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Diploma Thesis Title:

Market integration between German and Czech electricity markets and their major production resources

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Abstract

This paper uses weekly averages prices of Brent oil, ARA coal, EUR/CZK exchange rate, German electricity and Czech electricity in order to analyse their relation. Data are tested by Johansen procedure for cointegration. The impulse response function of structural vector autoregression and vector error correction models show that shocks in production resources have strong effect to final electricity prices and moreover shocks in electricity prices have significant effect to each other. Forecast error variance decompositions indicate that ARA coal prices have the highest prediction power for both electricity prices. Relation between electricity prices is mainly defined by Germany. German electricity price discovery is the main leading element for the Czech electricity price discovery. The paper concludes, that major market has significant influence to minor markets and thus minor market should closely follow major market price discovery.

Key words: Electricity, Brent, ARA coal, cointegration, price discovery, structural vector autoregression

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1. Introduction

European countries are dependent on the supply of vital energy resources, so any change in prices influences a wide range of stakeholders starting from countries, industries, other commodities or households. The EU aims to reach the European common electricity market. The interdependency of energy and electricity markets between countries will become even stronger. Common energy market will increase the decision power of the major markets and deepen dependency of minor markets. This paper tries to analyze the relationship between Germany and Czech Republic and their mutual dependency. The dynamics of their relationship is given as follows, Germany, the regional and European market leader, who strongly influences energy prices for the surrounding region. Czech Republic is the minor market in the Central and Eastern Europe (CEE), which strongly focuses on electricity export to neighbor countries. Since energy prices are mainly defined on leader market (Germany), follower markets (Czech Republic) need to accept the predefined energy commodity prices, which can negatively influence energy independence, national security and also export and import volumes. A sharp increase in energy commodity prices can push electricity prices to unreasonable price height, which is transferred to every part of the countries industry and household. These assumptions leads to the main research question of the thesis: *Does German market predefine the electricity prices for Czech market, but German electricity price discovery do not necessarily take into account influence of Czech price contribution?* The set of sub-questions help to answer the main question: Sub-questions: *What is connection link between German and Czech energy markets? What are the main energy resources used for electricity production in the German and Czech market? What is the energy commodity price fluctuation between countries due to the exchange rate movement? How does crude oil price influence other energy commodity prices?*

The purpose of this paper is to estimate the interstate electricity price relation between Germany and Czech Republic and to estimate effect of production resources to the final electricity price. Since electricity supply and demand has to be in balance from the production and consumer point of view. A risk for the retailers arises when consumer excessively consume electricity and risk for producer is high when spot prices do not cover their marginal costs. The unstable situation between the supply and demand leads to high volatility in the electricity market. Thus future markets derivatives for electricity production sources are crucial for the risk management against high volatility. According to Furió & Chuliá (2012) hedging has a positive effect to the price stability due to the risk reduction of adverse price movements on the spot market. Price discovery is another important function provided by future energy commodity markets. As long as the future markets have sufficient liquidity, producers use the future prices for the estimation of supply on the spot electricity market.

Several scientific papers focus on the similar topic but they draw their attention towards other markets or commodities. Ferkingstad, Løland, & Wilhelmsen (2011) built electricity price relation model between Germany and Nordic region with focus on country's electricity production orientation. Mjelde & Bessler (2009) presents vector error correction model for estimation of relation between oil, natural gas, coal, uranium and electricity prices in USA. Yu & Mallory (2013) use structural vector auto-regression model (SVAR) for description of relation between natural gas, coal and their relation to carbon emitting allowances. Furió & Chuliá (2012) examine relation between Brent oil, natural gas and electricity by VECM, which uncover influence or production resources to the final electricity prices.

This paper draws its attention to the relation among energy markets in Central and Eastern European (CEE) region. CEE region has received little attention compare to develop economy markets. Deregulation of energy markets led to the power increase of short-term contracts (futures and options) and power reduction of long-term contracts for oil and coal (10 – 20 years contracts). Thus prices of energy commodities are tailored according to the law of supply/demand and the long-term contract strength of international oil and gas behemoths is reduced. Deregulation also led to the creation of new energy commodity exchanges (EEX, EPEX SPOT or OTE), which provide cross-border interconnection of energy and electricity markets. Price discovery from energy exchanges provide better correlation to the current market demand than long-term contracts. However Czech Republic is not yet fully participating in the European market price coupling system. Thus the relation in this region needs to be examined more closely to uncover dynamics of energy commodity exchange between countries. To my best knowledge, the analysis for production resources and electricity prices between Germany and Czech Republic is the first of its kind.

As Germany is the biggest consumer of energy resources in the region, final electricity price information is principally defined in German market. Thus Germany have significant influence to Czech electricity price. However Czech has also influence to German price discovery but comparatively smaller then German influence. The relation suggest that regional leader predefines the prices of electricity for the surrounding countries and keep significant influence on the national electricity prices.

The paper is organized flowingly: **Literature review** on the electricity and productions resources. **Specification of national markets**

provides insight into national energy policies. **Data** section described all commodities used in the analysis. **Methodology** section describe model and approaches used for the analysis. **Results**

section describes estimated finding. **Discussion**

answers main and sub questions and suggest area for further research. **Conclusion**

conclude the paper as whole. Literature reviewLiterature reviewLiterature reviewLiterature review

2. Literature review

Only few researches focus on the commodity cointegration relationship of markets and countries to each other, especially in CEE region. Thus there is knowledge gap about CEE region and its relation to the Western markets. The cointegrative relationship could be used for better understanding of energy commodity price discovery between countries. Since there are major and minor players on the electricity market, it is vital to understand the dynamics between them. The results of this thesis aim to help the minor market countries to develop/direct policies, which would benefit them to unfavorable prices, which were pre-defined on the major energy commodity market.

Crude oil is one of the commodities, which has an effect on the majority of known commodities. Bachmeier & Griffin (2006) used daily price data for several different crude oils over the world (e.g. WTI, Brent) and find out that world oil market is single highly integrated entity. The final result showed that US markets of crude oil, natural gas and coal are very weakly cointegrated. Filis, Degiannakis, & Floros (2011) focused their attention towards correlation between stock markets and oil prices for importing and exporting countries. They came to the conclusion that oil prices do not have significant influence on the stock markets and therefore do not provide save investment possibility. Correlation of both markets increase, if global turmoil event occur (e.g. war). Despite the fact, oil does not provide a "safe haven" investment, as it the investment into gold. Elyasiani, Mansur, & Odusami (2011) examined relationship between oil prices and oil-substitute (coal) with the GARCH model and find out that oil prices negatively affects the prices of substitutes and also oil related industry (petroleum industry and oil and gas extraction)

Exchange rate has strong influence to commodities, since national economies define its strength and their purchase power. Chen & Chen (2007) find relationship between G7 countries (e.g. US, Germany and UK), where increase in oil prices depreciates the real exchange rate in long run. They showed the relation between domestic country and US, if domestic country is more dependable on the oil than US, the increase in price of energy prices in domestic country would be higher than in US, thus the domestic currency depreciate against US dollar. The relationship clearly shows that the country with its own resources or better supply channels gets a comparative advantage over the country that relies on one supply channel.

Amano & Van Norden (1998) support the theory about the relationship between US exchange rate and price of oil, where oil was the main cause of the exchange rate shocks. Timera Energy (2011) refers to 3 key currencies, which influence the whole European energy market: EUR, USD and GBP. These currencies have impact on all levels of energy markets. However there are local currencies, which effect on national or regional level: CHF, NOK, SEK, PLN and CZK. Local exchange rate is influenced by national policies and regulations, which can significantly influence the price of energies bought from pan-European market.

Most of the current literature is focused on advanced economies, where US market is the most extensively studied, followed by Western Europe and Nordic countries. Compare to that attention to CEE region is much less significant. As CEE region grows rapidly and the level of integration within European Union is constantly increasing. There is need to understand change in market dynamics, where CEE region increase its market power. Germany is the leader of the CEE region and steer the direction of region. Thus significant amount of literature study German market.

3. Specification of national markets

3.1 German market

The German wholesale electricity market is controlled by four major companies, which own around 85% of conventional power plant capacity. Therefore elements, such as vertical integration, low transparency with high complexity of price creation and insufficient international trade, occur on the market (Weigt & Hirschhausen, 2008).

Academic studies try to describe the previously mentioned problematic areas. Since European Energy exchange (EEX) has been established in Germany many researchers focus their attention to the effect to energy prices. Melzian & Ehlers (2007) focused on the EEX and detected that EEX prices are above the producers price levels and thus producers acquire comparative advantage. Nevertheless EEX provides needed liquidity for the wholesale electricity price generation and for international trading. Compare to that Ehlers & Erdmann (2007) concluded that EEX traded volumes and supply and demand curves do not allow any significant manipulation. Thus the wholesale price is generated by free market power.

Weigt & Hirschhausen (2008) assume that prices created on EEX can be taken as benchmark for long term trades made in German electricity market.

Cullmann & von Hirschhausen (2008) compared CEE countries (Czech Republic, Hungary, Poland and Slovakia) to Germany, where the main examined subject was: efficiency of electricity distribution network. Czech Republic took the position of the most effective network compared to all studied countries. Since EU aims for unitary electricity market, Czech Republic is able to be incorporated to the network.

3.2 Czech market

Energy markets in the CEE region have been less studied because market liberalization and deregulation occurred more recently compared to other Western and Northern European countries.

