The impact of refinery and oil demand shocks on the motor fuel market in Sweden

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Abstract

This paper examines the link between the oil market and the motor fuel market in Sweden by developing a joint oil and motor fuel market in a structural VAR model. We explore the dynamic relationship between the oil market and motor fuel market (both gasoline and diesel) by focusing on the effects of oil demand and refinery shocks on motor fuel price and consumption. The results reveal opposite responses of gasoline and diesel consumption to positive oil demand shocks. Moreover, motor fuel price response to both oil demand and refinery shocks is greater than that of motor fuel consumption. We also assess the immediate and long-run contributions of each of the shocks to the total variation of motor fuel price and consumption in the Swedish motor fuel market

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1. Introduction

Most of the discussions on high energy prices are often focus on crude oil prices with less attention paid to gasoline and diesel prices. Implicitly treating both the crude oil market and motor fuel market as one and therefore ignoring the potential differences between the two markets. It is however important to differentiate the two markets, since they are likely to respond differently to shocks. More importantly, there is the need to know how domestic motor (transport) fuel price react to unexpected movements in the crude oil market such as unexpected demand increases. Crude oil is the main input for refinery firms and therefore accounts for the largest share of the marginal cost of refinery firms. The implication is that, price increases in the crude oil market will also increase the cost of producing refinery products. The increase cost of production due to increases in oil prices are often passed on to the final consumer in the form of higher gasoline prices (plus the tax component), which has implications on the responses of motor fuel demand to oil demand and refinery shocks.

Irrespective of this, most of the previous literature tends to focus on crude oil prices and its impact on macroeconomic variables such as inflation and output, without jointly considering both the crude oil market and the motor fuel market. A comprehensive review of the literature on this strand of research is in Hamilton (2008). Recent studies not reviewed in Hamilton (2008) include Esfahani et al. (2012), Cashin et al. (2012), Peersman and Van Robays (2012) and Kilian (2010). None of these studies incorporated both the crude oil market and the motor fuel market into one model except Kilian (2010). The Kilian (2010) study however was focused on the U.S., and did not consider the diesel market.

The objective of this study is to integrate both the crude oil market and the gasoline market into one model as done in Kilian (2010), but also to extend it to the diesel market given the EU policy that favor diesel relative to gasoline. Given the integration, we can trace the responses of each of the market to demand, supply and refinery shocks. This will aid better policy formulation regarding the response to the various shocks.

The second objective is to apply the integrated model to a small open economy with significant refinery capacity but depend entirely on imported crude oil in order to assess the dynamic responses of the various market particularly to refinery shocks.

The study makes the following contributions to the extant literature; first it incorporates both the gasoline and diesel market into the analysis. This is the first study to do this, by combining gasoline, diesel and the crude oil markets into one model. Irrespective of the intuitive possibility of differential impacts of crude oil market shocks on gasoline and diesel market dynamics, the joint dynamics is often ignored in most of the empirical work. Second, we focused on a country that has a long-term goal in decarbonizing the transport sector but at the same time it is one of the major exporting countries of refined oil products. Given the conflicting long-term policy goal and the market interest in regard to refined oil products for exports, evidence from Sweden will be important for other countries that are interested in going into the oil refinery industry but with low or no domestic crude oil production and with ambitious goal(s) towards fossil fuel usage in the transport sector.

The key findings from our study is that, gasoline and diesel consumption reacted differently to oil demand shocks, whereas gasoline consumption reacted negatively to an unexpected positive oil demand shocks, diesel consumption reacted positively confirming our initial suggestions that gasoline and diesel market might respond differently to shocks from the crude oil market. As expected, gasoline price reacted positively to unexpected positive oil demand increase, which impact lasted close to 9 months. Refinery shocks positively influence gasoline prices but with a larger impact relative to oil demand shocks. Refinery shocks also have differential impacts on gasoline and diesel consumption.

The rest of the paper is organized as follows. Section 2 presents a brief review of the literature and a brief on the structure of the oil market, section 3 present the data and the empirical model for the study with the identification strategy and estimation method discussed. The empirical results with discussions are reported in section 4, while section 5 presents the conclusion of the study.

2. Literature review

Several studies over the years have examine various aspect of oil market on macroeconomic variables. A comprehensive review of the literature on this can be found in Hamilton (2008). Hamilton (2008) review is however limited to studies prior to 2008 and does not include recent studies such as Kilian (2010), Esfahani et al. (2012), Cashin et al. (2012), Peersman and Van Robays (2012). Below we provide a brief review of some of the key studies in this strand of research.

Hamilton (1983) examined the impact of oil price shocks on US economy for the period 1949–1972. Using Granger causality test, he finds that changes in oil prices Granger-caused changes in GNP and unemployment.

Burbridge and Harrison (1984) examined the impact of oil price shocks on selected macroeconomic variables in five industrialised countries (USA, Canada, UK, Japan and Germany). Using a VAR model, they reached the similar conclusions as in Hamilton's work.

Gisser and Goodwin (1986) found that oil price shocks affect a set of macro variables. Using Hamilton's data, they detect a relationship between the crude oil price and employment. Furthermore, they examine whether oil shocks have a different impact on the macro economy before 1973 than after. However, they could not provide support for that hypothesis. Their results are similar to those of Hamilton (1983) and Burbridge and Harrison (1984).

Mork and Olsen (1994) examines the correlation between oil price movements and gross domestic products (GDP) fluctuations in six industrial countries (USA, UK, Germany, France, Japan and Norway). Finding from the study supported a negative correlation between oil price increase and GDP growth for most of the countries, except the case of Norway where there was a positive correlation. Further, the study affirms that most of the countries in the study show evidence of asymmetric oil price effects. Furthermore, the correlation pattern of oil prices and growth differ somewhat from country to country.

Papapetrou (2001) study the dynamic relationship among oil prices, real stock prices, interest rates, real economic activity and employment in Greece. Using VAR approach, the author find evidence that suggest that changes in oil price affect real economic activity and employment in Greece. Also, oil prices are important in explaining stock price movement.

Jiménez-Rodríguez (2005) explores further the findings of Hamilton (1883) by empirically testing the effect of oil price shocks on the real economic activity of the main industrialized countries. Using both linear and non-linear models within a VAR framework, the author find evidence of a non-linear impact of oil prices on real GDP. In particular, the magnitude of the effect of oil price increases on GDP growth is larger than that of oil price declines. Among oil importing countries, oil price increases are found to have a negative impact on economic activity in all cases but Japan. Moreover, the effect of oil shocks on GDP growth differs between the two oil exporting countries in the sample, with the UK being negatively affected by an oil price increase and Norway benefiting from it.

Other studies within this research team focus more on industrialised countries and the impact of oil price shocks on industrial output (Jiménez-Rodríguez,2008), oil price shock on both output and prices for the G7 countries (Cologni and Manera,2008) and the macroeconomic consequences of several types of oil shocks across a set of industrialized countries (Peersman and Robays, 2012). The findings from the three studies are as follows:

In the case of Jiménez-Rodríguez (2008), finding suggest that the pattern of responses to an oil price shock by industrial output is diverse across the four European Monetary Union (EMU) countries under consideration (France, Germany, Italy, and Spain) but similar for the UK and US. The evidence from Cologni and Manera (2008) study reveals that in general oil price changes impact inflation rate of most of the countries and that Inflation rate shocks are transmitted to the real economy by increasing interest rates. Furthermore, the results also show evidence of different monetary policy reactions to inflationary and growth shocks.

The finding from Peersman and Robays (2012) indicate that whereas net oil and energy-importing countries typically face a permanent fall in economic activity, the impact is insignificant or even positive in net energy-exporting countries. In addition, countries that improved their net energy-position the most over time, became less vulnerable to oil supply shocks relative to other countries.

Killian (2008) examine the impact of oil supply shock on US real GDP by proposing a new measure of exogeneous oil supply shock that may reflect different timing, magnitude and sign of the shock relative to existing state of the art estimates. Finding from the study shows that only a small fraction of the observed oil price increases during oil crisis period can be attributed to oil exogeneous oil production disruption. The overall impact of exogeneous oil supply shock on the evolution of the US economy is remarkably small.

