THE DEMAND FOR MOTOR FUELS IN THE CENTRAL EUROPEAN REGION AND ITS IMPACTS ON INDIRECT TAX REVENUES

V. Píša

Charles University Prague, Faculty of Humanities

Abstract

In this paper, I use computionally intensive econometric methods to estimate the elasticity of the demand for motor fuels and to derive the effects of indirect taxation on tax revenues. The topic is important as the consumer price of motor fuels is created (approx. 50 %) by indirect taxes and therefore the changes in indirect tax rates can have substantial influence on the level of motor fuel consumption in particular region. The demand for motor fuels can be very elastic because of the so called tank tourism, which is currently a frequently discussed issue in the EU. If the tank tourism causes the demand elasticity being greater than one, the increase in indirect tax rates could even lead to a decrease in the tax revenues. Currently, there is a little research that would incorporate such spatial aspects in the estimation of the demand for motor fuels in Central European Region. This paper contributes to filling the gap. I compare results and implementation of various econometric models to estimate the demand elasticities for motor fuels in six Central European countries (Austria, Czech Republic, Germany, Hungary, Poland and Slovakia). Among considered models, there are models that incorporate the above-mentioned spatial aspects to improve the estimators in all types of regressions. All data adjustments, statistical data/exploration, and econometric estimations are done in Matlab.

1 Introduction

The motor fuel consumption represents a very important attribute of each economy. While there are more factors influencing the consumption, the prices of motor fuels and real income are its predominant determinant. The end user price of relevant fuels is significantly (approx. 50 %) constituted by indirect taxes. Therefore the changes in the tax rates has not only price but also fiscal impacts.

The impacts of an increase in indirect tax rates on tax revenues are currently frequently discussed in the context of Middle European Region. These impacts are usually discussed in association with price competitiveness between these regions. As a consequence of the debate, Slovakia decreased excise duty rates on diesel in 2010 and Hungary decreased the excise duty rates on diesel for large haulers in 2011. From academic point of view Novysedlák and Šrámková [9] concluded that the decrease in excise duty rates on diesel in Slovakia had a negative effect on tax revenues. On the contrary, Ševčík and Rod [13] propose to decrease an excise duty for the case of the Czech Republic. According to their paper boosted fiscal competitiveness would lead to positive impacts on the Czech fiscal revenues.

Both papers are contributive from the economic perspective. However, both studies suffer from relatively restricted database and simple econometric estimates. The latter study does even not describe the estimation procedure and does not provide particular values of the parameters as well as relevant confidential statistics. On the other hand, for example, Brůha and Ščasný [2], [1], used Czech data for econometric estimates of price elasticities of demand for motor fuels, but only with particular focus on households.

From the European perspective, the summary of different approaches to motor fuel demand estimation is provided, for example, by the European Commission [3]. Important approach to analysis of motor fuel demand and relevant elasticities provide Houthakker and Taylor [8] with their flow adjustment model. This model is applied by Pock [11] in analysis of demand for gasoline and diesel in Europe. The paper employs more sophisticated econometric methods usually utilized in panel data analysis [1]. However, it does not consider data for some countries of Middle European region (Czech Republic, Hungary, Slovakia and Poland) which can be characterized by higher price elasticities due to transit nature of the countries (excluding Poland).

This paper attempts to fill the gaps. It uses essential econometric techniques to estimate the main parameters of interest, ie. price and income elasticities of demand for considered motor fuels.

The paper is organized as follows. Section 2 approaches sources of data that is used for the analysis. The data is inspected by simple graphs and statistical methods. The section 3 provides simple OLS estimations of main parameters of interest. The basic estimations are consequently followed by estimations stemming from panel data methods. Finally, following Geweke [6], the paper applies Bayesian methods to estimate the parameters where unexpected signs of parameters have been estimated. The section 4 concludes.

2 Data and Stylized Facts

The data for the analysis comes from various sources. The data on prices come from the website of European Commission [2]. The prices are provided in Eur per 1000 liters, in each quarter, approximately 13 measurements are recorded. From these measurements arithmetic average per quarters were taken for all considered regions. Data on taxes was also gathered from this database. The source of the data on motor fuel consumption is Jodi Database [3]. This database provides data monthly. Therefore the monthly data had to be counted up in order to get quarterly consumptions. The quarterly data on GDP and harmonized index of consumer prices comes from Eurostat database. [4]. The quarterly data on exchange rates comes from European Central Bank [5]. Finally, the data on lengths of boarders were downloaded from internet.

2.1 Prices

The prices of motor fuels in EU countries are affected by following main determinants: prices of crude oil, exchange rates of particular currency to USD, profits margins of distributors and domestic indirect taxes (VAT and excise tax). The prices of crude oil are usually denominated in USD. As the prices of crude oil rise the refineries realize higher input costs and pass it on the final consumer. If the nominal exchange rate of national currency appreciates to USD, than ceteris paribus, crude oil denominated in USD becomes cheaper. Therefore this creates room for decrease of domestic prices of motor fuels. The effect of taxes is not so clear. While increase in taxes is usually fully passed on the consumers, lowering indirect tax rates can be partly absorbed by profit margins in production and distribution chain. Apart from VAT, the effect of excise taxes can evaporate during time. This is because excise duty rate is eroded by inflation.

In this part, the graphs of development of real prices of petrol and diesel fuel in six analyzed regions are shown. These changes in prices of motor fuels are decomposed into changes in excise duty rates, changes in ratio of VAT, changes in crude oil prices and changes in nominal exchange rate of particular currency and USD.[6] These graphs are consequently compared to graphs explaining composition of final price of motor fuels.

[1] See for example Wooldridge [14].

[2] http://ec.europa.eu/energy/observatory/oil/bulletin_en.htm

[3] http://www.jodidata.org

[4] http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/

[5] http://www.ecb.int/stats/exchange/eurofxref/html/index.en.html

[6] Similar, but multiplicative decomposition was provided by Píša and Brůha at the last TCB workshop in Prague [10].

2.1.1 Austria

Firstly, let see at the data on prices in Austria (see Figures 1 and 2). We can see that the real price of petrol and diesel have been rising since 1Q/2009 after significant drop in 4Q/2008. The changes in prices were clearly prevailingly affected by the price of crude oil. As a consequence, for example, the prices of motor fuels in Austria reached their peak in the same quarter as do the prices of crude oil (in 2Q/2008). Furthermore, the sharp decline in both motor fuels and crude oil prices is clearly visible in 4Q/2008 and 1Q/2009.

The changes in exchange rates and their impacts on final price can be seen, for example, in 4Q/2005, when appreciation of Euro caused prices of motor fuels to decrease although the prices of crude oil slightly increased. Moreover in the second half of the year 2009 a decrease in crude oil prices was accompanied by appreciation of Euro which implied that final prices of motor fuels decreased more than crude oil prices. Furthermore, the positive effect on prices can also be affected by a decrease in profit margins.

From the graphs of composition of prices, we can also infer that profit margins in Austria are higher for diesel than for petrol.

With regard to taxes, we see that the ratio of taxes on final price was permanently decreasing from 1Q/2009. Austria did not change the VAT rate (20 %) in whole analyzed period. However an increase in excise taxes can be seen in 3Q/2007 (petrol rates rates grew about 13.2 % during two quarters and diesel rates increased by 14.9 %) and 1Q/2011 (petrol rates increased by 8.2 % and diesel rates by 12.9 %). Both changes happened in the time of rising crude oil prices and boosted the effect on the increase in final prices of motor fuels. Because of the inflation, the real excise rates slowly declined whenever they had been increased. However, at the end of the analyzed period these rates were higher in comparison with the beginning.