Kočenda & Čábelka (1998) analyzed the market for the Czech Republic and CEE countries in their transition process from the communist system to market oriented system. Their conclusion suggested to break up the state owned monopolies and induces private ownership and new legislation process. However, the process of implementation is lengthy and not always successful.

Estrin, Hanousek, Kočenda, & Svejnar (2009) re-opened the topic of market liberalization. They worked with data and events collected over 20 years of transition. Expectation of policy makers and academics were significantly high about the improvement of the energy market situation. They concluded that privatization of Czech market has been successful in terms of performance and foreign investments but the progress could have been even better. Nevertheless Czech market rose to the position, where collaboration with other European energy markets can realize efficiently. According to Sensfuss, Ragwitz, & Genoese (2008) Czech electricity market is fully deregulated since 2006, where OTE organizes the day-ahead auction of electricity. Hungary and Slovakia participate in the auction. Thus regional coupled auction support the electricity networks.

3.3 Relationship of markets

European desire to establish common electricity market has lead members countries to follow the European Union energy directives. The directives require that: cross border trade is without obstacles, opened market and that entry to the network is not restricted to the third party. The progress towards interconnected market is substantial, however the objective of common market has not been reached yet. European Union states have established power exchanges to allow exchange between member countries. Germany and Czech Republic are interconnected by National stock exchanges (Deutsche Boerse AG, Prague Stock Exchange) and also by power exchanges (EEX, OTE, PXE). Despite differences in structure, market mechanisms and liquidity. Czech power market exchange (OTE), Prague exchange central Europe (PXE) and European energy exchange (EEX) have similar operation protocol. Nevertheless the size, revenues and traded volume of EEX is significantly higher than OTE and PXE, which is operating with low liquidity and low traded volumes. Despite that, it shows there is active connection between both countries in term of electricity exchange and also in term of commodity exchange (Zachmann, 2008).

The Czech Republic uses mainly solid fuels as the key electricity generator. Nuclear (32.7%) and coal (55%) are dominant electricity production sources in Czech production mix, generating nearly 90% of whole production. The rest of the mix is taken by natural gas (4.8%) and by renewables (7.5%), which tend to increase their output. German market has similar electricity production mix, where substantial part is produced by coal (42.4%) and nuclear energy (22.7%). The rest is divided between natural gas (15.6%) and renewable (17.8%). Renewable energy sources are about to take even more significant part of the electricity production mix, the plan is to produce 35% of electricity in 2020. (European_Commission, 2011). See **Figure *1***
Figure *1*Figure *1*Figure *1*Figure *1*Both countries have significant reserves of lignite (brown coal), so they satisfy their national requirements. The case of hard coal is slightly different. Czech Republic export un-significant amount to the neighbor countries and has minimal imports. Germany has high requirement for the hard coal imports, since it is European industrial leader. Germany was largest EU importer of coal in recent years, where most of the imports come from Russia (24%), USA (25%) and Colombia (21%). (Euracoal, 2013)

4. Data

For the analysis of the price movement I will use the following data: Brent oil, EUR/CZK exchange rate, coal, German electricity prices and Czech electricity prices. Electricity prices are available in spot prices, other commodities are taken in future prices with the closest maturity to spot price. All price series are transferred to EUR. Effect of the currency dependency will be observed independently to energy price fluctuations. It is expected that economic data are non-stationary. Furthermore it is expected that prices for fuels and electricity are interconnected and dependent to each other. Even if different energy markets are under influence of similar economic force, then it is expected that price movements for commodities will follow the same trend. Thus the commodity prices in one market will not completely lose touch with other price markets, so the prices will not be completely independent (Mjelde & Bessler, 2009; Samuelson, 1971).

All price series are given in weekly averages. Even though daily data would provide a more detailed view, the use of weekly data is more suitable. Since producers aim to minimize their costs, prices do not change significantly during the week. Data are from the period first week in 2008- last week of 2014. All prices are taken in logarithms.

4.1 Brent Oil

The Brent oil price (€/barrel) is taken from Energy Information Administration. Brent oil is highly correlated to other crude oil derivate. The price of oil is mainly disturbed by military events on Middle East, embargos to exporter countries and decision of OPEC. Main event, which has dropped the oil price to minimum, was the banking crisis. Since then markets began to raise again, oil continued to rise with small disturbances caused by overproduction and lower demand. Nevertheless overproduction, use of shale gas extraction in USA and disagreement between OPEC and non-OPEC countries lead to the decrease in prices in year 2014 (Commodities-now, 2014).

4.2 Exchange Rate EUR/CZK

Chen & Chen, Yu & Mallory (2007; 2013) have proved the effect of major currencies (USD, EUR) on the energy commodities market. This study focus on the regional dependency, thus EUR/CZK exchange rates are included. Currency exchange rate are taken from European Central Bank (ECB). Financial crisis was the main event, which had an influence on all commodities and exchange rate EUR/CZK has not been exception. However the effect had been slight delayed by Czech non-participation in Eurozone, even so the bearish trend of all market inevitably comes in effect. Stabilization after the crisis predicted return to the pre-crisis rates, but collapses of several EU members' national economies and negative prediction of national gross product kept the exchange rate unstable. (CNB, 2013; CTK, 2014). **Figure** 2 Presents significant events of exchange rate changes. Exchange rate prices will be referred as EUR/CZK.

4.3 Coal ARA

Coal is the main input in the electricity production energy mix for both countries. Therefore it has significant influence to the price discovery. Coal has comparative disadvantage to other electricity production resources. Since it is extreme pollutant compared to natural gas, oil, nuclear and other renewable sources. Current energy policies aim to reduce the pollution effect, mainly by substitution for less polluting source, such as oil and natural gas (IEA, 2012; Joëts & Mignon, 2012). The main two events, which influenced coal prices, were Fukushima nuclear power plant disaster and production of shale gas in USA. First event increased consumption of coal because of nuclear power plants shot downs. Second event decreased US consumption of coal and thus US coal is imported to Europe for lower prices. Even though electricity production from coal requires purchase of carbon allowances, it is comparatively more profitable to low carbon emitting electricity production resources, such as natural gas (EIA, 2013).

4.4 German Electricity

German electricity prices are coupled with Austrian prices, since the markets co-operate together. However Austrian market has similar size as Czech market or even smaller size, so the price is still defined by German market. German Electricity spot prices are taken from EPEX SPOT, which operates the spot market for electricity in CWE region. Even though CEE is not part of the coupled market, the German prices are used as the reference price for CEE region. Hereby all action on German electricity market should reflect to the Czech electricity market. Nevertheless German market liquidity give opportunity to higher spikes thanks to EEX and compare to that Czech prices have lower volatility due to the underdevelopment of short-term energy trading markets and transition network. See **Figure 3** for electricity price charts. German electricity prices will be referred as GEE

4.5 Czech Electricity

The Czech electricity market is dominated by state owned monopoly CEZ, which uses mainly two nuclear power plants and small fleet of coal based power plants supplied by local lignite. The market operator OTE organizes the wholesale market, which is currently emerging and so the liquidity on market is very low. Due to the low liquidity OTE mainly rely on EEX, which is bigger and thus more liquid market (Glachant, 2009). Czech electricity price will be referred as CZE

5. Methodology

5.1 Vector auto-regression model (VAR)

The VAR model is advantageous to characterize exogenous shocks based on underlying economic theory and to assess how the shock drives other endogenous variables to move together (Breitung, Brüggemann, & Lütkepohl, 2004).

The general formula is specified by:

$$yt = A_1 yt - 1 + \cdots + A_p yt - p + B_0 xt + \cdots + B_q xt - q + CDt + ut \qquad (1)$$

Where, $yt = (y1t, \ldots, yKt)$ is a vector of K of endogenous variables (Brent oil (BRENT), coal (ARA), German electricity price (GEE) and Czech electricity price (CZE)), $xt = (x1t, \ldots, xMt)$ is a vector of M exogenous variables (EUR/CZK), D_t contains all other deterministic variables, which may include trends, seasonal dummy variable in case of coal and u_t represents vector of residuals. Endogenous variable and exogenous variable are y_t and x_t where both are observed in vector interval (time) t = 1, 2… n. $A_i, B_j and\ C$ are coefficient matrixes for related dimension (Lütkepohl, Kratzig, & Boreiko, 2006). Modeling with VAR can be divided in two direction, either all variables are stationary I(0), which would result in standard case of VAR model or all variables are non-stationary, I(M), M>1 , which gives two potential solution of the model. The first solution suggests to differ variables M times in order to get stationary variables for VAR model. The second solution suggests to use VECM model in case of cointegration between variables (Juselius, 2006).

5.2 Structural Vector auto-regression model (SVAR)

In order to identify the structural shocks in the VAR model, there are two main assumptions required: normalization and recursion. Normalization determines the structure of diagonal element of A_0 equal to one, which indicates that elements and their shock strength are comparable to each other. Recursion refers to the Cholesky decomposition, which is used for the identification of unique matrix A_0 , where the element in higher rows of diagonal are equal to zero. Recursion assure the strict order in structural shocks, where shock in p^{th} row of vector u_t does not a significant effect on the variable (y_t) in the higher row (Sims, 1980).

$$yt = A^{-1}A_1yt - 1 + \cdots + A^{-1}A_pyt - p + A^{-1}B_0xt + \cdots + A^{-1}B_qxt - q + A^{-1}CDt + A^{-1}\varepsilon_t$$

$$u_t = \begin{pmatrix} u_t^{BRENT} \\ u_t^{ARA} \\ u_t^{GEE} \\ u_t^{CZE} \end{pmatrix} = \begin{pmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{pmatrix} X \begin{pmatrix} \varepsilon_t^{BRENT\ shock} \\ \varepsilon_t^{ARA\ shock} \\ \varepsilon_t^{GEE\ shock} \\ \varepsilon_t^{CZE\ shock} \end{pmatrix} \quad (2)$$

Firstly equation (2) shows the reduction of the equation (1) into SVAR. Secondly it shows the restriction matrix for u_t, which are transferred in to the structural disturbances ε_t. If A^{-1} is known, it is possible to derive structural shocks ε_t from the equation $\varepsilon_t = A * u_t$. Nevertheless the coefficients for A^{-1} are unknown. Equations (2) defines the theoretical restriction needed for the structural parameter discovery of VAR model.