Killian (2009) explore the different shocks to oil price and macroeconomic aggregates based on US data in order to explain why regressions of macroeconomic aggregates on oil prices tend to be unstable. Whereas Killian (2010) integrate both the US gasoline market and the global crude oil market into one model and examine the demand and supply shocks on both the US gasoline price and global crude oil price. Finding from Killian (2008) shows that the recent surge (after 2003) in oil prices was driven primarily by global demand shocks, which explain why this shock so far has failed to cause a major recession in the United States. Evidence from the Killian (2010)'s joint model suggest that each demand and supply shock have distinct dynamic effects on the real price of imported crude oil and on the real retail price of gasoline in the U.S. In the short-run, 80% of the fluctuations in real price of gasoline is driven by refinery shocks and 20% by oi-market specific demand shock. In the long-run refinery shocks only accounted for 4% of the variation in real price of gasoline, whiles oil-market specific demand accounted for 54% of variation.

Cashin et al (2014) employ a Global VAR model for 38 countries/regions over the period 1979Q2–2011Q2. The results indicate that the economic consequences of a supply-driven oil-price shock are very different from those of an oil-demand shock driven by global economic activity. The effects also vary for oil-importing countries compared to energy exporters. While oil importers typically face a long-lived fall in economic activity in response to a supply-driven surge in oil prices, the impact is positive for energy-exporting countries that possess large proven oil/gas reserves. However, in response to an oil-demand disturbance, almost all countries in the sample experience long-run inflationary pressures, an increase in real output, a rise in interest rates, and a fall in equity prices.

The common feature of the studies cited above is that most of them are focus on oil price shocks on aggregate GDP relations for the US or a group of industrial countries, others are focus on a larger macroeconomic effects of oil price changes, whereas a few consider oil price changes on disaggregate output by considering manufacturing output and employment for industrialised countries. Others such as Killian (2009) looked at the effect of different shocks on both oil price and macroeconomics aggregates. In all the reviews, only one study integrated both the domestic gasoline market and the global oil market in the analysis. There is however no study from the cited review that have also incorporated the gasoline market, diesel market and the global oil market jointly in analysing the dynamic effects of demand, supply and refinery shocks. It is within this gap that the current study provides some contribution to the existing literature.

Moreover, none of the cited studies focus on a small open economy with a significant refinery capacity but depend entirely on imported crude oil such as Sweden. Furthermore, most previous studies on Sweden (including studies on OECD countries, where Sweden is in the dataset) focused on estimating transport fuel price and income elasticities (see,e.g., Brännlund, and Nordström, 2004; Karimu, 2014; Sterner, 1991; Sterner,1992), with no analysis on the impact of oil demand shocks or refinery shocks on the domestic motor fuel market. The other studies that included Sweden in their analysis of crude oil demand/ or supply shocks on selected macroeconomic variables (see, e.g., Cashin et al., 2012; Dhaoui and Saidi, 2015), did not consider the domestic transport fuel market in the analysis. For instance, Dhaoui and Saidi (2015) focused on oil demand and supply shocks on stock prices, while Cashin et al., (2012) considered both supply and demand driven oil price shocks on inflation, exchange rate and GDP, which no separate analysis was done for Sweden but rather aggregated into European major importing countries as a group. It is therefore important to provide information on the link between the oil and motor fuel market in Sweden, which is at least different from the exiting information, mostly focused on motor fuel price and income elasticities. More importantly, outcomes on the dynamic reaction of the domestic motor fuel market to global demand shocks will be important for fiscal and monetary policy analysis, as such information can be extended to macroeconomic variables to assess the impact of both crude oil and domestic motor fuel market shocks on such variables. This will help in the design of both optimal fiscal and monetary policy in periods of such shocks and depending on whether the shocks have permanent or temporary effects in the Swedish context.

The Oil Market Structure in Europe

Despite the significant progress attained with renewable energy uptake, demand for cars and industrialisation is driving the market share of refined fuels in Europe. Insights of this market feature convey valuable information for forecasting as Lukach *et al*. (2015) did, an increasing demand for gasoil/diesel within this market in the next decade. At the same time, there is evidence to suggest crude oil prices volatility remains a feature of the European oil market (Reboredo, 2014; Ibrahim *et al*., 2018).

Variations in consumer demands, EU specifications and taxes further explain the current market structure. For example, the European car market has responded to the wishes of consumers to produce fuel efficient vehicles with the view to mitigate shocks from crude oil prices (European Commission, 2008), this was partly driven by policy towards energy efficiency and security concerns within the EU. In terms of absolute demand and the impact of tax, gasoline is relatively more taxed in the EU relative to diesel. The tax uptake alone has drawn prices up; ten times higher in Europe compared to the US market (i.e. the consumer price is 2.5 times higher in Europe, European Commission, 2008).

The fuel tax structure may have further accounted for the changes in demand patterns in Europe`s oil market. This is because whilst, gasoline is taxed as a consumer “luxury” diesel is taxed at a lower level to reflect its significant contribution to European countries’ transport, construction and manufacturing (Grigolon *et al*., 2014). Moreover, given the CO2 emissions concern and that diesel engines are 20 to 40 percent more efficient, over the last decade, policies tend to be favourable for diesel cars, with the goal of shifting consumers demand towards diesel. Consequently, sectors such as the auto-mobility industry favour the production of diesel engine cars to take advantage of the price discrimination in the market. Despite that the recent advancement in gasoline engines which includes fuel efficiency, the market evidence shows the CO2 emissions in the latest gasoline engines remain higher than those from diesel- powered equivalent, given that existing policies tends to favour diesel in addition to the "feel good" effect on consumers' behaviour, demand for gasoline in the Europe market may lag behind diesel (Morgadinho *et al*., 2015).

Structurally, cost of refinery significantly affects the production profile and the relative market price for both gasoline and diesel. Broadly speaking, the nature and cost of refinery production exhibits sensitivity and reveals exposures in the fuel economy. For example, analysis of crude prices (before refinery) in comparison to refined product prices from 2004 through to 2006 in Europe provides an indication that, production cost is a major driver of refined products price behaviour (European Commission, 2008). Drawing from this evidence, it is difficult to decouple the oil retail market from the refinery industry. Despite these claims, few studies have empirically examined the effects of these two especially in places such as Sweden, where there has been a deliberate effort by policies makers to decarbonise the energy sector since the first oil crisis in early 1970s. These efforts included the carbon and energy taxes introduced by the Swedish government, carbon trading such the European Union Emission Trading System (EUETS), developing renewables for the transport sector, such as biofuels and promoting electric vehicles, with greater penetration of renewables into power generation (IEA,2014).

In 2011, though the overall oil demand has decreased in Sweden over the 2000 value, that in the transport sector increased to about 66 percent, which is an increase over the 2000 value (about 0.6 annual increase). The increase in the transport share of oil demand is due to the continue shifting towards diesel demand, which has increased about 4.7% per year over the period 2000 to 2011, whereas that of gasoline declined by 1.2 % per year (IEA,2014).

The refinery sector is dominated by three companies (Preem AB, St1 and Nynas) with most of the crude oil in 2012 (82%) imported from Russia, Norway and Denmark, while the retailing of oil products is dominated by four companies (Preem, Statoil, QK-Q8 and St1), suggesting a less competitive market for oil and oil products in Sweden

3. Data and the Empirical Model

The data used for the study were taken from the Swedish Petroleum Institute (SPI) and the Thomson DataStream for the period January 2001 to November 2014. This is a monthly data and the choice of the starting date was determined by data availability for our key variables, especially gasoline and diesel prices at monthly frequency from the SPI. The variables included in the dataset are; crude oil price in U.S. dollars per barrel, gasoline consumption[1], gasoline price in Swedish kronor (SEK) per liter, diesel consumption, diesel price in SEK per liter, exchange rate (the rate between the Swedish kronor and the U.S. dollar) and consumer price index (CPI). The world crude oil price was taken from DataStream. This variable is weighted by the Swedish CPI to convert it into real prices. The reason for the conversion of the nominal price to real is to avoid the influence of inflation dynamics on oil and motor fuel market shocks.