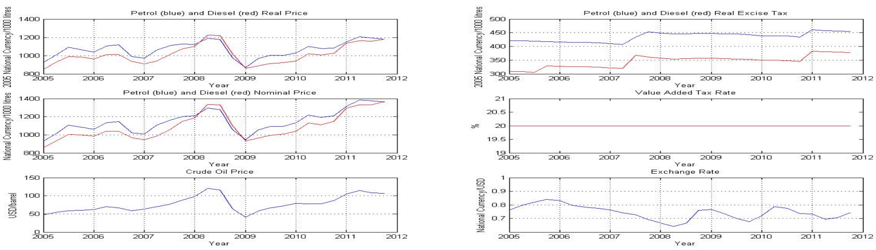

Figure 1: Motor Fuel Prices in Austria

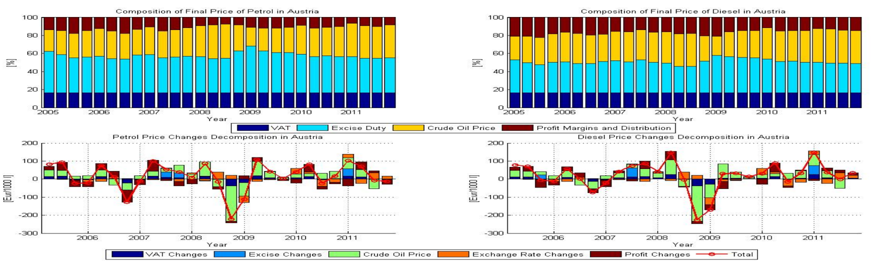

Figure 2: Composition of Consumer Price of Motor Fuels and Decomposition of its Changes in Austria

2.1.2 Czech Republic

From the data on prices of motor fuel price in the Czech Republic (see Figures 3 and 4) we can see strong effect of crude oil price. Motor fuel prices reached the peak one quarter after does the crude oil price (3Q/2008).

The effect of exchange rate was surprisingly lower in the years of relatively strong appreciation. However, from 3Q/2005 to 2Q/2006 the appreciation of CZK slightly contributed to decrease in prices of motor fuels. Further, a significant appreciation of CZK in 1Q/2008 caused that the domestic motor fuel prices did not reach their peak in the same time as does the crude oil price.

The profit margins evolved differently but more significantly in the first part of analyzed period. After that, they stabilized and did not contribute to growth in prices more than ± 1 CZK per litre. As for the case of Austria, the profit margins and distribution costs constitute more in the final price of diesel than petrol.

As regards taxes, the Czech Republic increased VAT (from 19 % to 20 %) and excise tax on motor fuels (by 1 CZK per liter, ie. petrol rate grew by 8.45 % and diesel rate increased by 10.05 %) in 1Q/2010. However, the effect on final price of motor fuels was soften by stagnating crude oil price (in 1Q/2010 and 2Q/2010) and appreciation of CZK (from 2Q/2010). Because of inflation, the real excise tax rate is lower than at the beginning of analyzed period, although the nominal rates increased in 1Q/2010. Moreover, the ratio of indirect taxes decreased from the year 2005.

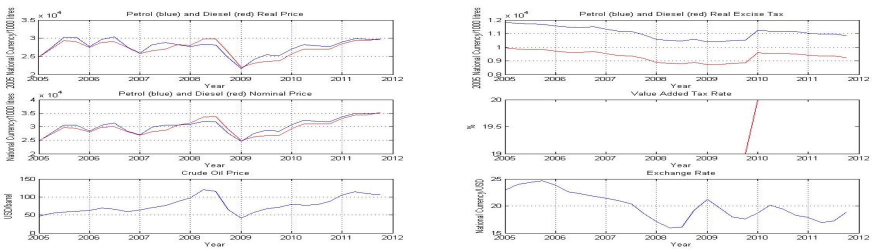

Figure 3: Motor Fuel Prices in the Czech Republic

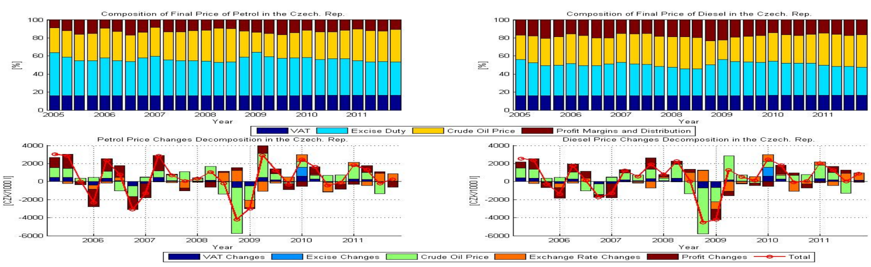

Figure 4: Composition of Consumer Price of Motor Fuels and Decomposition of its Changes in the Czech. Rep.

2.1.3 Germany

From the data on Germany (see Figure 5 and 6) we can again see the substantial influence of crude oil price on motor fuel prices (real and nominal). The price of diesel reached the peak in the same period as does the crude oil price. However, the price of petrol reached the peak in 2Q/2011. This is caused by small depreciation of Euro to USD when compared these two quarters.

The effect of exchange rate can, for example, be seen in the second half of the year 2009, where prices of motor fuels in Germany dropped slowly than prices of crude oil because of depreciation of Euro to USD.

The effect of production costs and profit margins can be visible, for example, in 3Q/2005, when the prices of motor fuel increased sharply although tax rates did not change and crude oil prices grew moderately. Further, profit margins and distributional costs increased slightly, perhaps because of mandatory blending quotas of ethanol in petrol. Looking at the composition of prices, the rule of higher production costs and distributional margins for diesel also holds for Germany.

As regards taxes, VAT rate changed in Germany once in the analyzed period in 1Q/2007 (from 16 % to 19 %), which resulted in more rapid changes of prices of motor fuels than prices of crude oil. The excise duty imposed on motor fuels did not change in Germany during the whole analyzed period causing real excise duty rate to decrease. The ratio of taxes on final price in 4Q/2011 on final price was significantly lower than in 1Q/2005.

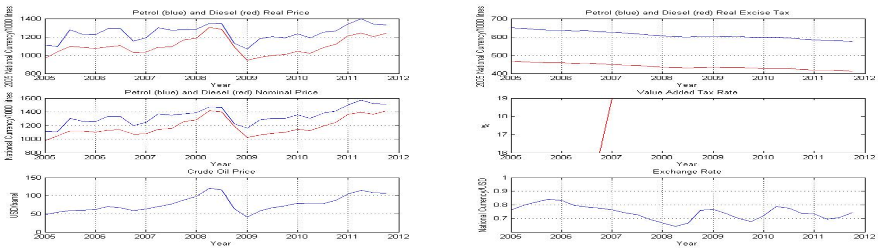

Figure 5: Motor Fuel Prices in Germany

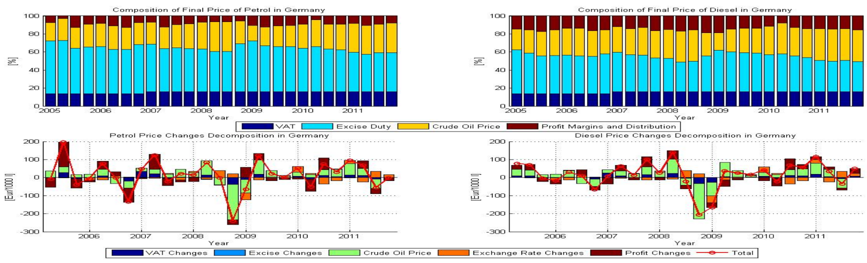

Figure 6: Composition of Consumer Price of Motor Fuels and Decomposition of its Changes in Germany

2.1.4 Hungary

The data on prices in Hungary (see Figure 7 and 8) shows again most important effect of crude oil prices. Furthermore, the effect of exchange rate is relatively strong in Hungary.

It can be seen, for example, in 3Q or 4Q/2011, when the prices of crude oil went down but significant depreciation of HUF caused prices of petrol and diesel to increase. The increase in prices was also supported by an increase in excise duty rate on diesel in 4Q/2011 [7]. A strange situation is recorded in 3Q/2007, when nominal prices of crude oil increased, prices of diesel also increased. However, prices of petrol slightly declined which would indicate that the effect of appreciation of domestic currency and reduction in profit margins prevailed.

The profit margins and producing and distributional costs are generally higher for diesel than for petrol. In the analyzed period as whole, the ratio of profits and distributional costs on final price slightly decreased in the case of petrol and remain almost the same in the case of diesel.

During the period, Hungary changed twice VAT rates (from 25 % to 20 % in 4Q/2005 and from 20 % to 25 % in 3Q/2007). The changes in VAT in 3Q/2005 led to decrease in final prices although the prices of crude oil were growing and exchange rate of HUF depreciating.

[7] However, Hungary introduced so called professional diesel which refund part of excise tax to haulers

Than prices of motor fuels increased again in 1Q/2006 and 2Q/2006 (because of growing crude oil prices and depreciation of HUF).

As regards excise tax rates, Hungary increased more significantly rates of diesel twice (in 1Q/2010 by 7.6 % and in 4Q/2011 by 13.4 %) and petrol only once (in 1Q/2010 by 10.1 %). Unfortunately, in the same periods prices of crude oil also increased, which supported negative effect on final price of motor fuels. Nevertheless, in real terms, the excise rates in 4Q/2011 were lower than in 1Q/2005 and the ratio of indirect taxes in the final price of motor fuel decreased in both cases.