Matrix in (2) shows the structural form of VAR, where a_{k1} … a_{k3} represents unrestricted parameters and zeros are restricted parameters. The structural form of the model ensure that all variables do not respond simultaneously and with the same strength. Matrix in equation (2) presents the order of variables, where BRENT is not effected by shocks in ARA, GEE and CZE prices within the week. Since crude oil market influences majority of commodities, shocks in coal or local electricity prices do not have sufficient strength to influence BRENT prices thus shocks from ARA, GEE and CZE has been restricted. ARA is under influence of BRENT shocks but shocks for GEE and CZE are restricted. Since coal is the main production resource for electricity production, it induces link between electricity and coal prices. GEE shock are expected to have influence CZE and be under effected by shock in BRENT and ARA. Since German economy is more significant compare to Czech economy. It indicate the significance of GEE shock to CZE shock. CZE is under influence of all previously mentioned commodities. The reasons vary from worldwide significant commodity, to significant production resources and to stronger neighbor economy.

5.3 Johansen estimation procedure

The main assumption is, that prices are related but the level of dependency or integration is unknown. Johansen estimation procedure will be used for estimation of Eigenvalues (λ) in order to test the cointegration between variables. If at least one of the $\lambda_i \neq 0$, where $i = 1,2, \dots . n - 1$, than it will be proven existence of cointegration between variables (Lütkepohl & Krätzig, 2005; Moutinho, Vieira, & Carrizo Moreira, 2011).

5.4 Vector error correction model (VECM)

It is expected that cointegration exists between variables and that data are non-stationary. VECM provides the appropriate model to analyze cointegrative relationship, where examined variables can have negative or positive relationship to the y_t.

If y_t variables are equal to I (1), which means that variables are differenced at least one time in order to be perceived as stationary. VECM can be derived from the VAR model in (1)

$$\Gamma_0 \Delta yt = \Pi y_{t-1} + \Gamma_1 \Delta y_t - 1 + \cdots + \Gamma_p \Delta y_{t-p} + B_0 xt + \cdots + B_q xt - q + CDt + ut \quad (3)$$

, Where Δ is the difference operator ($\Delta y_t = y_t - y_{t-1}$), where y_t is a 4×1 vector of prices estimated in period t and Γ_p is a 4×4 matrix of coefficients, where variables (y_t) are lagged by *p* periods to the current price change ofy_t. $\Pi = \alpha\beta'$, Where $\alpha \; and \; \beta'$ are of dimensions $n \times r$, where the rank r provides preliminary information about the level of cointegration between studied variables. Symbols α also represents the convergence speed of the different variables for equilibrium or adjustment parameters of VECM and symbol β represents the long-term coefficient matrix, which determines the number of cointegrating vectors. The r linearly independent columns of $\beta'$are the cointegrated vectors, each representing one long-run relationship between the series, and $\beta' x_{t-1}$ is then stationary (Ferkingstad et al., 2011; Juselius, 2006; Lütkepohl & Krätzig, 2005).

If $r = n$, it indicates that stationary $y_t$in (2) is similar to a non-stationary Πy_{t-1} with addition of some lagged stationary variables. In case of $r = 0$, there is not existing matrix Π, so model can be treated as VAR and it is not feasible to specify model as a VECM (Juselius, 2006).

6. Results

6.1 Initial analysis

The first step is the estimation for the presence of unit root. KPSS test is used to test, if the prices are stationary. Null hypothesis is defined, as prices are stationary. If the null hypothesis is rejected, than values are non-stationary I (1). The results in **Table 1** shows that based on the KPSS test (Kwiatkowski, Phillips, Schmidt, & Shin, 1992), the null hypothesis is rejected at all significance levels, thus all price series are non-stationary. Number of lags for variables is estimated by Schwarz criterion (SIC).

As all prices series have a unit root, in other words they are non-stationary I (1), the following step is to test the price series for cointegration relationship between them. The economic view see the cointegration as relationship between variables on short and long run, where variables can drift apart on short run, but still have long run equilibrium. The null hypothesis for cointegration is that there are none cointegrative relationship between variables. The alternative hypothesis is that there is at least one cointegrative relationship. **Table 2** shows results of Johansen cointegration test between all endogenous variables. Number of lags is estimated by (SIC, L = 1).

The results of Johansen trace test in **Table 2** show that there is at least 1 cointegrative relationship because trace test values are higher than the critical trace values. The trace test value for 2 cointegrative relationships is not higher than critical values thus alternative hypothesis is rejected.

Since it was proven that there is a cointegrative relationship between logarithms of endogenous variables. VECM model provide the best fit for the following analysis, because the model describes the deviations from the long-run equilibrium and short-run causal relation. However if cointegration does not occur in subgroup model, then VAR model will be used.

Estimation of the whole system in one model could lead to the misspecification of short-run relationships and also it would be too difficult to interpret the cointegration vectors. Thus price series and divided to subgroups, which provide closer look for the economical phenomena.

6.2 Complete model estimation

Production resources and electricity are ordered according to the equation (2). Where BRENT is first commodity, which is not influenced by the following commodities. ARA is the second in the order, followed by GEE and CZE. Johansen test (AIC, L = 1) indicated there is one cointegrative relationship between variables (BRENT, ARA, GEE and CZE) see **Table 2**. Since Johansen trace test does indicate cointegrative relation between variables, VECM model will be used for the estimation. Data are tested for normality, autocorrelation and heteroskedasticity, see appendix.

6.3 Subgroup GEE and production resources

Electricity is output of production resources, where some resources are either used for direct production (ARA) or for the transportation of resources needed for electricity production (BRENT). Production resources in model are ordered according to equation (2), where CZE is excluded. Starting BRENT as commodity with strong influence to any energy commodity, followed by ARA. Johansen test (SIC, L = 1) indicated there is not any cointegrative relationship between variables (BRENT, ARA, GEE) see **Table 2**. Since Johansen trace test does not indicate cointegrative relation between variables, VAR model will be used for the estimation. Variable are transferred into first difference.

6.4 Subgroup CZE and production resources and effect of EUR/CZK

For analysis of Czech market will be used the same approach, as was used for German market. However the main difference is that production resources are mainly traded on German or World energy exchanges, so Czech market has higher distance to the price discovery. Another factor, which influence the final price is the delivery place. Since EEX has delivery places in Germany, energy commodities sold to Czech will be under influence of transport fees and exchange rate. The model will include production resources according to the equation (2), where GEE is excluded. In order to estimate number of cointegrative relations in this subgroup, Johansen trace test will be conducted (SIC, L = 1). **Table 2** indicates that between variables is not any cointegrative relation at all significance levels. Thus VAR model is used for estimation. Variable are transferred into first difference.

Table 3 examine on the relation of exogenous variable (EUR/CZK) and endogenous variables of the subgroup. Table clearly shows that all energy commodities except CZE are influenced by the exchange rate EUR/CZK. It is interesting to notice that commodities, which are traded on EEX or World energy exchanges are under effect of exchange rate, whether CZE is not. As commodities have to be purchased in EUR, there is always a significant risk of exchange rate short-run spike (EUR/CZK). The exchange rate risk is connected to economic decisions of either CNB or ECB, which can influence prices of production resources in positive or negative direction.

6.5 Subgroup Effect of EUR/CZK to GEE and CZE

Even though exchange rate is not directly involved in the electricity production, they still have effect to the final price discovery. Since Czech Republic is not part of the Eurozone, all transactions between Czech Republic and Germany are effected by EUR/CZK exchange rate. Electricity prices are treaded as endogenous and exchange rate as exogenous. Johansen trace test (SIC, L = 1) indicated that there is one cointegrative relation between variables thus VECM is used. See **Table 2**.

Chyba! Nenalezen zdroj odkazů.presents results of exogenous effect towards GEE and CZE prices. None of the adjustment coefficients are significant. Thus EUR/CZK does not have significant influence on the price discovery of electricity between Germany and Czech Republic.

6.6 Impulse response functions

This sections focus on the battery of impulse response functions of previously described VECM and VAR, in order to support relations between commodities mentioned in previous chapter. The confidence interval is estimated to 95% with the notion of one impulse response to one standard deviation shock. The number of bootstrapping iterations of estimated to 1500 in order to obtain reliable confidence interval (Hall, 1992). A solid line represents the mean impact. A dotted line represents the standard deviation from the mean impact in both directions (Runkle, 2002).

Name of figure is used in order to describe the effect. Just significant events will be described in order to focus on important relation, which take place on the energy markets.

