Oil price shocks and stock market: a Vector Autoregressive Analysis

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Chapter 1

Introduction

After the major oil price shocks of the 1970s, a large literature is dedicated to the study of the relationship between oil prices and real economic activity. The effect that oil price shocks have on the economy cannot be downplayed. As stated in Adelman (1993)[1]:

Oil is so significant in the international economy that forecasts of economic growth are routinely qualified with the caveat: 'provided there is no oil shock.

Hamilton (1983)[16] showed in a seminal paper that oil price increases were at least partly responsible for every post-World War II US recessions except the one in 1960. Since then, Hamilton’s findings have been tested using alternative data and estimation procedures. In contrast to the large volume of studies that investigate the link between oil price shocks and macroeconomic variables, a relatively little work is dedicated to the relationship between oil price shocks and financial markets.

There are two channels through which changes in oil prices could affect economic activity:

- the change in the price of crude oil,
- the increase in uncertainty about future values (volatility).

This study aims to estimate the effects of oil price shocks and oil price volatility on the real stock returns of USA, UK, Germany and France over the period 1990:1-2013:12. Monthly data are used.

According to this, a multivariate VAR analysis is conducted with two different specifications for the oil prices. The first is the linear specification of oil price shock, that is defined as the percentage change in the real price of oil; the second is a measure of the uncertainty about oil prices, represented by a realized oil price variance series, constructed from daily crude oil future prices. After the description of the included variables and the presentation of the VAR model, the study proceeds with the analysis of the VAR coefficients, of the Granger causality, of the impulse response functions and of the variance decomposition.
I considered important to conduct this analysis on different countries, in order to better identify effects that may be systematic across countries rather than country specific.

Another significant aspect is to consider the measures of real oil price shocks calculated as world real oil price as well as national real oil price, to find out which of the two specifications has highest explanatory power.

Attention is also paid to the asymmetry hypothesis, which states that positive and negative oil price shocks have different impacts on the macroeconomic variables.

1.1 Previous literature and empirical evidence

Given the crucial role of crude oil in the global economy, the relationship between oil prices and economic activity has received great attention by economists over the years, especially since the early 1980s. Hamilton (1983)[16] notes that seven of eight regressions in the period 1948 to 1980 were preceded by significant oil price increases and hence establishes a causal oil-price-GDP link for the USA. These findings were then confirmed by Burbidge and Harrison (1984)[7], Gisser and Goodwin (1986)[14], Mork (1989)[28], Ferderer (1996)[12] and others.

A corresponding study for other major OECD countries by Mork et al. (1994)[29], revealed that the negative oil-price-GDP effect prevails in almost all industrialized economies, and it is surprisingly similar considering both net importers and exporters of oil.

Blanchard and Gali (2007)[4] suggest that industrialized countries have become less sensitive since the 1970s for various reasons, including reduced reliance on oil as an input factor to industrial production.

Due to limited availability of data, the majority of existing literature analyzed the oil-price-GDP relationship in major OECD economies. Notable exceptions are Lee et al. (2001)[25] who study the impact of oil price shocks on Japanese monetary policy and macroeconomy; as well as Cunado and Gracia (2005)[9] who conduct cointegration and Granger causality test for six Asian economies. They find that there exist no long-run cointegrating relationship between oil prices and economic growth, but oil prices indeed Granger cause economic growth in the short run.

In contrast, relatively little work has been done regarding the relationship between oil price shocks and financial markets. Three notable exceptions are Jones and Kaul (1996)[24], Huang et al. (1996)[23] and Sadorsky (1999)[33]. Jones and Kaul, using quarterly data from 1947 to 1991, found that oil prices do have an effect on aggregate stock returns, and that the reaction of Canadian and US stock prices to oil price shocks can be completely accounted for by the impact of these shocks on real cash flows. Sadorsky reports that oil price increases have significantly negative impact on US stock returns and that the magnitude of the effect may have increased since the mid 1980s. Contrarily, Huang et al. used data from 1979 to 1990 and found no evidence of a relationship between
CHAPTER 1. INTRODUCTION

oil future prices and real stock returns.

Notably, Guo and Kliesen (2005)[15] differ from the existing literature by constructing the “realized volatility” variable suggested by Andersen et al. (2004)[2], rather than employing the standard method of considering oil price shocks directly. This allows them to account for the input channel as well as the uncertainty channel. Using the same realized volatility measure, Rafiq et al. (2009)[32] extend Cunado and Gracia’s study by analyzing the effect of oil price volatility for various macro-indicators in the Thai economy. Using VAR and VECM, they show that the realized volatility of oil prices Granger causes GDP growth, investment, unemployment and inflation. Impulse response functions confirm that impacts of realized volatility are most distinct in the short-run, particularly for GDP. This result, together with the variance decomposition, supports Bernanke’s (1983)[3] theoretical explanation of postponed investments due to expected oil price volatility and the associated uncertainty.

In order to understand the relationship between oil prices and macroeconomic variables, it is crucial to consider the possible existence of asymmetry, which means that adverse effects of oil price increases are greater than stimulating effects of oil price decreases (or the opposite). However, the empirical evidence for the nature of this asymmetry is ambiguous. While it is generally agreed that increases have adverse effects, evidence for the effects of decreases is far from conclusive. Mork (1989)[28] distinguishes between positive and negative oil price shocks and finds that oil price increases reduce GDP while decreases have hardly any impact. However, Mork et al. (1994)[29] find that oil price increases and decreases both have negative consequences for the US economy, while results for UK, Japan, France, Norway, Germany and Canada are inconclusive.
Chapter 2

Variables and data description

In this study, a Vector Autoregressive Model is used to capture the complexities of the dynamic relations between oil price shocks and real stock returns, and other variables, such as short-term interest rate, consumer prices and industrial production, that may influence the effect of oil price shocks on real stock returns. The variables included in the system were chosen in the attempt to reflect the transmission channels which oil price fluctuations and shocks are likely to work through.

The industrial production index is one of the best short term indicators and predictors of economic activity. Thus, it is included in the model as a proxy for the overall economic activity.

It is also natural to include some kind of interest rate in the model, as the interest rate changes as the economic climate changes, and the interest rate is used as a tool for stimulating and controlling the economy. It could be used as a direct response to stimulate consumption and employment, or to fight inflation, which both are usually the priorities of the national central banks.

The West Texas Intermediate price is chosen as measure for the nominal oil price. It is a grade of crude oil used as a benchmark in oil pricing. The WTI is the underlying commodity of Chicago Mercantile Exchange’s oil future contracts, and its price is often referenced in news reports on oil prices, alongside the price of Brent crude from the North Sea. Those two measures, Brent and West Texas Intermediate, have been traded closely across the time, but currently WTI has been discounted against Brent.

Historical price data for WTI can be found at a website by the Energy Information Administration of the Department of Energy. It is listed as WTI, Cushing, Oklahoma, and the price in expressed in Dollars per Barrel. Historical data for industrial production, consumer prices, share prices and short term interest rates are taken from OECD for UK, Germany and France.
CHAPTER 2. VARIABLES AND DATA DESCRIPTION

Industrial production data are seasonally adjusted, from the dataset “Production and Sales (MEI)”. The consumer price index, from the dataset “Consumer Prices (MEI)”, is taken as percentage change on the previous period, and the base year is chosen to be 2010 (2010 = 100). It is seasonally adjusted. The share price index is found in the dataset “Monthly Monetary and Financial Statistics (MEI)”, the base year is 2010; here monthly data are averages of daily quotations, calculated by the stock exchange. From the same dataset come the short term interest rates, calculated as percentage per annum; data are provided by the national central bank. For the USA, industrial production data, consumer prices, producer prices and short term interest rates are taken from FRED. The industrial production indicator (INDPRO) is seasonally adjusted, and the base year is 2007. The consumer price index that is considered is the Consumer Price Index for All Urban Consumers: All Items, seasonally adjusted. The producer price index is taken for all commodities, the base year is 2013. The short term interest rate is the 3-month Treasury Bill (TB3MS). As a measure for the USA stock prices, the S&P 500 is taken from COMPU-STAT. This index includes 500 leading companies in leading industries of the US economy, which are publicly held either on the NYSE or the NASDAQ, and covers 75% of US equities.

For each country, real stock returns are defined as the difference between the continuously compounded return on stock price index and the inflation rate given by the log difference in the consumer price index.

2.1 Real oil price

World real oil price is calculated as nominal oil price deflated by the US Producer Price Index and is shown in Fig.2.1. It reflects a change in the relative price of oil faced by a firm. As an alternative to the world real oil price, national real oil price is obtained for each country using the exchange rate and CPI of each country to adjust the nominal price of oil, in the following way: Nominal real oil price * Exchange rate (#/US$) / CPI

Causes of oil price changes

The oil price is traditionally considered to be determined on the commodity exchange in the equilibrium between demand and supply. It is often treated as a highly exogenous variable, meaning that its movements can’t be explained well by other economic variables, but rather by non-economic components. For example, Hamilton (1985)[17] has showed that several of the principal causes of increases in crude oil prices from 1947 to 1981 were labor strikes, political disturbances such as the Iranian revolution or the Suez Canal crisis, and wars.
CHAPTER 2. VARIABLES AND DATA DESCRIPTION

Figure 2.1: World real oil price

For this reason, in this subsection the major level changes of real oil price are analyzed together with the contemporaneous non-economic events that affected the oil market, such as geopolitical events or natural disasters. This narrative approach can be also applied to the analysis of the periods of major oil price volatility, that will be dealt in the relative discussion.

The inflation adjusted price of a barrel of WTI in the first semester of 1990 was lower than 40$: between July and October, it rose from 30 to 60$ per barrel. This oil price spike occurred in response to the Iraqi invasion of Kuwait on August 2, 1990. On the heels of the invasion, prices rose to a peak of 60$ per barrel in October. The United States’ rapid intervention and subsequent military success helped to mitigate the potential risk to future oil supplies, calming the market and restoring confidence. After only three quarters the spike had subsided.

Lasting only 9 months, this price shock was less extreme and of shorter duration than the previous oil crisis of 1973 and 1979-80. Anyway, it is widely believed to have been a significant factor in the recession of the early 1990s.

After the 1990 shock and until 2003, the oil price has been generally under 40$ per barrel, never exceeding 50$. Between 2002 and 2003, the average WTI price rose from around 38$ per barrel to 42$, corresponding to a percentage increase of more than 10%. The 2003 USA invasion of Iraq marked a significant event for oil markets because Iraq contains a large amount of global oil reserves. The conflict coincided with an increase in global demand for petroleum, but it also reduced Iraq’s current oil production and has been blamed for increasing oil prices. Therefore the invasion of Iraq is associated with the start of long term increase in oil prices.

Real oil price has been above 70$ per barrel since June 2005; after the destruc-
tion of Hurricane Katrina in the United States, oil price reached a record in the last week of August and the first week of September 2005 (82$ per barrel). In the meanwhile, oil production in Iraq continued to decline as a result of the ongoing conflict, causing a further increase in prices.

In the mid-2006, WTI crude oil was traded for almost 90$ per barrel, setting an all-time record. Reasons for this increase can be found in geopolitical tensions resulting from North Korea's missile launch, the ongoing Iraq as well as Israel and Lebanon going to war. The higher price of oil substantially cut growth of oil demand in 2006, including a reduction of oil demand for the OECD.

Between October and November 2007 the oil price broke the barrier of 100$, due to a combination of tensions in eastern Turkey and the reducing strength of US dollar.

In the first half of 2008, prices continued to rise; in April it reached 117$ per barrel, after a Nigerian militant group claimed an attack on an oil pipeline. On June 6, WTI crude oil price rose 11$ in 24 hours, the largest gain in history due to the possibility of an Israeli attack on Iran, and on July 3, it reached the trading record of 145$, while the monthly average was of 132$ per barrel.

On July 15, 2008, a bubble-bursting sell-off began after remarks by President Bush the previous day that the ban on oil drilling would be lifted. This caused an immediate drop in oil prices, that decreased of the 11% by the end of the week, also affected by the tensions between USA and Iran.

By August 13 prices had fallen to 113$ per barrel, and by the middle of September below 100$, for the first time in over six months. In the same days, prices fell below 92$ in the aftermath of the Lehman Brothers bankruptcy. Lehman’s bankruptcy has been the largest in US history, and is thought to have played a major role in the unfolding of the late-2000s global financial crisis. By the end of December, 2008, oil had bottomed out at 32$.

In January 2009, oil price rose temporarily because of tensions in the Gaza Strip. Oil prices stabilized by October, establishing a trading range between 60$ and 80$ per barrel. Due to the concerns over how European countries would reduce budget deficits, on May 2010 the oil price dropped in two weeks from 88$ to 70$; if the European economy slowed down, this would mean less demand for crude oil. Also, if the European economic crisis caused the American economy to have problems, demand for oil would be reduced further. Other factors included the strong dollar and high inventories. Political tension in Egypt, Libya, Yemen, and Bahrain drove oil prices to 95$ per barrel in late February 2011. Crude oil price remained high in the following months, until mid-June, when the WTI fell as a consequence of the European economic crisis, with the dollar up and the euro and other currencies down, and concerns over some European countries’ debt crisis. 2012 registered the main fall in May, after voters in France and Greece ousted government officials who would cut spending to solve the debt crisis. In 2013, the trading range for crude oil attested between 100$ and 115$ per barrel.
CHAPTER 2. VARIABLES AND DATA DESCRIPTION

Implications of oil price changes

Oil price changes impact real economic activities on both the supply and demand side, through many transmission channels.