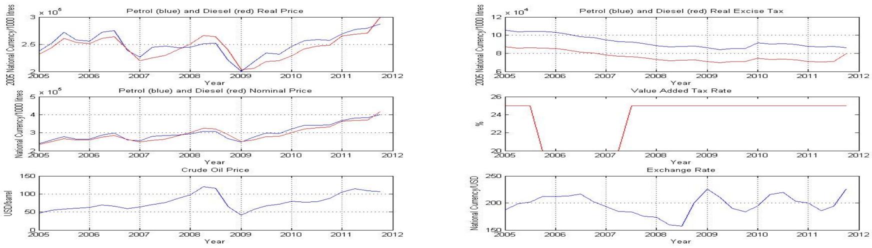

Figure 7: Motor Fuel Prices in Hungary

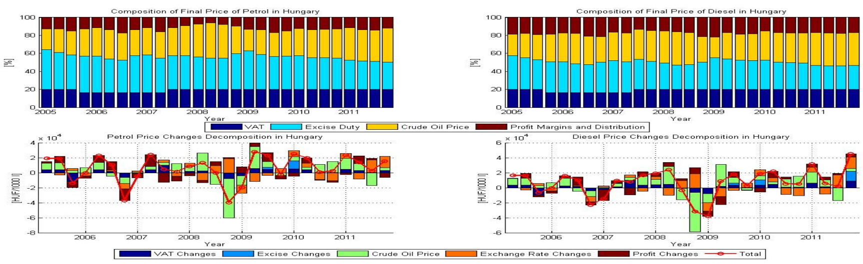

Figure 8: Composition of Consumer Price of Motor Fuels and Decomposition of its Changes in Hungary

2.1.5 Poland

From the data on Poland (see Figure 9 and 10) it can be seen that the strong effect of crude oil prices prevails again. However, the peak in prices of motor fuels is realized in other quarter (4Q/2011) than peak in crude oil prices (2Q/2008). The reason is significant depreciation of PLZ between these two periods and in the case of diesel growth in excise tax in 1Q/2010.

The ratio of profit margins and distributional costs is again higher for diesel. When looking at the composition of final price, the ratio of profit margins and distributional costs decreased during the period while the ratio of crude oil price increased.

In the analyzed period, Poland did not change VAT rate keeping it at the same 22 % level. The other indirect tax rates on diesel were visibly decreased in 1Q/2009 (by -4.1 %) and again increased in 1Q/2010 (by 12.1 %). In the case of petrol, the other indirect taxes were significantly decreased in 4Q/2005 (by -15.2 %) and again increased in 1Q/2007 (by approx. 18 %). In the case of diesel in 1Q/2009, we can see that a decrease in indirect tax accompanied by appreciation of PLZ was outweighed by increase in crude oil price. Rapid depreciation of PLZ in 1Q/2009 and associated inflation rate caused real excise tax rates to decline and the ratio of indirect taxes on final price of both motor fuels also decreased.

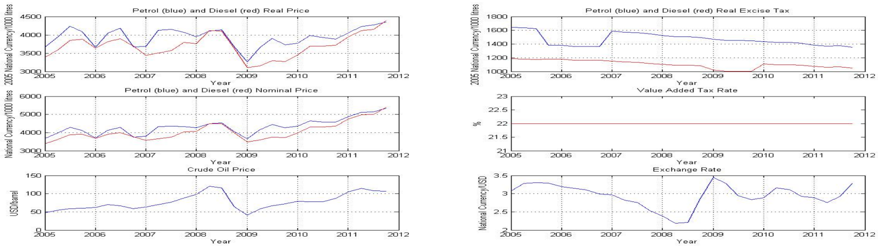

Figure 9: Motor Fuel Prices in Poland

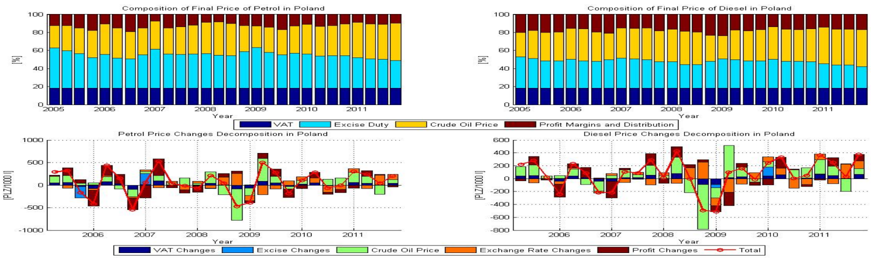

Figure 10: Composition of Consumer Price of Motor Fuels and Decomposition of its Changes in Poland

2.1.6 Slovakia

Data on Slovakia (see Figure 11 and 12) shows that the main determinant of motor fuel prices is again the price of crude oil. The prices of diesel reached their peak in the same quarter (2Q/2008) as do the prices of crude oil. This is also caused by a very significant slump in the excise tax on diesel in 1Q/2010. On the other hand, petrol prices reached their peak in 2Q/2011 also as a result of increased excise tax in 1Q/2011.

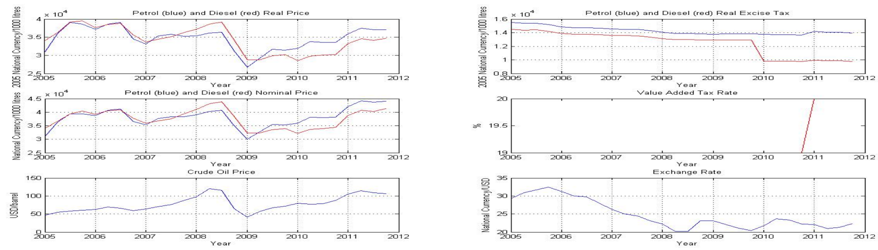

Figure 11: Motor Fuel Prices in Slovakia

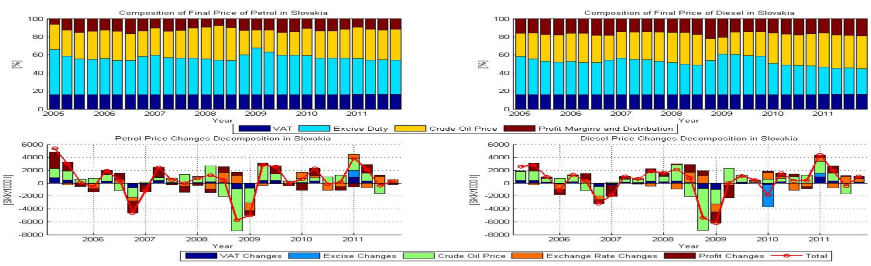

Figure 12: Composition of Consumer Price of Motor Fuels and Decomposition of its Changes in Slovakia

The exchange rate effect is relatively significant for Slovakia. For example, this effect caused that in 3Q and 4Q/2008 when prices of crude oil sharply decreased, the prices of motor fuels prices due to depreciation did not decreased in the same amount. Further, a decrease in excise tax in 1Q/2010 was not fully passed on final diesel price because of depreciation of Euro in that time.

The ratio of profit margins and distributional costs is in the case of diesel higher than at the beginning of the inspected period. The same surprisingly holds for petrol. Again, the profit ratio is higher in the case of diesel than petrol.

During the inspected period, Slovakia changed VAT rate only once in 1Q/2011 (from 19 % to 20 %). The excise tax on diesel sharply decreased once in 1Q/2010 (by -23.5 %). The effect on price was visible only in that quarter. After that depreciation of Euro and growing crude oil prices caused that effect of decreased excise duty was absorbed. On the other hand, excise tax rates on both motor fuels increased slightly in 1Q/2011 (by 7 % in the case of petrol and by 5 % in the case of diesel). As a result, Slovakia has moderately lower real excise tax rate on petrol and significantly lower real excise tax rate on diesel than in 1Q/2005. Also the ratio of taxes on final price decreased significantly for both types of fuel.

2.2 Consumption of Motor Fuels

The consumption of motor fuels can be affected by several factors: prices of motor fuels in relevant countries, prices of motor fuels in competing regions, GDP, number of cars combusting particular type of product, and level of their efficiency in combustion. In the case of prices in selected region, one can expect negative influences of growing own domestic prices and growing efficiency in combustion on consumption of relevant fuels, in the case of price in other regions, prices of substitutes, GDP, and number of cars one can expect positive influence.