Figure 5 shows all commodities and their effect to each other. All series responds strongly and positively to shocks for BRENT. This suggests that BRENT has significant effect to all tested commodities. ARA shocks create significant shock to all tested commodities but the level of significance is lower than in BRENT shocks. GEE and CZE do not have any significant effect to production resources but they have significant effect to each other. Since GEE and CZE are minor market compare to BRENT and ARA markets, it shows that local markets do not have significant power to effect worldwide traded commodities. However the mutual influence in local market is strong.

Figure 6 shows effects of energy commodities towards final product (GEE). One standard deviation of BRENT – GEE caused the strong negative effect to GEE for short period. In other words BRENT prices have negative short-run effect to GEE prices. Since BRENT effects all commodities, a shock influences the whole German economy and also electricity production. However the shock is slowly incresing to positive values, which indicates restoration after the shock. Another relation is ARA – GEE, where one positive shock has direct effect. The shock indicates that ARA has highly sginificant effect on the final electricity prices. Since coal is heavily used for electricity production, it proves that changes in coal prices have significant effect to final GEE prices.

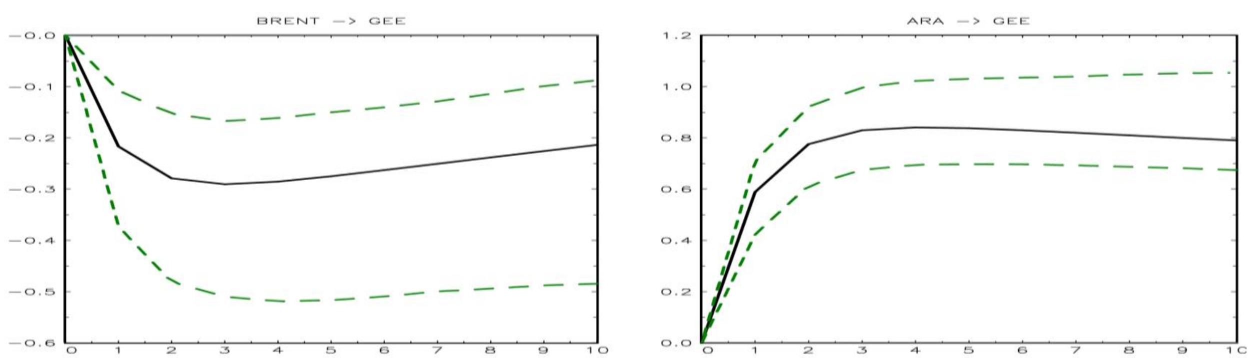

Figure 6 IRF of VAR for GEE

Figure 7covers relations of all production resources to each other. Figues shows that BRENT has significant effect to ARA prices but ARA does not have significant effect to BRENT. BRENT initially does not have effect but it steadily raise with prediction of further increase. Increase in BRENT influence transportation cost thus cost for coal transportation follow the increasing trend. Shock in ARA are not strong enough to ifluence the BRENT. Coal has mainly use for electricity production compare to that crude oil is used in differential industries, where other commodities have stronger influence than coal. According to Moutinho et al. (2011) coal follow the trend of crude oil in general, nevertheless there are short-run disturbances, the long- run equilibrium is in general achieved. The results prove that BRENT has significant influence to ARA. **Figure *4*** shows the price relation of BRENT and ARA, which clearly shows that both commodities follow similar trend with occurrence of short-run disturbances.

Figure 8 shows effects of energy commodities towards the final product (CZE). ARA – CZE has the highest response to one standard deviation. The shock is similar to the ARA – GEE shock, it shows that both electricity prices are under same influence. It indicates that GEE and CZE follow the same trend and possibly are cointegrated. BRENT shock indicates negative effect to CZE prices. If BRENT affects the whole Czech economy negatively, the electricity price is not an exception.

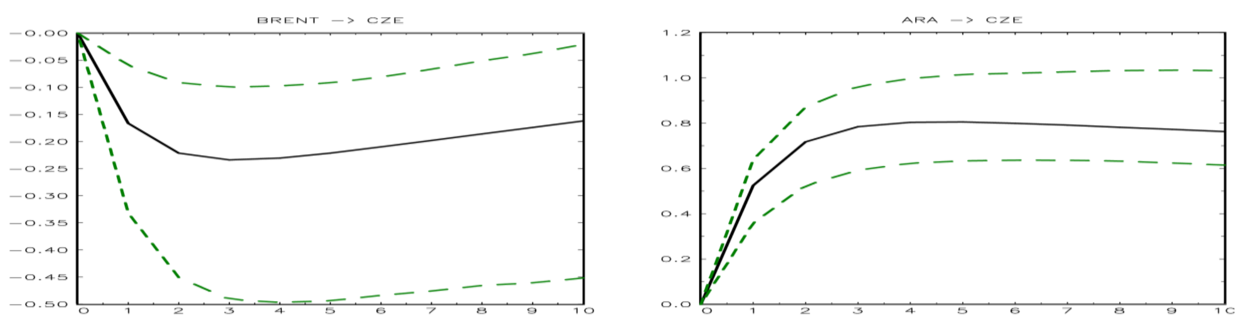

Figure 8 IRF of VAR for CZE

Figure 9 shows impulse response function for CZE and GEE. Surprisingly CZE has higher first impulse of standard deviation. However the shock decrease directly and in week 5 there is another shock, which is still in significance level, but it does not have same effect as the initial shock. After that IRF line follows steady direction with minor disturbances. IRF indicates, that GEE responds for the first shock effectively and decrease it in timely manner. Week 5 and 7 are especially important because after initial shock both prices search for new mutual equilibrium, where prices go in reverse direction. Since new equilibrium is not defined just by price discovery but also by electricity consumption equilibrium, where produced electricity amount must correspond to demanded amount. If not the electricity needs to be exported to electricity network with shortage. These two shocks indicate search for price and electricity equilibrium in the electricity networks and energy exchanges. GEE price shocks towards CZE indicate lower significance than in reverse relation. According to Kristoufek & Lunackova (2013) electricity prices are sensitive to unexpected events, such as temperature or macroeconomics predictions. However unexpected events do not have long nor medium lasting effect, they are mainly short-run effective. IRF support this theory because significant effects occur in short term period. Another finding from Kristoufek & Lunackova (2013) shows that electricity are mean reversing, which would suggest better predictability of electricity. Nevertheless another important factor is non-storability of electricity, which makes harder to predict prices for future movements. Unexpected change in demand evoke raise of the price because more expensive production resources needs to be used or electricity needs to be imported.

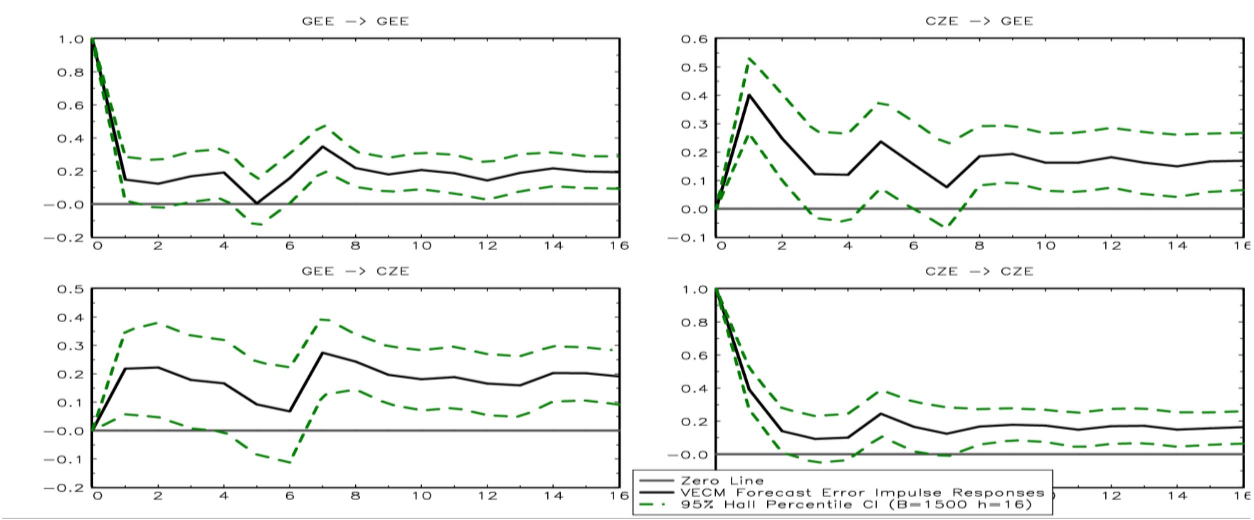

Figure 9 IRF of VECM for GEE and CZE

6.7 Forecast Error Variance Decomposition

Forecast error variance decomposition (FEVD) shows percentage contribution of shock to variables. Shocks are mainly induced by production resources, which affect the final products (GEE and CZE). Shocks within the production resources are examined and also shock between electricity prices.

Figure 10 shows that restriction of structural shock for BRENT is effective and thus BRENT is not influenced by any other commodity on significant level. ARA is under influence of BRENT shock starting from the first period. According to SVEC BRENT affect commodities on lower rank in model. Thus BRENT influences the forecast of ARA prices. GEE is mainly effected by CZE shock, which slowly increase the power over time. However effect of GEE to CZE is highly significant, where in 2nd week GEE covers 50% of prediction power and continuously increase.

Figure 11 supports results of IRF, where ARA has significant influence to GEE and CZE price. Since ARA is directly used for GEE and CZE production, it proves that production resource has effect to final electricity price. IRF indicated the similarity of ARA shocks to GEE and CZE. FEVD just support the theory about the significance of ARA in for the prices of electricity.