First, since oil is a vital input for the production, an increase in oil price will lead to a higher production cost, that in turn will cause adverse effects on the supply. As a consequence of the supply-side shock, the growth of output and productivity decreases. The decline in productivity growth lowers real wage growth and increases the unemployment rate at which inflation accelerates. If the higher oil prices are expected to be temporary, consumers will try to smooth out their consumption by saving less or borrowing more, which pushes the equilibrium real interest rate. As a consequence, the investment demand is affected negatively. The demand for real cash balance will lower because of the declining output growth and higher real interest rate, leading to higher consumer spending and ultimately a greater rate of inflation.

Second, rising oil prices impacts the term of trades: in particular, it deteriorates the term of trade for oil-importing countries and improves that of oil-exporting countries (Dohner, 1981)[10]. In this way the wealth is transferred from oil-importing to oil-exporting nations, diminishing consumer demand in oil-importing nations and increasing consumer demand in oil-exporting nations. Since, historically, the increase in demand in oil-exporting countries is less than the reduction in the oil-importing, the result will be than, on net, the world consumer demand for goods diminishes, and the world supply of savings increases (Fried and Schulze 1975[13], Brown and Yucel 2002[6]).

Third, monetary policy can determine the effect of an oil price shock on the economy. If the oil price shock leads to a higher real interest rate as mentioned, the velocity of money will increase. The national central bank can then respond in one of three ways (Brown and Yucel 1999[5]). The first way is to hold the growth rate of nominal GDP constant through the implementation of contractionary policies, to reduce the growth rate of monetary aggregate. The second way is to keep the growth rate of the monetary aggregate at a constant level. With an increasing velocity of money, the growth in nominal GDP will accelerate, and inflation will rise by more than GDP growth slows. The third way is to leave the real interest rate unchanged. This accelerates the growth of the monetary aggregate and increases the rate of inflation.

Fourth, as the demand of money rises in oil-importing countries to support the higher value of transactions initiated by rising oil prices, interest rate rises at a given supply of money and retards economic growth as a result (Pierce and Enzler 1978[31]; Mork 1989[28]).

Fifth, oil price shocks can lead to aggregate unemployment by inducing workers of adversely affected sectors to remain unemployed while waiting for conditions to improve in their own sectors rather than moving to positively affected sectors (Lilien 1982[26]; Loungani 1986[27]; Hamilton 1988[18]). Aggregate unemployment rises with increased variability in the price shocks.
2.2 Oil price volatility

Various studies (Hamilton 1996[19], 2003[20]; Hooker 1996[22]) have found that a direct measure of volatility for the oil prices is more powerful in explaining the GDP-oil relationship than oil prices in level. The classical approach that considers oil price innovations in levels, as first suggested by Mork (1989)[28], seems to fail in remaining statistically significant in subsequent sample periods. For this reason, the second VAR model that will be considered in this study takes into account a measure for oil price volatility: the Realized Volatility (RV) measure as suggested by Andersen et al. (2003)[2].

A price process \( \pi_t \) is expressed as a stochastic differential equation:

\[
d\log(\pi_t) = \mu_t dt + \sigma_t dW_t
\]  

(2.1)

where \( \mu_t \) denotes a predictable drift term with finite variance, \( \sigma_t \) corresponds to volatility and \( W_t \) denotes standard Brownian Motion. The continuously compounded price change \( r_t \) in the unit time interval is denoted:

\[
r_t = \log(\pi_t) - \log(\pi_{t-1}) = \int_{t-1}^{t} \mu_u du + \int_{t-1}^{t} \sigma_u dW_u
\]  

(2.2)

where \( t-1 \leq u \leq t \). First and second moments are obtained, based on the assumption that \( d\sigma_u \) and \( dW_u \) are uncorrelated. Since standard Brownian Motion has increments distributed according to \( W_t - W_s \sim N(0, t-s) \) for \( 0 \leq s \leq t \), the mean of \( r_t \) conditional on information set \( \Omega_{t-1} \) is given by:

\[
E[r_t|\Omega_{t-1}] = \int_{t-1}^{t} \mu_u du
\]  

(2.3)

Accordingly, conditional variance, or Integrated Volatility \( IV_t \), is given by:

\[
Var[r_t|\Omega_{t-1}] = IV_t = \int_{t-1}^{t} \sigma_u^2 du
\]  

(2.4)

Return and volatility computations in practice are restricted to discrete time intervals, hence \( IV_t \) is latent and can only be approximated. An elegant non-parametric method is to estimate volatility of daily changes by a month realized volatility series.

In this study, the oil price volatility measure is constructed using daily prices of crude oil futures traded on the New York Mercantile Exchange (NYMEX) over the period 1990-2013.

The monthly realized oil price variance series is obtained as the sum of squared first log differences in daily future crude oil price:

\[
RV_t = \sum_{i=1}^{M} r_i^2
\]  

(2.5)

with \( M \) the number of days in the considered month.
Based on the quadratic variation theory, Andersen et al. demonstrate that the volatility measure $RV_t$ converges uniformly in probability to $IV_t$ as $t \to 0$; and hence is an unbiased and efficient estimator.

Figure 2.2 shows the level trend of oil price volatility.

The main peak corresponds to 1990, when prices rose sharply due to the first Gulf War and therefore volatility increased dramatically. Volatility stayed at relatively low level in the following years, even during the second Gulf War in 2003, although oil prices continued to exhibit large swings.

The second peak occurs in 2008-09, in correspondence with the third oil crisis.

**Causes of oil price volatility**

Indeed, one of the main questions is what explains oil price volatility. Unanticipated economic developments could roil crude oil markets and increase volatility, such as an unexpected surge in energy demand from some countries, as well as other exogenous events that are non-economic in nature. This investigation is similar to the one already faced for the causes of oil price changes.

Guo and Kliesen (2005)[15] show that there are two methods that can be used to test whether economic or non-economic developments are the principle cause of oil price volatility.

The first method is the narrative approach, that associates the largest percentage changes to events such as political instabilities in the Middle East or developments among the Organization of Petroleum Exporting Countries (OPEC). This narrative approach has been used already in the previous section, regarding changes in oil price level.

The second method relies on formal statistical tests, investigating whether standard macrovariables forecast one-quarter-ahead realized oil futures variance. The main result of the Guo and Kliesen’s analysis is that realized oil price
volatility seems to be strongly autocorrelated, while the other macrovariables don’t appear to have a significant impact. This suggests that oil price volatility originates mainly from exogenous shocks to the economy, rather than endogenous responses to these shocks, and that it tends to persist at high levels after it rises.

**Implications of oil price volatility**

Large oil price changes, either increases or decreases, may affect the economy adversely because they delay business investments by raising uncertainty or by inducing costly sectoral resources allocation.

Bernanke (1983) offers theoretical explanation of the uncertainty channel by demonstrating that, when the firm is affected by increased uncertainty about the future price of oil, the optimal choice is to postpone irreversible investment expenditures. If a firm is facing a choice between adding energy-efficient or energy-inefficient capital, increased uncertainty caused by oil price volatility raises the option value associated with waiting to invest. When the firm waits for more updated information, it increases the chance of making the right investment decision, but it loses the returns potentially obtained by making an early commitment. Thus, as the level of oil price volatility increases, the option value rises and the incentive to investment declines (Ferde rer, 1996).

The downward trend in investment incentives ultimately transmits to different sectors of the economy.

The sectoral resource allocation channel was examined by Lilien (1982), Loungani (1986) and Hamilton (1988), and it has been demonstrated that volatility in the prices could lead to higher aggregate unemployment, by inducing workers of adversely affected sectors to remain unemployed while waiting for conditions to improve in their own sectors rather than moving to other positively affected sectors.

**2.3 Expectations**

Oil prices are expected to be negatively correlated to the industrial production, since an increase in the oil price represents a higher production costs. Consequently, it will also affect the earnings of the companies, causing them to decline. Hence, a rise in oil prices is negatively correlated with real stock returns as well.

On the other hand, with higher oil prices the consumers will try to reduce their consumption, by saving less and borrowing more, which will lead to an increase of the short term interest rate. Hence, those two variables are expected to be positively correlated.

Oil price volatility, influencing the economy through the uncertainty channel, is expected to be negatively correlated with industrial production and real stock returns. In fact, as explained, as the level of oil price volatility increases, the returns associated with delays in investment increase and the incentive for im-
mediate investment declines, which results in lower output level and earnings for the entire macroeconomy.

2.3.1 Correlation matrix

Table 2.1 presents the correlation matrices between all the variables that will be taken into account.

For all the four countries it can be seen that the variable realstockreturns is negatively correlated with both worldrealoilprice and the realizedvariance. The main aim of this study is indeed to prove this negative relationship between oil price specifications (world real oil price and realized volatility) and real stock returns, using the tools of econometric analysis, starting with the VAR estimation and proceeding with the analysis of impulse response functions and variance decomposition. Hence, most of the times the attention will be focused on the effects that oil prices and oil price volatility have on the stock returns.
### USA:

<table>
<thead>
<tr>
<th></th>
<th><code>ip</code></th>
<th><code>r</code></th>
<th><code>op</code></th>
<th><code>rv</code></th>
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</table>

Table 2.1: Correlation matrices
Chapter 3

Vector Autoregressive Model

Economic and financial data are usually not only autocorrelated, but as well cross-correlated for some time lags. It is hence necessary to build models that take into account the intertemporal relations between the variables.

In the analysis of multivariate time series, one of the most used is the VAR model; it was first proposed by Sims (1980)[34], as an alternative to the Simultaneous Equation Model (SEM), which at that time was the basic tool for macroeconomic analysis but presented problems in the identification phase.

Conceptually VAR models are the multivariate generalization of the AR (autoregressive) models. A VAR process is hence a system of equations that expresses each variable in the system as a linear function of its own lagged value and lagged values of all the other variables in the system.

Consider a set of $k$ variables, called endogenous variables, over a certain sample period, $t = 1, \ldots, T$. All the variables are collected in a $k \times 1$ vector $y_t$, which has as the $i$th element, $y_{i,t}$, the time $t$ observation of the $i$-th variable.

A $p$-th order VAR, denoted VAR($p$), where $p$ represents the number of lags, is

$$ Y_t = \alpha_0 + A_1 y_{t-1} + A_2 y_{t-2} + \ldots + A_p y_{t-p} + \epsilon_t \quad (3.1) $$

where $\alpha_0$ is a $k \times 1$ vector of deterministic constant terms, $A_i$ is a $k \times k$ time-invariant matrix of unknown coefficients, $y_{t-1}$ is the first lag of $y$, and $\epsilon_t$ is a $k \times 1$ vector of error terms.

The error term vector has to satisfy certain conditions:

- $E[\epsilon_t] = 0$ every error term has zero mean
- $E[\epsilon_t \epsilon'_t] = \Sigma$ the contemporaneous covariance matrix of error terms is $\Sigma$, a $(k \times k)$ positive-semidefinite matrix
- $E[\epsilon_t \epsilon_{t-k'}] = 0$ for any non-zero $k$, there is no correlation across time

All the variables in a VAR model have to be of the same order of integration.
CHAPTER 3. VECTOR AUTOREGRESSIVE MODEL

3.1 Time serie properties

The intended VAR model relies on the assumption of covariance stationarity; hence, it is essential to know the integration order of the variables in the model. To explain stationarity, consider a time series variable $Y_t$. According to Hamilton, if neither the mean $\mu$ nor the auto-covariances $\gamma_{j,t}$ depend on the date $t$, then the process $Y_t$ is said to be covariance-stationary or weakly stationary:

$$E[Y_t] = \mu \quad \text{for all } t$$

$$E[Y_t - \mu][Y_{t-j} - \mu] = \gamma_j \quad \text{for all } t \text{ and any } j$$

3.1.1 Stationarity test

A KPSS test is conducted on the log levels and first log differences of real oil price, short term interest rates and industrial production, and on real stock returns and realized variance, to investigate the presence of unit roots and the stationarity of the time series around a deterministic trend.

The null hypothesis of the test is the stationarity of the time series, the alternative hypothesis is the presence of a unit root.

Table 3.1 reports the results of the KPSS test. The superscript * denotes the rejection of the null hypothesis at the 5% level of confidence.

First consider the variables interest rate, real oil price and industrial production. The null hypothesis that the variables in log level are level and trend stationary is rejected at the 5% level, and the null hypothesis that variables in first log differences are level and trend stationary is not rejected at the 5% level. Regarding real stock returns and realized variance of oil prices, the null hypothesis that the variables have a unit root is rejected at the 5% level.

This means that in log levels, the interest rate, the real oil price and the industrial production are I(1) processes, and that real stock returns and realized variance, and first log differences of interest rate, real oil price and industrial production are I(0) processes.

3.1.2 Cointegration test

Since the log levels of interest rate, real oil price and industrial production each contain a unit root, it is possible to conduct a cointegration test, to investigate the presence of a common stochastic trend.

The procedure used is the one suggested by Johansen and Juselius. The Johansen-Juselius procedure is following an algorithm of three steps to estimate the maximum likelihood of model parameters and estimation of the cointegrating relations.