In this part, the graphs of consumption of relevant fuels (and total in sum) are shown. Additionally, graphs of real GDP in 2005 prices are depicted. It can be seen that the data are highly cyclical, ie. the peaks are recorded in the third quarters of relevant years while the bottoms in first quarters. The graphs help to determine seasonality and possible trends in time series.

This is further inspected by application of Hodrick Prescott filter that helps to identify long-term paths of analyzed variables and fluctuations around these paths.[8] The fluctuations can be caused, for example, by seasonality in the data, business cycle, etc. The filter therefore distinguish between long-term path of the variable and cyclical component. Ie. we assume that:

$$y_t = g_t + c_t, \tag{1}$$

where y_t stands for considered variable, g_t for growth component and c_t for cyclical component.

The filter is represented as an optimization problem shown in (2).

$$\min_{\{g_t\}_{t=-1}^{T}} \{\sum_{t=1}^{T} c_t^2 + \lambda \sum_{t=1}^{T} [(g_t - g_{t-1}) - (g_{t-1} - g_{t-2})]^2\}, \tag{2}$$

where as shown before $c_t = y_t - g_t$.

As proposed Hodrick and Prescott for quarterly data, $\lambda = 1600$ was chosen for the purpose of the analysis.

2.3 Austria

The data on consumption in Austria (see Figure 13) shows downward sloping trend in the case of both motor fuels. In the case of petrol, the trend is more visible. On the other hand, GDP is

[8]For more information about the filter see [7]

growing. This fact can be caused by relatively saturated market for motor fuels. Consumers are relatively rich. Therefore they do not travel more with growing GDP but could buy new, more effective cars. The gap on GDP shows that the economy was "overheated" between 1Q/2006 and 3Q/2008. At the end of analyzed period petrol was consumed under it under its potential while diesel moreless at the potential level.

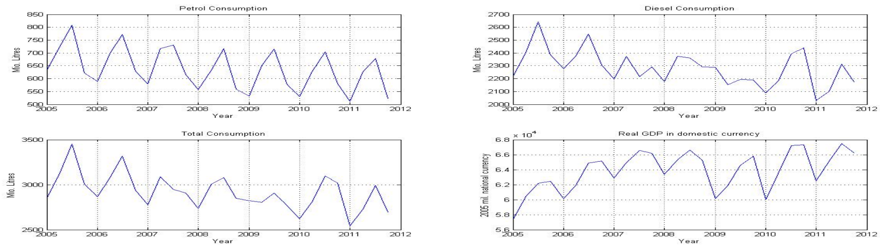

Figure 13: Motor Fuel Consumption and GDP in Austria

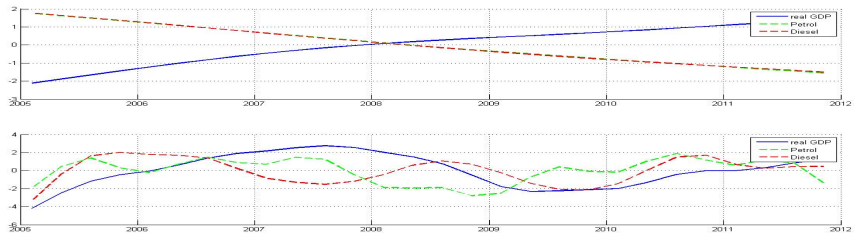

Figure 14: Hodrick Prescott Filter Trend and Gaps in Austria

2.3.1 Czech Republic

The data on consumption in the Czech Republic (see Figures 15 and 16) shows visible downward sloped trend in petrol consumption. The trend became even more negative in the year 2007. When smoothed, the upward sloping trend in diesel consumption has its peak in 2008, when become slightly to decrease. Moreover diesel consumption is more tight to the GDP than diesel.

A relatively large drop in consumption of both motor fuels in 1Q/2010 could be caused by an increase in excise duty rate. This effect could be boosted by unpleasant situation of GDP. However, as a whole, the consumption of diesel has increasing trend. This can be caused by switching fuel cars to diesel cars resulting from higher income (diesel engines are more expensive), more pleasant price of diesel (resulting from lower excise duty rates) and lower consumption of diesel engines per km.

The gaps show that the economy was "overheated" between 2006 and 2009. Further, positive values of motor fuel consumption between 2007 and 2010 can be seen. Than the both motor fuel consumptions are under their potential. This was possibly caused by relatively significant drop in consumption due to an increase in excise duty rate in 1Q/2010. The gap became again positive in 3Q/2011 again.

2.3.2 Germany

The data on consumption in Germany (see Figure 17) shows downward sloping trend of petrol consumption, which is probably caused by more effective cars and switches from petrol cars to alternative fuels like diesel. Diesel consumption, taken as whole on the first sight, is stagnating and oscillating around 16.000 mio. litres per quarter. But after smoothing, we can also see downward sloping trend. Nevertheless, not so steep as in the case of petrol.

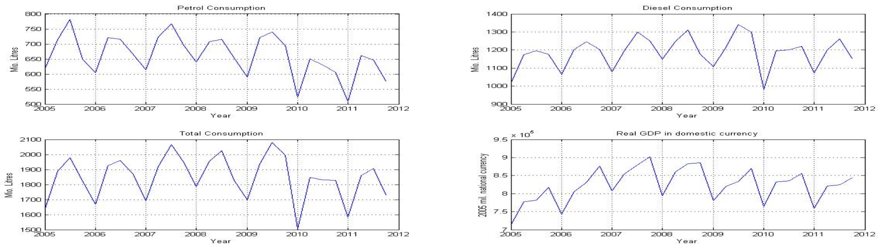

Figure 15: Motor Fuel Consumption and GDP in the Czech Republic

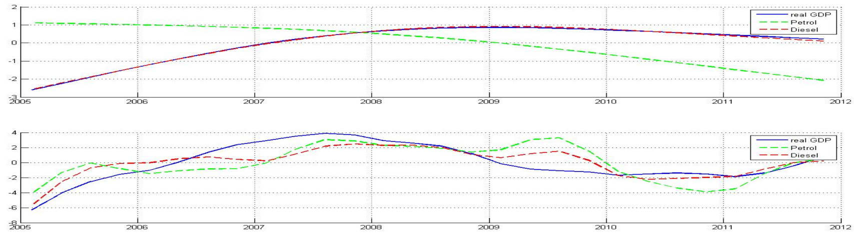

Figure 16: Hodrick Prescott Filter Trend and Gaps in the Czech Republic

This fact could, as in the case of Austria, result from a saturated market (most of the consumers own car and do not need travel more) and they only substitute the old ones by more efficient new ones while not need to travel more. It can also be seen that changes in motor fuel consumption often happen one period after GDP. The trend on GDP is upward sloping with a positive gap between 2009 and 2011.

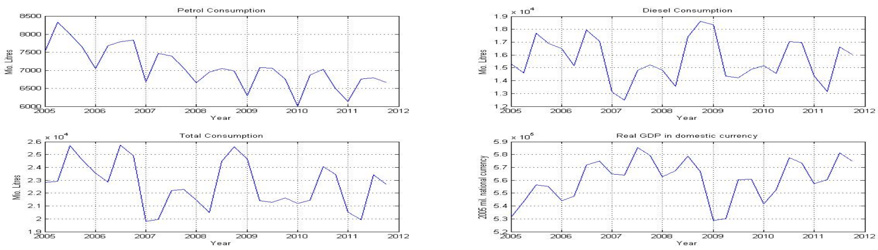

Figure 17: Motor Fuel Consumption and GDP in Germany

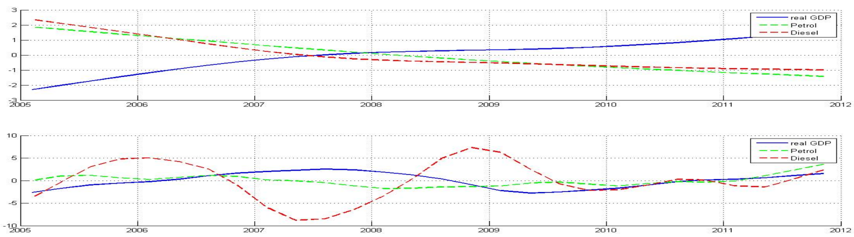

Figure 18: Hodrick Prescott Filter Trend and Gaps in Germany

2.3.3 Hungary

The data on consumption of motor fuels in Hungary (see Figure 19) shows that petrol consumption was increasing until 2007 when it began to drop. The trend on diesel consumption was rising up to 2Q/2009, than there is a moderate decrease. This could be a result of substitution of petrol cars by diesel cars. The drop in diesel consumption can result from drops in GDP. In the case of motor fuels the gaps became negative in 1Q/2010 after an increase in excise duty rates and have not become positive until the end of the analyzed period.