Gasoline and diesel consumption are in cubic meters and were taken from the SPI web site (www.spbi.se). Gasoline and diesel prices are in nominal terms but converted into real terms using the CPI; these variables are also from the SPI, while the exchange rate variable was taken from the Swedish Central Bank (SCB). The purpose of the exchange rate variable is to help convert the crude oil price in U.S. dollars to SEK per barrel, since the motor fuel price variables (gasoline and diesel) are all in SEK. The summary statistics for these variables are in Table A1 in the appendix, while figure 1 present the evolution of some of key variables over the sampled period. Figure 1 shows similar pattern in terms of trend in the evolution of both real crude oil price and Swedish gasoline price (real). Both variables (crude oil price and gasoline price) depict an increasing trend till around late 2008 that we see a sharp drop in prices.

[Insert Figure 1 Here]

A similar pattern is shown by the real diesel price. The sharp drop in both prices, especially crude oil and gasoline prices coincided with the 2008 financial crisis that affected the world economy. The two series however, recovered in the early 2010. The gasoline consumption variable on the other hand fluctuated frequently but with a decreasing trend especially, after mid-2008. This variable shows seasonal fluctuations that peaked in the month of July every year and reach the lowest point in February each year. For the estimation, we seasonally adjusted this variable. The diesel consumption series on the other hand shows an increasing trend with seasonal fluctuations similar to those shown by the gasoline consumption variable. We also seasonally adjusted the diesel consumption variable before including it in the VAR model for the estimation. The different patterns in trend depicted by the consumption variables are in line with the Swedish policy that favors vehicles that run on diesel fuel.

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[1] Throughout the article we used consumption and demand interchangeably.

The Swedish energy policy among other things promoted the demand for diesel vehicles and diesel consumption relative to gasoline. Comparing the price variables to that of consumption, the following are apparent; (1) in general, the prices trended upwards while gasoline consumption depicts a downward trend and that of diesel an upward trend, (2) whereas the decreasing trend for Swedish gasoline consumption is very evident throughout the period after mid-2008, the increasing trend for both the crude oil and gasoline price variables disappear after the mid-2012 and become constant with fluctuations until late 2014 that they start to decline. The declining gasoline trend could be explained by the increasing move away from gasoline driven automobiles to diesel-based engines as a result of many factors including changes in consumer preference, growth in heavy vehicles, policy effects, efficiency concerns among the Swedish population and the impact of the recession that followed the 2008 financial crisis. Last but not the least, both diesel price and consumption reveal increasing trends in general.

The boxplot presented in figure 2 indicates significant variation around the mean for diesel price relative to gasoline price as shown by the size of the box reflecting the interquartile rage for each of the variables. Also, the median value of gasoline price is higher than that of diesel (the median value is the solid line inside each box). Considering the boxplot for the consumption variables, the reverse in terms of variability around the mean is shown. Gasoline consumption is slightly more variable around the mean relative to that of diesel consumption. This shows that over the sampled period covered by the data, gasoline is still the fuel that is consumed the most relative to diesel. Diesel consumption is however catching up strongly in terms of consumption, likely influenced in part by the relative lower diesel prices induced by both Swedish and EU level energy policies, among other things.

[Insert Figure 2 Here]

3.1. Econometric Model

Our modeling strategy is based on a structural vector autoregressive (SVAR) framework, similar to the model implemented in Kilian (2008, 2009, and 2010) and Davis and Kilian (2011). The structural VAR model is specified as:

$$A_0 y_t = c + \sum_{i=1}^{p} A_i^* y_{t-i} + \varepsilon_t \ , \qquad (1)$$

where y_t is a $k \times 1$ vector of observed variables, *p* denote the lag length, A^*_i for *i=1,…..,p*, are the structural coefficients and ε_t denotes the vector of serially and mutually uncorrelated structural innovations. We assume a recursive structure for the matrix A_0 with a lower triangular restriction imposed for identification. Given the recursive nature of the matrix A_0 together with the identifying restriction outline under the section “identification of shocks” below, the reduced-form errors e_t can be decomposed according to $e_t = A_0^{-1}\varepsilon_t$:

$$e_t = \begin{pmatrix} e_t^{\text{Crude oil Price}} \\ e_t^{\text{Motor fuel Price}} \\ e_t^{\text{Gasoline Consumption}} \\ e_t^{\text{Diesel Consumption}} \end{pmatrix} = \begin{bmatrix} a_{11} & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix}^{-1} \begin{pmatrix} \varepsilon_t^{\text{Oil demand shock}} \\ \varepsilon_t^{\text{Refinery shock}} \\ \varepsilon_t^{\text{Gasoline demand shock}} \\ \varepsilon_t^{\text{Diesel demand shock}} \end{pmatrix}$$

The three variables are World crude oil price (CP), before tax Swedish gasoline price (GP, a proxy for motor fuel price, henceforth it will be called motor fuel price) weighted by the consumer price index to convert it into real prices and both gasoline (GC) and diesel (DC) consumption, details on each of the series is in the data section.

3.2. Identification of Shocks

Following Kilian (2010), we decomposed the innovations into oil market demand shocks, refinery shocks to capture Swedish motor fuel market supply shocks and motor fuel demand shocks that reflects Swedish gasoline and diesel demand shocks, respectively. We however did not consider explicitly global supply shocks as done in Kilian (2010). The reason is that, our interest lies in assessing the impact of oil demand shocks on Swedish motor fuel prices and consumption and from the fact that previous literature, especially on the United States (Kilian and Vega, 2011) finds insignificant effects of global supply shocks on domestic gasoline prices, especially on monthly frequency. Further, we postulate that any world supply disruption is captured via world demand shocks, especially in the short run.

The identifying assumptions are that, (1) in the same month, only oil market demand shocks affect world crude oil price, (2) while both oil market demand and refinery shocks affect real Swedish motor fuel prices. Finally, (3) oil demand, refinery and gasoline demand shocks affect gasoline consumption in a month, and (4) oil demand, refinery, gasoline demand and diesel demand shocks affect diesel consumption.

These identification restrictions are reasonable, for instance, Swedish oil demand in 2012 was close to 310 thousand barrels per day (IEA, 2014) compared to world demand that was 91.98 million barrel per day (IEA, 2015). This indicates that Swedish demand is relatively small to significantly affect world oil demand and price. We therefore imposed the restriction that both Swedish demand

and refinery (real gasoline price shocks) do not affect crude oil prices in the same month. The implication of this restriction is that innovations in crude oil prices is due to world market oil demand shocks, which includes precautionary demand to hedge possible future supply shortfalls, increased in energy-using durables such as automobiles, especially in the developing countries and possible unexpected weather shocks such as extreme winters and summers. Unlike Kilian (2009), we do not rule out any of the factors stated above as possible drivers for oil demand shocks since we are only interested in the shocks not the factors that specifically drive the shocks. Likewise, we do not expect Swedish motor fuel price shocks to affect world crude oil prices, given that the share of Swedish oil demand is relatively small, any responses of local demand to gasoline prices will not have a significant impact on world crude oil price.

The exclusion restriction for real motor fuel price innovations is that, gasoline demand shocks do not affect motor fuel prices in the same month, implying predetermine motor fuel prices. This assumption of predetermine motor fuel prices is valid given the monthly frequency of the data, but less appropriate in the context of annual frequency, as one cannot completely rule out feedback effects from motor fuel consumption to prices. Further, we expected both crude oil demand shocks and refinery shocks to have an impact on Swedish gasoline consumption. An unexpected increase in world oil demand will impact motor fuel prices via refinery cost and this will have consequences on Swedish gasoline consumption. Last but not the least, unexpected increases in crude oil demand, refinery, gasoline and diesel demand to affect diesel consumption.

3.4. Reduced form VAR Specification

The underlying VAR for our SVAR model estimation used 3 lags for each of the variables, chosen based on both Akaike information criterion (AIC) and Schwarz information criterion (SC), with a maximum lag length of 12. The restriction of the optimal leg length to 12 is due to the time period covered in the dataset and number of variables in our VAR model (a vector of 4 variables). The estimation is done in the “vars-package” in R, which utilizes least squares methodology for the estimation. Before the estimation, it is generally recommended to check for the time series properties of each of the variables in the VAR specifically, the unit root properties. However as argued in Kilian (2010) “unit root test is notoriously uninformative about the presence of a unit root, when data are so persistent and time series are short”. We treat the unit root test results with some caution since we have a highly persistent and short data, which poses challenges to the existing unit root testing approaches.