The first step is to estimate a $(p-1)$th-order VAR for $\Delta Y_{i,t}$, by regressing $\Delta Y_{i,t}$ on the lagged differences of the variables:

$$\Delta Y_t = \gamma_0 + C_1\Delta Y_{t-1} + C_2\Delta Y_{t-2} + \ldots + C_{p-1}\Delta Y_{t-p+1} + \mu_t \quad (3.2)$$

where $C_i$ denotes the $(k \times k)$ matrix of OLS coefficients and $\mu_t$ the $(k \times 1)$ vector of residuals.
### CHAPTER 3. VECTOR AUTOREGRESSIVE MODEL

<table>
<thead>
<tr>
<th>Real oil price</th>
<th>in log level</th>
<th>in first log difference</th>
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<tr>
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<table>
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<table>
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<td>France</td>
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Table 3.1: KPSS test for stationarity
Then a second set of regression is estimate, with \( Y_t = [Y_{1,t}, Y_{2,t}, \ldots, Y_{k,t}]' \) as the dependent variable and the same regressors as 3.2:

\[
Y_{t-1} = \beta_0 + \Theta_1 \Delta Y_{t-1} + \ldots + \Theta_{p-1} \Delta Y_{t-p+1} + \nu_t \tag{3.3}
\]

where \( \nu_t \) is the \((k \times 1)\) vector of residuals for the second regression.

The next step is to estimate the sample covariance matrices of \( \mu_t \) and \( \nu_t \):

\[
\Sigma_{\mu\mu} = \frac{1}{T} \sum_{t=1}^{T} \mu_t \mu_t' \tag{3.4}
\]

\[
\Sigma_{\nu\nu} = \frac{1}{T} \sum_{t=1}^{T} \nu_t \nu_t' \tag{3.5}
\]

\[
\Sigma_{\mu\nu} = \frac{1}{T} \sum_{t=1}^{T} \mu_t \nu_t' \tag{3.6}
\]

\[
\Sigma_{\nu\mu} = \Sigma_{\mu\nu}' \tag{3.7}
\]

and the eigenvalues and eigenvectors of the matrix

\[
\Sigma_{\mu\mu}^{-1} \Sigma_{\mu\nu} \Sigma_{\nu\nu}^{-1} \Sigma_{\nu\mu}' \tag{3.8}
\]

with the eigenvalues ordered \( \delta_1 > \delta_2 > \ldots > \delta_k \). Given that there is \( r \) cointegrating relationships, the maximum log likelihood is given by

\[
L_* = -\frac{Tk}{2} \log 2\pi - \frac{Tk}{2} \log |\Sigma_{\nu\nu}| - \frac{Tk}{2} \sum_{i=1}^{r} \log(1 - \delta_i) \tag{3.9}
\]

Two tests can be applied for determining the cointegrating rank \( r \), the maximum eigenvalue test and the trace test.

The maximum eigenvalue test, given by

\[
LRT_{MET} = -T \log(1 - \delta_{r+1}) \tag{3.10}
\]

tests the hypothesis \( H_0 : r \) is the number of cointegrating relations versus \( H_1 : r + 1 \) is the number of cointegrating relations. If the test statistic is greater than the critical value, the test is rejected.

The trace test, given by

\[
LRT_{TT} = -T \sum_{i=r+1}^{k} \log(1 - \delta_i) \tag{3.11}
\]

tests the hypothesis \( H_0 : r \) is the number of cointegrating relations versus \( H_1 : k \) is the number of cointegrating relations.

In table 3.2 are shown the results of the Johansen-Juselius test for the four countries.

The null hypothesis of no cointegration is rejected only for UK, at the 10% level of confidence regarding the trace test, and at the 5% level regarding the
CHAPTER 3. VECTOR AUTOREGRESSIVE MODEL

Number of equations = 3  
Lag order = 5  
Sample period: 1990:06 - 2013:12 (T = 238)

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Table 3.2: Johansen-Juselius test for cointegration
eigenvalue test. For all the other countries the null hypothesis of no cointegration cannot be rejected.

Given this outcome and the findings by Engle and Yoo (1987)\[11\], Clements and Hendry (1995)\[8\] and Hoffman and Rasche (1996)\[21\] that unrestricted VAR is superior in terms of forecast variance to a restricted VECM at short horizons when the restriction is true, and by Naka and Tufte (1997)\[30\] that the performance of unrestricted VAR and VECM for orthogonalized impulse response analysis over short-run is nearly identical, in this study unrestricted VAR models will be run for all the countries.

3.2 Granger causality

An application for which VAR models are widely used is the analysis of causality. In general, in the empirical analysis of economic data, cause-effect relations are difficult to establish. If two variables \(X_t\) and \(Y_t\) are highly correlated, we can say that they tend to move together, but without further information we cannot make statements on the direction of the causality. In other words, it is impossible to establish the causality links; it could be that \(X_t\) determines \(Y_t\), or vice versa, or that a third variable \(Z_t\) causes both of them.

To investigate whether a variable \(X_t\) causes another variable \(Y_t\), an easy tool is the Granger causality test. A variable \(X_t\) is said to Granger-cause another variable \(Y_t\) when \(X_t\) provides statistically significant information about \(Y_t\) in a regression of \(Y_t\) on lagged values of \(Y_t\) and \(X_t\).

The Granger test can be easily performed verifying the joint significance of \(X_t\) lags in the equation for \(Y_t\). The test is realized with a simple F statistic. Consider for example a VAR model for the variables real oil price \(op\) and industrial production \(ip\):

\[
ip_t = \alpha_0 + \sum_{i=1}^{p} A_i ip_{t-i} + \sum_{i=1}^{p} B_i op_{t-i} + \epsilon_t \tag{3.12}
\]

\[
op_t = \gamma_0 + \sum_{i=1}^{p} C_i ip_{t-i} + \sum_{i=1}^{p} D_i op_{t-i} + \mu_t \tag{3.13}
\]

For each of the equations F statistics are used to test for the significance of lagged values of an independent variable in forecasting values of the dependent variable, while controlling for lagged values of the dependent variable. For example, to test whether past values of \(op\) predict \(ip\), the first equation can be used to set up two equations as follows (suppose \(p = 1\)):

\[
ip_t = \alpha_0 + A_1 ip_{t-1} + \epsilon_t \tag{3.14}
\]

\[
ip_t = \alpha_0 + A_1 ip_{t-1} + B_1 op_{t-1} + \epsilon_t \tag{3.15}
\]

Considering the first as a restricted model where \(B = 0\) and the second as an unrestricted model where \(B \neq 0\), the null hypothesis is set as \(B = 0\) and the
alternative hypothesis as $B \neq 0$.

Should the null hypothesis be rejected, lagged values of $op$ correlate to $ip$, implying that $op$ Granger-causes $ip$. Residual sum of squares for each equation can be computed to derive a F test statistic that either rejects or fails to reject the null hypothesis.

Next the equation for $op$ is used to set up another two equations, where $op$ becomes the dependent variable and $ip$ the independent variable. This way is necessary since by definition, if $op$ Granger-causes $ip$, $ip$ doesn’t necessarily Granger-cause $op$.

The Granger causality test suggests which of the variables in the models have statistically significant impacts on the future values of each of the variables in the system. However, the result will not, by construction, be able to explain the sign of the relationship or how long these impacts will remain effective in the future. Impulse response function and variance decomposition give those informations.

Moreover, estimated coefficients from VAR models often appear to be lacking of statistical significance. According to Sims (1986) this may be due to the inaccuracy of the technique in estimating standard errors. Consequently, it is often suggested that a better test of a model’s specification is the pattern of impulse response function.

### 3.3 Impulse Response Function

An impulse response function traces the response of the system to an innovation (one standard deviation shock) in one of the variables. This represents how a sudden and unexpected change in one variable impacts another variable over time.

While VAR coefficients and Granger causality inform about the sign, extent and causal direction, the IRFs give informations about the persistence and dynamics of the relationships between oil prices and economic indicators.

There is one impulse response function for each innovation and each endogenous variable; thus a 4-variable VAR has 16 impulse response functions, a 5-variable VAR has 25 impulse response functions.

To find the Impulse Response Function, the previous VAR is transformed into its Wold representation, that is an infinite vector moving average process $VMA(\infty)$, which expresses exogenous variables as a function of all past shocks. The previous VAR(p) model can be rewritten using lag-operators L, such that:

$$Y_t = \alpha_0 + A_1LY_t + A_2L^2Y_t + ... + A_pL^pY_t + \epsilon_t \quad (3.16)$$

By defining the matrix lag polynomial

$$A(L) = I_k - A_1L - A_2L^2 - ... - A_pL^p \quad (3.17)$$

the original VAR can be expressed as
CHAPTER 3. VECTOR AUTOREGRESSIVE MODEL

\[ A(L)Y_t = \alpha_0 + \epsilon_t \]  

(3.18)

This VAR process can be rewritten as an infinite vector moving average process. To do so, a necessary condition is the invertibility of \( A(L) \) matrix. Since \( Y_t \) is stationary, invertibility can easily be shown.

For the unconditional expectation of \( Y_t \) it must hold that

\[ E[Y_t] = \alpha_0 + A_1 E[Y_t] + A_2 E[Y_t] + \ldots + A_p E[Y_t] = A(1)^{-1}\alpha_0 \]  

(3.19)

The VAR process can thus be expressed as a vector moving average process by pre-multiplying with \( A(L)^{-1} \):

\[ Y_t = A(1)^{-1}\alpha_0 + A(1)^{-1} + \epsilon_t \]  

(3.20)

The first term is equivalent to the unconditional expectation of \( Y_t \), while the second term can be expressed as a weighted sum of past and current innovations by defining \( A(L)^{-1} = I_k + A_1 L + A_2 L + \ldots \):

\[ Y_t = E[Y_t] + \sum_{i=1}^{\infty} \Phi_i \epsilon_{t-i} \]  

(3.21)

where \( \Phi_s \) is a matrix of coefficients given by:

\[ \Phi_s = \frac{\partial Y_{t+s}}{\partial \epsilon_t} \]  

(3.22)

Each \((i, j)\) element of \( \Phi_s \) measures the respective effect of a one-unit increase of \( \epsilon_{t,j} \) on \( Y_{j,t+s} \).

For example, assuming that there is a shock to \( \epsilon_{t,1} \) (the first element of \( \epsilon_t \)) the effect on the \( j \)-th variable is given by the first column and \( j \)-th element of \( I_k, \Phi_1, \Phi_2, \ldots \).

An impulse response function hence plots the dynamic response of \( Y_{j,t+s} \) to an impulse in \( Y_{1,t} \).

This partial derivative is meaningful just if it assumed that the shocks on the relative variables are not correlated; if they are, the impulse response matrix would be not diagonal and hence the results will be distorted.

3.4 Variance Decomposition

Forecast errors variance decomposition can be used to confirm the results from the impulse response analysis. Variance decomposition allows distinguishing between respective shocks to the elements of a VAR, in order to explain variations in an endogenous variable. Hence, it investigates the importance of each random shock in affecting variables of a VAR.

Consider, for example, the extent to which shocks of oil price level \((op)\) explain the \( \tau \)-step-ahead industrial production forecast error variance, \( \sigma_{ip}(\tau)^2 \).
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The $\tau$-step-ahead conditional mean forecast of the infinite vector moving average process is:

$$E[Y_{t+\tau} | \Omega_t] = E[Y_t] + \sum_{i=\tau}^{\infty} \Phi_i \epsilon_{t+\tau-i}$$  \hspace{1cm} (3.23)

Accordingly, the $\tau$-period forecast error $e_{t+\tau}$ is given by:

$$e_{t+\tau} = Y_{t+\tau} - E[Y_{t+\tau} | \Omega_t] = \sum_{i=0}^{\tau-1} \Phi_i \epsilon_{t+\tau-i}$$  \hspace{1cm} (3.24)

Consider again the case $Y_t = [ip_t, op_t]':$ the $\tau$-period forecast error $e_{ip,t+\tau}$ for the $ip_t$ sequence is:

$$e_{ip,t+\tau} = \sum_{i=0}^{\tau-1} \Phi_{1,1}(i)e_{ip,t+\tau-1} + \sum_{i=0}^{\tau-1} \Phi_{1,2}(i)e_{op,t+\tau-1}$$  \hspace{1cm} (3.25)

The $\tau$-step-ahead forecast error variance of $ip_{t+\tau}$ is denoted as $\sigma_{ip}(\tau)^2$:

$$\sigma_{ip}(\tau)^2 = \sigma_{ip}^2 \sum_{i=0}^{\tau-1} \Phi_{1,1}(i)^2 + \sigma_{op}^2 \sum_{i=0}^{\tau-1} \Phi_{1,2}(i)^2$$  \hspace{1cm} (3.26)

Furthermore, $\sigma_{ip}(\tau)^2$ can now be decomposed into the proportions that are due to shocks in $e_{ip,t}$ and $e_{op,t}$ sequences respectively:

$$\frac{1}{\sigma_{ip}(\tau)^2} \sigma_{ip}^2 \sum_{i=0}^{\tau-1} \Phi_{1,1}(i)^2$$  \hspace{1cm} (3.27)

$$\frac{1}{\sigma_{ip}(\tau)^2} \sigma_{op}^2 \sum_{i=0}^{\tau-1} \Phi_{1,2}(i)^2$$  \hspace{1cm} (3.28)

This decomposition states the extent to which movements in industrial production are due to its own shocks, as opposed to shocks to oil prices.

As for the impulse response function, the variance decomposition requires orthogonalized shocks. Since the VAR is a reduced form of a closed system, it is difficult that its residuals are orthogonal. It is hence necessary to proceed with a transformation of the VAR residual, to make them orthogonal.

For this purpose, the structural VAR is considered.

