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OIL AND THE MACROECONOMY

Empirical evidence from 10 OECD countries

Economics
Master´s Thesis

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”…Now oil prices and many broader indices of commodity prices are again at or near all-time highs in nominal terms, and are very high in real terms as well. Copper, platinum, nickel, zinc and lead, for example, all hit record highs in 2006, in addition to crude oil. As a result, commodities are once again hot. It turns out that mankind has to live in the physical world after all!…” Jeffrey Frankel, 2006

Abstract

This paper examines the oil price-macro economy relationship by means of analyzing the impact of oil price on Industrial production, real effective exchange rate, real long term interest rate and inflation rate for a sample of ten OECD countries using quarterly data for the period 1970q1-2011q1. The impact of oil price shock on industrial production is negative and occurs with a lag of one year. However, the impact has weakened considerably compared to the 1970s. The impact on real effective exchange rate is negative/positive for a net importer/exporter, and the magnitude of the shock depends on the county´s share of net import/export of total world demand/supply. Real interest rates are affected negatively, through increase in inflation rates following the oil price shock. The effect tends to die out after 5-8 quarters following the shock for most of the variables and countries. This paper also applies alternative methods to test for unit root and cointegration, which takes into account for structural breaks in the data. The weakness of Phillips-Peron test is clearly demonstrated in the case of inflation rates and real interest rates, where the test falsely considered the series to be non-stationary when they in fact are stationary around a structural break. There is also strong evidence of cointegration between oil price and inflation rates and between oil price and real interest rates, especially when taking account for structural breaks.

This study also highlights the relevance of oil scarcity and oil peak theory. It is shown that these two terms should receive more attention than they have received so far as more oil exporters have reached their production peaks and more are likely to be followed. Oil scarcity seems not to be reflected in the price of oil, this in turn will increase the risk for the search for alternatives being initiated too late. Scarcity could then pose a serious limitation to the economy before a substitute resource or technology has been found. According to the data, renewable source of energy are not likely to dominate OECD countries energy mix in the short term, instead, there is a trend of increasing natural gas consumption among most of OECD countries. Natural gas markets are likely to play an equal role in the future as oil markets do today. The dilemma that importing countries are facing today, particularly in Europe, is whether to expose their markets to Russia or to the Middle East.

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Chapter 1: Introduction

Crude oil price behave much as any other commodity prices with wide price swings in times of shortage or oversupply. The cycle of oil price may extend over several years responding to changes in demand and as well as OPEC and non-OPEC supply. In the 1960s and the early 1970s, many countries were experiencing high growth and this growth coincided with a period of rapidly rising energy prices and disruptions in petroleum supply. Today, oil prices are again in the headlines, reflecting worries about stagnating world oil production, the uncertainty around the future in the Middle East, and the term "growth" itself has become a questionable term. To give a glimpse of the magnitude of the historically recorded supply disruptions, and recent geopolitical changes in the Middle East, below follows a short summary on these. These events are described in a more detail in A13 in appendix. Figure 1 below plots the oil price evolution along with these events.

1956. On October 29, 1956 Israeli troops invaded Egypt, followed by French and British. In the ensuing crisis, oil tankers were prevented from using the Suez Canal. The major pipeline that carried oil from Iraq through Syria was sabotaged, and exports of Middle East oil to Britain and France were blockaded. Overall, Middle East production fell by 1.7 million barrels per day (1.7 mbd) between October and November of 1956, or 10.1% of total world production of 16.8 mbd.[1]

1973. On October 17, 1973 war between Israel and its neighbors broke out causing the Arab members of OPEC to announce an embargo of oil shipments to countries showing sympathies toward Israel. Production of oil in these nations[2] fell from 21.1 mbd in September 1973 to 16.7 mbd in November, or a loss of 7.6% of total world production in September 1973.

1978. In 1978, revolution broke out in Iran (the Iranian Revolution) which led to drop in Iranian production from 6.1 mbd in September 1978 to 0.7 mbd in January 1979, or a loss of 8.6% of total world production in September 1978.

1980. The war between Iraq and Iran which lasted for eight years led to a fall in Iraqi production from 3.3 mbd in July 1980 to 0.1 mbd in October 1980, while production in Iran fell from 1.7 mbd to 0.5 mbd during the same period. The combined drop from these two nations represented 7.2% of total world production in July 1980.

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[1] Hamilton (2000), original source: Oil and Gas Journal, November 12, 1956, pp. 122-125.

[2] According to the data provided by U.S. energy Information Administration (EIA), the countries who reduced their production during this period were Algeria, Kuwait, Libya, Qatar, Saudi Arabia, United Arab Emirates and Venezuela. Angola and Ecuador had stable production, whereas Iran, Iraq, Nigeria increased production with 3.7%, 1.7% and 4.6% respectively during the same period.