Against this background, irrespective of the unit root test outcome for the real price variables, we will include them in levels not in first difference in order to capture the cyclical variation and the impact of that on motor fuel consumption similar to Kilian (2010). The benefit of the level specification for the real price variables is that, the VAR model is still consistent whether the variables are integrated or not (see, e.g., Lütkepohl, 2007, Kilian, 2010), and it also makes it possible to capture shocks that coincide with cyclical variations. The unit root test, reported in Table A2 in the appendix are based on both Dickey–Fuller generalized least squares (dfgls) with 3 lags and Kwiatkowski, Phillips, Schmidt, and Shin (KPSS, 1992) unit root test. Both results indicate that each of the variables are integrated of order zero, except in the case of gasoline consumption variable, which is not integrated in the dfgls unit root test, whereas the null of trend stationary series could not be rejected at the 5% significance level based on the KPSS test. The implication of the outcome of the two-unit root test on gasoline consumption is that the variable is likely fractionally integrated. We decided to impose stationary process on the gasoline consumption, since for most cases, fractionally integrated series are stationary[2].

4. Results and Discussion

The four variables set in our model is (CP, GP, GC, DC), each of them is in logarithm. We apply the SVAR model as described in eq. (1) and the respective impulses response functions for the variable of interest are presented below. Before we discuss the impulse responses, it is important to discuss the model diagnostics to be sure our model passes the required tests for a good model. We focus on four diagnostic features of the model, thus if the model residuals pass serial correlation test (Portmanteau-Q test), heteroscedasticity (multivariate arch-LM test), normality (Jarque-Bera test) and stability of the model.

Table 1 present the estimated model diagnostics related to serial correlation, heteroscedasticity and normality, while the stability result is reported in figure A1 in the appendix. The results reported in Table 1 shows that the model is a good one, since it passes all three tests. Implying that the model residuals are not serially correlated, no problems of heteroscedasticity and the residuals are normally distributed. Moreover, the stability plot in figure A1 also shows that each of the estimated equation residuals in the underlying VAR model for the SVAR is stable as they fall within the unit root band.

[2] Irrespective of the unit root test outcome of stationary series for our variables of interest, we still checked for cointegration using Johansen procedure. The test results indicates presence of three co- integration vectors, we did not report this since the formal unit root test support stationary process for the set of variables in our VAR set-up

[Insert Table 1 Here]

4.1. Responses to Oil Demand Shocks

The first set of results is to understand the evolution of the impact of unexpected changes in oil demand shocks on crude oil price, domestic motor fuel price and motor fuel consumption (gasoline and diesel). Figure 3 present the evolution of these responses to one standard deviation of oil demand (0.0052) shocks along with the 90% bootstrap confidence interval. 9 months after an unexpected increase in global oil demand, motor fuel price response drops close to zero and completely dissipates after 12 months. The implication from this is that as global demand for crude oil increases, it pushes up oil prices, which in turn increases the cost of the refineries. The high cost of crude oil is reflected in the producer price of motor fuel, and this explains the positive response of motor fuel prices to oil demand shocks as presented in figure 3. Global oil price response is positive to a positive oil demand shock, which is in line with demand theory. The response is immediate and large within the first 6 months and decline towards zero after a year. Given the normalization, these results indicate that oil price reacted more to oil demand shocks (one standard deviation of the shocks) relative to the reaction by motor fuel price to the same shock.

Figure 3 also indicate a negative response of gasoline demand to a positive oil demand shock. The response peaks in the first month and sharply declines and lies below 0.2% after the 6^{th} month. There is a one-month delay in the response of diesel demand to one standard deviation of oil demand shock. The response, which is positive only lasted for five months (From February to May) and become indistinguishable from zero thereafter. Both gasoline and diesel demand response to oil demand shock is small and short lived relative to both oil and motor fuel price responses. This finding is in line with the finding from Killian (2009), which suggested that the effect of precautional demand shocks (which is related to gasoline and diesel specific demand shocks) on prices is immediate and large relative to aggregate demand shock. The reason is that these types of shocks are driven by uncertainty about future oil supply shortfalls, which immediately triggers behavioral responses to the price changes much more than production disruption or aggregate demand shocks.

[Insert Figure 3 Here]

4.2. Response to Refinery Shocks

The next result is to examine the responses of motor fuel price, both gasoline and diesel demand to one-standard deviation (0.0011) refinery shocks. This is very important as it allows us to analyze the impact of refinery shocks on both Swedish motor fuel price and consumption, which has implication for both precautionary demand and motor fuel insecurity issues. That is, the nature of the dynamic responses could help determine the level of responsiveness of both Swedish motor fuel demand and prices to refinery disruptions. This set of result is presented in figure 4 and reveals a refinery disruption that causes supply outage to immediately increase motor fuel price in Sweden. The motor fuel price response is large, peaks in the 3rd month declines thereafter with large impacts in the first 5 months. The impact of the refinery shocks completely dies off after a year.

An unanticipated increase in the disruption in Swedish refinery output causes a decrease in gasoline demand, with a significant reaction from the 4th to the 7th month. This means that refinery disruption that leads to supply outage causes an increase in motor fuel price, which has a negative consequence on gasoline demand as expected from demand theory. The response of diesel demand on the other hand is insignificant after the second month, as the impact is close to zero after the second month.

[Insert Figure 4 Here]

4.3. Fraction of the Variation in Swedish Motor Fuel Price, Gasoline and Diesel Consumption Attributable to each shock

Next, we decomposed the variation in both the domestic motor fuel price and consumption into the average contribution of each of the shocks. The idea is to highlight the contribution of each of the shocks to the total variation of domestic motor fuel price and consumption. The contributions of each of the shocks are reported in Table 2, 3 and 4, respectively for real motor fuel price, gasoline consumption and diesel consumption.

The values are in percentages and indicate that on impact 80% of the total variation of real motor fuel price is attributable to refinery shock, close to 20% to oil demand shock, while both gasoline and diesel demand shocks' contribution is zero. This finding is consistent with the finding in Kilian (2010) for the U.S. market. In the long-run, the contribution of refinery shocks decreased marginally to 79.6%, while that of oil demand shock decreased to 13.5%, gasoline demand shocks increased from 0% to 6% and diesel demand shocks from 0% to 0.9%.

On impact, 97.7% of the variation in gasoline consumption is attributable to gasoline demand shocks, 1.7% to oil demand shocks, 0.6% to refinery shocks and 0% to diesel demand shocks. In the long-run, the contribution of gasoline demand shocks decreases to 77.7%, whereas the contribution of both refinery and diesel demand shocks to the total variation in gasoline consumption increased. The impact of refinery shocks and diesel demand shocks increased to 11.7% and 9.7%, respectively. On the contrary, in the long-run, the impact of oil demand shocks decreased marginally to 0.9%.

Last but not the least, the immediate impact of diesel demand shocks on the total variation of diesel consumption is about 64.3%, gasoline demand shocks contribute 35.6% of the variation and the remaining contribution is from refinery shocks, implying a zero contribution on impact by oil demand shocks. In the long-run, the contribution by diesel demand decreased to 50.6%, while the impact of the other shocks increased. Specifically, gasoline demand shocks, oil demand shocks and refinery shocks increased to 45.6%, 2.5% and 1.3%, respectively.

[Insert Table 2 Here]
[Insert Table 3 Here]
[Insert Table 4 Here]

One caveat in the analysis presented above is that, we used real gasoline price as a proxy for motor fuel price. Which might mask the dynamic impact of diesel fuel market in the analysis, because using only gasoline price to reflect motor fuel price might not capture diesel fuel specific features and might over or underestimate the dynamic relationship between diesel consumption and refinery shocks. In order to address this, we created a motor fuel price by weighting the price of gasoline and diesel, using equal 0.5 weights for each of the prices (gasoline and diesel price). Re-estimating our main model by replacing gasoline price with the weighted motor fuel price produced comparable impulse response functions as reported in figure A2 (in the appendix). This suggest that, our use of gasoline price[3] as a proxy for motor fuel price is reasonable and appropriate to capture the dynamics between the motor fuel market and the oil market, at least for Sweden.

