $\Delta \ln Cr_{t-i}^{(-)} = \min\{\Delta \ln Cr_{t-i}, 0\}$ and $\alpha^{(+)}$, $\alpha^{(-)}$, $\beta_i^{(+)}$ and $\beta_i^{(-)}$ are the model parameters. Tables 6.5 and 6.6 present the results of asymmetric ECM estimated by OLS method. Based on Akaike's information criterion (AIC), ten lags of $\Delta \ln Cr_{t-i}^{(+)}$ and $\Delta \ln Cr_{t-i}^{(-)}$ are included to capture asymmetric short-run dynamics of both crude oil-gasoline and crude oil-diesel relations. The coefficients of lagged residuals are significant[9] and negative in both cases as we expected. Thus, gasoline and diesel prices are moving towards the long-run equilibrium in the short-run. The coefficient $\alpha^{(-)}$ is in absolute value higher than $\alpha^{(+)}$ in both cases indicating faster adjustment of fuel prices which are below the long-run equilibrium and slower adjustment of prices above the equilibrium. The highest and most significant coefficients of lagged changes in crude oil prices are those with lag from 5 to 10 day approximately. It indicates, together with significant and negative values of one or two day lagged coefficients, a time delay in the reaction of fuel prices. Fuel prices can move in opposite direction than the crude oil price at first or second day after the crude oil price change and they respond to right now arose change with a time delay counting around one week.

[9] However $\alpha^{(+)}$ for gasoline only on the 10% level of significance.

6.3 Testing of asymmetric behavior

We can draw a comparison of the size of the estimates $\hat{\alpha^{(+)}}$, $\hat{\alpha^{(-)}}$, $\hat{\beta_i^{(+)}}$ and $\hat{\beta_i^{(-)}}$ and arrive at a conclusion of an asymmetry. However, it should be formally tested whether the difference in the estimated parameters is statistically significant. For testing the null hypotheses $H_0 : \alpha^{(+)} = \alpha^{(-)}, \beta_i^{(+)} = \beta_i^{(-)}$ against the alternatives $H_1 : \alpha^{(+)} \neq \alpha^{(-)}, \beta_i^{(+)} \neq \beta_i^{(-)}$ we use the restricted and the unrestricted equations and employ the F statistic which is defined by

$$F = \frac{(SSR_r - SSR_{ur})/q}{SSR_{ur}/(n-k-1)} \tag{6.3}$$

where SSR_r denotes the sum of squared residuals in the restricted model, SSR_{ur} denotes the sum of squared residuals in the unrestricted model, q is the difference in degrees of freedom between the restricted and unrestricted model and $(n-k-1)$ denotes degrees of freedom in the unrestricted model.

At first, we examine a significance of the difference between estimated coefficients of past deviation from the long-term equilibrium. In the restricted model we apply the restriction $\alpha^{(+)} = \alpha^{(-)}$, thus we replace $\alpha^{(+)}\hat{\varepsilon}_{t-1}^{(+)} + \alpha^{(-)}\hat{\varepsilon}_{t-1}^{(-)}$ in the model 6.2 with $\alpha(\hat{\varepsilon}_{t-1}^{(+)} + \hat{\varepsilon}_{t-1}^{(-)}) = \alpha\hat{\varepsilon}_{t-1}$. The F statistic with p value higheg than 0.05[10] indicates that there is no significant difference in estimates of positive and negative error correction terms. In other words, fuel prices deviated from the long-run equilibrium are adjusted back at the speed comparable for positive and negative deviations.

For testing the asymmetric adjustment to changes in crude oil prices we restrict the model 6.2 by $\beta_i^{(+)} = \beta_i^{(-)}$. It is implication of hypothesis that fuel prices react to increases in crude oil prices in the same manner as to decreases, thus $\sum_{i=0}^{n} \beta_i \Delta \ln Cr_{t-i}^{(+)} + \sum_{i=0}^{n} \beta_i \Delta \ln Cr_{t-i}^{(-)} = \sum_{i=0}^{n} \beta_i \Delta \ln Cr_{t-i}$. Again, on the 5% level of significance, we cannot reject the hypothesis of symmetric responses[11] and we can say that fuel prices respond to changes in crude oil price without noticeable asymmetries.