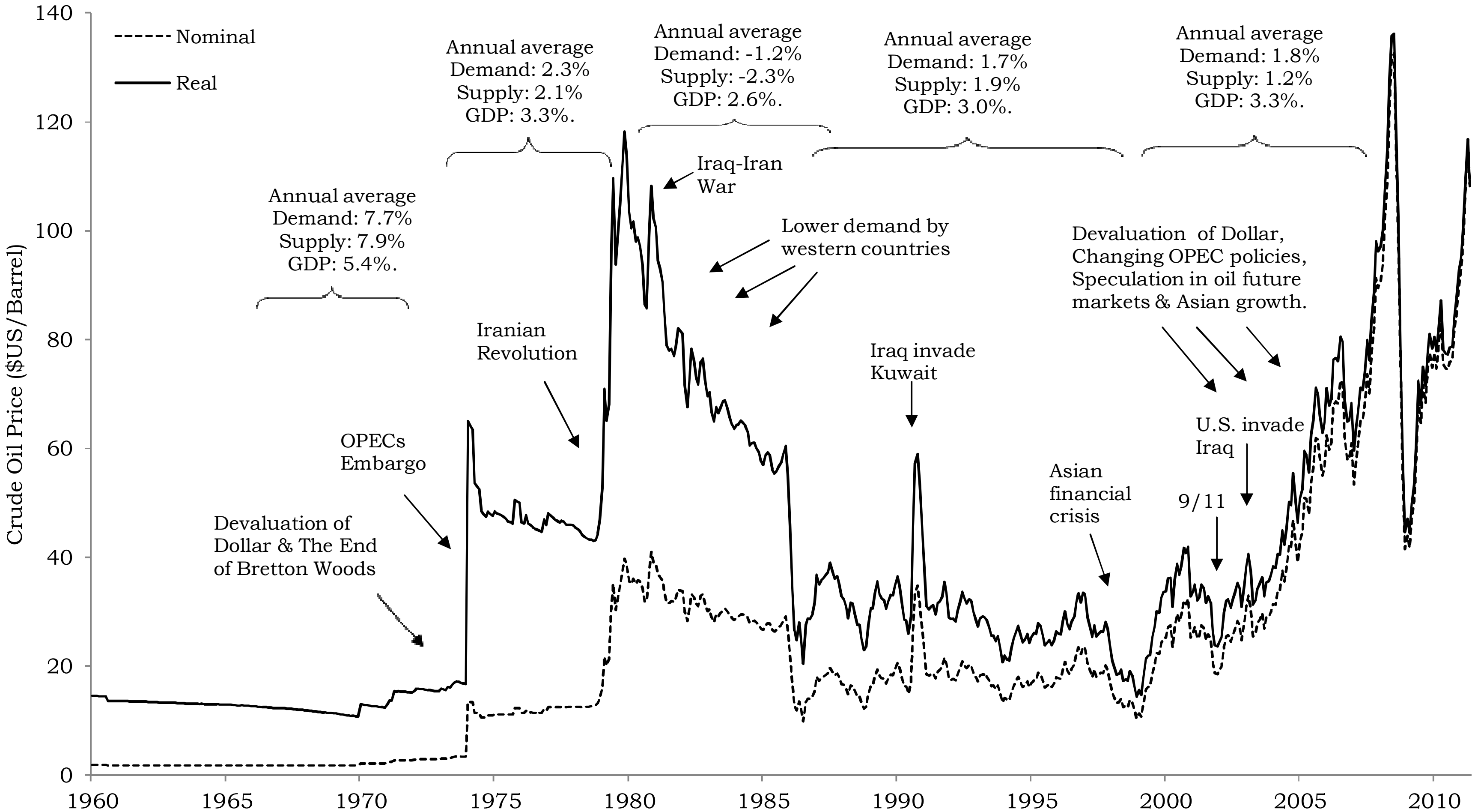

Figure 1. World Oil Price 1960 January- 2011 May. Source: International Financial Statistics.

1980 - 1986. Surplus of oil in world market caused by falling demand due to the earlier crisis mentioned above resulted in a sharp decline in prices during the first half of the 1980s. Demand fell by 17 percent in Europe, 19 percent in Japan, and 15 percent in the United States from 1979 to 1985[3]. OPEC tried in an attempt to dampen the fall in prices by reducing its output; however this strategy did not show much success. The beneficiaries of the price collapse were countries in Europe, Japan, United States and Third world nations. The collapse represented a serious loss in revenues for oil producing countries in northern Europe, the Former Soviet Union and OPEC. The price collapse played also a major role in the fall of the Soviet Union.

1990. The 1990s started with another war, where Iraq accused Kuwait of overproducing and hence lowering Iraq´s oil revenues especially at a time when Iraq was in a financial stress after the long Iraq-Iran war during the 1980s. Kuwaiti production fell from 1.9 mbd in July 1990 to 0.1 mbd in September 1990, while Iraqi production fell from 3.5 mbd to 0.5 mbd during the same period. The combined drop for the two countries represented 7.8% of total world production in July 1990. It should be noted here, that both these countries production levels continued to be low several years after the invasion[4], this is especially the case for Iraq.

2000 – 2009. Following the 9/11 attack and the U.S. invasion of Iraq in 2003, oil prices were gradually increasing after the beginning of 2000 to reach the peak of $132.55 per barrel in July 2008. What caused the oil price to peak as it did in July 2008, has several explanation. The major factor that contributed to the increase in price was the failure of world supply of oil to increase between 2005 and 2008 along with the increase in demand from Asian countries. Other factors are the devaluation of the dollar and the low interest rates on U.S. Government bonds, speculation in oil futures. However, there are factors that are worth considering which always have been in the background, such as the strategic restraint of OPECs capacity expansion, the militarism and unproductive use of capital and labor in the Middle East, economic sanctions and the "War on Terror" which I discuss in the appendices.

2010 - Present. Since the 18th of December, 2010 there have been revolutions in Tunisia and Egypt, a civil war in Libya, uprisings in Bahrain, Syria and in Yemen. Also minor protests have been observed in Algeria, Iraq, Jordan, Morocco, Oman, Kuwait, Lebanon, and Saudi Arabia. This revolutionary wave has become to be known as the "Arab Spring" and sometimes as the "Arab Spring and winter", "Arab Awakening" or simply "Arab Uprisings". Underlying factors to these revolutions, or uprisings, have been dictatorship, or absolute monarchy, human rights violations,

[3] BP Statistical Review 2011

[4] Average production for Kuwait in 1991, 1992 and 1993 was 0.190, 1.058 and 1.852 mbd respectively, while Iraq had an average of 0.850 mbd during the period 1991-1997, source: EIA.

government corruption, economic decline, unemployment just to mention a few. As of September 2011, these revolutions have resulted in the overthrow of three heads of state. Zine El Abidine Ben Ali (Tunisia) fled to Saudi Arabia in January 2011, President Hosni Mubarak (Egypt) resigned in February 2011 after 18 days of massive protests ending his 30 years in power and Muammar al-Gaddafi was overthrown in August 2011 after the National Transitional Council (NTC) took control. And more are likely to follow their footsteps, President Omar al-Bashir (Sudan) announced that he would not seek re-election in 2015[5], as did Prime Minister Nouri al-Maleki (Iraq) whose term ends in 2014[6]. In short, the region is changing and the future for the region is still much unknown. These events have been reflected in the price of crude oil lately and will continue to be reflected as long as there are uncertainties around the future in the region.

The importance of studying the historical evolution of oil prices and its impact on economic activity and other macroeconomic variables may not have been as important as it is today. This paper tries to find the answers to the following questions and highlight the following issues:

- Non-renewable natural resources and the importance of oil for OECD countries. More specifically, what relevance does the term oil scarcity have today?
- The influence of oil prices on economic activity and other macroeconomic variables. Much of the previous literatures have focused on the specific impact of oil price movements on gross domestic product (GDP) and especially on the US economy. This paper extend the scope of the analysis to the various links between oil price and other macroeconomic variables (industrial production, real effective exchange rate, real long term interest rate and inflation rate) for a sample of 10 OECD countries.
- The oil peak theory and its relevance today. Should we, today, be worried about peaking world oil supply? What are the alternatives in the short/long term?

The study is organized as follows; Chapter 2 discusses oil scarcity and OECD countries dependence on oil today. Chapter 3 provides some primarily words on the relationship between oil price and the other macroeconomic variables that are considered in this study. Chapter 4 reviews earlier empirical studies on the relationship between oil price and the other variables considered. Chapter 5, explains the theoretical methodology used in this paper and futures of the data are explained and the way they are used. Empirical analysis and results are presented in chapter 6. Finally, in chapter 7, conclusion and final comments are given along with suggestion of further studies.

[5] “Party: Bashir is not standing for re-election” Gulf Times. 22 February 2011.
[6] “Iraq PM plans no re-election”. Voice of Russia. 5 February 2011.