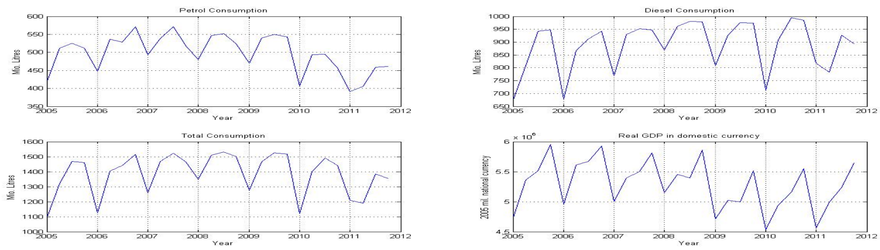

Figure 19: Motor Fuel Consumption and GDP in Hungary

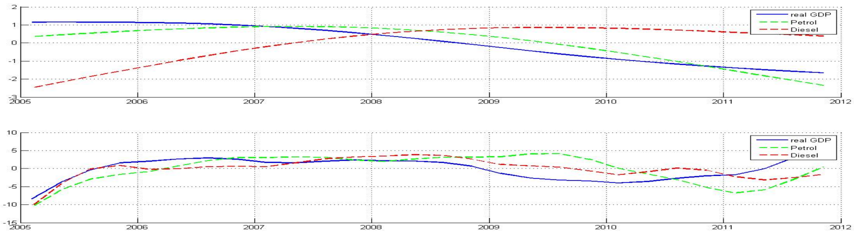

Figure 20: Hodrick Prescott Filter Trend and Gaps in Hungary

2.3.4 Poland

From the data depicted in Figures 21 and 22 we can see that while the petrol consumption more less stagnated in the analyzed period, the consumption of diesel was significantly and steadily growing. After smoothing petrol consumption it can be seen that increasing trend became decreasing in 2009. The consumption of diesel grew about 50 % from the 2005. Poland also realized relatively high growth in GDP. The GDP growth is closely tight to that of diesel.

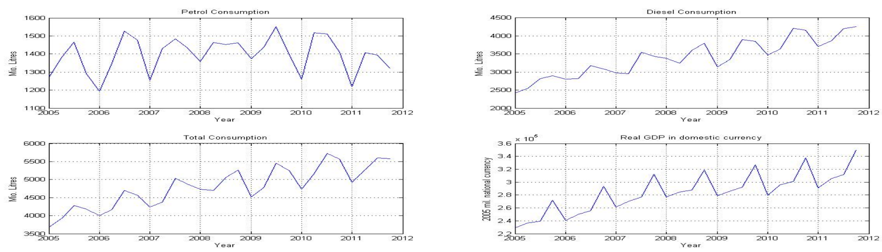

Figure 21: Motor Fuel Consumption and GDP in Poland

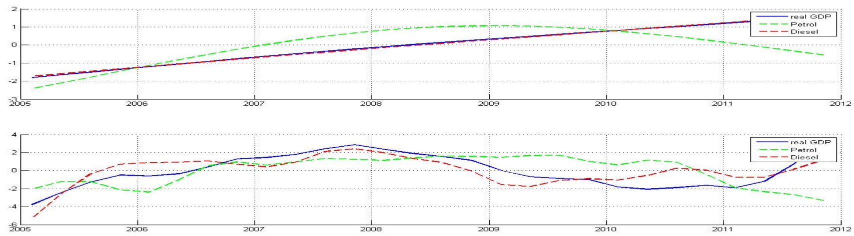

Figure 22: Hodrick Prescott Filter Trend and Gaps in Poland

2.3.5 Slovakia

The data on consumption of motor fuels in Slovakia (see Figures 23 and 24) shows that petrol consumption was more less stagnating (at the first sight) or slightly growing while the consumption of diesel has upward trend. When smoothed, petrol trend became quadratic with the peak in 2008. Moreover the consumption of diesel is closely related to development of GDP. After the decrease in excise tax, it can be seen that diesel consumption gap became positive.

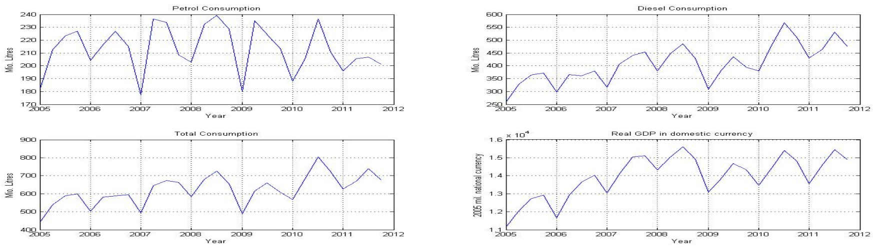

Figure 23: Motor Fuel Consumption and GDP in Slovakia

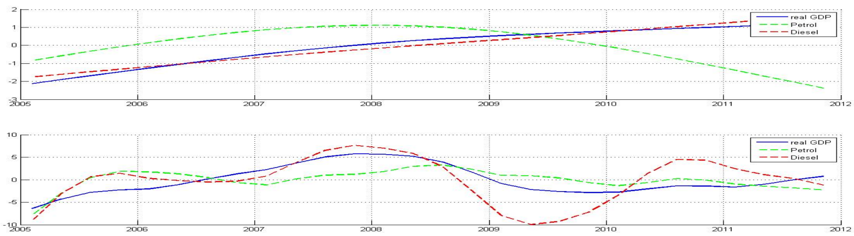

Figure 24: Hodrick Prescott Filter Trend and Gaps in Slovakia

Taking in mind the graphs above we could distinguish among following types of regions. Old member states Austria and Germany with slightly increasing trend in GDP and downward sloping trend in the case of both motor fuels. This can be caused by saturated market for motor fuels and possibly by little switch to alternative fuels in these countries.

Countries like Czech Republic and Hungary are characterized by downward sloping trend of petrol and rather stagnating (after initial growths) consumption of diesel. Finally Slovakia and Poland realized peak in consumption of petrol latter than previous two countries and diesel consumption is permanently growing.

Firstly, let see on the dependency between GDP and consumption of motor fuels in all regions. It shall be taken in mind that this dependency does not show the trend in time, it only says if the consumption of motor fuels tends to grow with increasing GDP. While neglecting other effects, these graphs further only show that positive relationship can be expected.

3 Estimates and Relationships

This part of the paper is devoted to practical results. First, simple OLS econometric estimates of elasticities are carried out, than the same characteristics are estimated by the means of panel data methods. Finally Bayesian methods are applied together with linear restrictions on parameters in order to get expected signs in some cases.

3.1 Estimation of Elasticities - Simple OLS

Firstly, simple OLS estimations are carried out. Very interesting parameters to estimate are dependencies of consumption of motor fuels on their prices and income. Good way to interpret them is via price and income elasticities of demand. Both parameters say about how much (in percentage points) would change the demand for motor fuels if the price/income would be changed by 1 %.

This is very interesting, for example, when the policy makers consider to change the tax rate. Therefore, if the demand for motor fuel is very elastic than increase in tax could lead to large drop in consumption which suppress the increase in revenues. In an extreme case, an increase in price resulting from increase in tax rate could lead to nil or negative increment in revenues. The equation is as follows:

$$R = \tau C(P(\tau), i), \tag{3}$$

where R are tax revenues, C is consumption of fuel dependent on income and price vector in the economy and τ denotes tax rate.

When taking derivative of equation 4 with respect to τ, we get

$$\frac{\partial R}{\partial \tau} = \tau \frac{\partial C(P(\tau), i)}{\partial P} \frac{\partial P}{\partial \tau} + C, \tag{4}$$

After some simple algebra we get:

$$E_\tau^R = E_P^C E_\tau^P + 1, \tag{5}$$

where E_τ^R denotes tax elasticity of revenues, E_P^C denotes price elasticity of demand for fuel and E_τ^P the elasticity of the final price w.r.t. tax.

From equation 5 we see that increase in tax rate leads to increase in revenues if:

$$E_P^C < -\frac{1}{E_\tau^P}, \tag{6}$$

The lower is the tax share on the final price the higher has to be the price elasticity to be on wrong side of Laffer curve.

Let assume that the amount of motor fuel demanded is dependent on price of relevant motor fuel and income, ie. $C = C(P, W)$, where C represents consumption of relevant motor fuel, P is price vector of commodities in the economy and W real income of consumers of considered motor fuel.