Another concern is the possibility that the underlying VAR coefficients and the variance-covariance might be time varying. If this is the case in the data, these time variations have to be modelled and incorporated in the estimation process to fully and accurately capture the responses to shocks. As a check on the time variations we apply a time varying parameter structural VAR (TVP-VAR) to the dataset. The results from this exercise indicated slight differences in the impulse response functions

[3] We also estimated a SVAR model with a set of five variables, in which both real gasoline and diesel price were included in the model. The model's diagnostics were not satisfactory, especially the residuals were serially correlated, not normally distributed and failed to pass the heteroscedasticity test. We therefore decided to stick with using gasoline price as a proxy for motor fuel price instead of including both gasoline and diesel prices. This result is not reported but available on request.

over time, but the differences are not significant. We therefore stick with the results from the constant SVAR. The TVP-VAR impulse response functions are reported in figure A3 (in the appendix).

5. Conclusion

The main objective of this study is to examine the impact of oil demand and refinery shocks on motor fuel price and consumption in Sweden. There are some prior reasons to expect a link between the oil market and motor fuel market and therefore modeling jointly these two markets is rather closer to reality than modeling them separately. More so in the production processes of refined products, both fuels (gasoline and diesel) are jointly produced. Hence, the need to model these fuels jointly. This, couple with the switching behavior towards diesel-based vehicles, imply a possibly different responses of both motor fuel price and consumption to various shocks, especially, oil demand and refinery shocks.

Our analysis implemented a SVAR approach, which imposed a recursive identification structure for the structural innovation. Our key results (especially on gasoline) are in line with previous literature that incorporate both the oil and gasoline market in to one model, specifically that of Kilian (2010). Consistent with the finding in Kilian (2010), unexpected increase in oil demand, possibly due to precautionary demand driven by uncertainty about future crude oil supply among other things causes a positive reaction of real motor fuel price. The results further showed that gasoline and diesel consumption reacted differently to oil demand shock. Gasoline consumption reacted negatively while diesel consumption positively. This highlights the evolution of motor fuel in Sweden and underlines the impact of energy policy that favors diesel fuel relative to gasoline. The implication is that, an unexpected increase in oil demand tends to have an opposite effect on the two fuels' consumption (gasoline and diesel), partly due to behavioral changes that favor diesel fuel and climate/energy policy both at national and EU-level, among other things.

Moreover, motor fuel price reacted positively to refinery shock. The reaction on impact of the shock is larger in the first month but gradually declines towards zero after the 9th month, evidently suggesting that in about a year, the motor fuel market adjust fully to refinery shocks in Sweden. This means that motor fuel supply disruption due to refinery shocks, significantly impacted domestic motor fuel price in the immediate periods after the shock, because it takes some time to import refined fuels from abroad to augment the shortfall in supply. However, after a year, both imports of refined products and domestic supply adjustment, tends to fully correct for the effects of the refinery shock. Gasoline demand shocks contribute close to 46% of total variation in diesel demand in the long-run, suggesting the significant influence of the gasoline market on the diesel market in Sweden. Diesel on the other hand only contributes close to 10% in the long-run on the total variation in Gasoline consumption.

Our analysis complements previous literature on the link between the oil market and motor fuel market, but with an interesting finding that the reaction of the gasoline market is different to the reaction of the diesel market to both oil demand and refinery shocks, at least in Sweden.

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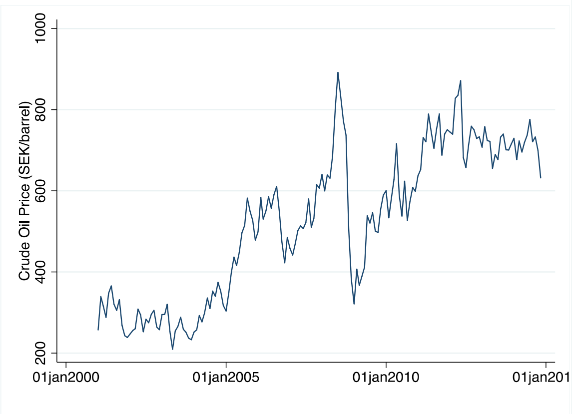
Appendix

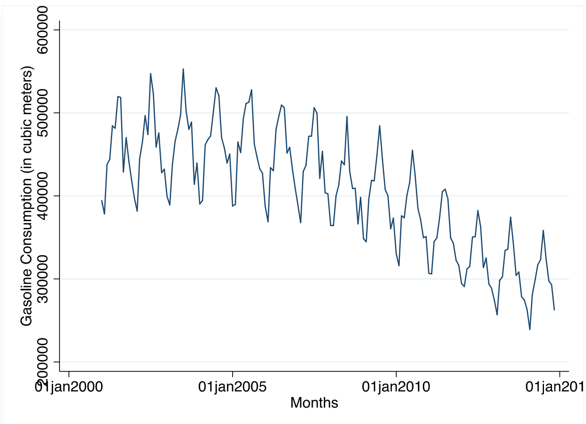
[Insert Table A1 Here]
[Insert Table A2 Here]

[Insert Figure A1 Here]

[Insert Figure A2 Here]

[Insert Figure A3 Here]





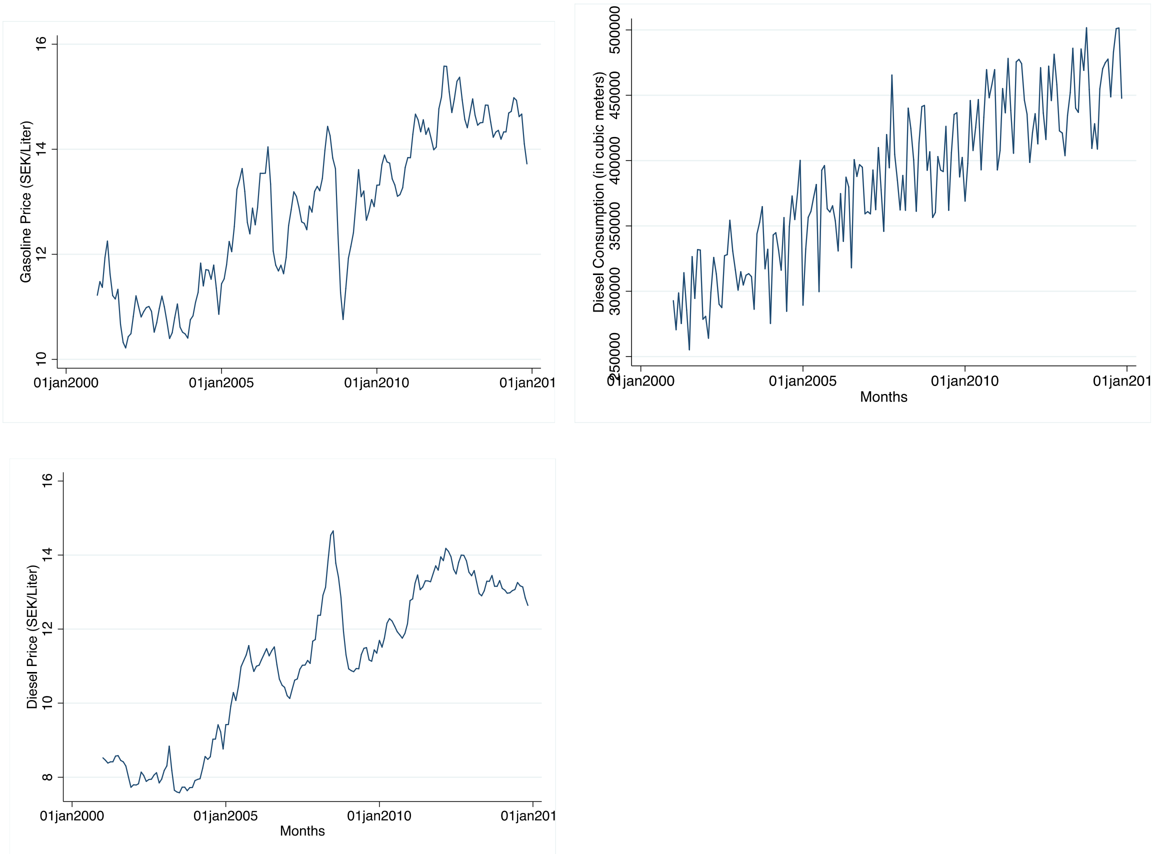
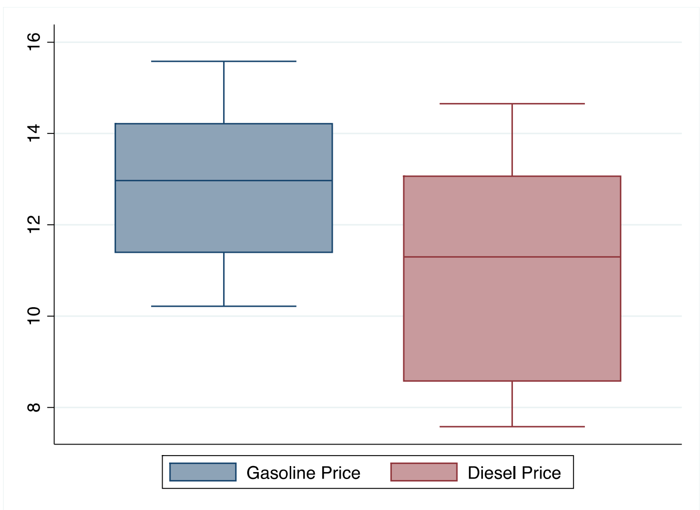