3.5 Structural VAR and identification

Consider again the following form of the VAR, where the constant is omitted for simplicity, that is:

$$A(L)Y_t = \epsilon_t$$  \hspace{1cm} (3.29)

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Imagine that the vector of forecast errors is a function (linear, for simplicity) of the structural shocks, so that is possible to write:

\[ \epsilon_t = \Phi u_t \]  

(3.30)

where \( \Phi \) is assumed to be a square and invertible matrix. The structural shocks \( u_t \) are assumed to be mutually uncorrelated and to have unit variance, so that \( \text{var}(u_t) = I \). Note that the vector \( \epsilon_t \) is observable, while the vector \( u_t \) and the matrix \( \Phi \) are not.

If \( \Phi \) was known, it would be possible to reconstruct the structural shocks \( u_t = \Phi^{-1} \epsilon_t \) and to calculate the structural impulse responses. Putting the previous equations together:

\[ A(L)Y_t = \Phi u_t \]  

(3.31)

and:

\[ Y_t = [A(L)]^{-1} \Phi u_t = \Phi u_t + C_1 \Phi u_{t-1} + ... \]  

(3.32)

Hence:

\[ \text{IRF}(i, j, n) = \frac{\partial y_{i, t}}{\partial u_{j, t-n}} = (C_n \Phi)_{ij} \]  

(3.33)

Is should be evident that the impulse response to a forecast error is not significant, while the impulse response to a structural shock allows to evaluate the effect on the variables of a shock that impacts the structural relation.

3.6 Cholesky decomposition

As said in the previous section, the matrix \( \Phi \) needs to be estimated; this is not easy, since the only observable statistic that could be used as basis for the estimation is the variance-covariance matrix of \( \epsilon_t \), that is \( \Sigma \).

Remembering that

\[ \epsilon_t = \Phi u_t \]  

(3.34)

it follows that

\[ \Sigma = \text{var}(\epsilon_t) = \Phi \Phi' \]  

(3.35)

obtaining an estimate of \( \hat{\Phi} \) for which the previous equation is satisfied.

But there is still a problem: for any symmetric and positive defined matrix (\( \Sigma \)) there is an infinite number of \( \Phi \) that satisfy the equation. For this reason is necessary to put some restrictions, in order that the equation has one and only one solution.

The most used solution consists in the triangularization of the system of equations that compose the VAR. It can be shown that the equation

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\[ \Sigma = \Phi \Phi' \quad (3.36) \]

has a unique solution if imposed that the matrix \( \Phi \) is lower triangular, that is, if all the elements \( \phi_{i,j} \) are zero for every \( i < j \). In this case the decomposition of \( \Sigma \) in the product \( \Phi \Phi' \) is called Cholesky decomposition; it states that any symmetric and positive defined matrix can be written as the product of a lower triangular matrix and its transposed, and that this lower triangular matrix is unique.

The solution suggested by Sims for the identification is to consider \( \Phi = I \) and \([I - C_0]^{-1}\) lower triangular. This hypothesis has strong implications, both on the statistic and the economic point of view; is assumed that the economy has a recursive structure, and that the impulse response functions and variance decomposition results depend on the ordering of the variables.

Consider a VAR with 2 variables and order 1:

\[
\begin{bmatrix}
y_t \\
x_t
\end{bmatrix} =
\begin{bmatrix}
a_{11} & a_{12} \\
a_{21} & a_{22}
\end{bmatrix}
\begin{bmatrix}
y_{t-1} \\
x_{t-1}
\end{bmatrix} +
\begin{bmatrix}
\epsilon_t \\
\epsilon_t
\end{bmatrix}
\quad (3.37)
\]

with

\[
\begin{bmatrix}
\epsilon_t \\
\epsilon_t
\end{bmatrix} \sim N \left( \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_{11} & \sigma_{12} \\
\sigma_{21} & \sigma_{22} \end{bmatrix} \right)
\]

Since \( \sigma_{12} \) and \( \sigma_{21} \) are different from zero, the residuals \( \epsilon \) are correlated and cannot be considered structural shocks.

For this reason, the structural form is used:

\[
\begin{bmatrix}
y_t \\
x_t
\end{bmatrix} =
\begin{bmatrix}
c_{01} & c_{02} & c_{11} & c_{12} \\
c_{03} & c_{04} & c_{21} & c_{22}
\end{bmatrix}
\begin{bmatrix}
y_t \\
x_t \\
y_{t-1} \\
x_{t-1}
\end{bmatrix} +
\begin{bmatrix}
u_{1t} \\
u_{2t}
\end{bmatrix}
\quad (3.38)
\]

with residuals

\[
\begin{bmatrix}
u_{1t} \\
u_{2t}
\end{bmatrix} \sim N \left( \begin{bmatrix} 0 \\ 1 \\ 0 \\ 1 \end{bmatrix} \right)
\]

In this case the relation between structural shocks and forecast errors takes the form:

\[ [I - C_0] \epsilon_t = \Phi u_t \quad (3.39) \]

where

\[ I = B; \quad C_0 = \begin{bmatrix} c_{01} & c_{02} \\
c_{03} & c_{04} \end{bmatrix} \]

The structural form is not identified; it can be obtained through triangularization, assuming \( c_{02} = 0 \) or \( c_{03} = 0 \). The first alternative has the statistic meaning of ordering the VAR putting \( y \) first and \( x \) second, and the economic meaning of assuming that \( x \) doesn’t have any contemporary effect on \( y \).
3.7 Ordering of the variables

Since the orthogonal responses derived from the Cholesky decomposition depend on the variable placement in the vector $Y_t$ and the resulting matrix is lower triangular, an order of the variables is necessary for the impulse response function to make sense.

The variables in the vector $Y_t$ should be placed in order of decreasing exogeneity, so that:

- $Y_{1,t}$ instantaneously causes $Y_{2,t}, \ldots, Y_{k,t}$
- $Y_{2,t}$ instantaneously causes $Y_{3,t}, \ldots, Y_{k,t}$
- \vdots
- $Y_{k-1,t}$ instantaneously causes $Y_{k,t}$

The ordering choice will be presented in the next section, together with the VAR specification.

3.8 VAR specification

In this study, two VAR models will be taken into account, in order to capture the dynamic relationships among the economic variables of interest. The first model considers just the linear measure for oil price shocks, the second one adds the specification for oil price volatility.

The reduced form can be written as:

$$ Y_t = \alpha_0 + \sum_{i=1}^{p} A_i y_{t-i} + \epsilon_t $$  \hspace{1cm} (3.40)

where:

$Y_t = \begin{bmatrix} r_t, op_t, ip_t, rsr_t \end{bmatrix}'$

or

$Y_t = \begin{bmatrix} r_t, op_t, rv_t, ip_t, rsr_t \end{bmatrix}'$

remembering that the variables $r_t, op_t, ip_t$ are taken in first log differences

$$ \epsilon = \begin{bmatrix} \epsilon^r, \epsilon^{op}, \epsilon^{ip}, \epsilon^{rsr} \end{bmatrix}' $$

or

$$ \epsilon = \begin{bmatrix} \epsilon^r, \epsilon^{op}, \epsilon^{rv}, \epsilon^{ip}, \epsilon^{rsr} \end{bmatrix}' $$

are vectors of innovations to the disturbances. The disturbances $\epsilon^r, \epsilon^{op}, \epsilon^{rv}, \epsilon^{ip}, \epsilon^{rsr}$ are interpreted as shocks to interest rate, oil price, oil price volatility, industrial production and real stock returns, respectively.

The lag length is taken for each country according to AIC, BIC and HQC criteria. Those are measures of the relative quality of a statistical model, for a given set of data. In doing so, they deal with the trade-off between the goodness of
fit of the model and its complexity. The Akaike information criterion (AIC) value of the model is the following:

\[ AIC = 2k - 2\ln(L) \] (3.41)

where \( k \) is the number of estimated parameters in the model and \( L \) the maximized value of the likelihood function for the model. Given a set of candidate models for the data, the preferred model is the one with the minimum AIC value.

The Bayesian information model (BIC) is defined as:

\[ BIC = -2\ln(L) + k\ln(n) \] (3.42)

where \( n \) is the number of observations, or equivalently, the sample size. Also in this case, the preferred model is the one with the minimum BIC value; the BIC generally penalizes free parameters more strongly than the AIC.

The Hannah-Quinn information criterion (HQC) is given as:

\[ HQC = n\ln(RSS/n) + 2k\ln(ln(n)) \] (3.43)

In the following chapters will be presented an analysis of the VAR coefficients, impulse response functions and variance decomposition, for each country. The coefficients are estimated by OLS. Attention is also paid to the F statistic automatically performed for each variable, in which the null hypothesis is that no lags of the variable \( x \) are significant in the equation for the variable \( y \), and corresponds to the Granger causality test.

While VAR coefficients and Granger causality inform about the sign, extent and causal direction, the IRFs give informations about the persistence and dynamics of the relationships between oil prices and economic indicators. There is one impulse response function for each innovation and each endogenous variable; thus a 4-variable VAR has 16 impulse response functions, a 5-variable VAR has 25 impulse response functions.

Since the aim of the study is to examine the impact of oil price shocks and oil price volatility shocks on the real stock returns, considering also some economic activity indicators that may influence this impact (industrial production and short term interest rates), only the impulse response functions of those economic indicators to shock to real oil prices and to shock to realized volatility will be traced.

Similarly, the variance decomposition analysis will be focused on the forecast error variance decomposition of real stock returns due to all the other variables of the model, after some chosen periods.

### 3.8.1 Model with WOP

The first considered VAR model has four stationary variables:

- first log difference of short-term interest rate \((r)\)
- first log difference of world real oil price \((wop)\)
first log difference of industrial production \((ip)\)
real stock returns \((rsr)\)
The order of variables in this VAR model is indicated by the notation \(VAR(r,wop,ip,rsr)\).
This ordering assumes that shocks to the interest rates, oil prices and industrial production have possible contemporary effect on real stock returns, but not the other way around. It also assumes that monetary policy shocks are independent of contemporaneous disturbances to the other variables.

### 3.8.2 Model with WOP and RV
The second considered VAR introduces the measure for oil price volatility. The ordering is the following:
- first log difference of short-term interest rate \((r)\)
- first log difference of world real oil price \((op)\)
- realized variance \((rv)\)
- first log difference of industrial production \((ip)\)
- real stock returns \((rsr)\)
The order of variables in this VAR model is indicated by the notation \(VAR(r,wop,rv,ip,rsr)\).
Also here, the ordering assumes that the interest rate is the most exogenous variable, followed by the two specifications for oil prices.
In this case, the attention will be mainly focused on the effect that lags of realized volatility may have on the other economy indicators. Regarding the effects of the world real oil price on the considered equations, the results are found to be almost the same as the ones in the previous analysis. For this reason, in this case they could be neglected.

### 3.8.3 Alternative VAR specifications
#### National real oil price
The same VAR model (the second one, including the specification for oil price volatility) is run with a measure of national real oil price. The model is indicated by the notation \(VAR(r,nop,rv,ip,rsr)\).
The national real oil price is obtained by adjusting the nominal oil price for the respective country’s exchange rate and Consumer Price Index.
The aim of this analysis is to find out which one of the two specifications for the real oil price, world rather than national, leads to more statistically significant impacts on the economy indicators, especially on real stock returns. For this reason, the attention is focused on the F test performed after the estimation of the VAR model, as well as on the coefficients of the single equations.
It will be found that real oil price shocks measured as world oil price yield more cases of statistically significant impacts on the economic indicators, and in particular on real stock returns, than do real oil price shocks measured as national oil price. This result might indicate that markets anticipate significant effects.
of oil price and this effect is better captured by WTI (dollar index)/ US PPI, than by a measure of real national oil price that reflects offsetting movements in the exchange rate.

For this reason, in what follows the attention will be confined to the impacts of world real oil price.

**Asymmetric effects of oil price shocks**

Asymmetric oil price shocks can be investigated by decomposing the variable world real oil price $wop$ (remember that $wop$ indicates the log difference of world real oil price) into one variable that represents positive shocks, $wop^+$, and another variable that represents negative shocks, $wop^-$. The variable $wop^+$ is equal to the positive values of $wop$ and zero elsewhere, while $wop^-$ is equal to the negative values of $wop$ and zero elsewhere.

To investigate whether positive oil price shocks result to have higher impact on the real stock returns than do negative oil price shocks, it is necessary to look at the decomposition of the variance. Hence, this analysis is postponed to the relative chapter.

In addition, some summary statistics for the variables $wop^+$ and $wop^-$ are computed. Over the full sample period, 53% of the shocks are positive and 47% are negative. The average value of a positive shock is 0.0337, while the average value of a negative shock is -0.0299. The highest positive oil price shock (+0.4489) is registered in August 1990, in correspondence with the Iraqi invasion of Kuwait during the First Gulf war; the lowest negative oil price shock (-0.2661) is registered in November 2008, as a consequence of the Lehman Brothers bankruptcy.

The summary statistics indicate that there are more positive oil price shocks than negative, and that the average value of a positive shock is in absolute value larger than the average value of a negative oil price shock.
Chapter 4

USA

The model used for analyzing the USA economy is

\[ Y_t = \alpha_0 + A_1 y_{t-1} + A_2 y_{t-2} + A_3 y_{t-3} + A_4 y_{t-4} + \epsilon_t \]  

(4.1)

where \( \alpha_0 \) is a vector of constant, \( A_i \) is a time-invariant matrix, \( y_{t-1} \) is the first lag of \( y \), and \( \epsilon_t \) is the error term. The lag order is chosen to be \( p = 4 \), according to the AIC and HQC criteria.