Figure 12 presents production resources. BRENT is mainly effect by ARA. However the level of significate is very small. Thus it support the IRF, where ARA did not have any significane effect to BRENT. Shocks in ARA are mainly induced by BRENT.

Figure 13 show relation between CZE and GEE. The significance of GEE is visible in both forecasts. CZE has small influence to GEE prices but GEE shocks to CZE prices are significantly higher. After 10th period GEE prices have higher impact to CZE prices, than CZE by itself. This proves theory that CZE prices are pre-discovered on German market and CZE follows the price definition of major market. Thus IRF initial shock CZE – GEE was not completely induced by CZE shock but GEE has significant effect on itself through CZE prices. FEVD results show that Germany directs the electricity prices for itself and also for Czech Republic. Nevertheless CZE participate in the price discovery for both price series and so it is not completely excluded from price discovery process. Zachmann (2008) points out that Czech electricity price are strongly linked or nearly predefined by German EEX prices. Thus GEE has significant effect to CZE prices.

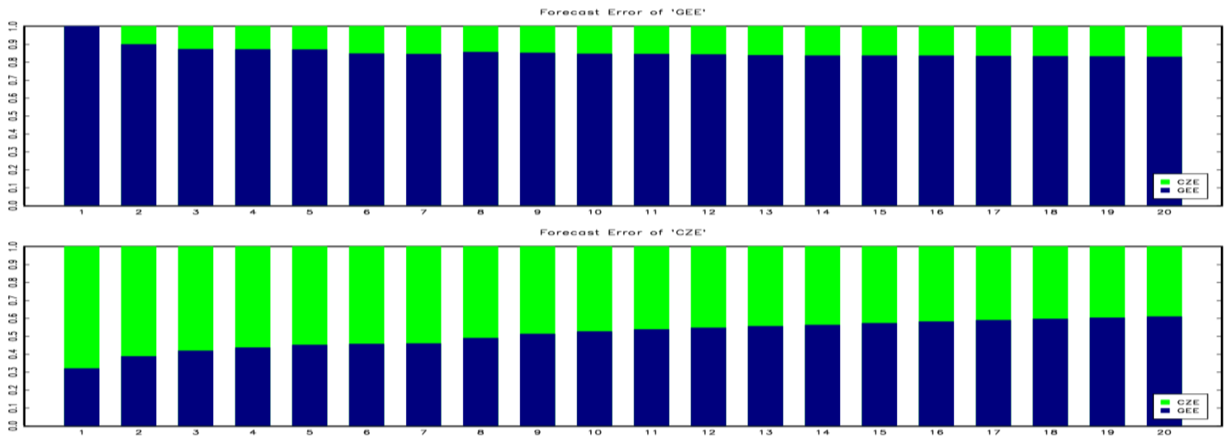

Figure 13 FEVD for GEE and CZE

7. Discussion

In order to answer the main research question correctly and with sufficient knowledge of the problem. The Sub-questions are answered first and main research question is answered in the end. Sub-questions are answered in the same order, as they are ordered in problem statement.

Coal is the most used production resource for electricity generation. It has established strong relation towards electricity prices for both countries. The results support the strength of relation, as ARA describes the most significant part of the forecast errors for GEE and CZE. Another electricity production resources have not been used due to insignificance or complexity. Renewables resources were not used because of the difficulty to obtain standardized data for both countries. Since renewable source electricity is obtained from several different production processes, such as wind, water or photovoltaic, it is complicated process to merge all data into one standardized electricity input. However it open gap for further research, where potential studies can focus on integration of one or more resources into the model. Each source could be studied separately, which would lead to the discovery of most effective renewable source or all sources will be merged in one universal group and compared to traditional resources. Wind electricity production could be the most promising area for further research. According to Galetka (2009) Germany invest massively into wind parks, however the instability of production creates several problems in network. Firstly insufficiency of German transmission network does not handle the produced amount and thus electricity flow to other network (Czech Republic, Poland or Austria). Secondly, the over production of wind electricity cause decrease of price on EEX. The price decrease is then transmitted to neighbor exchanges. This phenomenon could be exploited and neighbor electricity network can benefit from cheap electricity. Nevertheless the problem of transmission needs to be addressed in order to avoid loss of electricity. Another production resource (Uranium) is not taken in account because of the relative taciturnity of the market and robustness against the commodity shocks. Since construction of the nuclear power plant requires astronomical investments, then minor differences in price of uranium will not lead to the faster return of investments.

Mjelde & Bessler (2009) found that uranium is influenced by shocks in coal and crude oil, which shows that uranium based production of electricity is connected to real market electricity demand. It opens up new area for further research, where European countries with high usage of uranium for electricity production will be studied. Since Germany is reducing number of nuclear power plants, it does not provide promising area. On the other hand Czech Republic aims to increase usage of nuclear power plant and thus further research of the future usage is required. The last of the production resources (Natural gas) is not used because of the low percentage score in energy mixes of studied countries. Even though Yu & Mallory (2013) suggests the interchangeability of coal and natural gas, there is another important factor in the relation. The factor is European Union Emission Trading Scheme (EU-ETS), which plays important role in the coal-natural gas relation, where one resource is taken as clean (natural gas) and second as dirty (coal). Since natural gas takes just a small part of the energy mix. I have decided to not include gas into model. EU-ETS is not included because of it interlink between coal and natural gas. If one of the commodities is not included in the relation, then EU-ETS does not provide correct comparison between both commodities. Another reason is the increase in the size of the model, which would lead to the lower prediction accuracy.

EUR/CZK is used as exogenous variable to find out, if the production resources and electricity prices are under exchange rate influence. Results indicated that both production resources are under influence of the exchange rate (EUR/CZK). Since BRENT and ARA are traded mainly in USD or EUR, the CZK exchange rate effects all transaction for Czech market made in different currencies. Even though USD is not used in the model, it is expected that USD has significant effect to energy commodities; several researches support the relation (Chen & Chen, 2007; Dauvin, 2014; Rautava, 2004). Majority of studies focus on the worldwide relation between crude oil and exchange rates but there are also minor currencies (CZK, PLN or HUF), which could have significant effect on the local level. Therefore dynamics between local currencies and energy commodities should be studied to increase the accuracy of price discovery on regional scale.

The effect of crude oil has significant effect to every studied commodity. It proves that crude oil should not be left out of any energy model because of its significance and predictive power. (Bachmeier & Griffin, 2006) suggest that other commodities influence BRENT, mainly by other crude oil prices. The results shows that BRENT has significant effect to ARA, results are supported by Moutinho et al. (2011), who found similar relation between crude oil and coal, where coal is following the trend of crude oil. The trend suggests that any shocks in crude oil (BRENT) are passed to coal (ARA) and consecutively to electricity prices. As ARA has higher impact to the GEE and CZE prices, this proves that production resources, which are directly used for the production, have higher significance for the final price discovery, where crude oil shock are already taken in account. National economies are exposed to the shock in crude oil and so significant amount of literature cover the topic. Nevertheless the focus should be directed to the local issues, which are caused by international market decision. Risk aware decisions on local level could improve the protection against the risk originated from international shocks. Thus further literature could focus on regional markets and their relation to the frequently traded energy commodities, such as crude oil.

The aim of the paper is to find the mutual relation between Germany and Czech energy markets. The main assumption is that Germany has more significant influence to price discovery than Czech Republic. The assumption is proven as correct because results show that Germany is the stronger partner in the relation and predefine the price of electricity for Czech Republic. As the forecast error values of CZE are highly influenced by GEE and later GEE has higher prediction power than CZE by itself. This support theory of Zachmann (2008), where he states that the connection between both markets is established by Energy exchanges, which provide liquidity between markets. EEX provide higher liquidity because it operates in larger scale, compare to that OTE suffers under low liquidity, and thus EEX is the main power for the price discovery of Czech electricity prices. According to Zugno, Pinson, & Madsen (2013) Germany is exporting electricity in case of overproduction of renewables, the prices are defined on EEX. Since renewables production resources are not constant in production, it leads to the high differences between high and low output. The price shocks are then transferred to surrounding countries, which need to diminish the price spikes. The FEVD results showed that GEE has significant effect to CZE price discovery. German renewable electricity production is potentially strong aspect of the GEE price discovery and thus it should be studied in greater detail in further literature.

BRENT and ARA are influence by neither of electricity prices. Since both energy commodities are comparably bigger markets, shock in minor local markets does not have a significant influence. On the other hand the effect of ARA to electricity is strongly significant. Since coal is the major electricity production resource, it proves its value for the price discovery of electricity. According to Crampes & Fabra (2005) any increase of coal prices directly cause reduction of profits and increase of production costs of electricity companies. The electricity prices rises due to the need to increase company revenues. As electricity is sensitive to coal shocks, protection against them should priority for electricity generation companies. Thus relation of electricity and coal provide further research opportunity especially oriented on national energy policies.

There are certain weaknesses of the analysis. The first weakness of the analysis is incomplete coverage of all production resources, such as uranium, renewables or natural gas. Reasons for exclusion have been mentioned in first sub-question answer. The second weakness of the analysis are Czech electricity prices. Since OTE prices have low liquidity, where just minimal amount is traded through OTE and rest is set up by electricity monopoly company (CEZ), the prices are not completely transparent. Thus OTE prices mirror real prices but there is certain deviation from the real market price. The third weakness is the shortness of the data series. Since energy exchange contracts for majority of studied commodities exist just for past six year. The length of the data series does not provide sufficient reliance and robustness for results. In order to acquire reliable results the length of the data series need to be extended. Since data are up to 2014, the acquirement of the long data set will take several coming years.