For the price elasticity holds:

$$E_{dpf} = \frac{\partial C\,(P, W)}{\partial P_f} \frac{P_f}{C\,(P, W)} \tag{7}$$

where E_{dpf} is own price elasticity for motor fuels, C is the demand for motor fuels dependent on price vector in the economy (P) and real income (W). The symbol P_f denotes own price of motor fuels.

Following the chain rule and using equation 7 it can be further derived that:

$$E_{dpf} = \frac{\partial \log C\,(P, W)}{\partial \log P_f} \tag{8}$$

And this is parameter β to estimate in log-log type of equation. The same can also be inspected for income, ie. income elasticity of demand. The income is characterized by real GDP in the estimations.

For each country and motor fuel type, also cross price elasticities of demand are attempted to estimate.

Further, the differences in prices with other regions are tested. For the sake of this estimation, artificial "foreign" price variable was created as following:

$$P_i^{For} = w_{ij} P_{f,j}, \tag{9}$$

where P_i^{For} stands for weighted average of foreign price of relevant motor fuel in Euro, w_{ij} is a ratio of length of boarders between two regions i and j in the total length of boarders of region i with other analyzed regions, ie. $\forall_i \sum_j w_{i,j} = 1$, and finally $P_{f,j}$ is the price of motor fuel in region j.

Because the data are characterized by seasonality, the dummy variables for each quarter are also put in the model to estimate. [9]

3.1.1 Austria

In the case of petrol (see table 1), GDP does not affect the petrol consumption very much, which can be explained by saturation of the automobile market and possible switch to diesel cars (see section 2). From this reason, GDP was excluded from the model. All dummy variables are very statistically significant which indicate seasonality in the data. Time trend is significant and, as expected, negative sloping. Although own price elasticity and foreign elasticity are statistically insignificant, they get expected values. According to these estimates, petrol demand is inelastic. The Durbin Watson statistics show there is rather no autocorrelation between residues.

Table 1: Simple OLS - Austria Petrol

Explanatory variable	Value	t-stat	p-value
Time trend	-0.009708	-4.619652	0.000148
Real Petrol Price	-0.468969	-1.513348	0.145097
Foreign Price Petrol	0.441895	1.416670	0.171244
Seasonality – Q1	6.580113	12.840113	0.000000
Seasonality – Q2	6.770039	13.102047	0.000000
Seasonality – Q3	6.866821	13.251888	0.000000
Seasonality – Q4	6.651843	12.933909	0.000000
R squared	0.9643		
Rbar squared	0.9541		
Durbin Watson	1.4379		

The diesel consumption results were insignificant. However, the estimated parameters show expected signs. Income elasticity of demand is equal approximately 0.04 but was not included in the results shown in table 2 since it has not large explanatory power. Nevertheless, with this value of the parameter the diesel is "normal" necessary good.

The price elasticity of diesel demand is 0.2 which is less than in the case of petrol and implying inelasticity of demand for diesel. This is mostly consistent with results of studies summarized by Dahl [4]. However, it shall be noted that these estimates are statistically insignificant.

[9] However, if there is assumed a constant in the model, it can only be used three of four dummy variables. The reason is that the matrix of explanatory variables would became singular because of perfect muulticollinearity.

Interesting is that foreign price elasticity is lower than in the case of petrol. The international "mobility" should be higher in the case of diesel since diesel is combusted in trucks which rather move across boarders. The Durbin-Watson statistics implies no autocorrelations between residues.

Table 2: Simple OLS - Austria Diesel

Explanatory variable	Value	t-stat	p-value
Time Trend	-0.005478	-2.115120	0.046544
Real Diesel price	-0.208557	-0.391819	0.699140
Foreign Price	0.267952	0.499991	0.622280
Seasonality – Q1	7.317299	11.409395	0.000000
Seasonality – Q2	7.364412	11.410611	0.000000
Seasonality – Q3	7.409526	11.453642	0.000000
Seasonality – Q4	7.379042	11.444131	0.000000
R squared	0.5905		
Rbar squared	0.4472		
Durbin Watson	1.9413		

3.1.2 Czech Republic

In the case of petrol, income elasticity is equal to 0.26 but is statistically insignificant (see table 3, which implies normal necessary good. Price elasticity of petrol demand is higher than in Austria, but still implies inelastic demand. On the other hand foreign price elasticity is lower than in Austira and shows inelastic response to changes in price in other regions. Time trend is significant and, as expected, has negative slope. The Durbin Watson statistics indicates no autocorrelation between residuals.

Table 3: Simple OLS - Czech Republic Petrol

Explanatory variable	Value	t-stat	p-value
Time trend	-0.009771	-4.814384	0.000105
GDP	0.263401	0.886746	0.385755
Real Petrol Price	-0.568231	-2.479084	0.022202
Foreign Price Petrol	0.368672	1.588362	0.127889
Seasonality – Q1	6.113603	1.331332	0.198057
Seasonality – Q2	6.298854	1.364706	0.187504
Seasonality – Q3	6.324621	1.368634	0.186292
Seasonality – Q4	6.225169	1.344322	0.193895
R squared	0.8892		
Rbar squared	0.8504		
Durbin Watson	1.8754		

The diesel consumption results are relatively significant. Income elasticity of demand is equal approximately 0.32, which implies normal good. The price elasticity of diesel demand is 0.48 which implies inelastic demand and is less than in the case of petrol. This is mostly consistent with results of studies summarized by Dahl [**?**]. Again, foreign price elasticity is lower than for petrol. The Durbin Watson statistics indicates no autocorrelations between residuals.

3.1.3 Germany

In the case of petrol, the influence of GDP/income indicated that petrol is inferior good and the paramter was statistically very insignificant. Therefore it was removed from the model. Own price elasticity of petrol demand is relatively small indicating inelasticity and so does foreign price

Table 4: Simple OLS - Czech Republic Diesel

Explanatory variable	Value	t-stat	p-value
Time Trend	-0.003122	-1.885403	0.073988
GDP	0.327291	1.401174	0.176489
Real Diesel price	-0.484907	-2.264923	0.034779
Foreign Price	0.351980	1.966632	0.063257
Seasonality – Q1	5.058015	1.322810	0.200825
Seasonality – Q2	5.165443	1.344199	0.193934
Seasonality – Q3	5.211032	1.354510	0.190680
Seasonality – Q4	5.155285	1.337953	0.195927
R squared	0.8596		
Rbar squared	0.8105		
Durbin Watson	2.1775		

demand elasticity. Both estimates suffer from statistical insignificance. Time trend is significant and, as expected, negative sloping. The seasonality leads to significance in quarterly dummy variables. The Durbin Watson statistic approaches the level where there can be autocorrelation between residuals.

Table 5: Simple OLS - Germany Petrol

Explanatory variable	Value	t-stat	p-value
Time trend	-0.007934	-7.167899	0.000000
Real Petrol Price	-0.167611	-0.906937	0.374730
Foreign Price Petrol	0.066818	0.491237	0.628353
Seasonality – Q1	9.622302	14.979694	0.000000
Seasonality – Q2	9.730579	15.110347	0.000000
Seasonality – Q3	9.740892	15.087109	0.000000
Seasonality – Q4	9.709265	15.139553	0.000000
R squared	0.9139		
Rbar squared	0.8893		
Durbin Watson	1.1784		

The data on diesel indicates that diesel is strongly inferior good in Germany. This can be biased by saturation of the market and possible purchases of new cars with more effective engines. Other values express "more" expected signs. The diesel demand in Germany is very elastic in comparison to other countries, which indicates that Germany is transit country. Large elasticity also holds for foreign price. High seasonal pattern brings importance to dummy variables.

Table 6: Simple OLS - Germany Diesel

Explanatory variable	Value	t-stat	p-value
Time Trend	-0.009809	-2.378104	0.027485
GDP	-2.875678	-3.160485	0.004920
Real Diesel price	-1.135815	-1.682092	0.108100
Foreign Price	1.227398	2.340587	0.029729
Seasonality – Q1	47.169454	4.232056	0.000409
Seasonality – Q2	47.076569	4.222844	0.000418
Seasonality – Q3	47.339001	4.234613	0.000406
Seasonality – Q4	47.337070	4.235877	0.000405
R squared	0.6785		
Rbar squared	0.5660		
Durbin Watson	1.3065		

3.1.4 Hungary

In the case of petrol, all interesting parameters indicate expected signs and are statistically significant. Time trend is negative sloping, income elasticity is equal to 0.84 indicating necessity of petrol but brings it near the boarder of luxury good. Own price elasticity of demand is -0.81, which is inelastic demand. Foreign price elasticity is approximately 0.5 meaning inelasticity. The dummy variables could be removed since the seasonality is explained also by the GDP. Durbin Watson statistics rather shows there are no strong autocorrelation between residuals.