Chapter 2: Non-renewable natural resources

A non-renewable resource is a natural resource which cannot be produced, grown, generated, or used on a scale which can sustain its consumption rate. Once the resource is used, there is no more remaining. Examples of these resources are coal, petroleum and natural gas. These resources exist in a fixed amount and are consumed much faster than nature can create them. This chapter discusses the following issues; the importance of oil for OECD countries (historical perspective), the concerns about "Oil Scarcity" today, and the long term behavior of oil price.

2.1 The importance of oil for oil-importing OECD countries

In the 1970s, energy was the core of economic and social activity in industrialized countries. Energy costs affect not only industries with large energy consumption but also industry as a whole and even the cost living of citizens, notably because the impact of energy prices on transport cost and heating. Following World War II, the importance of oil escalated and Western economies were increasingly restructured physically, politically and economically around oil. Oil ushered in different forms of transportation (such as personal automobile and planes), meaning that people could travel further distances in shorter periods of time. People no longer had to live close to their places of work and many chose to move to the suburbs, away from the hectic city life. It was also not necessary for shopping to be done close to home, thus the explosion of urban sprawl, car oriented shopping centers and the decline of local neighborhood stores, Fusco (2006).

The increase in oil prices during the 1970s acted as a wake-up call for many oil importing countries. Ever since, these countries have formed policies towards minimizing their dependency on oil. One of the key differences between the economic context in the 1970s and today concerns the dependence on oil. In the 1970s, oil-import intensities (measured as Barrels per 2000 year´s GDP dollars) were much higher than today and have been following a decreasing trend since the first oil shock, as illustrated in Figure 2 below.

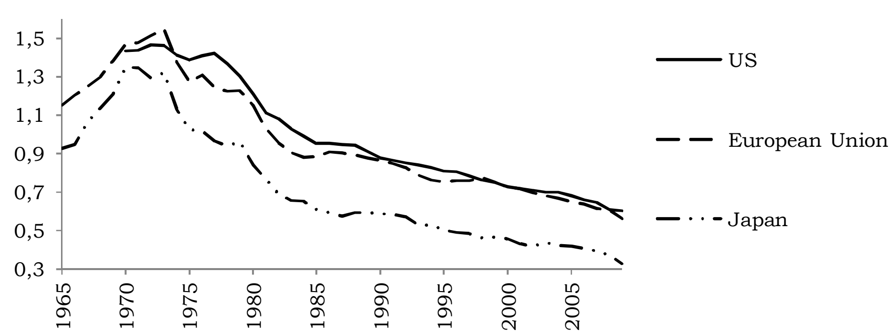

Figure 2. Oil intensity (Barrels per 2000 US dollars GDP). Source: author calculations based on BP statistical review 2011 and World Bank data.

The fall in oil intensity may be explained by three processes. First, at the sectoral level, important improvements in terms of energy efficiency were accomplished between the first shock and the counter ones. Second, the economic structure of industrial countries has evolved, leading to an increase in less energy-intensive activities (such a services) and a decrease in more energy-intensive activities (such as industry) in the GDP, Figure 3 below.

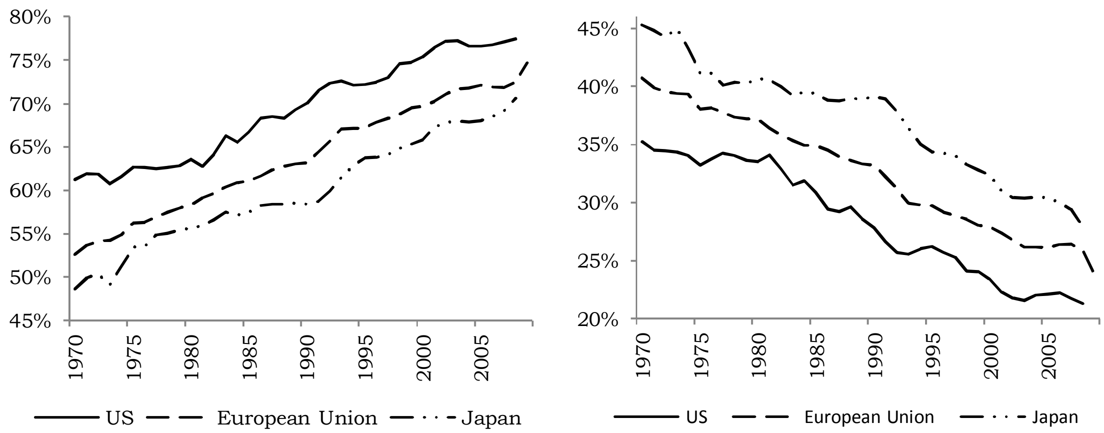

Figure 3. Services etc (left), Industry (Right). Value added (% of GDP). Source: World Bank Data.

Finally, the optimization of the energy mix allowed these countries to reduce total consumption by substituting energetic products in order to use them at best according to their characteristics.

The substitution away from oil towards alternatives source of energy is also evident when looking at oil used to produce electricity in oil-importing countries, Figure 4-6 below. Most OECD countries saw a big switch away from oil in electric power generation in the early 1980s. After oil prices rose sharply compared to the prices of other fossil fuels in the 1970s, the power sector switched from oil to other inputs: some countries went back to coal (for example, the United States); others increased their nuclear capacity (for example, France) or turned to alternative energy sources. The largest switch away from oil was seen in Japan. Japan was highly dependent on oil for producing its electricity during the 1970s; oil that was used to produce electricity peaked at 73.2 percent of total input in 1973. By 1980, the same figure was down to 46.2 percent and by 1986 the figure was down to 26.8 percent. Today, the power sector is no longer an important oil consumer in OECD countries, the amount of oil needed to produce electricity for the US amounts to 1.2 percent, for European Union 2.9 percent and for Japan 7.1 percent of total input used.

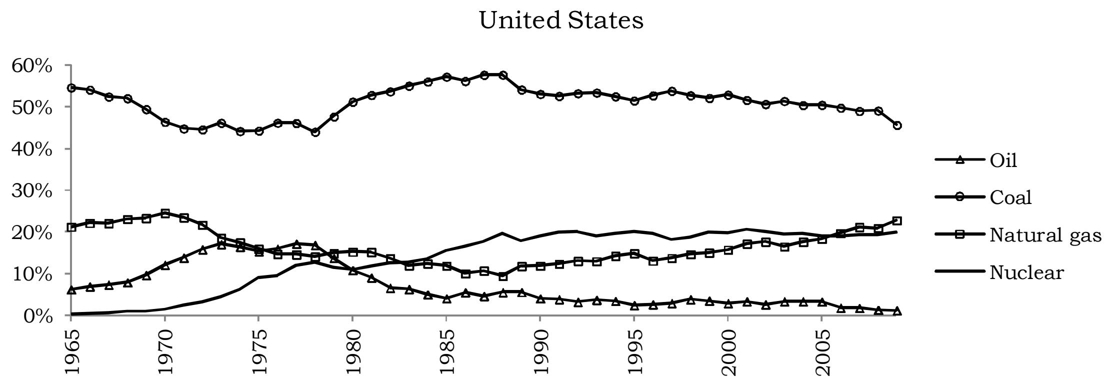

Figure 4. Energy mix used in the production of electricity for the United States. Source: World Bank Data.