Figure 1: Plot of real price of crude oil, gasoline consumption, real gasoline price, diesel consumption and real diesel price over the sample period



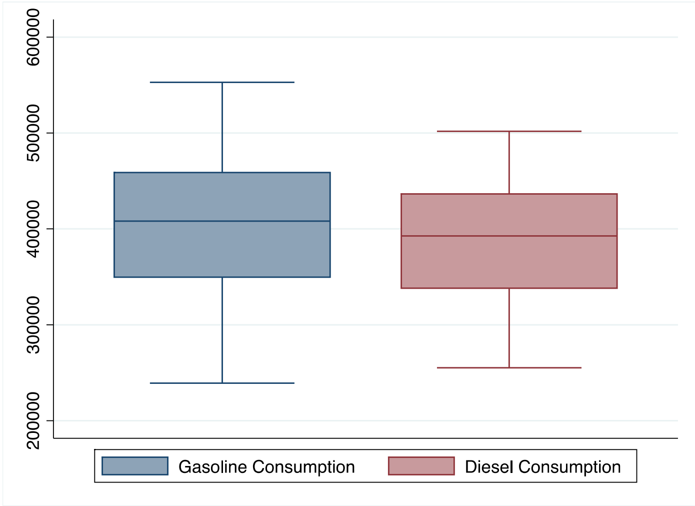


Figure 2: Boxplot for real gas price, real diesel price, and diesel and gasoline consumption.

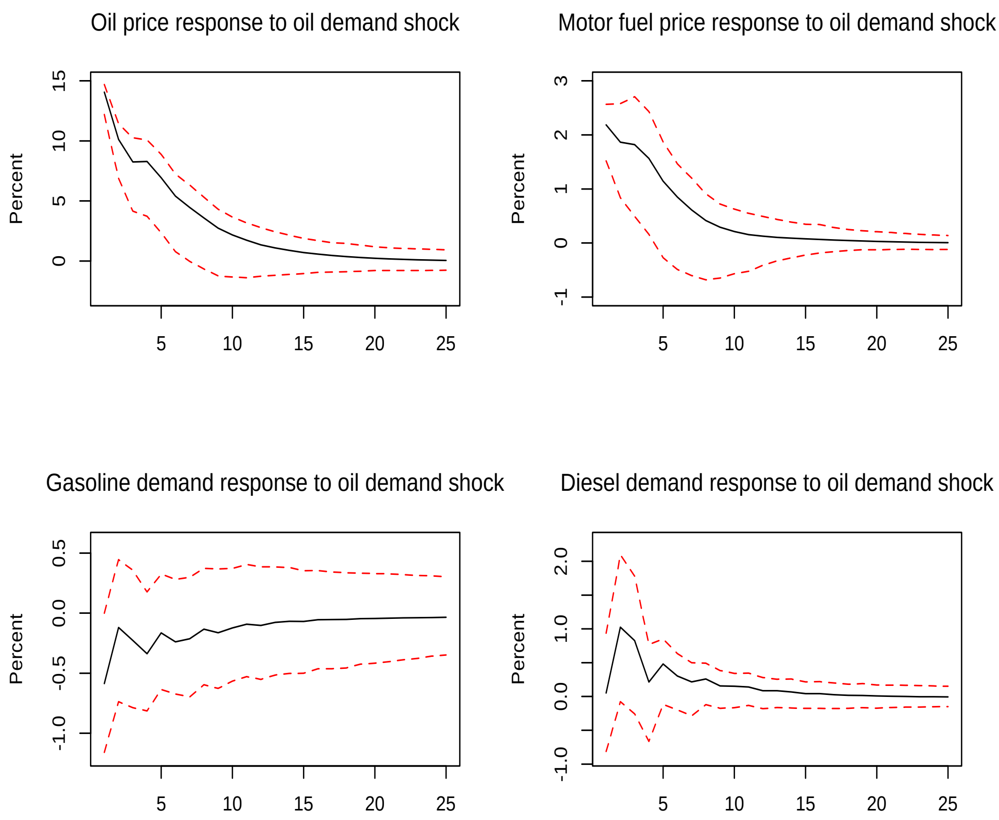


Figure 3: Oil Price, Motor fuel price, Gasoline demand and Diesel demand responses to one standard deviation in oil demand shocks.

Note: The vertical axis is the response to the shocks (in percentage) and the horizontal axis is the period (in months). The solid lines are the responses and the dash lines are the 90% bootstrap confidence intervals.

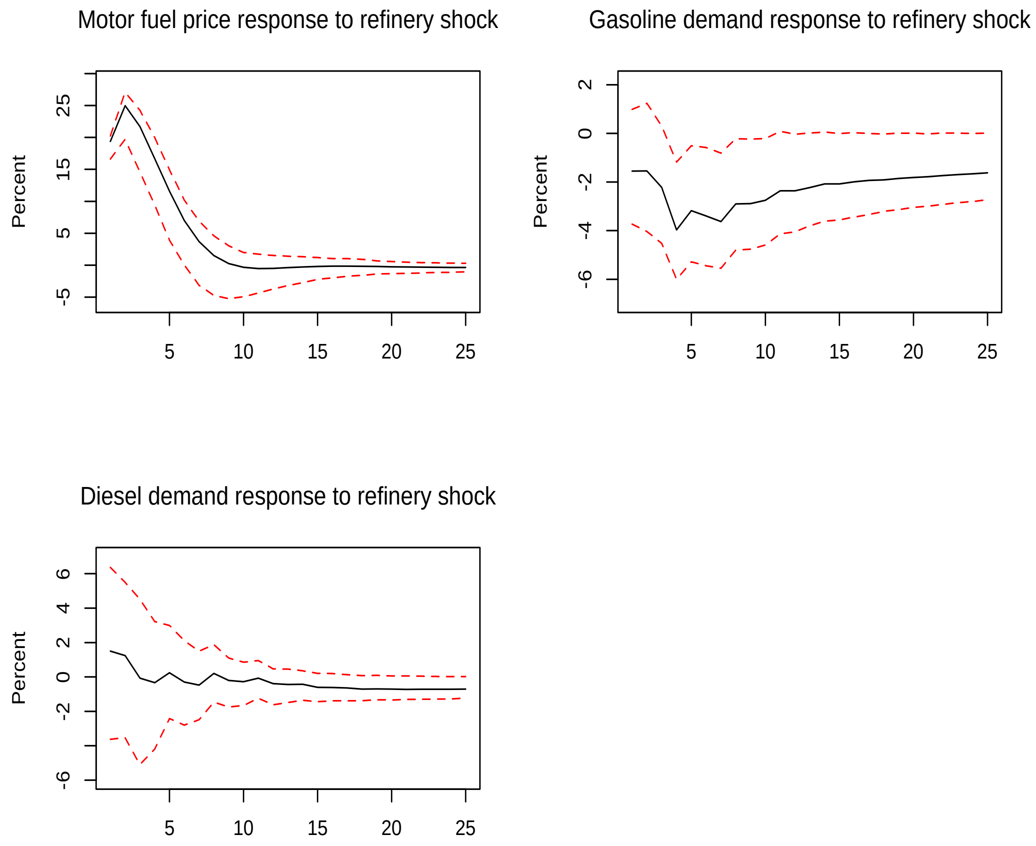


Figure 4: Motor fuel price, Gasoline demand and Diesel demand responses to one standard deviation in refinery shocks.