8. Conclusion

I conduct analysis, which firstly to evaluate all endogenous and exogenous variables, which lead to the understanding of the studied system as whole. Secondly aims to evaluate energy and electricity markets of one country, in order to understand price discovery without influence of neighbor country. Thirdly to evaluate mutual relation between electricity markets, in order to find price discovery leader in relation. I use production resources and final products (BRENT, ARA, GEE, CZE) and exchange rate EUR/CZK for the first analysis. The results show, that any other examined commodity does not influence BRENT. ARA has significant effect to GEE and CZE, which makes ARA the most influencing commodity for price discovery of electricity prices. EUR/CZK has significant effect to energy production resources (BRENT, ARA) but not significant effect to electricity (GEE, CZE). Secondly, the country oriented analysis confirm the finding of the first analysis. Thirdly, the results shows cointegrative relation between GEE and CZE thus electricity prices follow the same long-run trend with short-run disturbances. Forecast error results indicate that GEE has significant influence to price discovery of CZE prices. Thus it has high predictive power to prices of CZE. It proves the assumption, that Germany is the main decider in price discovery process between both countries. Czech influence to German price discovery is comparably smaller and thus Germany is less influenced by shock originated in the Czech Republic. It shows that market leader influence minor market with high level of significance, but reverse influence is comparably lower.

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10. Appendix

10.1 List of Figures

Figure 1 Gross electricity generation of Czech Republic (as % of TWh), Gross electricity generation of Germany (as % of TWh), source (European_Commission, 2011)

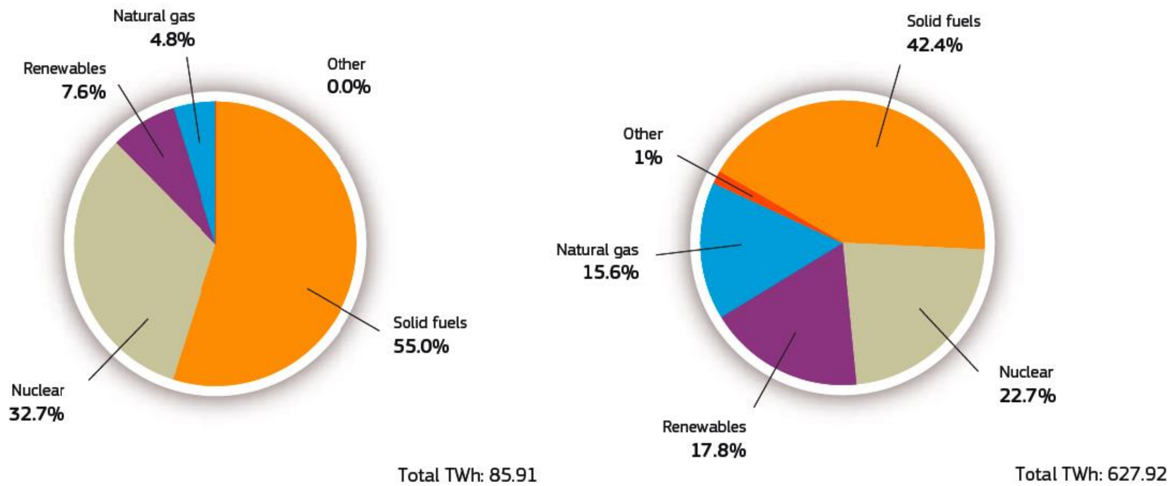


Figure 2 Currency exchange rate of EUR/CZK, source (ECB, 2015)