Table 7: Simple OLS - Hungary Petrol

Explanatory variable	Value	t-stat	p-value
Time trend	-0.007631	-2.236831	0.034851
GDP	0.836019	7.149411	0.000000
Real Petrol Price	-0.813680	-4.136084	0.000373
Foreign Price Petrol	0.494687	1.954625	0.062373
R squared	0.6525		
Rbar squared	0.6091		
Durbin Watson	1.6366		

In the case of diesel, all estimated parameters have expected signs and are statistically significant. Income elasticity is relatively high which means that diesel is a luxury good and can result from unsaturated market in diesel engines. Own price elasticity is lower than in the case of petrol. Foreign price elasticity is relatively significant. The seasonal dummy variables were removed since seasonality od GDP covers them. Also constant brings better result than trend. Durbin Watson statistics does not reveal autocorrelations between residuals.

Table 8: Simple OLS - Hungary Diesel

Explanatory variable	Value	t-stat	p-value
Constant	-6.266385	-2.132352	0.043411
GDP	1.102767	5.955903	0.000004
Real Diesel price	-0.633321	-3.136080	0.004482
Foreign Price	0.546427	3.832241	0.000804
R squared	0.6607		
Rbar squared	0.6183		
Durbin Watson	1.6493		

3.1.5 Poland

In the case of petrol, all interesting parameters indicate expected signs and are statistically significant. Time trend is negative sloping, income elasticity is equal to 0.84 which approaches petrol to luxury good but still be "neccessary". Own price elasticity of demand is -0.81 (inelastic) and foreign price elasticity is approximately 0.5 (also inelastic). The dummy variables could be removed since the seasonality is fully explained by the GDP. The Durbin Watson statistics does not show autocorrelations between residuals.

Estimations of parameters explaining changes in demand for diesel are shown in table (10). The time trend is statistically significant and upward sloping. Also income elasticity records high level of significance, but indicating necessity nature of diesel. Own and foreign price elasticities are statistically insignificant but have expected values, which means inelasticity - larger than in case of smaller regions. The dummy variables on seasonality were excluded from the model because when included together with GDP, statistical insignificance occurred. Durbin Watson statistics does not point out autocorrelations between residuals.

Table 9: Simple OLS - Poland Petrol

Explanatory variable	Value	t-stat	p-value
Time trend	-0.008213	-2.680748	0.013994
GDP	0.890256	3.035802	0.006285
Real Petrol Price	-0.365564	-2.898479	0.008594
Seasonality – Q1	-0.853644	-0.219708	0.828220
Seasonality – Q2	-0.738541	-0.189527	0.851500
Seasonality – Q3	-0.697726	-0.178895	0.859735
Seasonality – Q4	-0.872592	-0.222112	0.826373
R squared	0.8198		
Rbar squared	0.7683		
Durbin Watson	1.9943		

Table 10: Simple OLS - Poland Diesel

Explanatory variable	Value	t-stat	p-value
Time Trend	0.008938	3.615421	0.001383
GDP	0.574573	7.598239	0.000000
Real Diesel price	-0.083538	-0.366647	0.717095
Foreign Price	0.208176	0.945091	0.354031
R squared	0.9014		
Rbar squared	0.8890		
Durbin Watson	2.4864		

3.1.6 Slovakia

In the case of petrol, all interesting parameters got expected signs. However, price elasticities are statistically insignificant. Time trend is negative sloping and statistically significant. GDP explains variability in petrol consumption intensively revealing normality of petrol (necessity good). The petrol demand in Slovakia is relatively inelastic. The dummy variables could be removed since the seasonality is fully explained by the GDP. Durbin Watson statistics does not confirm autocorrelation between residuals.

Table 11: Simple OLS - Slovakia Petrol

Explanatory variable	Value	t-stat	p-value
Time trend	-0.006941	-1.950870	0.062842
GDP	0.580781	3.890233	0.000695
Real Petrol Price	-0.132538	-0.599835	0.554238
Foreign Price Petrol	0.185713	0.725690	0.475046
R squared	0.4239		
Rbar squared	0.3519		
Durbin Watson	2.0524		

In the case of diesel, all parameters indicate expected signs and are strongly statistically significant. Income elasticity is greater than in the case of petrol showing that diesel is more "luxurious" than petrol but still keep its character of "necessity". The same holds for price elasticities which indicates inelasticity of demand for diesel. Durbin Watson, again, does not confirm autocorrelations between residuals.

3.2 Estimation of Elasticities - Panel Data

In this section, panel data estimates are described. The panel data estimation is carried out for all analyzed regions together. In the first phase unobserved effect model is estimated. This

Table 12: SIMPLE OLS - SLOVAKIA DIESEL

Explanatory variable	Value	t-stat	p-value
GDP	0.763450	5.319706	0.000016
Real Diesel price	-0.612300	-6.019803	0.000003
Foreign Price	0.731110	4.964720	0.000041
R squared	0.8244		
Rbar squared	0.8103		
Durbin Watson	1.7396		

method is usually applied when model suffers from omitted variable problem. The unobserved effect can capture all unobserved features that can affect the diesel demand for motor fuels. In this case regional differences between regions. These are presumed to be fixed over 6 years of the analysis. The estimated equation 10 is:

$$C_{i,t} - \bar{C}_i = \beta_1(\ln GDP_{i,t} - \ln \bar{GDP_i}) + \beta_2(\ln P^f_{i,t} - \ln \bar{P^f_i}) + \beta_3(\ln P^{sf}_{i,t} - \ln \bar{P^{sf}_i}) + u_{i,t} - \bar{u_{i,t}}, \quad (10)$$

where C stands for consumption of relevant fuel, P^f marks price of motor fuel, P^{sf} is price of alternative motor fuel, GDP gross domestic product and $u_{i,t}$ idiosyncratic error. All the variables have their time average counterparts, ie. $\bar{x}_i = T^{-1}\sum_{i=1}^{T} x_{i,t}$.

3.2.1 Petrol

In the case of petrol, we can see negative trend which is expected. Further, the income elasticity shows normality (necessity) nature of petrol with statistical significance. Own price elasticity of petrol demand appears to get unexpected signs and is statistically insignificant. Further checks has to be done in this case.

Table 13: FIXED EFFECT ESTIMATE - PETROL

Explanatory variable	Value	t-stat	p-value
Trend	-0.0066	-8.4905	0.0000
GDP	0.7689	8.5037	0.0000
Real Petrol Price	0.0442	0.5837	0.5602
R squared	0.3908		
Rbar squared	0.3834		

3.2.2 Diesel

The fixed effect model shows much more better results in the case of diesel. Statistical significance can be seen at all estimated parameters. The estimates mean that diesel is rather luxury good with income elasticity greater than 1. Further, the demand is inelastic (own price elasticity equal to 0.47 and cross price elasticity shows that diesel and petrol are substitutes.

Table 14: FIXED EFFECT ESTIMATE - DIESEL

Explanatory variable	Value	t-stat	p-value
GDP	1.2979	14.6279	0.0
Real Diesel Price	-0.4763	-3.6524	0.0003
Real Petrol Price	0.4376	2.8749	0.0046
R squared	0.5779		
Rbar squared	0.5728		

3.3 Estimation of Elasticities - Bayesian Methods with Linear Equality Constraints imposed on Parameters

One way of overcoming the 'wrong' signs of parameters is to use Bayesian techniques, which by the appropriate choice of the prior distribution, can force the estimates into the 'correct' part of the real line. One particular way of doing that is the Geweke (1995) approach. He suggested a computationally intensive algorithm to estimate the regression model subject to linear constraints, which trivially include constraints on parameters' signs[10].

The following figures show the difference between the OLS estimates and the Bayesian estimates subject to the sign constraints. For the sake of this analysis, totals of motor fuel consumptions in particular regions are used. The following pictures reveal that Bayesian techniques are suitable for treating the constraints on parameters signs. Indeed, the constraints do not affect only own parameters but other parameters as well and at the same time the magnitude is reasonable.