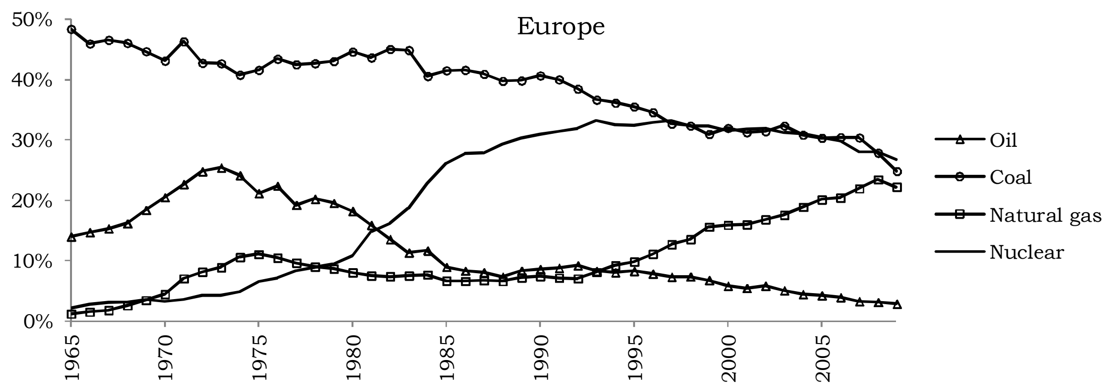

Figure 5. Energy mix used in the production of electricity for Europe. Source: World Bank Data.

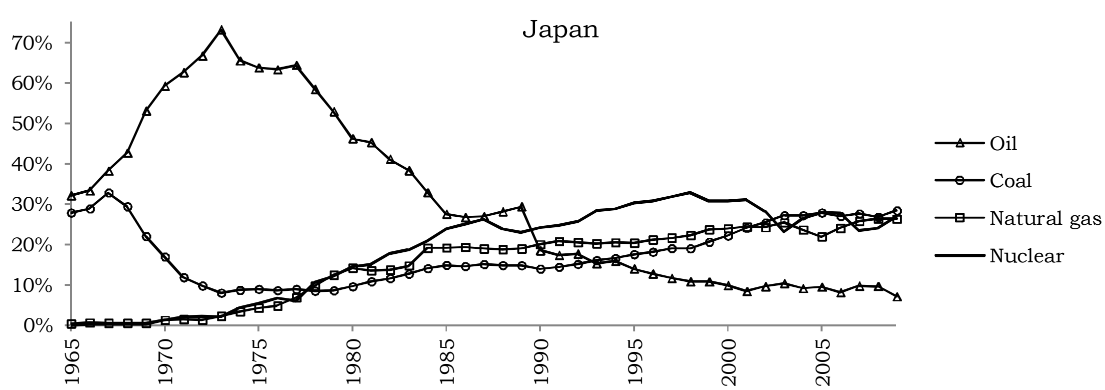

Figure 6. Energy mix used in the production of electricity for Japan. Source: World Bank Data.

Furthermore, although economies in the West and Japan have been very efficient and successful in their usage of oil in the sectors mentioned above, the transportation sector still remains as a challenging task. The transportation sector relies almost exclusively on liquid hydrocarbons as the energy source. One reason for why cars, trucks, buses, trains, airplanes etc. prefer to use liquid hydrocarbons is their high volumetric energy density and convenience of use. Road sector energy consumption, measured as percentage of total energy consumption, has been increasing since the mid 1960s, except for Japan were the rates seems to have been stagnating at around 15 percent during the 1990s followed by a downward trend during the 2000s, Figure 7 below.

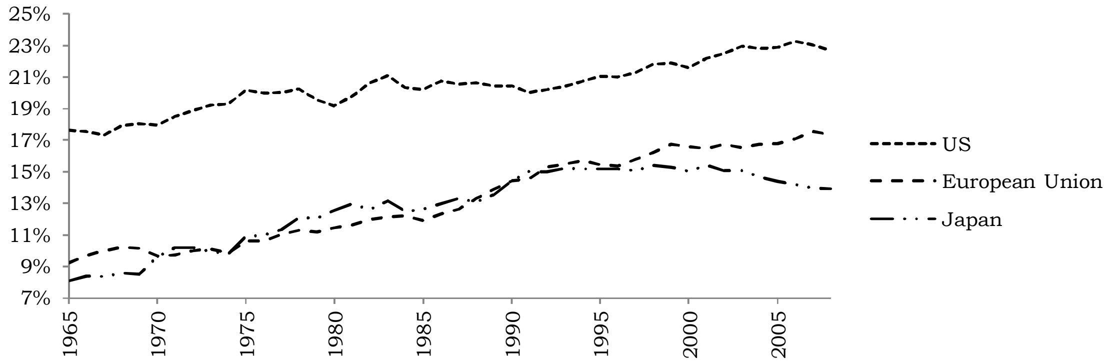

Figure 7. Road sector energy consumption (% of total energy consumption). Source: World Bank Data.

Expanding motorization around the world has caused a steady increase in CO_2 emissions from the global transport sector and in 2008 this sector accounted for about 22 percent of total world CO_2 emissions[7]. In Japan, CO_2 emissions from the transport sector accounted for about 22 percent of total CO_2 emissions, the same figure for the US and European Union was 32 and 29.5 percent respectively. While CO_2 emissions from the transport sector have been steadily increasing (US and European Union), CO_2 emissions from Japan´s transport sector peaked in 2001 and have been on a declining trend ever since, Figure 8 below. The sector´s total CO_2 emissions in 2001 amounted to 231.7 million tons, but by 2008 this decreased to 202.6 million tons. For the US and European Union comparable figures were 1433 million tons (US) and 1228 million tons (European Union) in 2001 whereas in 2008, the same figures increased to 1456 million tons (US) and 1341 million tons (European Union)[8].

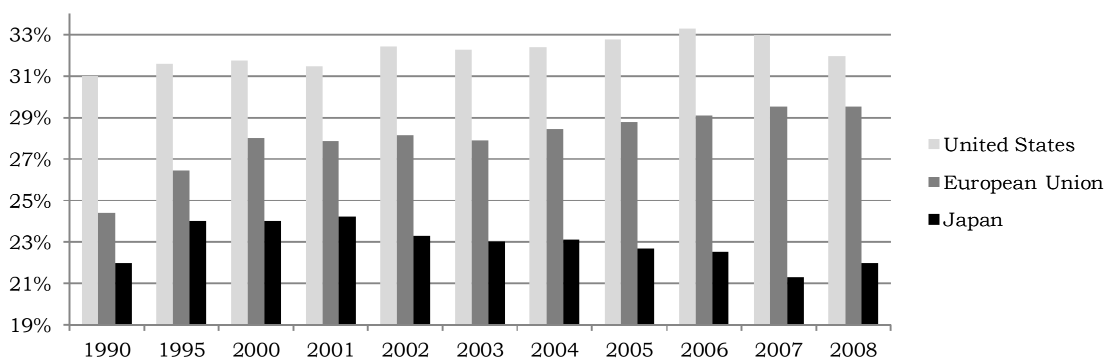

Figure 8. Transport CO2 as percentage of total CO2 from fuel combustion. Source: International Transport Forum (OECD)

[7] CO2 Emissions from fuel combustion only.