The ordering of the variables respects the previously commented variable dynamics, which place the interest rate in the first position, as the most exogenous variable, followed by world real oil price and realized volatility (for the second model), with as well high degree of exogeneity, and industrial production and real stock returns in the last positions.

4.1 VAR coefficients estimates and F test

In this section the results of the regressions are presented; as anticipated in the previous chapter, attention is paid to the F test performed to investigate the jointly significance of the lags of a certain variable in the equation for another variable, as well as a brief analysis of significant coefficients. Recall that the null hypothesis of the F test is that no lags of the considered variable are significant in explaining another variable.

The results are collected in a table and listed according to the equation to which they refer, while the estimated coefficients for the regression are omitted. For this study’s purposes is important to analyze the statistically significant impact that oil price specifications may have on the other variables of the system.

In addition, the last subsection presents the same analysis applied to the VAR model with a national real oil price specification. In this case, the results of the regression are omitted, since they appear to be extremely similar to the ones obtained with the world oil price specification. It will be found that, in general, real oil price shocks measured as national oil price lead to less cases of statistically significant impacts on economic indicators.
4.1.1 Model with WOP

Table 4.1 reports the results of the F test.

In the equation for the short term interest rate, the p-value assigned to the lags of world real oil price is 0.2642 hence meaning that the null hypothesis of no significance cannot be rejected.

In the oil price equation, the only coefficients that are found to be significant at a level of 1% are associated to the world real oil price itself (first and fourth lag).

In the equation for industrial production, none of the lags of world real oil price are significant. As shown by the F statistic, only for lags of real stock returns and of the industrial production itself the null hypothesis of no significance could be rejected. However, the F test for joint significance is indicating that the null hypothesis that the coefficients are jointly zero should be rejected.

Regarding the last equation, the null hypothesis that lags of world real oil price are not significant in the equation for real stock returns is rejected at a 10% level of confidence. The first lag of world real oil price is significant at a level of 5%, almost 1%, with a p-value of 0.01301. The coefficient is negative, as expected, suggesting that an increase in oil price negatively affects real stock returns.

4.1.2 Model with WOP and RV

Table 4.2 reports the results of the F test.

The results regarding the impact of world real oil price lags on the other economic variables doesn’t appear to change significantly, adding the measure of oil price volatility. This means that the model is robust to the inclusion of the variable \( r_v \). As a consequence, in this subsection the attention will be mainly focused on the impact of oil price volatility, neglecting the analysis for world oil price.

The realized volatility seems to have no effect on the short rate, none of the coefficients is statistically significant. The null hypothesis of the F test cannot be rejected.

In the equation for world real oil price, the only coefficients that are significant at the 1% level are assigned to lags of the oil price itself. Once again, the other variables included in the model seem to have no effect on the equation for oil prices.

The second and third lags of realized volatility in the volatility equation are associated to a positive coefficient, significant at the 1% level. The realized volatility appear to be highly regressive.

Three out of five lags of realized volatility are found to be significant in the equation for industrial production. The second lag is significant at the 5%, with a negative coefficient; the fourth and fifth lags are, respectively, significant at the 5% and 1%, this time with a positive coefficient. A positive shock of the realized volatility leads to a reduction of the industrial production, then
### USA

#### Short term interest rate

- All lags of $l_d(r, 4, 266) = 6.0669 [0.0001]
- All lags of $l_d(wop, 4, 266) = 1.3161 [0.2642]
- All lags of $l_d(ip, 4, 266) = 6.2561 [0.0001]
- All lags of $r(4, 266) = 3.9618 [0.0039]
- All variables, 4 lags: $F(4, 266) = 1.1752 [0.3220]

#### World real oil price

- All lags of $l_d(r, 4, 266) = 0.4079 [0.8029]
- All lags of $l_d(wop, 4, 266) = 5.1193 [0.0005]
- All lags of $l_d(ip, 4, 266) = 2.5115 [0.0422]
- All lags of $r(4, 266) = 2.5824 [0.0376]
- All variables, 4 lags: $F(4, 266) = 3.8867 [0.0044]

#### Industrial production

- All lags of $l_d(r, 4, 266) = 0.63209 [0.6400]
- All lags of $l_d(wop, 4, 266) = 0.70576 [0.5886]
- All lags of $l_d(ip, 4, 266) = 9.7362 [0.0000]
- All lags of $r(4, 266) = 9.663 [0.0000]
- All variables, 4 lags: $F(4, 266) = 4.9358 [0.0007]

#### Real stock returns

- All lags of $l_d(r, 4, 266) = 1.5993 [0.1748]
- All lags of $l_d(wop, 4, 266) = 2.1342 [0.0769]
- All lags of $l_d(ip, 4, 266) = 2.999 [0.0191]
- All lags of $r(4, 266) = 0.53401 [0.7109]
- All variables, 4 lags: $F(4, 266) = 0.60976 [0.6559]

Table 4.1: F test for lags significance, model $VAR(r, wop, ip, rsr)$, USA
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#### Short term interest rate

- All lags of ld\_r(4,266) = 4.6934 [0.0004]
- All lags of ld\_wop(4,266) = 1.5149 [0.1855]
- All lags of rv(4,266) = 1.0669 [0.3792]
- All lags of ld\_ip(4,266) = 5.818 [0.0000]
- All lags of rsr(4,266) = 3.8228 [0.0023]
- All variables, 4 lags: F(5,266) = 2.4177 [0.0365]

#### World real oil price

- All lags of ld\_r(4,266) = 0.35887 [0.8763]
- All lags of ld\_wop(4,266) = 3.7498 [0.0027]
- All lags of rv(4,266) = 0.47963 [0.7913]
- All lags of ld\_ip(4,266) = 1.8887 [0.0967]
- All lags of rsr(4,266) = 2.196 [0.0552]
- All variables, 4 lags: F(5,266) = 0.67699 [0.6413]

#### Realized volatility

- All lags of ld\_r(4,266) = 0.45808 [0.8072]
- All lags of ld\_wop(4,266) = 3.0001 [0.0119]
- All lags of rv(4,266) = 9.4088 [0.0000]
- All lags of ld\_ip(4,266) = 2.2955 [0.0459]
- All lags of rsr(4,266) = 2.1194 [0.0636]
- All variables, 4 lags: F(5,266) = 3.1215 [0.0094]

#### Industrial production

- All lags of ld\_r(4,266) = 0.61649 [0.6874]
- All lags of ld\_wop(4,266) = 0.95957 [0.4432]
- All lags of rv(4,266) = 2.8732 [0.0152]
- All lags of ld\_ip(4,266) = 5.1433 [0.0002]
- All lags of rsr(4,266) = 6.2311 [0.0000]
- All variables, 4 lags: F(5,266) = 1.3047 [0.2623]

#### Real stock returns

- All lags of ld\_r(4,266) = 0.62362 [0.6819]
- All lags of ld\_wop(4,266) = 1.7687 [0.1197]
- All lags of rv(4,266) = 1.9011 [0.0946]
- All lags of ld\_ip(4,266) = 3.4285 [0.0051]
- All lags of rsr(4,266) = 0.34405 [0.8858]
- All variables, 4 lags: F(5,266) = 0.62976 [0.6772]

Table 4.2: F test for lags significance, model VAR(r,wop,rv,ip,rsr), USA
followed by a raise. The null hypothesis of no significance is rejected at the 1% confidence level.

In the equation for real stock returns, the null hypothesis is rejected at the 10% level of confidence. Just one significant coefficient is found related to the oil price volatility, associated with the fourth lag. The coefficient is positive.

4.1.3 Model with NOP

The coefficients associated to lags of the national oil price in the equations for the economic indicators are nearly identical to those obtained with the measure of world real oil price, and so are the results for the F statistic.

In particular, in the equation for real stock returns, the first two lags of both specifications (world and national oil price) are statistically significant, with a level of significance of the 5% for the first lag and of the 10% for the second lag. The F tests, performed to test the joint significance of oil price lags on real stock returns equation, lead to the following p-values: 0.1197 for world real oil price and 0.1258 for national oil price.

4.2 Granger causality

As explained in section 3.2, a variable $X_t$ is said to Granger cause another variable $Y_t$ when $X_t$ provides statistically significant informations about $Y_t$ in the regression of $Y_t$ on lagged values of $Y_t$ and $X_t$. To investigate for Granger causality, it is possible to refer to the results of the F test. Should the null hypothesis of no significance be rejected, lagged values of $X_t$ correlate to $Y_t$, implying that $X_t$ Granger causes $Y_t$.

From the results of the F test statistic, it is possible to conclude that:
- world real oil price Granger causes real stock returns
- oil price realized volatility Granger causes industrial production
- oil price realized volatility Granger causes real stock returns.

4.3 Impulse Response Function

The impulse response functions are reported in rates; multiplying these values by 100 gives percentage values.

Confidence bounds at 95% level are provided to judge the statistical significance of the impulse response functions.

Figures 4.1 to 4.3 show the impulse response functions of the three economic variables, short term interest rate, industrial production and real stock returns, to a structural shock in the oil price level. Figures 4.4 to 4.6 show the impulse response functions of short term interest rate, industrial production and real stock returns, to a structural shock in the oil price volatility.

The most significant result is the response of real stock returns to a one standard deviation innovation of world real oil price (Fig.4.3). An oil price shock has a negative and significant effect on real stock returns. This impact
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Figure 4.1: Effect of one standard deviation shock of oil price on short term interest rate, USA

Figure 4.2: Effect of one standard deviation shock of oil price on industrial production, USA

Figure 4.3: Effect of one standard deviation shock of oil price on real stock returns, USA
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Figure 4.4: Effect of one standard deviation shock of oil price realized volatility on short term interest rate, USA

Figure 4.5: Effect of one standard deviation shock of oil price realized volatility on industrial production, USA

Figure 4.6: Effect of one standard deviation shock of oil price realized volatility on real stock returns, USA
is immediate, and reaches its maximum in the first month after the oil price shock, and it is reabsorbed within 10 months.

The initial effect of a shock in world real oil price on short term interest rate (Fig.4.1) is positive; the one-month-after increase is then followed by a steady fall, a period of stagnation and an ulterior decrease. The positive response is consistent with the idea that increases in oil prices are often indicative of inflationary pressure; however, considering the width of the confidence bands, this result is not particularly statistically significant.

The same applies to the response of industrial production to a shock in the world oil price (Fig.4.2): given the width of the confidence intervals, the results are found to be insignificant. This results confirms the findings obtained by the interpretation of the VAR coefficients, where lags of the world real oil price were in general not much statistically significant in the equations for the industrial production.

The response of the short term interest rate to a shock of the oil price volatility (Fig.4.4) doesn’t appear to be significant as well, according again to the width of the confidence bands.

The immediate response of industrial production to a volatility shock (Fig.4.5) is negative; this negative impact persists until the fourth month, and is later gradually reabsorbed.

The effect of a shock in oil realized volatility on real stock returns (Fig.4.6) is ambiguous; the first response is a decline, followed by an increase within the first month, and then a positive peak around the fourth month. This is consistent with the previous finding that the fourth lag of oil price volatility is significant, and associated with a positive coefficients.

### 4.4 Variance decomposition

A separate variance decomposition is calculated for each endogenous variable. The second column is the forecast error of the variable for different forecast horizons; the source of the forecast error is variation in the current and future values of the innovations. The remaining columns give the percentage of the variance due to specific innovations. One period ahead, all of the variations in a variable comes from its own innovation, so the first number is always 100 percent.

Table 4.3 presents the forecast error variance decomposition of real stock returns due to all the variables in the model VAR(r,wop,rv,ip,rsr), after 8, 16 and 24 periods.

As explained, the main source of variation in the real stock returns is due to innovations of the stock returns themselves. However, it can be noticed that the related percentage decreases across the time, while the percentages associated with the other innovations rise.

In particular, the contribution of oil price shock to real stock returns raises from 3.39% of the 8th month to 3.63% in the 24th; the contribution of oil price volatility is 2.19% in the 8th month and 2.52% in the 24th. Is interesting to
notice that both those contributions are greater than that of interest rate. Thus, variance decomposition suggests that oil price shocks and oil price volatility shocks are a significant source of monthly volatility in real stock returns.

Asymmetric effect

Table 4.4 presents the variance decomposition of real stock returns computed with regard to the asymmetric effect of oil price shock. As presented in the relative section, $wop^+$ stays for a positive oil price shock and $wop^-$ for a negative oil price shock.

In this case, positive oil price shocks explain more of the forecast error variance in real stock returns than do negative oil price shocks.
Chapter 5

UK

The model used for analyzing the UK economy is

\[ Y_t = \alpha_0 + A_1 y_{t-1} + A_2 y_{t-2} + A_3 y_{t-3} + A_4 y_{t-4} + \epsilon_t \]  \hspace{1cm} (5.1)

where \( \alpha_0 \) is a vector of constant, \( A_i \) is a time-invariant matrix, \( y_{t-1} \) is the first lag of \( y_t \), and \( \epsilon_t \) is the error term. The lag order is chosen to be \( p = 4 \), according to the AIC criteria; the BIC and HQC criteria suggest 1 lag. The choice of including 4 lags is taken in the attempt to analyze the possible effects that more distant shocks (until 4 months before) of certain variables may have on the present value of other variables.

Again, the ordering of the variables assumes the interest rate and the oil price measures to be exogenous in the system, placing them in the first positions followed by industrial production and real stock returns.

5.1 VAR coefficients estimates and F test

5.1.1 Model with WOP

Table 5.1 reports the results of the F test.