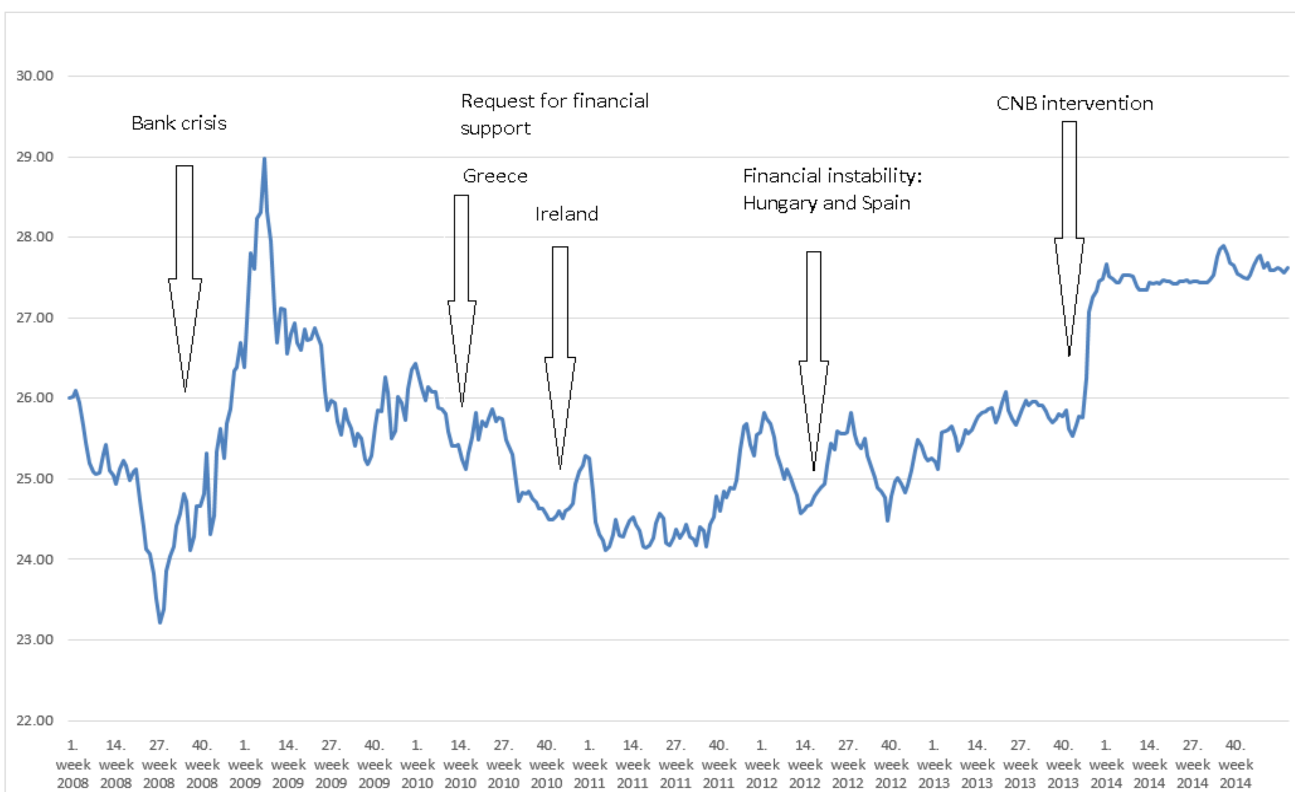


Figure 3 Electricity price Germany and Czech Republic

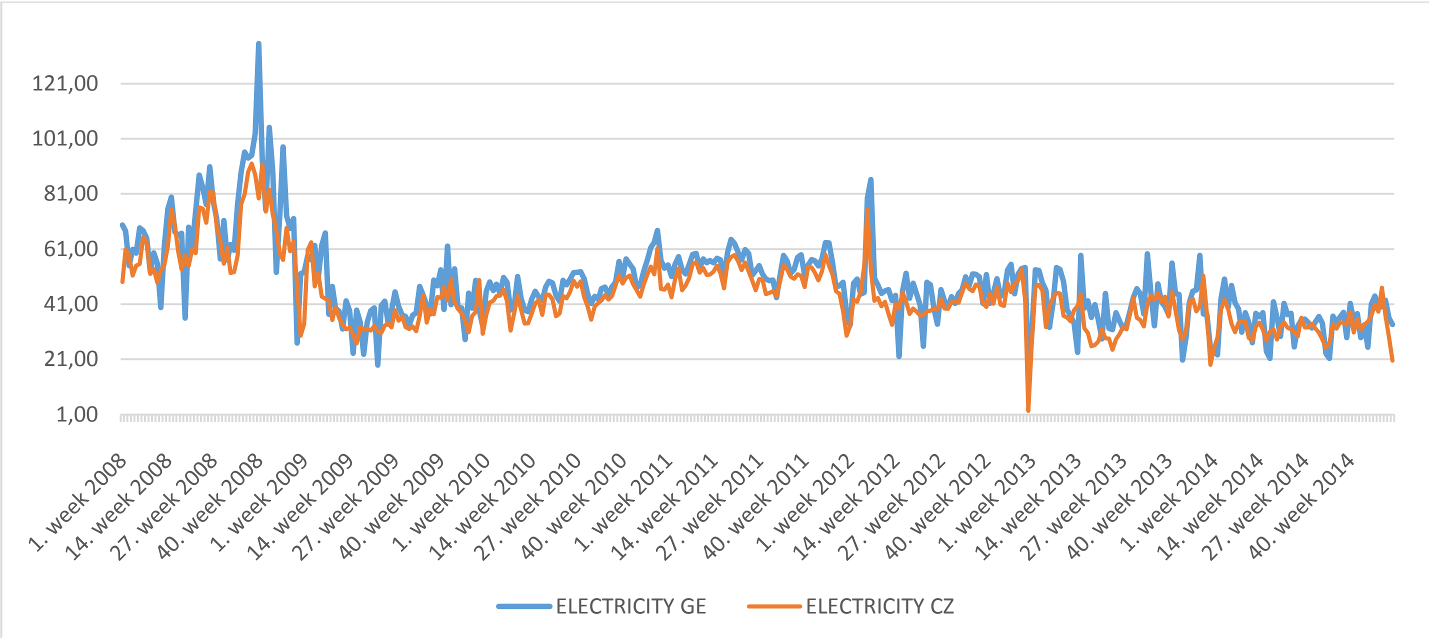


Figure 4 ARA COAL – BRENT OIL relationship

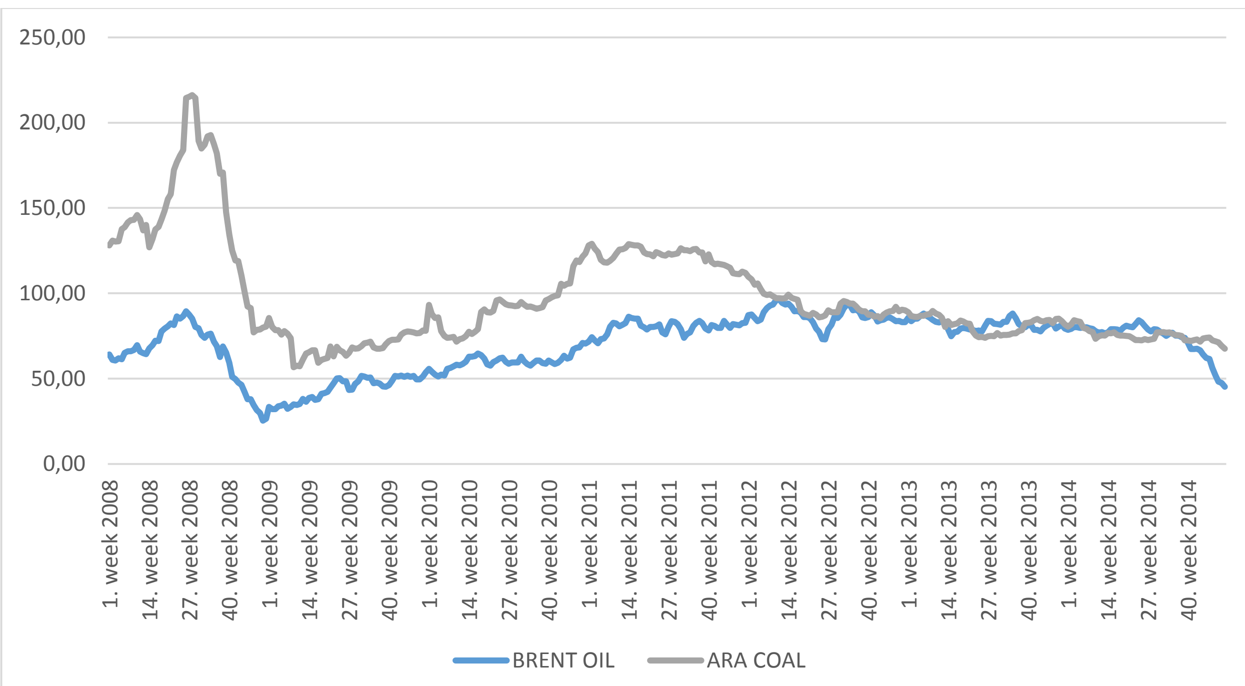


Figure 5 VEC IRF of BRENT, ARA, GEE and CZE

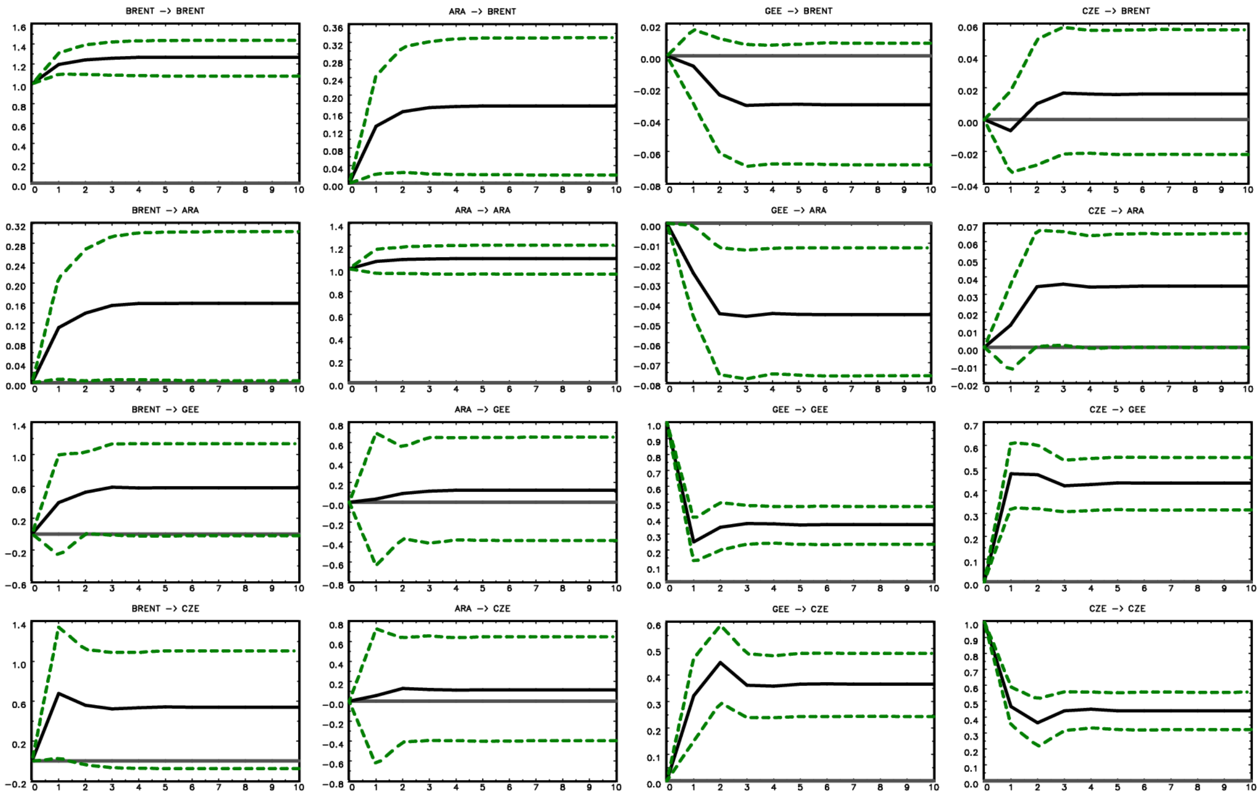


Figure 7 IRF of VAR to BRENT and ARA

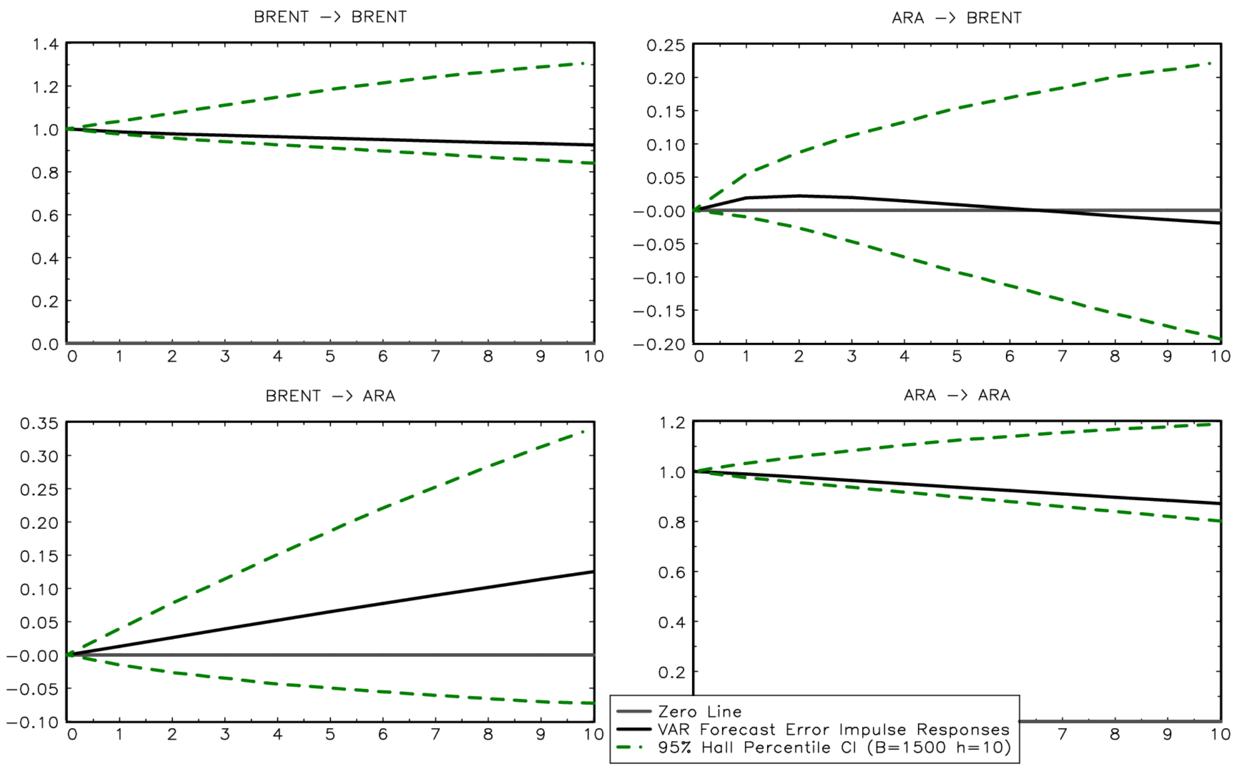


Figure 10 FEVD VEC of BRENT, ARA, GEE and CZE

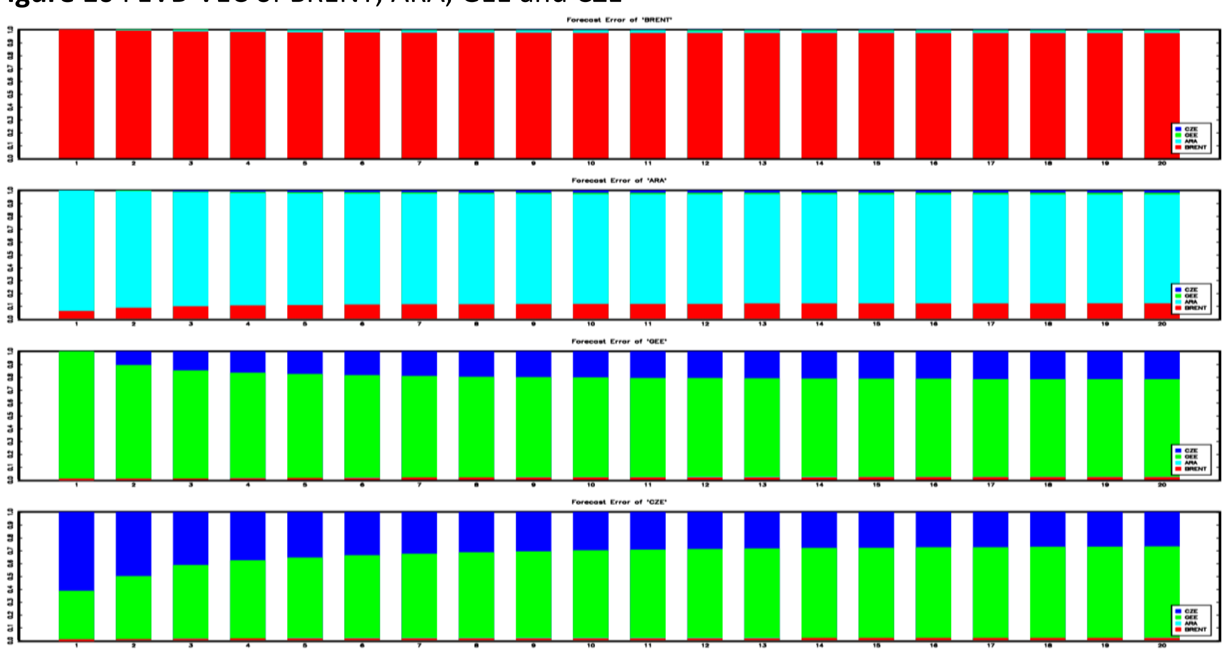


Figure 11 FEVD of GEE and CZE

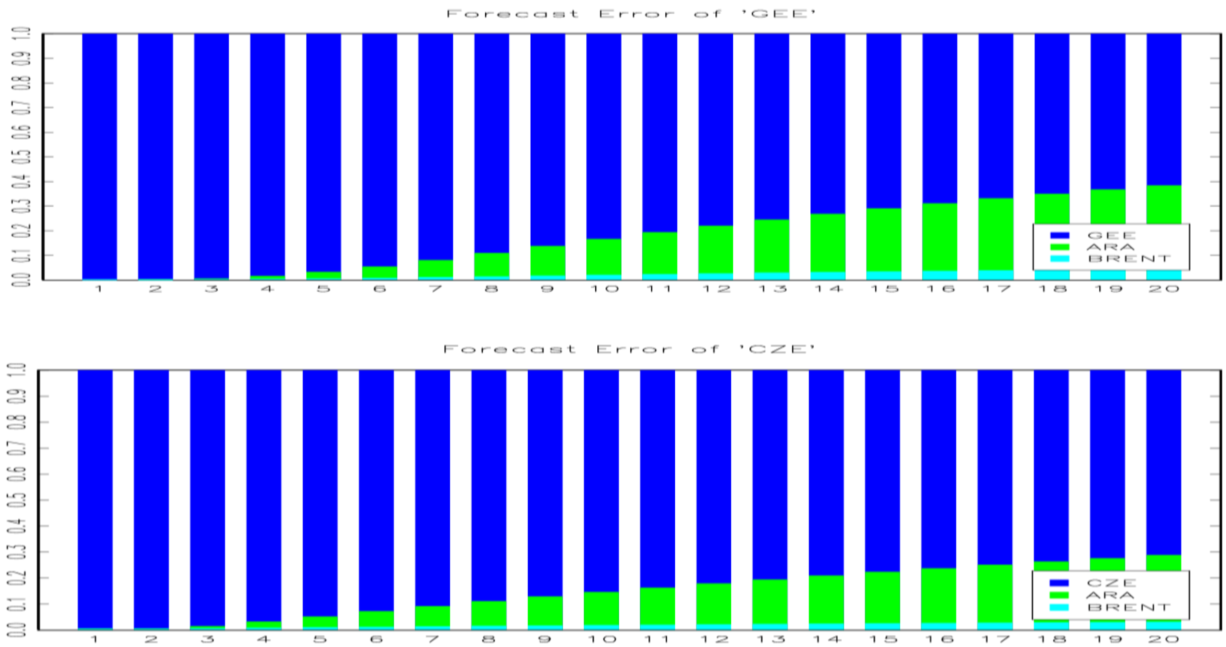
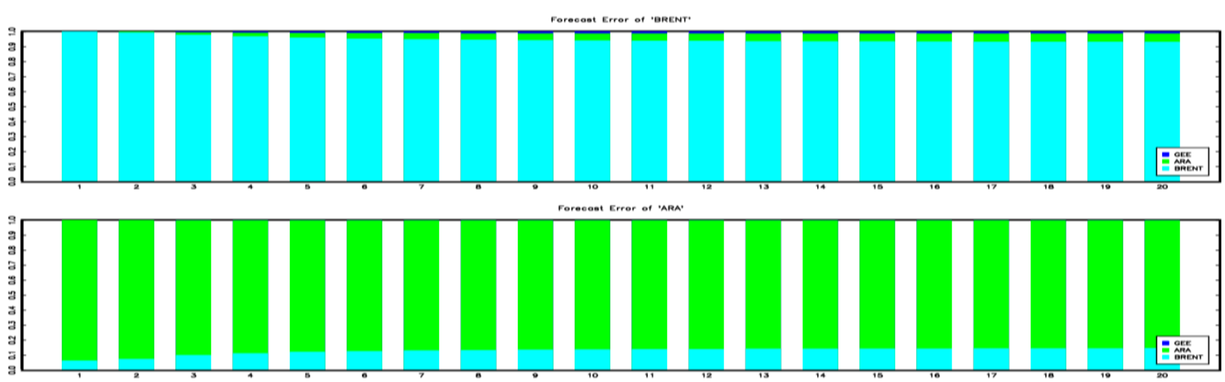


Figure 12 FEVD of BRENT and ARA



10.2 List of tables

Table 1 KPPS results for non-stationary of variables

Series	T-test Value	Number of lags
CZE	2.6428***	4
GEE	2.1357***	6
BRENT	7.7252***	1
ARA	2.2677***	2

Note: *, ** and *** indicates that test statistic is significant at 10%, 5% and 1% significance levels

Table 2 Johansen trace test for all variables

ALL	Trace test value	P – value	90%	95%	99%
0	408.68***	0.0000	50.50	53.94	60.81
1	135.95***	0.0000	32.25	35.07	40.78