[8] The underlying data for all figures were taken from International Transport Forum (OECD).

The story behind Japan´s success to reduces these CO2 emission levels have been; (1) increase vehicle fuel efficiency, (2) improve traffic flow and promote eco-driving, and (3) reduce travel distances, Edahiro (2010).

In sum, the world road sector energy consumption today amounts to 14.2 percent of total energy consumption, however, including jet fuel for aviation, bunker fuel as a naval propellant, and diesel fuel (used in trucks, industrial machinery, and cars), the figure is 50 percent of total energy consumed. A substantial part of the oil left goes to the petrochemical industry and for other miscellaneous uses outside the power sector. Given current technologies, it is harder to substitute other factors for oil in these sectors. Even though there has not been any substantial substitution away from oil in recent years, new technologies are emerging in the transportation sector. However, predicting the scope for substitution using these new technologies in the coming years is difficult, but a big switch cannot be ruled out over the medium term[9].

2.2 Oil Scarcity

Oil is a key factor of production, including in the production of other commodities and in transportation, and is also a widely used consumption good. Oil is the most traded commodity, with world exports averaging $1.8 trillion annually during 2007-09, which amounted to about 10 percent of total world exports in that period. Changes in oil market conditions have direct and indirect effects on the global economy, including on growth, inflation, external balances, and poverty. Oil supply constraints are widely perceived to have contributed to the rising oil prices since the late 1990s. This has raised concerns that the oil market is entering a period of increased scarcity. The declining availability of oil typically reflects technological and geological or a shortfall in the required investment in capacity. Oil scarcity can be exacerbated by its low substitutability. Oil has unique physical properties that make rapid substitution difficult, which in turn mean that the price may be determined largely by supply capacity. In contrast, if other, more abundant natural or synthetic resources can eventually replace oil in the production process, then relatively small increases in prices may redirect demand toward these substitutes[10].

Fossil fuels currently (2010) provide 87.3 percent of US energy (of which coal 26.3 percent, natural gas 31.1 percent and oil 42.6 percent), 79.4 percent of European Union Energy (of which coal 19.6 percent, natural gas 32.2 percent and oil 48.2 percent) and 81.9 percent of Japan´s energy (of which coal 30.1 percent, natural gas 20.7 percent and oil 49.1 percent). No doubt, oil is the most important source of primary energy for these nations. Renewable sources of energy are in a

[9] World Economic Outlook April 2011. Chapter 3: "Oil Scarcity, Growth, And Global Imbalances".
[10] World Economic Outlook April 2011. Chapter 3: "Oil Scarcity, Growth, And Global Imbalances".

rapid growth phase, but they still account for only a small fraction of primary world energy supply (Figure 9, right). Much of the current concern about oil scarcity is the increase in the growth rate of global primary energy consumption in the past decade (Figure 9, left).

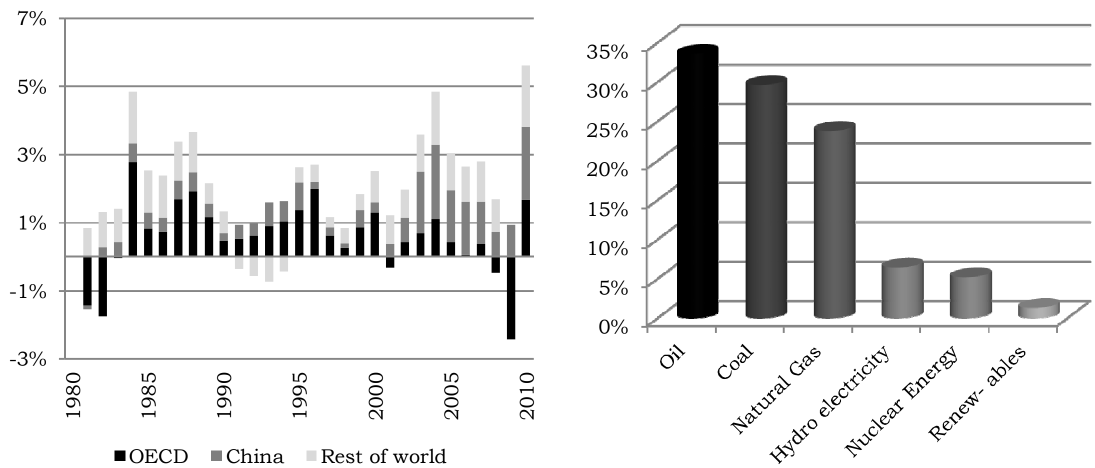

Figure 9. Growth Rate of Primary Energy Consumption (Left). Primary energy supply by fuel- World (Right). Source: BP Statistical Review 2011

The acceleration in Primary Energy Consumption primarily reflects an upward shift in the growth of energy consumption in China. One thing that China needs to keep its economic growth is fuel and a lot of it. From being a net-exporter of oil in 1992, China has headed quickly in the opposite direction and is now more dependent on foreign oil. In 2000, China was importing 31.8 percent of its daily consumption whereas last year the figure was up to 55.0 percent. China is now the largest energy consumer in the world accounting for 20.3 percent of total world energy demand. This is becoming an increasingly difficult task for China to handle since growth is likely to continue in China as more and more of its people joining the middle class.

According to IMF´s latest World Economic Outlook (WEO), chapter 3 on "Oil Scarcity, Growth and Global Imbalances", global oil markets have entered a period of increased scarcity. Furthermore, the chapter suggests that gradual and moderate increases in oil scarcity may not present a major constraint on global growth in the medium to long term. The report however, barely touches on the decline of exports by oil producing countries: "Finally, the simulations do not consider the possibility that some oil exporters may reserve an increasing share of their stagnating or decreasing oil output for their domestic use… If this were to happen, the amount of oil available to oil importers could shrink much faster than world oil output, with obvious negative consequences for growth in those regions"(p.109). This part of the report is well underestimated; below, I have plotted the share of oil output used domestically (Figure 10, below) by some key oil exporting countries which together accounted in 2010 for about one third of total world production and had proven reserve equal to 62 percent of total world proven reserves. As observed, these countries share of oil used domestically have rather increased in the past 13 years.