In the short term interest rate equation, the null hypothesis of no significance of the F test for lags of world real oil price is rejected at the 1% confidence level. The first lag of world real oil price is significant at a 1% level, and the coefficient is positive. As found for USA, an increase in the oil price is associated with an increase of the short rate one month after.

Three out of four lags of the world real oil price are significant in the oil price equation, the first and the fourth at a level of 1%, the third at a level of 10%. Lags of the short term interest rate and of industrial production seem to be not significant in the oil price equation, confirmed by the F test results.

The oil price doesn’t seem to have a statistical significance on the UK industrial production. None of the coefficients is significant. The F test confirms
### Short term interest rate

- All lags of ldₙ(4,266) = 43.692 [0.0000]
- All lags of ldₙ_wop(4,266) = 4.1093 [0.0030]
- All lags of ldₙ_ip(4,266) = 3.809 [0.0050]
- All lags of rsr(4,266) = 4.32068 [0.0021]
- All variables, 4 lags: F(4,266) = 2.5382 [0.0404]

### World real oil price

- All lags of ldₙ(r(4,266) = 1.0038 [0.4060]
- All lags of ldₙ_wop(4,266) = 6.2159 [0.0001]
- All lags of ldₙ_ip(4,266) = 0.72961 [0.5724]
- All lags of rsr(4,266) = 2.304 [0.0588]
- All variables, 4 lags: F(4,266) = 3.5776 [0.0073]

### Industrial production

- All lags of ldₙ(r(4,266) = 3.0666 [0.0171]
- All lags of ldₙ_wop(4,266) = 0.79635 [0.5284]
- All lags of ldₙ_ip(4,266) = 6.2526 [0.0001]
- All lags of rsr(4,266) = 4.2937 [0.0022]
- All variables, 4 lags: F(4,266) = 2.7758 [0.0275]

### Real stock returns

- All lags of ldₙ(r(4,266) = 1.8734 [0.1154]
- All lags of ldₙ_wop(4,266) = 3.2381 [0.0129]
- All lags of ldₙ_ip(4,266) = 2.9295 [0.0214]
- All lags of rsr(4,266) = 2.465 [0.0455]
- All variables, 4 lags: F(4,266) = 1.6545 [0.1610]

Table 5.1: F test for lags significance, model VAR(r,wop,ip,rsr), UK
that the lags of world real oil price may not influence the level of industrial production. The most significant coefficients in the industrial production equation are associated with the first two lags of the industrial production itself.

World real oil price has a statistical influence on real stock returns, since the null hypothesis is rejected at a confidence level of 5%. The first lag of world real oil price presents a negative coefficient, which is statistically significant at 1% confidence level. An oil price increase causes a decrease in the real stock returns of the following month.

5.1.2 Model with WOP and RV

Table 5.2 reports the results of the F test.

As found for the USA, the model appears to be robust to the inclusion of the oil price volatility measure; the statistics for the world real oil price don’t change significantly, so again this section can be focused on the effects of oil price volatility.

No lags of realized volatility significantly impact on the level of short term interest rate and, accordingly, the null hypothesis of the F test cannot be rejected.

As found before, variations of world oil price seem to be explained just by its previous values. Realized volatility doesn’t influence oil price levels.

All the four lags of realized volatility are highly significant in its own equation. All of them have a positive coefficient, suggesting that an augment in the volatility of oil prices is followed by further increases.

UK industrial production is negatively affected by realized volatility. The first three lags are negative and statistically significant at the 5% level of confidence, only the fourth is positive. The null hypothesis of no significance is rejected at the 1% level of confidence. An increase in the volatility of oil prices leads to a reduction of the industrial production.

In the equation for real stock returns, the null hypothesis of the F test is rejected at a level of 10%. The third lag of realized volatility is found to be significant in the expression for stock returns. The coefficient is negative, significant at the 5% level. This means that an increase in the volatility three months ago is associated with a decrease of the real stock returns. The fourth lag presents a positive coefficient, but the degree of significance is much lower (the p-value is 0.07521).

5.1.3 Model with NOP

Also in this case, the results of the two regressions are almost the same. Lags of oil price appear to be statistically significant in the equation for short term interest rate; for both the oil price measures, the first lag is significant at the 1% and the third at the 5% level.

Regarding the real stock return equation, the first oil price lag is significant at 5% level of confidence; the null hypothesis of no joint significance is rejected in both cases.
### Short term interest rate

All lags of $\text{ld}_r(4, 266) = 38,634 [0.0000]$

All lags of $\text{ld}_wop(4, 266) = 3,3293 [0.0111]$

All lags of $\text{rv}(4, 266) = 0.89932 [0.4649]$

All lags of $\text{ld}_ip(4, 266) = 3.6169 [0.0068]$

All lags of $\text{r}_sr(4, 266) = 3.7015 [0.0060]$

All variables, 4 lags: $F(5, 266) = 2.0253 [0.0755]$

### World real oil price

All lags of $\text{ld}_r(4, 266) = 0.88058 [0.4760]$

All lags of $\text{ld}_wop(4, 266) = 5.5731 [0.0003]$

All lags of $\text{rv}(4, 266) = 0.88782 [0.4717]$

All lags of $\text{ld}_ip(4, 266) = 0.77301 [0.5436]$

All lags of $\text{r}_sr(4, 266) = 2.5336 [0.0407]$

All variables, 4 lags: $F(5, 266) = 3.0813 [0.0101]$

### Realized volatility

All lags of $\text{ld}_r(4, 266) = 0.71303 [0.5843]$

All lags of $\text{ld}_wop(4, 266) = 1.6037 [0.1737]$

All lags of $\text{rv}(4, 266) = 14.495 [0.0000]$

All lags of $\text{ld}_ip(4, 266) = 0.99979 [0.0063]$

All lags of $\text{r}_sr(4, 266) = 3.6706 [0.0063]$

All variables, 4 lags: $F(5, 266) = 2.5253 [0.0297]$

### Industrial production

All lags of $\text{ld}_r(4, 266) = 2.6502 [0.0338]$

All lags of $\text{ld}_wop(4, 266) = 0.30229 [0.8763]$

All lags of $\text{rv}(4, 266) = 5.1528 [0.0005]$

All lags of $\text{ld}_ip(4, 266) = 8.0963 [0.0000]$

All lags of $\text{r}_sr(4, 266) = 3.6258 [0.0068]$

All variables, 4 lags: $F(5, 266) = 2.8943 [0.0146]$

### Real stock returns

All lags of $\text{ld}_r(4, 266) = 1.4849 [0.2071]$

All lags of $\text{ld}_wop(4, 266) = 2.7567 [0.0284]$

All lags of $\text{rv}(4, 266) = 2.0068 [0.0855]$

All lags of $\text{ld}_ip(4, 266) = 3.0389 [0.0179]$

All lags of $\text{r}_sr(4, 266) = 2.8693 [0.0236]$

All variables, 4 lags: $F(5, 266) = 2.2831 [0.0469]$

Table 5.2: F test for lags significance, model VAR($r, wop, rv, ip, rsr$), UK
CHAPTER 5. UK

The p-value of the F test is 0.0284 in the regression with world oil price measure, and 0.0303 in the regression with national oil price.

5.2 Granger causality

From the results of the F test statistic, performed on the two models VAR(r,wop,ip,rsr) and VAR(r,wop,rv,ip,rsr) it is possible to conclude that:

- world real oil price Granger causes short term interest rate
- world real oil price Granger causes real stock returns
- oil price realized volatility Granger causes industrial production
- oil price realized volatility Granger causes real stock returns.

5.3 Impulse response function

Figures 5.1 to 5.3 show the impulse response functions of the three economic variables, short term interest rate, industrial production and real stock returns, to a structural shock in the oil price level. Figures 5.4 to 5.6 show the impulse response functions of short term interest rate, industrial production and real stock returns, to a structural shock in the oil price volatility.

The effect of a shock in world real oil price is an increase in the short term interest rate for the UK (Fig.5.1). The first month after the shock registers the main peak, followed by two months of further positive influence and afterward the progressive decline. The shock is reabsorbed within 7-8 months.

The impulse response function for the industrial production (Fig.5.2) displays an initial positive effect, which turns negative after the 5th month. However, as found for the USA, the confidence bounds are wide, and hence it can be concluded that those results are not particularly significant. This confirms the absence of Granger causality of oil price on industrial production.

An impulse in the oil price is followed by a decline of the real stock returns, as for the USA (Fig.5.3). This time the effect is delayed, and becomes evident one and two months after the shock.

The confidence intervals in the IRF of the short term interest rate to a volatility shock (Fig.5.4) are extremely wide, and hence the effect is not statistically significant.

The response of industrial production to a volatility shock (Fig.5.5) is negative. This negative impact is found to persist until the 4th month after the shock, with its strongest influence between the second and the third. The positive rebound that appear around the 4th month is associated with low t-ratio, hence it is not so statistically significant. It is confirmed that realized oil price volatility negatively Granger causes the industrial production.

The effect of a shock in oil realized volatility on the real stock return (Fig.5.6) is again ambiguous, rises alternate to drops and periods of stagnation. The first response is a decline, followed by an increase in the first and second month, and then again a decline in the third.
CHAPTER 5. UK

Figure 5.1: Effect of one standard deviation shock of oil price on short term interest rate, UK

Figure 5.2: Effect of one standard deviation shock of oil price on industrial production, UK

Figure 5.3: Effect of one standard deviation shock of oil price on real stock returns, UK
CHAPTER 5. UK

Figure 5.4: Effect of one standard deviation shock of oil price realized volatility on short term interest rate, UK

Figure 5.5: Effect of one standard deviation shock of oil price realized volatility on industrial production, UK

Figure 5.6: Effect of one standard deviation shock of oil price realized volatility on real stock returns, UK
CHAPTER 5. UK

Table 5.3: Variance decomposition for real stock returns, VAR(r,wop,rv,ip,rsr), UK

<table>
<thead>
<tr>
<th>Period</th>
<th>std.err.</th>
<th>r</th>
<th>wop</th>
<th>rv</th>
<th>ip</th>
<th>rsr</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0.0339077</td>
<td>6.4977</td>
<td>3.5799</td>
<td>4.8657</td>
<td>5.2388</td>
<td>79.818</td>
</tr>
<tr>
<td>16</td>
<td>0.0354929</td>
<td>6.7696</td>
<td>6.1623</td>
<td>5.4786</td>
<td>7.3771</td>
<td>74.2123</td>
</tr>
<tr>
<td>24</td>
<td>0.0357082</td>
<td>6.9045</td>
<td>6.6478</td>
<td>5.4552</td>
<td>7.5738</td>
<td>73.4188</td>
</tr>
</tbody>
</table>

Table 5.4: Variance decomposition for real stock returns, VAR(r,wop⁺,wop⁻,ip,rsr), UK

<table>
<thead>
<tr>
<th>Period</th>
<th>std.err.</th>
<th>r</th>
<th>wop⁺</th>
<th>wop⁻</th>
<th>ip</th>
<th>rsr</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0.0368431</td>
<td>6.1612</td>
<td>2.7388</td>
<td>3.6392</td>
<td>80.6282</td>
<td>6.8326</td>
</tr>
<tr>
<td>16</td>
<td>0.0369003</td>
<td>6.2451</td>
<td>2.7527</td>
<td>3.7044</td>
<td>80.458</td>
<td>6.8397</td>
</tr>
<tr>
<td>24</td>
<td>0.0369018</td>
<td>6.2449</td>
<td>2.753</td>
<td>3.707</td>
<td>80.4548</td>
<td>6.8403</td>
</tr>
</tbody>
</table>

5.4 Variance decomposition

Table 5.3 presents the forecast error variance decomposition of real stock returns due to all the variables in the model VAR(r,wop,rv,ip,rsr), after 8, 16 and 24 periods.

The contribution of oil price shocks to the variability real stock returns increases sharply within the 8th and the 16th month after the shock, from a value of 3.58% to 6.16%. Also the contribution of the realized volatility increases, from 4.87% of the 8th month to 5.48% and 5.46% of, respectively, the 16th and the 24th month after the shock.

In this case, the contribution of oil price and oil price volatility shocks is not greater than that of interest rate.

Asymmetric effect

Table 5.4 presents the variance decomposition of real stock returns computed with regard to the asymmetric effect of oil price shock.

For the UK, negative oil price shocks appear to have larger impact on the forecast error variance of the real stock returns than positive shocks. This result is the opposite of that found for the USA, but it confirms the existence of asymmetric effects.
Chapter 6

Germany

The model used for analyzing the German economy is

\[ Y_t = \alpha_0 + A_1 y_{t-1} + A_2 y_{t-2} + A_3 y_{t-3} + A_4 y_{t-4} + A_5 y_{t-5} + \epsilon_t \]  

(6.1)

where \( \alpha_0 \) is a vector of constant, \( A_i \) is a time-invariant matrix, \( y_{t-1} \) is the first lag of \( y \), and \( \epsilon_t \) is the error term. The lag order is chosen to be \( p = 5 \), according to the AIC criteria.

The variables ordering is again short term interest rate, world real oil price, oil price realized volatility, industrial production and real stock returns.

6.1 VAR coefficients estimates and F test

6.1.1 Model with WOP

Table 6.1 reports the results of the F test.

Oil price coefficients are significant for the first two lags in the short rate equation, at a level of 5%. A positive variation in oil prices is followed by an increase of short term interest rate in the next two periods. The null hypothesis of no significance for oil price lags is rejected at a confidence level of 5%.