2	8.25	0.8016	17.98	20.16	24.69
Subgroup GEE					
0	165.68***	0.0000	32.25	35.07	40.78
1	7.99	0.8227	17.98	20.16	24.69
Subgroup CZE					
0	152.81***	0.0000	32.25	35.07	40.78
1	8.27	0.8004	17.98	20.16	24.69
Subgroup GEE, CZE					
0	312.41***	0.0000	17.98	20.16	24.69
1	46.63***	0.0000	7.60	9.14	12.53

Table 3 Exogenous effect of EUR/CZK to production commodities of CZE Subgroup and exogenous effect to CZE and GEE

	EUR/CZK	
	α coefficient	p-value
BRENT	**-0.685**	**0.003*** **
ARA	**-0.560**	**0.015*** **
CZE	1.043	0.427
CZE	-1.251	0.337
GEE	0.745	0.592

Test for normality, autocorrelation and heteroskedasticity

Normality test, H0 data are non-normally distributed	
joint test statistic	181765.3861
p-value	**0.000*** **

Autocorrelation H0 data are correlated	
LM statistic	44.4731
p-value	**0.0002*** **

Heteroskedascity	**H0 data are homoscedastic**			
variable	Test statistic	p-Value	Skewness	kurtosis
BRENT	326.5351	**0.0000*** **	0.2479	7.6328
ARA	2738.0748	**0.0000*** **	-1.3553	16.2168
GEE	799.4403	**0.0000*** **	-0.1510	10.2840
CZE	132082.8820	**0.0000*** **	-6.3643	95.8392