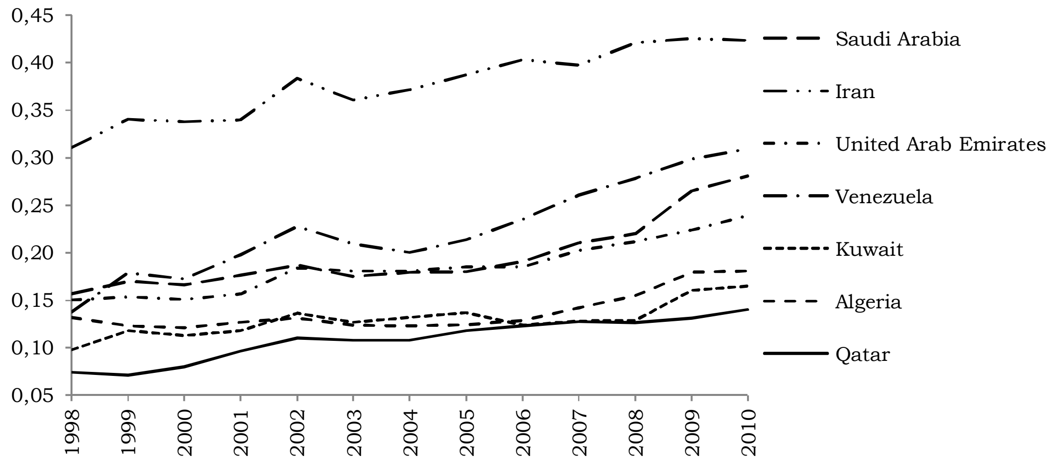

Figure 10. Share of oil output for domestic use in some OPEC member countries. Source: author calculations BP Statistical Review 2011

Thus, the declining exports by key producers cannot be considered as a "possibility" but rather an eventual certainty.

2.3 Why do oil prices not increase in the long-term?

There is a mystery regarding the issue of why oil prices do not increase in the long term. The yearly production or supply of oil to world market has increased more than three fold since 1965, but the long-term price trend has been fairly flat (aside from the historical oil price shocks that most people agree was due to factors other than the existence of long-term oil scarcity). It may seem natural to think that increasing supply helps to keep prices down; however, this is about a non-renewable resource which at one point in the future will cease to exist.

Looking at the issue from an oil producer´s point of view, if oil prices are relatively flat, then the oil producer would be better off to extract all of the oil from the ground, sell it, and deposit the revenues at the bank and earn the interest rate. If on the other hand, prices rise faster than the returns from the bank, it is obviously better to wait and extract the resource at some point in the future. This leads us to the following conclusion; the price of oil should be at par with the interest rate. This is generally known as the Hotelling´s rule which states that efficient exploitation of a non-renewable resource would, under otherwise stable economic conditions, lead to a depletion of the resource. Furthermore, the rule states that this would lead to a net price or "Hotelling rent" for it that rose annually at a rate equal to the rate of interest, reflecting the increasing scarcity of the resource, Gaudet (2007).

How do we explain the price trends we are seeing today? Geopolitical factors can certainly explain one part; the development of future renewable substitutes explains another. Spiro (2011) examines another possible explanation. In his model, he takes a departure from rational expectations[11] by assuming that economic agents have a finite time horizon and then cannot correctly predict the price trends, meaning that they make a plan over a finite number of years but update this plan on a regular basis. This kind of behavior is observed in the business plans of firms, in US social security and in the extraction decisions of natural resource owners. The result he reached when assuming finite time horizon in a standard model of capital accumulation were almost identical with the result reached when assuming infinite time horizon using the same model. However, using the assumption of finite time horizon in models of natural resources had the effect of removing the scarcity consideration of resource owners. Thus letting only operating costs and demand determine the extraction rate which imply that the extraction will be non-decreasing and the resource price non-increasing for a long period of time, this is in line with the behavior of oil price we have observed so far (aside from the historical shocks).

Spiro (2011) calibrated the model to the oil market and yielded a price which closely fits the gradually falling real price up to 1998 and the sharply increasing price thereafter. His results imply that resource owners' decisions are based on finite time horizon and not on infinite time horizon assumptions. The interesting point he makes is that; while it is commonly expected that if oil prices were to rise, a substitute for the resource would be searched for and eventually found, but, if the trend and level of the resource price do not reflect the scarcity of the resource (which was the case with finite time horizon) then this search will be initiated too late. Scarcity may then pose a serious limitation to the economy before a substitute resource or technology has been found.

[11] Assuming rational expectations is to assume that agents´ expectations may be individually wrong, but are correct on average. In other words, although the future is not fully predictable, agents´ expectations are assumed not to be systematically biased and use all relevant information in forming expectations of economic variables, Snowdon, Vane & Wynarczyk (1994).

Chapter 3: Some words on the relationship between oil prices and macroeconomic variables

3.1 Oil price and Industrial production

There is a strong link between the demand for oil and global economic growth (see for example figure 19), this because oil is an important input into many industries. A good example of this is the growth in Chinese economy which basically consists of growth in energy-intensive sectors that has led to a surge in demand for crude oil into the Chinese economy. In general one should expect a negative correlation between oil prices and the performances of industries. Industries that use oil as a key input into their production process, rising oil price leads to higher input costs and the more an industry relies on oil, the bigger will be the impact on its costs and profitability, and hence the bigger the fall in its production. Figure 11 below plots the industrial production indexes for some industrialized countries along with real oil price. The effect of oil price shock is not observed immediately but rather after few quarters as demonstrated by the shock in 1973, this is explained by the fact that industries in general face difficulties in switching away from an important input as in the case with oil towards other substitutes. Following an increase in oil prices (or energy prices in general), industries move from energy intensive sectors towards sectors that are less energy intensive, and because this change cannot be achieved quickly, there will be an increase in unemployment rates and less efficient use of resources in the short-run, Pindyck and Rotemberg (1983). Also, in times of high uncertainty around the future movement of oil prices, industries have an incentive to postpone investment decisions.

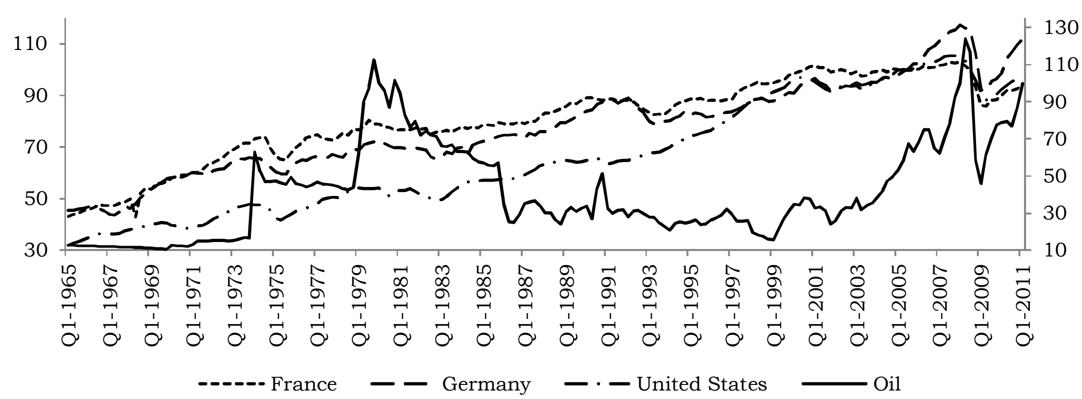

Figure 11. Industrial Production for some industrialized countries (left axis) and real oil price (right axis).