As found for the previous two countries, it seems that the only explanatory variable in the oil price equation is the world oil price. The first and the fourth lags are significant at the 1% level. The F test suggests that short term interest rate, industrial production and real stock return may not have explanatory power with regard to the level of world real oil price.

In the equation for industrial production, the first two oil price lags present positive significant coefficients, at a level of 5%. The industrial production increases, consequently to a rise of world real oil price. With a p-value of 0.0074, the null hypothesis of no significance for oil price lags is rejected.

Real stock returns are negatively affected by an increase of world real oil price. The coefficients for the first and fifth lags are negative, with statistical significance at, respectively, 1% and 5% level. For all the variables included in
CHAPTER 6. GERMANY

<table>
<thead>
<tr>
<th>Variable</th>
<th>All lags of ( l_d r ) &amp; ( r )</th>
<th>All lags of ( l_d wop ) &amp; ( wop )</th>
<th>All lags of ( l_d ip ) &amp; ( ip )</th>
<th>All lags of ( rsr ) &amp; ( rsr )</th>
<th>All variables, 5 lags: ( F(5,261) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short term interest rate</td>
<td>( 31.783 \pm 0.0000 )</td>
<td>( 2.3863 \pm 0.0386 )</td>
<td>( 0.36843 \pm 0.8700 )</td>
<td>( 1.6704 \pm 0.1421 )</td>
<td>( 0.32622 \pm 0.8603 )</td>
</tr>
<tr>
<td>World real oil price</td>
<td>( 0.43787 \pm 0.8219 )</td>
<td>( 4.384 \pm 0.0008 )</td>
<td>( 0.65185 \pm 0.6603 )</td>
<td>( 1.0525 \pm 0.3873 )</td>
<td>( 0.37937 \pm 0.8233 )</td>
</tr>
<tr>
<td>Industrial production</td>
<td>( 1.94 \pm 0.0881 )</td>
<td>( 3.2409 \pm 0.0074 )</td>
<td>( 11.464 \pm 0.0000 )</td>
<td>( 3.7896 \pm 0.0025 )</td>
<td>( 1.6527 \pm 0.1615 )</td>
</tr>
<tr>
<td>Real stock returns</td>
<td>( 1.8854 \pm 0.0972 )</td>
<td>( 2.9456 \pm 0.0132 )</td>
<td>( 2.0324 \pm 0.0745 )</td>
<td>( 5.0566 \pm 0.0002 )</td>
<td>( 2.6023 \pm 0.0365 )</td>
</tr>
</tbody>
</table>

Table 6.1: F test for lags significance, model VAR(\(r\),wop,ip,rsr), Germany
6.1.2 Model with WOP and RV

Table 6.2 reports the results of the F test.

None of the six lags of oil price volatility are significant in the equation for the short rate. The null hypothesis of no statistical significance cannot be rejected.

Oil price volatility doesn’t show any statistical significance either in the world oil price equation. The first, fourth and sixth oil price lags are statistically significant, with respective p-values of 0.00063, 0.00381 and 0.02097. Again, changes in the world real oil price are mostly explained by its previous variations.

As expected, previous values of oil price volatility are highly significant in explaining the present value. The first three lags are positive and significant, with a level of confidence of 5% for the first lag and of 1% for the second and third.

The second lag of realized volatility has a negative significant impact on the industrial production. An increase in the volatility appear to be followed by a fall of the industrial production two months after. Looking at the F test, the p-value associated to the null hypothesis of no significance of volatility lags is 0.1466; this value is somehow close to the level of significance of the 10%, and for the analysis’ purposes it will be concluded that the null hypothesis can be rejected.

The F test performed for the significance of volatility lags in the stock returns equation suggests that the null hypothesis cannot be rejected.

6.1.3 Model with NOP

In this case, the VAR regression with national oil price specification leads to results that are a bit less statistically significant compared to the VAR with world oil price.

The coefficient associated with the first world oil price lag in the industrial production equation is significant at the 10% level, while this doesn’t happen in the regression with national oil price.

Consider the equation for short term interest rate; in both cases, the second and the third oil price lags are statistically significant. In the world oil price model, they are both significant at the 5% level, while in the national oil price model they are significant at the 10% and 5% level, respectively.

Similarly, in the equation for real stock returns, the first world oil price lag is significant at the 5% level, while for the national oil price the level of significance in just of the 10%.
### CHAPTER 6. GERMANY

#### Short term interest rate

<table>
<thead>
<tr>
<th>Variable</th>
<th>( \text{ld}_r(5,261) )</th>
<th>( \text{ld}_{wop}(5,261) )</th>
<th>( \text{ld}_{rv}(5,261) )</th>
<th>( \text{ld}_{ip}(5,261) )</th>
<th>( \text{ld}_{rsr}(5,261) )</th>
<th>( F(5,261) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( r )</td>
<td>23.688 [0.0000]</td>
<td>2.2231 [0.0415]</td>
<td>0.4746 [0.8269]</td>
<td>0.97406 [0.4433]</td>
<td>1.5308 [0.1685]</td>
<td>1.6581 [0.1453]</td>
</tr>
</tbody>
</table>

#### World real oil price

<table>
<thead>
<tr>
<th>Variable</th>
<th>( \text{ld}_r(5,261) )</th>
<th>( \text{ld}_{wop}(5,261) )</th>
<th>( \text{ld}_{rv}(5,261) )</th>
<th>( \text{ld}_{ip}(5,261) )</th>
<th>( \text{ld}_{rsr}(5,261) )</th>
<th>( F(5,261) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( r )</td>
<td>0.40417 [0.8759]</td>
<td>4.4895 [0.0002]</td>
<td>0.92378 [0.4783]</td>
<td>0.6466 [0.6928]</td>
<td>1.207 [0.3031]</td>
<td>1.6344 [0.1514]</td>
</tr>
</tbody>
</table>

#### Realized volatility

<table>
<thead>
<tr>
<th>Variable</th>
<th>( \text{ld}_r(5,261) )</th>
<th>( \text{ld}_{wop}(5,261) )</th>
<th>( \text{ld}_{rv}(5,261) )</th>
<th>( \text{ld}_{ip}(5,261) )</th>
<th>( \text{ld}_{rsr}(5,261) )</th>
<th>( F(5,261) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( r )</td>
<td>0.72599 [0.6290]</td>
<td>3.21991 [0.0046]</td>
<td>11.718 [0.0000]</td>
<td>0.62572 [0.7096]</td>
<td>1.459 [0.1928]</td>
<td>1.3775 [0.2332]</td>
</tr>
</tbody>
</table>

#### Industrial production

<table>
<thead>
<tr>
<th>Variable</th>
<th>( \text{ld}_r(5,261) )</th>
<th>( \text{ld}_{wop}(5,261) )</th>
<th>( \text{ld}_{rv}(5,261) )</th>
<th>( \text{ld}_{ip}(5,261) )</th>
<th>( \text{ld}_{rsr}(5,261) )</th>
<th>( F(5,261) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( r )</td>
<td>1.312 [0.2522]</td>
<td>2.2765 [0.0370]</td>
<td>1.03636 [0.1466]</td>
<td>11.309 [0.0000]</td>
<td>2.3215 [0.0336]</td>
<td>1.3741 [0.2345]</td>
</tr>
</tbody>
</table>

#### Real stock returns

<table>
<thead>
<tr>
<th>Variable</th>
<th>( \text{ld}_r(5,261) )</th>
<th>( \text{ld}_{wop}(5,261) )</th>
<th>( \text{ld}_{rv}(5,261) )</th>
<th>( \text{ld}_{ip}(5,261) )</th>
<th>( \text{ld}_{rsr}(5,261) )</th>
<th>( F(5,261) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( r )</td>
<td>1.5365 [0.1666]</td>
<td>2.4503 [0.0255]</td>
<td>0.95167 [0.4587]</td>
<td>1.7135 [0.1183]</td>
<td>6.4579 [0.0000]</td>
<td>2.6564 [0.0232]</td>
</tr>
</tbody>
</table>

Table 6.2: F test for lags significance, model VAR(r,wop,rv,ip,rsr), Germany
6.2 Granger causality

From the results of the F test statistic, performed on the two models VAR(r,wop,ip,rsr) and VAR(r,wop,rv,ip,rsr) for the German economy it is possible to conclude that:

- world real oil price Granger causes short term interest rate
- world real oil price Granger causes industrial production
- world real oil price Granger causes real stock returns
- oil price realized volatility Granger causes industrial production.

6.3 Impulse response function

Figures 6.1 to 6.3 show the impulse response functions of the three economic variables, short term interest rate, industrial production and real stock returns, to a structural shock in the oil price level. Figures 6.4 to 6.6 show the impulse response functions of short term interest rate, industrial production and real stock returns, to a structural shock in the oil price volatility.

The effect of a shock in world real oil price on the short term interest rate (Fig.6.1) is positive. Within one month after the shock a first increase is registered, followed by a further raise and the maximum peak in the third month; afterward the decline begins, and the shock is reabsorbed.

The confidence bands for the IRF of industrial production to an oil price shock (Fig.6.2) are very wide since the first period, suggesting that the result is not particularly significant.

An oil price shock has a negative and statistically significant effect on real stock returns (Fig.6.3). As for the UK, the effect is delayed, becoming evident one month after the shock. So again, an increase in oil price level is associated with a decrease of real stock returns.

The confidence intervals calculated for the responses of short term interest rate and real stock returns to a one standard deviation shock of the oil price volatility (respectively, Fig.6.4 and 6.6) are very wide, confirming the result of no Granger causality.

The immediate response of industrial production to a shock in the oil price volatility (Fig.6.5) is negative. The strongest influence is registered three months after the shock, and it is afterward slowly reabsorbed.

6.4 Variance decomposition

Table 6.3 presents the forecast error variance decomposition of real stock returns due to all the variables in the model VAR(r,wop,rv,ip,rsr), after 8, 16 and 24 periods.

The contribution of oil price shocks to the variability of real stock returns doesn’t increase greatly after the 8th month (from 4.26% to 4.47% of the 16th and 4.49% of the 24th month), but it is all the time higher than that of interest rate (between 3.19 and 3.67%).
CHAPTER 6. GERMANY

Figure 6.1: Effect of one standard deviation shock of oil price on short term interest rate, Germany

Figure 6.2: Effect of one standard deviation shock of oil price on industrial production, Germany

Figure 6.3: Effect of one standard deviation shock of oil price on real stock returns, Germany
Figure 6.4: Effect of one standard deviation shock of oil price realized volatility on short term interest rate, Germany

Figure 6.5: Effect of one standard deviation shock of oil price realized volatility on industrial production, Germany

Figure 6.6: Effect of one standard deviation shock of oil price realized volatility on real stock returns, Germany
<table>
<thead>
<tr>
<th>Period</th>
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<th>r</th>
<th>wop</th>
<th>rv</th>
<th>ip</th>
<th>rsr</th>
</tr>
</thead>
<tbody>
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<td>3,1911</td>
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<td>2,8622</td>
<td>5,3034</td>
<td>84,3756</td>
</tr>
<tr>
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<td>0,049316</td>
<td>3,6685</td>
<td>4,4757</td>
<td>2,9013</td>
<td>5,4977</td>
<td>83,4569</td>
</tr>
<tr>
<td>24</td>
<td>0,0493638</td>
<td>3,753</td>
<td>4,49</td>
<td>2,9001</td>
<td>5,5848</td>
<td>83,3499</td>
</tr>
</tbody>
</table>

Table 6.3: Variance decomposition for real stock returns, \( \text{VAR}(r,wop,rv,ip,rsr) \), Germany

<table>
<thead>
<tr>
<th>Period</th>
<th>std.err.</th>
<th>r</th>
<th>wop(^+)</th>
<th>wop(^-)</th>
<th>ip</th>
<th>rsr</th>
</tr>
</thead>
<tbody>
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<td>4,2028</td>
<td>2,8015</td>
<td>85,2559</td>
<td>4,3308</td>
</tr>
<tr>
<td>16</td>
<td>0,0493089</td>
<td>3,9091</td>
<td>4,1827</td>
<td>2,9511</td>
<td>84,5432</td>
<td>4,4139</td>
</tr>
<tr>
<td>24</td>
<td>0,0493433</td>
<td>3,9138</td>
<td>4,1776</td>
<td>2,9527</td>
<td>84,5009</td>
<td>4,4551</td>
</tr>
</tbody>
</table>

Table 6.4: Variance decomposition for real stock returns, \( \text{VAR}(r,wop^+,wop^-,ip,rsr) \), Germany

The contribution of oil price realized volatility is around the 2.9%, and it can be noticed that between the 16th and the 24th period it starts to decrease.

**Asymmetric effect**

Table 6.4 presents the variance decomposition of real stock returns computed with regard to the asymmetric effect of oil price shock.

As for the case of the USA, positive oil price shocks appear to have larger impact on the forecast error variance of the real stock returns than do negative shocks (around 4.2% for the former and around 2.9% for the latter).
Chapter 7

France

The model used for analyzing the French economy is

\[ Y_t = \alpha_0 + A_1 y_{t-1} + A_2 y_{t-2} + A_3 y_{t-3} + A_4 y_{t-4} + A_5 y_{t-5} + A_6 y_{t-6} + \epsilon_t \]  

(7.1)

where \( \alpha_0 \) is a vector of constant, \( A_i \) is a time-invariant matrix, \( y_{t-1} \) is the first lag of \( y \), and \( \epsilon_t \) is the error term. The lag order is chosen to be \( p = 6 \), according to the AIC criteria; BIC and HQC suggest just 1 lag, which is considered not to be sufficient for the aim of the analysis.