Note: The vertical axis is the response to the shocks (in percentage) and the horizontal axis is the period (in months). The solid lines are the responses and the dash lines are the 90% bootstrap confidence intervals.

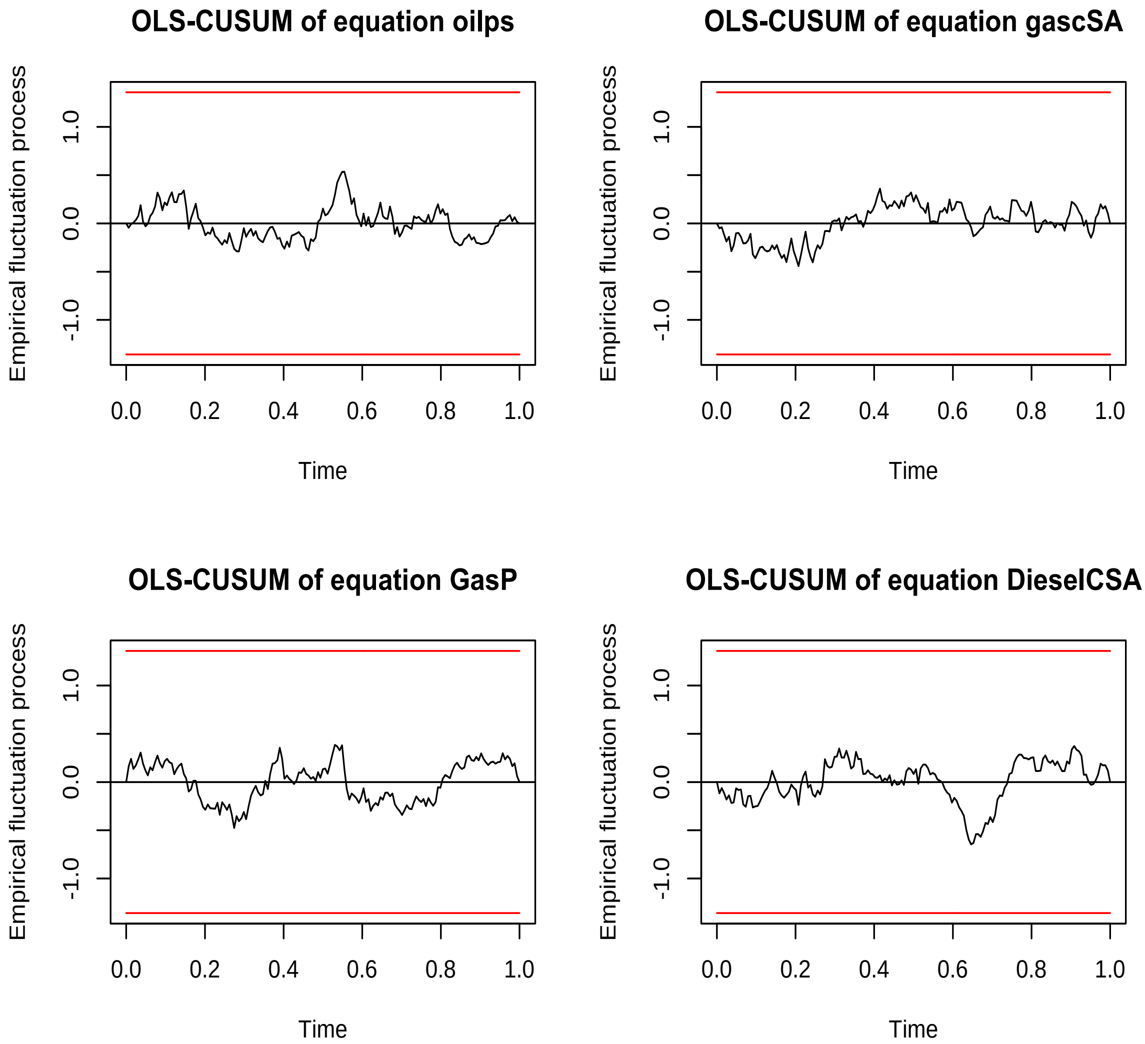


Figure A1: Stability test for the estimated underlying VAR model

Oilps, gascSA, GasP, DieselCSA denote real oil price, gasoline consumption, and real gasoline price and diesel consumption, respectively.

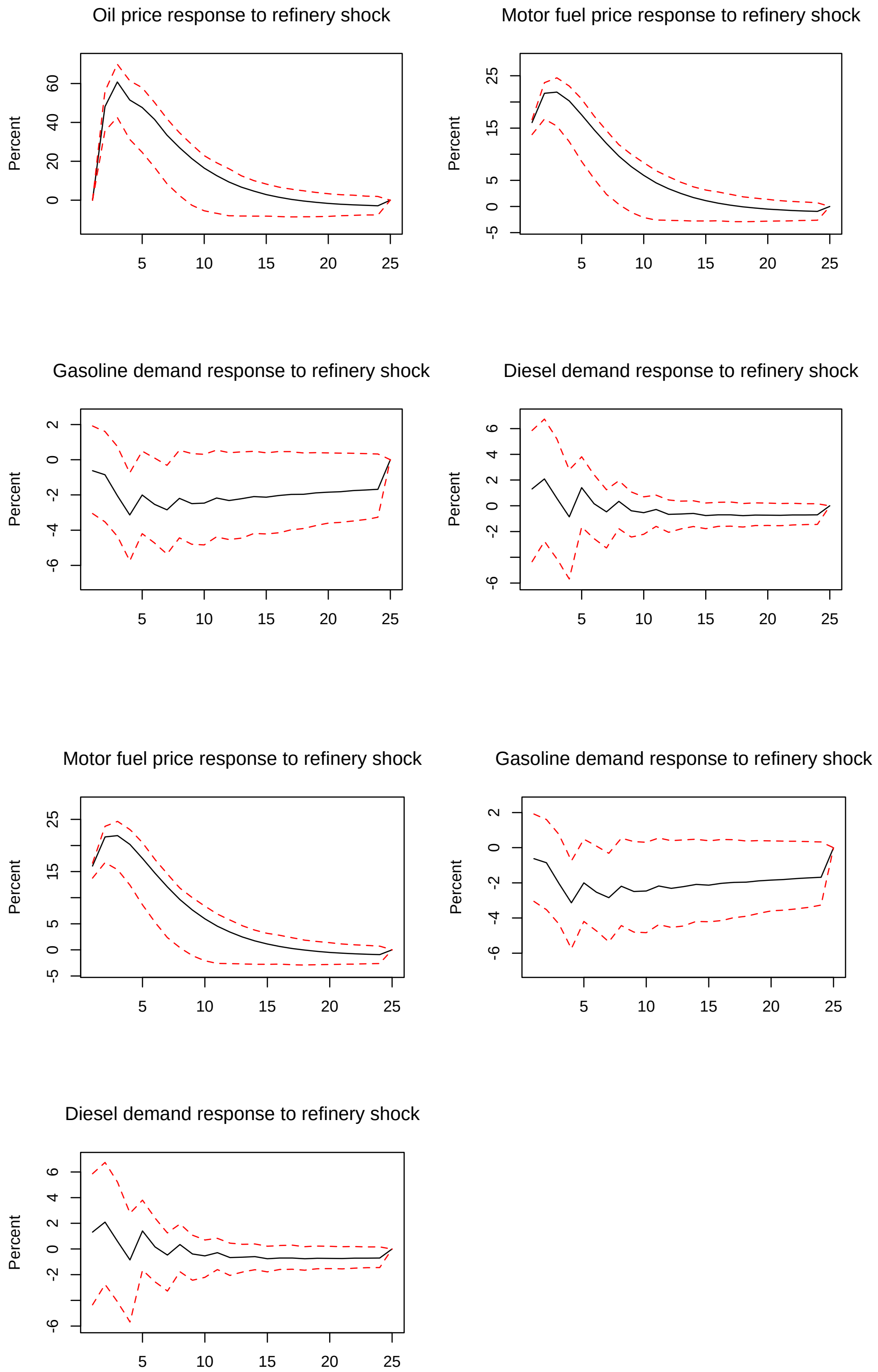


Figure A2: Impulse response function for oil demand and refinery shock with motor fuel price constructed as a weighted price of real gasoline and diesel prices.