The demand by OECD countries in general was much higher pre 1973; however, after the experiences of the 1970s, most of OECD countries were forced into restructuring away from oil use in their industries. As a result, the impact of oil price shocks on industrial production is much less now than during the 1970s.

3.2 Oil price and real effective exchange rates

To analyze the impact of oil price movement on the real exchange rate for a country, one has first to understand the impact of terms of trade on the exchange rate. Terms of trade are defined as the export price relative to import price and can be expressed as:

$$ToT = \frac{P_{ex}}{EP_{im}}$$

Where $\mathrm{P_{ex}}$ is export price, E is nominal exchange rate and $\mathrm{P_{im}}$ is import price. Theoretically, there are two effects, working in the opposite direction, for which terms of trade can affect the exchange rate. If one consider an improvement in terms of trade. On the one hand, national income increases, which results in increasing demand for particularly non-tradeable goods (income effect); this then cause a rise in the general price level, which induces an appreciation of the exchange rate. On the other hand, consumption of imported goods increases to the detriment of domestic goods (substitution effect); this then cause a drop in demand for non-tradeable goods, which in turn results in a depreciation of the exchange rate, Coudert, Coubarde and Mignon (2009).

For oil exporting countries, income effect generally prevails over substitution effect. The substitution effect has little significance because the exported product and imported products (manufactured products) are used in different manner. Therefore it is difficult for households to substitute an important product such as oil for other products in their consumption basket based on price variation. For oil importing countries, the terms of trade worsen following an oil price increase because they now have to pay more per barrel and therefore have to export greater volume of export to pay for this. Another way to put it, following an increase in oil prices, exporting countries afford more unit of import per unit of export while oil importing countries have to pay more unit of export per unit of import, Coudert, Coubarde and Mignon (2009).

Figure 12 below plots the net barter terms of trade index[12] for a group of net oil exporting countries and net oil importing countries. An increase in the index means that the terms of trade for the country in question have improved. As shown in the figure, terms of trade were improved for oil importing countries following the declining oil prices during the first half of the 1980s, whereas it was worsened for Norway. Throughout the 1990s the indexes were relatively stable, reflecting a period of stable oil price. However, following the increase in oil price after 2002-2003, the indexes for exporting and importing countries were going in the opposite direction, demonstrating the positive (negative) impact of higher oil prices on net oil exporting (importing) countries. This in turn should have induced the currency to appreciate (depreciate) for oil exporters

[12] Net barter terms of trade index is calculated as the percentage ratio of the export unit value indexes to the import unit value indexes, measured relative to the base year 2000. Source: World Bank.

(importers). Interesting to note from the below figure is the index for Australia, which acts as if the country were an oil exporting country when it is in fact a net oil importing country. The improvement in Australia´s terms of trade is not due to higher oil prices but rather due to higher gold prices. The country is the third largest exporter of gold in the world and historically, gold price have followed oil price quite well (see Figure 32 in A13).

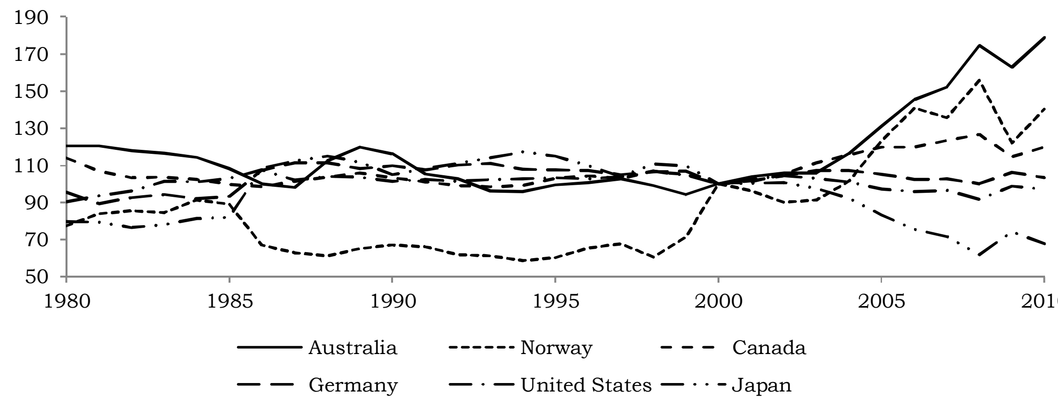

Figure 12. Net barter terms of trade index (2000=100) for Australia, Norway, Canada, Germany, United States and Japan. Source: World Bank.

Figure 13 below plots the real effective exchange rate index for Canada and the United States along with real oil price. An increase in real effective exchange rate index means a real appreciation of the country´s currency in question. Clearly, one can observe the negative correlation between the real effective exchange rate for the US and the real price of oil. Also, one can observe this negative relationship during the first half of the 1980s. The drop in oil prices during this period which was due to lower demand for oil from the industrialized world was accompanied by a large appreciation of the US dollar.

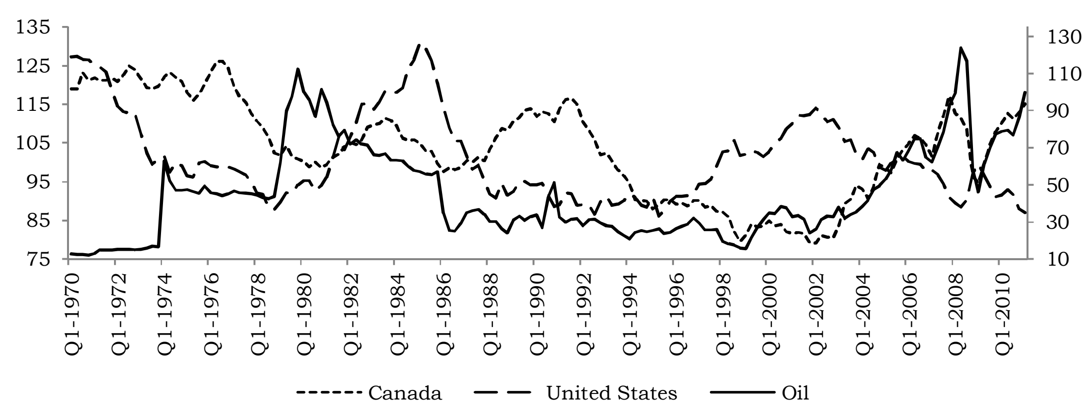

Figure 13. Real effective exchange rate for Canada and United States (left axis) and real oil price (right axis).