[10] For gasoline:F(1, 1810) = 1.08698, with p-value = 0.297282, for diesel:F(1, 1810) = 0.472967, with p-value = 0.491713

[11] For gasoline:F(12, 1810) = 1.03304, with p-value = 0.415023, for diesel: F(12, 1810) = 1.46029, with p-value = 0.132169.

Table 6.5: Asymmetric ECM for gasoline

OLS, Dependent variable: d_l_Ga

	Coefficient	Std. Error	t-ratio	p-value	
rez_Ga_pos	−0.00869541	0.00499491	−1.7409	0.0819	*
rez_Ga_neg	−0.0174210	0.00553190	−3.1492	0.0017	***
d_lnCr__pos	0.0377189	0.0155274	2.4292	0.0152	**
d_lnCr__pos_1	−0.0320323	0.0157728	−2.0309	0.0424	**
d_lnCr__pos_2	−0.00396095	0.0157474	−0.2515	0.8014	
d_lnCr__pos_3	0.0223019	0.0157936	1.4121	0.1581	
d_lnCr__pos_4	0.0200214	0.0157023	1.2751	0.2025	
d_lnCr__pos_5	0.0560402	0.0156724	3.5757	0.0004	***
d_lnCr__pos_6	0.0241027	0.0156009	1.5450	0.1225	
d_lnCr__pos_7	0.0791167	0.0154918	5.1070	0.0000	***
d_lnCr__pos_8	0.0574416	0.0153338	3.7461	0.0002	***
d_lnCr__pos_9	0.0350701	0.0152493	2.2998	0.0216	**
d_lnCr__po_10	0.0239860	0.0150797	1.5906	0.1119	
d_ln_Cr_neg	−0.0274745	0.0158186	−1.7368	0.0826	*
d_ln_Cr_neg_1	0.00201812	0.0159795	0.1263	0.8995	
d_ln_Cr_neg_2	0.0102345	0.0159451	0.6419	0.5210	
d_ln_Cr_neg_3	0.0234164	0.0160989	1.4545	0.1460	
d_ln_Cr_neg_4	0.0318115	0.0161445	1.9704	0.0489	**
d_ln_Cr_neg_5	0.0288377	0.0161695	1.7835	0.0747	*
d_ln_Cr_neg_6	0.0555379	0.0161735	3.4339	0.0006	***
d_ln_Cr_neg_7	0.0619355	0.0162454	3.8125	0.0001	***
d_ln_Cr_neg_8	0.0697361	0.0161608	4.3151	0.0000	***
d_ln_Cr_neg_9	0.0484298	0.0161912	2.9911	0.0028	***
d_ln_Cr_ne_10	0.0422032	0.0161398	2.6149	0.0090	***

* Indicates significance at the 10% level.