The variables ordering is once more the following: short term interest rate, world real oil price, oil price realized volatility, industrial production and real stock returns. The first variables influence the following, but not the other way around.

7.1 VAR coefficients estimates and F test

7.1.1 Model with WOP

Table 7.1 reports the results of the F test.

Oil price lags seem not to be significant in the equation for short term interest rate. The only explanatory variable result to be the short rate itself, which indicate that the short rate is determined outside the model suggested. In fact, the hypothesis of no significance for all the other variables cannot be rejected.

Variations in world real oil price appear to be explained just by previous oil price changes. None of the other variables present a statistically significant lag. The observation is confirmed by the F test, which indicates that just for only lags of oil price the null hypothesis is rejected.

The first and the second lag of world real oil price are found to be significant in the industrial production equation. The assigned coefficients are both positive, the first at a level of significance of the 5% and the second of the 10%. From the results of the F test we can conclude that oil price has a significant influence on the level of industrial production.
CHAPTER 7. FRANCE

Short term interest rate

All lags of ld_r(6,256) = 12,976 [0.0000]
All lags of ld_wop(6,256) = 1,1288 [0.3459]
All lags of ld_ip(6,256) = 1,1042 [0.3603]
All lags of rsr(6,256) = 0.84475 [0,5364]
All variables, 6 lags: F(4,256) = 2,0246 [0,0914]

World real oil price

All lags of ld_r(6,256) = 0,64698 [0.6925]
All lags of ld_wop(6,256) = 4,9245 [0.0001]
All lags of ld_ip(6,256) = 0.65006 [0.6901]
All lags of rsr(6,256) = 0.49848 [0.8093]
All variables, 6 lags: F(4,256) = 1,4765 [0,2097]

Industrial production

All lags of ld_r(6,256) = 1,4211 [0,2068]
All lags of ld_wop(6,256) = 3,0733 [0.0064]
All lags of ld_ip(6,256) = 10,593 [0.0000]
All lags of rsr(6,256) = 2.0313 [0.0088]
All variables, 6 lags: F(4,256) = 1,8683 [0,1164]

Real stock returns

All lags of ld_r(6,256) = 1,2939 [0.2603]
All lags of ld_wop(6,256) = 2,2663 [0.0378]
All lags of ld_ip(6,256) = 1.5117 [0.1746]
All lags of rsr(6,256) = 5,2722 [0.0000]
All variables, 6 lags: F(4,256) = 1,7421 [0.1412]

Table 7.1: F test for lags significance, model VAR(r,wop,ip,rsr), France

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CHAPTER 7. FRANCE

The first oil price lag is highly significant in the real stock returns equation, with a level of confidence of the 1%. The coefficient is negative. This means that an increase of the oil price is followed, the next month, by a decrease in the stock returns. The F test reject the null hypothesis of no significance for the oil price lags, suggesting that the variable is significant in the real stock returns equation.

7.1.2 Model with WOP and RV

Table 7.2 reports the results of the F test. Similarly to the findings of the previous countries’ analysis, the results regarding the impact of world real oil price lags on the other economic variables doesn’t appear to change significantly. This means that the model is robust to the inclusion of the variable \( rv \).

The realized volatility doesn’t seem to have any impact on the short rate; none of the coefficients is significant. The null hypothesis of the F test cannot be rejected.

The level of world real oil price is not influenced by any lag of the other variables, including the oil price volatility. The only coefficients that show statistical significance are associated with the first and fourth lag of the world real oil price itself. Again, the result of the F test suggests that there is no statistical significance for volatility lags.

Once again, realized oil price volatility lags are found to be highly significant in explaining its present value. The first coefficient is significant at the 5% level of confidence, the second and the third at the 1% level of confidence.

Two lags of oil price volatility appear to have an impact on the industrial production level. The second is associated with a negative coefficient, the fourth with a positive coefficient. Both are significant at a level of 5%. The null hypothesis of the F test is rejected for a level of significance of the 10%.

The coefficients suggest that oil price volatility doesn’t have any explanatory power with respect to the real stock returns. In addition, as a result of the F test, the null hypothesis of no significance cannot be rejected.

7.1.3 Model with NOP

As found for Germany, the inclusion of the measure for world real oil price leads to more statistically significant results than do the inclusion of a national oil price measure.

In the industrial production equation, the coefficients of the first and second world oil price lags are statistically significant at the 10% level, while the same coefficients for national oil price are not.

Regarding the real stock returns, the first lag of world oil price is statistically significant with a p-value of 0.0058 (1% level of confidence), the first lag of national oil price is statistically significant with a p-value of 0.01009 (5% level of confidence).
### Short term interest rate

| All lags of $\text{ld}_r(6,256)$ | 16.507 [0.0000] |
| All lags of $\text{ld}_\text{wop}(6,256)$ | 1.092 [0.3652] |
| All lags of $\text{rv}(6,256)$ | 0.53622 [0.7488] |
| All lags of $\text{ld}_\text{ip}(6,256)$ | 0.81808 [0.5377] |
| All lags of $\text{r}_\text{srr}(6,256)$ | 0.92598 [0.4646] |
| All variables, 6 lags: $\text{F}(4,256) = 1.1962$ [0.3114] |

### World real oil price

| All lags of $\text{ld}_r(6,256)$ | 0.7876 [0.5594] |
| All lags of $\text{ld}_\text{wop}(6,256)$ | 4.1695 [0.0012] |
| All lags of $\text{rv}(6,256)$ | 0.70507 [0.6201] |
| All lags of $\text{ld}_\text{ip}(6,256)$ | 0.50161 [0.7749] |
| All lags of $\text{r}_\text{srr}(6,256)$ | 0.94065 [0.4552] |
| All variables, 6 lags: $\text{F}(4,256) = 0.27231$ [0.9280] |

### Realized volatility

| All lags of $\text{ld}_r(6,256)$ | 0.54998 [0.7383] |
| All lags of $\text{ld}_\text{wop}(6,256)$ | 3.7428 [0.0027] |
| All lags of $\text{rv}(6,256)$ | 14.124 [0.0000] |
| All lags of $\text{ld}_\text{ip}(6,256)$ | 0.96108 [0.4422] |
| All lags of $\text{r}_\text{srr}(6,256)$ | 4.424 [0.0007] |
| All variables, 6 lags: $\text{F}(4,256) = 2.342$ [0.0420] |

### Industrial production

| All lags of $\text{ld}_r(6,256)$ | 1.3061 [0.2617] |
| All lags of $\text{ld}_\text{wop}(6,256)$ | 3.0246 [0.0114] |
| All lags of $\text{rv}(6,256)$ | 1.8491 [0.1038] |
| All lags of $\text{ld}_\text{ip}(6,256)$ | 12.204 [0.0000] |
| All lags of $\text{r}_\text{srr}(6,256)$ | 3.1037 [0.0097] |
| All variables, 6 lags: $\text{F}(4,256) = 1.4401$ [0.2102] |

### Real stock returns

| All lags of $\text{ld}_r(6,256)$ | 1.5412 [0.1774] |
| All lags of $\text{ld}_\text{wop}(6,256)$ | 1.9672 [0.0839] |
| All lags of $\text{rv}(6,256)$ | 0.68337 [0.6364] |
| All lags of $\text{ld}_\text{ip}(6,256)$ | 1.8172 [0.1098] |
| All lags of $\text{r}_\text{srr}(6,256)$ | 5.4852 [0.0001] |
| All variables, 6 lags: $\text{F}(4,256) = 0.84556$ [0.5185] |

Table 7.2: F test for lags significance, model VAR($r, wop, rv, ip, rsr$), France
CHAPTER 7. FRANCE

7.2 Granger causality

From the results of the F test statistic, performed on the two models VAR(r,wop,ip,rsr) and VAR(r,wop,rv,ip,rsr) for the French economy it is possible to conclude that:
- world real oil price Granger causes industrial production
- world real oil price Granger causes real stock returns
- oil price realized volatility Granger causes industrial production.

7.3 Impulse response function

Figures 7.1 to 7.3 show the impulse response functions of the three economic variables, short term interest rate, industrial production and real stock returns, to a structural shock in the oil price level. Figures 7.4 to 7.6 show the impulse response functions of short term interest rate, industrial production and real stock returns, to a structural shock in the oil price volatility.

Most of the paths of the IRFs result to be very similar to those calculated for Germany.

The immediate response of interest rate to an oil price shock (Fig.7.2) is positive, peaking in the third month; then the decline starts. The confidence intervals appear wider than in the German case, meaning that the statistical significance is not so strong.

As suggested by the Granger causality, a one standard deviation innovation in the oil price doesn’t impact significantly the industrial production (Fig.7.2). The confidence bands are wide since the beginning.

In contrast, a shock in the oil price has a negative and statistically significant effect on the real stock returns (Fig.7.3); as for the other two European countries, this effect is delayed of one month.

Confirming the results of the Granger causality test, the impulse of an oil price volatility shock on industrial production (Fig.7.4) and on real stock returns (Fig.7.6) is not much significant.

The IRF of the industrial production to a volatility shock (Fig.7.5) is negative for the first 4 months after the shock, with the strongest influence in the second. The effect of the shock is then gradually reabsorbed from the fifth month.

7.4 Variance decomposition

Table 7.3 presents the forecast error variance decomposition of real stock returns due to all the variables in the model VAR(r,wop,rv,ip,rsr), after 8, 16 and 24 periods.

The contribution of oil price shocks to the variability of short term interest rate increases increases across the time, passing from 4.46% of the 8th period to 6.17% of the 24th period. For all this time, it is stronger than the contribution of interest rate.
CHAPTER 7. FRANCE

Figure 7.1: Effect of one standard deviation shock of oil price on short term interest rate, France

Figure 7.2: Effect of one standard deviation shock of oil price on industrial production, France

Figure 7.3: Effect of one standard deviation shock of oil price on real stock returns, France
CHAPTER 7. FRANCE

Figure 7.4: Effect of one standard deviation shock of oil price realized volatility on short term interest rate, France

Figure 7.5: Effect of one standard deviation shock of oil price realized volatility on industrial production, France

Figure 7.6: Effect of one standard deviation shock of oil price realized volatility on real stock returns, France

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Table 7.3: Variance decomposition for real stock returns, $\text{VAR}(r, w_{op}, r_{v}, i_{p}, r_{sr})$, France

<table>
<thead>
<tr>
<th>Period</th>
<th>std.err.</th>
<th>$r$</th>
<th>$w_{op}$</th>
<th>$r_{v}$</th>
<th>$i_{p}$</th>
<th>$r_{sr}$</th>
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<td>4.5756</td>
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<td>78.1297</td>
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</table>

Table 7.4: Variance decomposition for real stock returns, $\text{VAR}(r, w_{op^+}, w_{op^-}, i_{p}, r_{sr})$, France

<table>
<thead>
<tr>
<th>Period</th>
<th>std.err.</th>
<th>$r$</th>
<th>$w_{op^+}$</th>
<th>$w_{op^-}$</th>
<th>$i_{p}$</th>
<th>$r_{sr}$</th>
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<td>84.2236</td>
<td>4.1012</td>
</tr>
</tbody>
</table>

The percentage associated with realized volatility increases from 3.35% to 4.58%, becoming higher than that of interest rate.

**Asymmetric effect**

Table 7.4 presents the variance decomposition of real stock returns computed with regard to the asymmetric effect of oil price shock.

Similarly to the UK variance decomposition, negative oil price shocks appear to have larger impact on the forecast error variance of real stock returns, compared to positive shocks. The asymmetric effect is once again confirmed.
Chapter 8

Conclusion

The vast literature establishing robust results across many countries on the connection between oil price shocks and aggregate activity implies that connections should also hold between oil price shocks and stock markets. The aim of this study is to estimate the effects of oil price shocks and oil price volatility on the real stock returns of USA, UK, Germany and France using a VAR analysis.

The first findings obtained by the coefficients estimation and Granger causality test are that oil price variation significantly and negatively impact on the real stock returns, whereas no statistical significance is found for the oil price variance coefficients in the real stock returns equation. Instead, oil price realized variance seem to have a significant negative effect on the industrial production. Both world real oil price and oil price volatility appear to be highly autoregressive, in the extent that, in the respective regressions, the coefficients that show the highest level of significance are associated with lags of the variables themselves. Hence, while oil price movements seem to affect significantly the other macroeconomic variables, the converse is not found to be true.

An additional important result is that real oil price shocks measured as world real oil price lead to more statistically significant results that do the measures of national real oil price; this could be due to the fact that national oil price measures reflect offsetting movements of the exchange rate.

The impulse response analysis confirmed the negative impact of oil price shocks on the stock market, and showed that, while for the USA the response of real stock returns to an oil price shock is immediate, for UK, Germany and France this effect becomes evident within one or two months.

From the variance decomposition comes the result that, for three out of four countries (USA, Germany and France), the contribution of oil price shocks to variability in real stock returns is greater than that of short term interest rate, and similarly, the contribution of oil price realized variance is greater than that of interest rate for both USA and France.

Evidence is also found supporting the idea of asymmetric effects of oil price shocks: for USA and Germany positive shocks have higher impact on the forecast error variance of real stock returns, while for UK and France the opposite holds.
The result that both oil price volatility and level do impact the macroeconomy suggests that for purposes of macroeconomic prosperity, policy makers should not only focus on stabilizing price levels for the long-run, but on controlling the short-term, day-to-day fluctuations of the oil prices as well.
Bibliography


[33] Sadorsky, P. Oil price shocks and stock market activity Energy Economics, 21, 449 - 469, 1999

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