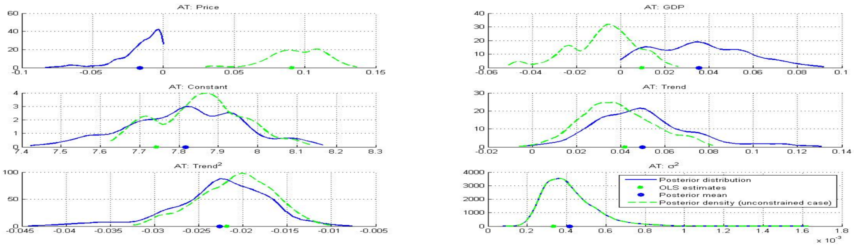

Figure 25: Bayesian Estimates with Linear constraints - Austria

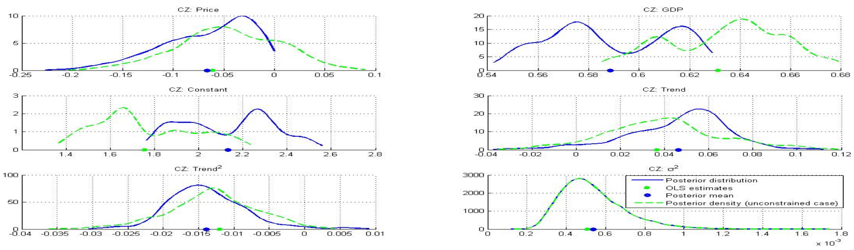

Figure 26: Bayesian Estimates with Linear constraints - Czech Republic

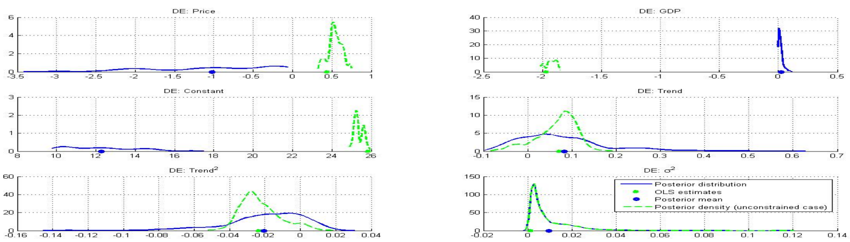

Figure 27: Bayesian Estimates with Linear constraints - Germany

4 Conclusion

The paper shows initial results of estimation of elasticities of demand for motor fuels. Firstly, initial data check were carried out. We can distinguish between three different regions: Austria and Germany are characterized by slightly increasing trend in GDP and downward sloping trend

[10]An implementation of Geweke routine in MATLAB is available in Appendix.

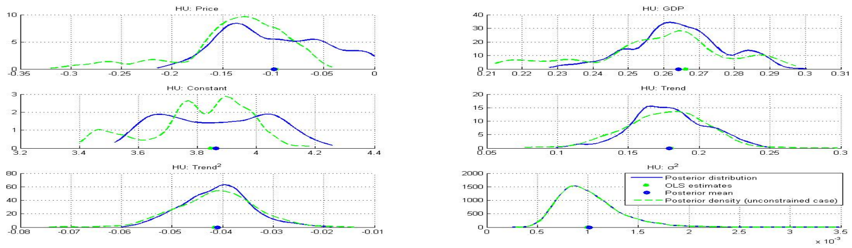

Figure 28: Bayesian Estimates with Linear constraints - Hungary

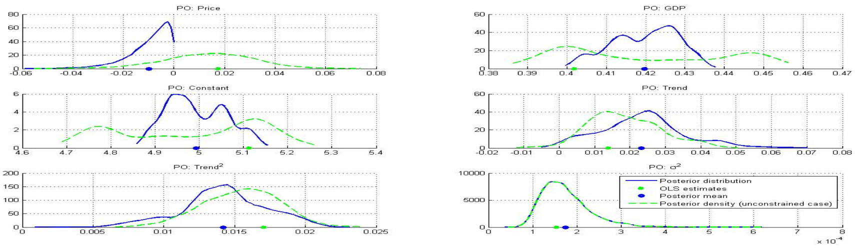

Figure 29: Bayesian Estimates with Linear constraints - Poland

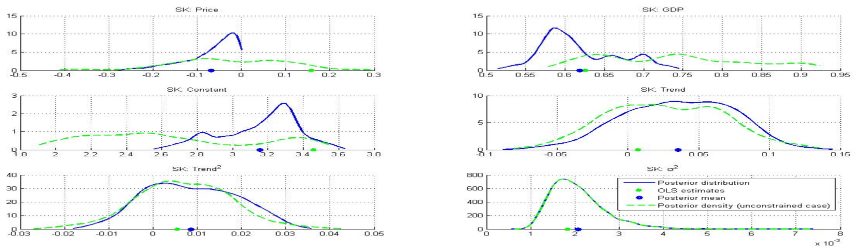

Figure 30: Bayesian Estimates with Linear constraints - Slovakia

in the case of both motor fuels, which could be mainly a result of saturated market for motor fuels. Czech Republic and Hungary are characterized by downward sloping trend of petrol and rather stagnating (after initial growths) consumption of diesel. Finally Slovakia and Poland realized peak in consumption of petrol latter than previous two countries and diesel consumption is permanently growing.

Simple OLS parameters usually indicated expected signs. Income elasticities usually points out that both types of motor fuels are normal (necessary) goods. Further, the demand for motor fuels was found to be inelastic. The inelastic demand for motor fuels imply that an increase in excise duty rate would clearly lead, ceteris paribus, to and increase in the revenues for all regions, except for diesel in Germany. But taking in mind the formula for changes in revenues (eqution 6), also in case of Germany, positive influence of changes in excise duty rate on revenues can be expected. The only exception Further, foreign prices were also found to be important in explaining changes in motor fuel demand. Finally, Bayesian methods with linear constraints were applied on parameters with unexpected signs. Also in this case the very elastic demands for motor fuels have not be obtained.

Acknowledgements

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A Matlab implementation of Geweke (1995)

```
function [beta_draws,s2_draws] = NLMconstraintsS(yy,XX,aa,bb,nburn,nsave)
% this function implements Geweke's bayesian estimator of the normal linear
% model subject to the linear constraints
% this is the same program as NLMconstraints.m, but DD is considered to be
% a square eye matrix
%
% yy = XX \beta + \eta, where
%                       aa <= \beta <= bb
%                       \eta ~ N(0,\sigma^2)
%
% see Geweke (1995) paper for further details


[TT,kk] = size(XX);
bOLS    = pinv(XX)*yy;
s2OLS   = 1/(TT-kk)*(yy-XX*bOLS)'*(yy-XX*bOLS);
XiX     = pinv(XX'*XX);

% some precomputation
az = -Inf(size(aa));
bz =  Inf(size(bb));
af = isfinite(aa);
bf = isfinite(bb);

az(af) = (aa(af)-bOLS(af));
bz(bf) = (bb(bf)-bOLS(bf));

% set some initial conditions
beta_i = min(bb,max(bOLS,aa));
zeta_i = beta_i - bOLS;
s2_i   = s2OLS;


% preallocation of outputs
beta_draws = zeros(kk,nsave);
s2_draws   = zeros(nsave,1);

for ti = 1:nsave+nburn

    % (1) draw from coefficients
    RR = s2_i*XiX;


    for tk = 1:kk

        nek    = setdiff(1:kk,tk);
        z_cond = RR(tk,nek)*pinv(RR(nek,nek))*zeta_i(nek);
        z_cVAR = RR(tk,tk) - RR(tk,nek)*pinv(RR(nek,nek))*RR(nek,tk);
```

```
        if and(af(tk),bf(tk))
            LB = normcdf(az(tk),z_cond,sqrt(z_cVAR));
            UB = normcdf(bz(tk),z_cond,sqrt(z_cVAR));

        elseif and(not(af(tk)),bf(tk))
            LB = 0;
            UB = max(normcdf(bz(tk),z_cond,sqrt(z_cVAR)),1e-005);

        elseif and(af(tk),not(bf(tk)))
            LB = min(normcdf(az(tk),z_cond,sqrt(z_cVAR)),0.9999);
            UB = 1;

        else
            LB = 0;
            UB = 1;
        end

        zeta_i(tk) = norminv(LB + (UB-LB)*rand,z_cond,sqrt(z_cVAR));

    end
    beta_i = bOLS + zeta_i;


    % (2) draw from s2
    REE  = (yy - XX*beta_i)'*(yy - XX*beta_i);
    s2_i = REE/muj_chi2rnd(TT);



    % (3) save for ti > nbrun
    if gt(ti,nburn)
       beta_draws(:,ti-nburn) = beta_i;
       s2_draws(ti-nburn)     = s2_i;
    end
end
```

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Vítězslav Píša
Charles University Prague, Faculty of Humanities, U Kříže 8, Prague 5
vitezslav.pisa@centrum.cz