** Indicates significance at the 5% level.

*** Indicates significance at the 1% level.

Table 6.6: Asymmetric ECM for diesel

OLS, Dependent variable: d_l_Di

	Coefficient	Std. Error	t-ratio	p-value	
rez_Di_pos	−0.0203617	0.00426189	−4.7776	0.0000	***
rez_Di_neg	−0.0248894	0.00411243	−6.0522	0.0000	***
d_lnCr__pos	0.0148782	0.0101660	1.4635	0.1435	
d_lnCr__pos_1	−0.0105954	0.0103340	−1.0253	0.3054	
d_lnCr__pos_2	−0.0195805	0.0102905	−1.9028	0.0572	*
d_lnCr__pos_3	0.00988898	0.0103194	0.9583	0.3380	
d_lnCr__pos_4	0.00208038	0.0102639	0.2027	0.8394	
d_lnCr__pos_5	0.0319724	0.0102342	3.1241	0.0018	***
d_lnCr__pos_6	0.0257730	0.0101963	2.5277	0.0116	**
d_lnCr__pos_7	0.0602824	0.0101223	5.9554	0.0000	***
d_lnCr__pos_8	0.0397078	0.0100242	3.9612	0.0001	***
d_lnCr__pos_9	0.0231314	0.00997552	2.3188	0.0205	**
d_lnCr__po_10	0.0150436	0.00987730	1.5230	0.1279	
d_ln_Cr_neg	−0.00468115	0.0103659	−0.4516	0.6516	
d_ln_Cr_neg_1	−0.0180732	0.0106615	−1.6952	0.0902	*
d_ln_Cr_neg_2	0.0122291	0.0106605	1.1471	0.2515	
d_ln_Cr_neg_3	−0.00495539	0.0107303	−0.4618	0.6443	
d_ln_Cr_neg_4	0.0242504	0.0107432	2.2573	0.0241	**
d_ln_Cr_neg_5	0.0102743	0.0107158	0.9588	0.3378	
d_ln_Cr_neg_6	0.0284453	0.0107398	2.6486	0.0082	***
d_ln_Cr_neg_7	0.0320552	0.0107596	2.9792	0.0029	***
d_ln_Cr_neg_8	0.0300398	0.0107055	2.8060	0.0051	***
d_ln_Cr_neg_9	0.0274276	0.0106860	2.5667	0.0103	**
d_ln_Cr_ne_10	0.0365689	0.0106384	3.4374	0.0006	***

* Indicates significance at the 10% level.

** Indicates significance at the 5% level.

*** Indicates significance at the 1% level.

Chapter 7

Conclusion

In this study we analyze daily gasoline and diesel prices in the Czech Republic and their responses to the crude oil prices in the world market over the period from January 2, 2004 to December 15, 2011. We focus primarily on possibly different reaction of fuel prices to increases and decreases in crude oil prices. To the best of our knowledge, similar analysis has not yet been done for the Czech Republic.

Empirical part of this study is divided into two parts. In the first, we provide basic data analysis and come to the conclusion that diesel prices are higher than gasoline over our sample period and that from the end of 2008 the Czech fuel market seems to be more competitive than earlier.

In second, most important, part we apply an asymmetric ECM based on cointegrating relation between variables on ln prices and estimate a long-run relationship between crude oil prices and fuel prices. We find a stable long-run equilibrium. After that we estimate a short-run dynamics of fuel prices and investigate their adjustment to crude oil prices. The estimation results show that gasoline and diesel prices respond to crude oil price changes with a time delay around one week and that fuel prices are adjusted upwards faster than downwards. However, it is not possible to reject at any reasonable level that the responses are the same for crude oil price increases and decreases. Thus we can say that the difference in responses is not statistically significant and that fuel prices respond to changes in crude oil price without noticeable asymmetries.

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Appendix A

Cointegration tests

Table A.1: Johansen cointegration test : gasoline-crude oil

Number of equations = 2 Lag order = 5 Case 3: Unrestricted constant Log-likelihood = 15630.3 (including constant term: 10408.6					
Rank	Eigenvalue	Trace test	p-value	Lmax test	p-value
0	0.036472	73.522	[0.0000]	68.363	[0.0000]
1	0.0027998	5.1588	[0.0150]	5.1588	[0.0150]

Table A.2: Johansen cointegration test : diesel-crude oil

Number of equations = 2 Lag order = 5 Case 3: Unrestricted constant Log-likelihood = 16399.9 (including constant term: 11178.2)					
Rank	Eigenvalue	Trace test	p-value	Lmax test	p-value
0	0.075502	150.37	[0.0000]	144.45	[0.0000]
1	0.0032124	5.9204	[0.0150]	5.9204	[0.0150]