Note: The vertical axis is the response to the shocks (in percentage) and the horizontal axis is the period (in months). The solid lines are the responses and the dash lines are the 90% bootstrap confidence intervals.

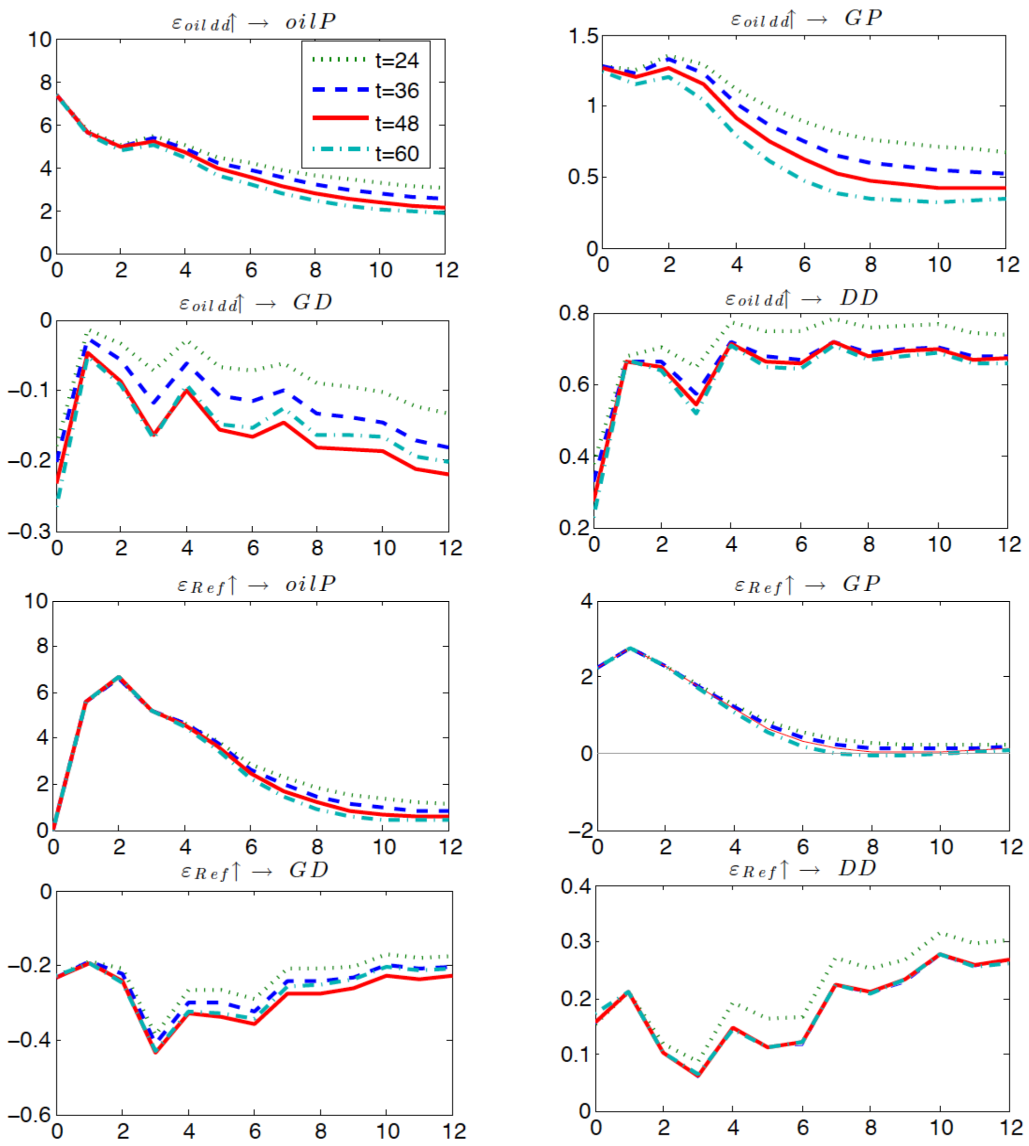


Figure A3: TVP-VAR impulse response functions for four different time periods, 24, 36,48 and 60th month.

Note: The vertical axis is the response to the shocks (in percentage) and the horizontal axis is the period (in months). The estimation was done in matlab based on Nakajima, J., 2011 code, which is however modified to suit our data and interest. *oilP, GP, GD and DD denote global real crude oil price, real gasoline price (a proxy for motor fuel price), gasoline consumption and Diesel consumption, respectively, while* $\varepsilon_{\mathrm{Oildd}}, \varepsilon_{\mathrm{Ref}}$ *represent oil demand and refinery shocks, respectively.*

Table 1. Diagnostic test for the estimated model

Model	Q_{10}	*p*-value	JB_4	*p*-value	M-$ARCH_5$	*p*-value
P=3	130.54	0.111	12.045	0.149	515.73	0.303

Notes: Q_{10} denotes the Portmanteau Q test with 10 lags. The null hypothesis for this test is that of no serial correlation. Small sample adjustment is made in the testing procedure for this study. JB stand for the Jarque-Bera normality test for multivariate case with four variables. The null hypothesis for this test is that of normal residuals. The M-ARCH stand for multivariate arch-LM test for heteroscedasticity, the test statistic is chi-square distributed and the null states that the variance of the residuals is the same over time. P is the lag length for the reduced-form VA R model

Table 2: Contribution of shocks to variation in real motor fuel price

Horizone	Oil shock	Demand	Refinery shock	Gasoline demand shock	Diesel demand shock
1	20.0		80.0	0.0	0.0
2	13.7		84.3	1.9	0.1
3	13.0		84.1	2.8	0.1
4	13.2		83.6	3.1	0.2
5	13.2		82.8	3.6	0.4
10	13.7		81.2	4.3	0.7
12	13.7		81.1	4.4	0.7
96	13.5		79.6	6.0	0.9

Table 3: Contribution of shocks to variation in Gasoline consumption

Horizone	Oil Demand shock	Refinery shock	Gasoline demand shock	Diesel demand shock
1	1.7	0.6	97.7	0.0
2	1.7	1.2	95.0	2.2
3	1.7	2.1	92.7	3.4
4	1.7	4.3	90.8	3.2
5	1.8	5.8	88.0	4.4
10	1.6	10.2	81.4	6.8
12	1.5	10.5	80.8	7.2
96	0.9	11.7	77.7	9.7

Table 4: Contribution of shocks to variation in Diesel consumption

Horizone	Oil Demand shock	Refinery shock	Gasoline demand shock	Diesel demand shock
1	0.0	0.2	35.6	64.3
2	1.4	0.3	37.4	60.9
3	2.3	0.3	37.4	60.1
4	2.2	0.2	40.1	57.4
5	2.5	0.2	40.4	56.9
10	2.7	0.3	42.2	54.8
12	2.7	0.3	42.7	54.4
96	2.5	1.3	45.6	50.6

Table A1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Crude Oil Price (real)	167	521.150	184.701	209.621	891.923
Gasoline Price(real)	167	12.823	1.477	10.216	15.581
Diesel Price(real)	167	11.049	2.113	7.580	14.651
Gasoline Consumption	167	404460	71243.47	239193.9	552799
Diesel Consumption	167	385922.6	60402.89	255207	501696
Consumer Price Index	167	0.931	0.052	0.831	1.000
Exchange rate	167	7.503	1.222	5.94	10.88

Table A2: Unit root test

variable	DGLS-Test Statistic	5% critical value	KPSS-Test Statistic	5% critical value
Crude Oil Price (real)	-3.008	-2.963	0.289	0.146
Gasoline Price(real)	-4.132	-2.963	0.177	0.146
Gasoline Consumption	-0.465	-2.963	1.010	0.146
Diesel Consumption	-3.116	-2.963	0.562	0.146

Note: DGLS-test denotes the Dickey–Fuller generalized least squares (dfgls) with 3 lags, KPSS stand for Kwiatkowski, Phillips, Schmidt, and Shin unit root test. These unit root results were obtained using Stata.