Figure A.1: Engle-Granger cointegration test, Gasoline-Crude oil

```
Step 1: testing for a unit root in l_Cr

Augmented Dickey-Fuller test for l_Cr
including 5 lags of (1-L)l_Cr
sample size 1839
unit-root null hypothesis: a = 1

   test with constant
   model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: -0.000
   lagged differences: F(5, 1832) = 1.075 [0.3722]
   estimated value of (a - 1): -0.00502587
   test statistic: tau_c(1) = -2.20372
   asymptotic p-value 0.2051

Step 2: testing for a unit root in l_Ga

Augmented Dickey-Fuller test for l_Ga
including 5 lags of (1-L)l_Ga
sample size 1839
unit-root null hypothesis: a = 1

   test with constant
   model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: -0.002
   lagged differences: F(5, 1832) = 34.519 [0.0000]
   estimated value of (a - 1): -0.00268511
   test statistic: tau_c(1) = -2.34683
   asymptotic p-value 0.1573

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 2004/01/02-2011/12/15 (T = 1845)
Dependent variable: l_Cr

             coefficient   std. error   t-ratio    p-value
  ---------------------------------------------------------
  const       -0.919620    0.0318058    -28.91    6.71e-152 ***
  l_Ga         1.22069     0.0125941     96.93    0.0000    ***

Mean dependent var   2.155138   S.D. dependent var   0.243366
Sum squared resid    17.91161   S.E. of regression   0.098584
R-squared            0.835997   Adjusted R-squared   0.835908
Log-likelihood       1657.648   Akaike criterion    -3311.296
Schwarz criterion   -3300.255   Hannan-Quinn        -3307.225
rho                  0.964467   Durbin-Watson        0.070716

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 5 lags of (1-L)uhat
sample size 1839
unit-root null hypothesis: a = 1

   model: (1-L)y = (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: -0.002
   lagged differences: F(5, 1833) = 1.969 [0.0803]
   estimated value of (a - 1): -0.0367815
   test statistic: tau_c(2) = -5.71733
   asymptotic p-value 4.802e-006
```

Figure A.2: Engle-Granger cointegration test, Diesel-Crude oil

```
Step 1: testing for a unit root in l_Di

Augmented Dickey-Fuller test for l_Di
including 5 lags of (1-L)l_Di
sample size 1839
unit-root null hypothesis: a = 1

   test with constant
   model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: -0.002
   lagged differences: F(5, 1832) = 42.132 [0.0000]
   estimated value of (a - 1): -0.00155707
   test statistic: tau_c(1) = -1.98301
   asymptotic p-value 0.2946

Step 2: testing for a unit root in l_Cr

Augmented Dickey-Fuller test for l_Cr
including 5 lags of (1-L)l_Cr
sample size 1839
unit-root null hypothesis: a = 1

   test with constant
   model: (1-L)y = b0 + (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: -0.000
   lagged differences: F(5, 1832) = 1.075 [0.3722]
   estimated value of (a - 1): -0.00502587
   test statistic: tau_c(1) = -2.20372
   asymptotic p-value 0.2051

Step 3: cointegrating regression

Cointegrating regression -
OLS, using observations 2004/01/02-2011/12/15 (T = 1845)
Dependent variable: l_Di

             coefficient   std. error   t-ratio   p-value
  -------------------------------------------------------
  const       1.15765      0.0143449     80.70    0.0000  ***
  l_Cr        0.676752     0.00661414   102.3     0.0000  ***

Mean dependent var   2.616147   S.D. dependent var   0.178608
Sum squared resid    8.805514   S.E. of regression   0.069122
R-squared            0.850311   Adjusted R-squared   0.850229
Log-likelihood       2312.688   Akaike criterion    -4621.377
Schwarz criterion   -4610.337   Hannan-Quinn        -4617.307
rho                  0.968941   Durbin-Watson        0.061436

Step 4: testing for a unit root in uhat

Augmented Dickey-Fuller test for uhat
including 5 lags of (1-L)uhat
sample size 1839
unit-root null hypothesis: a = 1

   model: (1-L)y = (a-1)*y(-1) + ... + e
   1st-order autocorrelation coeff. for e: -0.002
   lagged differences: F(5, 1833) = 2.075 [0.0658]
   estimated value of (a - 1): -0.0313972
   test statistic: tau_c(2) = -5.26801
   asymptotic p-value 4.341e-005
```

Appendix B

KPSS tests

Table B.1: KPSS test- gasoline

T = 1844			
Lag truncation parameter = 8			
Test statistic = 0.36165			
	10%	5%	1%
Critical values:	0.347	0.461	0.743
Interpolated p-value 0.094			

Table B.2: KPSS test- diesel

T = 1844			
Lag truncation parameter = 17			
Test statistic = 0.448878			
	10%	5%	1%
Critical values:	0.347	0.461	0.743
Interpolated p-value 0.056			