Considering Canada, which is an exporter of oil, one should expect a positive correlation between the Canadian dollar and the real price of oil, i.e. when oil price goes up the Canadian dollar appreciates. The value of the Canadian dollar has good reason to be sensitive to the price of oil. As of 2010, Canada is the sixth-largest producer of crude oil in the world and is expected to climb the list with oil sands production increasing regularly.

3.3 Oil price and real long term interest rates

The yield of a government bond describes the total amount of money one can make when investing in a government bond. In the U.S., Treasury notes or bonds are sold by the U.S. Treasury Department to pay for the U.S. debt. The yields go down when there is a lot of demand for Treasury products, and go up when these notes or bonds are not considered to be an attractive investment. When these yields increase, the interest rates on for example house mortgages increases. This in turn makes it more expensive to buy a house, so demand for houses decreases and so do prices. This then can have negative impact on the economy and therefore can slow GDP growth. Figure 14 below plots the real long term interest rates for France, Germany and the U.S. along with real oil price. As one observes, there is a clear negative correlation between these two variables, i.e. when oil price increase, real interest rates decrease and the opposite. So, why this negative correlation?

High interest rates reduce the demand for storable oil (and commodities in general), or increase the supply through variety of channels. First, higher rates increase the incentive for extraction today rather than tomorrow (one could think of the rates at which oil is pumped). Secondly, higher rates decreases firm´s desire to carry inventories (increasing costs for holding oil in tanks). Third, higher rates encourages speculators to shift out of oil contracts (or commodity contracts in general), and into treasury products. All these mechanisms reduce the market price of oil, as happened when real interest rates where high in the early 1980s.

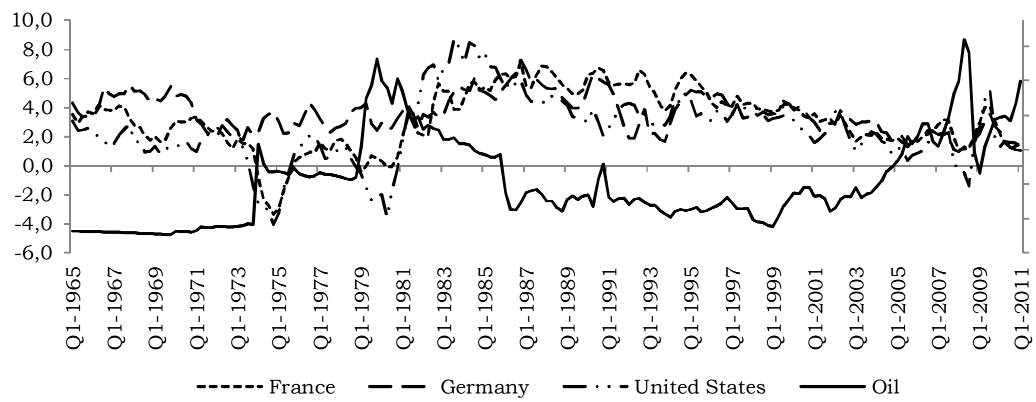

Figure 14. Real long term interest rates for France, Germany and United States (left axis) and real oil price (right axis).

The opposite happened during the steadily increase of the 2000s, i.e. real interest rates was historically low thus lowering the cost for holding inventories, increasing the inventiveness` of oil producers to extract the oil tomorrow rather than today, encouraging speculators into oil future markets and raising oil prices, Frankel (2006).

3.4 Oil price and Inflation rates

It is widely believed that oil prices and inflation are closely connected in terms of cause and effect relationship. When oil price goes up or down, inflation follows in the same direction. The explanation for this is that oil is an important product (and input in the economy) in producing many other various products such as plastic and is crucial for activities such as fueling transportation and heating homes. Taking plastic products as an example, when oil prices increase then it will cost more to produce plastic, the plastic company in turn pass through on some or all of this cost to the consumer which in turn raises prices and thus inflation rates.

Figure 15 below plots the inflation rates for France, Germany and the U.S. along with nominal oil price. As observed from the figure, the relationship between these two variables was much more evident during the 1970s. However the relationship started to deteriorate after the 1980s, for instance when oil prices doubled (in nominal terms) from $20 to $40 per barrels during the 1990s Gulf War, inflation rates were relatively stable. This weak relationship is even more apparent when considering the price increase posts the millennium shift, thus judging by the data; it appears that the strong correlation between oil prices and inflation has weakened significantly from the 1970s.

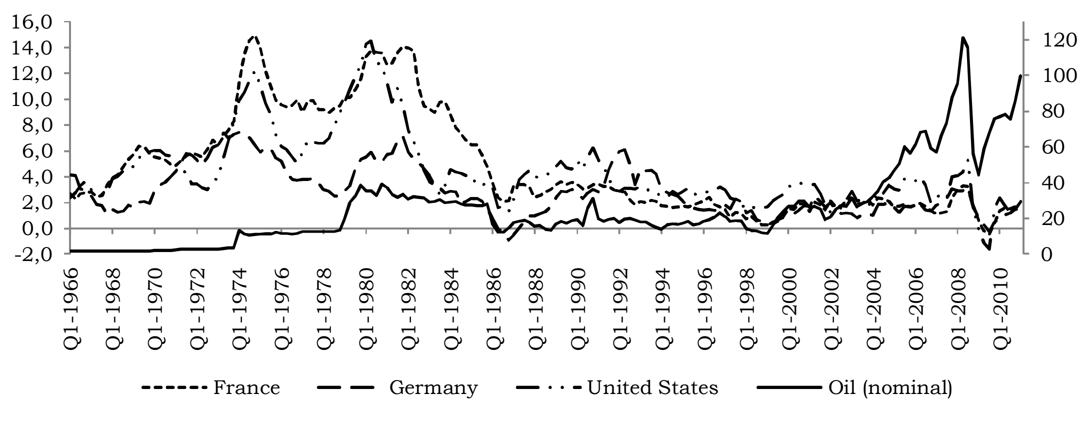

Figure 15. Inflation rates for France, Germany and United States (left axis) and nominal oil price (right axis).

In summarizing this chapter, the relationship between oil price movements and the movements in the other variables is clearly an important subject to study, not only in explaining the impact of oil prices on these variables but also in explaining these variables impact on the movement of oil prices. For instance, one theory that most economist agree on in explaining the increase of oil prices during the period 2002-2008 is due declining real interest rates on US government bonds. As interest rates in the US fell relatively to those abroad (see Figure 13), the dollar declined (see Figure 12), this in turn pushed oil prices and other commodities up because oil and most other commodities are priced in US dollar, by reducing their cost in terms of other currencies and hence increasing the demand for these commodities by people/countries using those currencies. It should however be noted that the price of commodities didn´t increase in terms of just the dollar during this period but in terms of most other currencies. So the declining rates on US government bonds were an important factor but not the only one.

The inventiveness of key oil producers to save the oil today and produce tomorrow due to low interest rates did also play an important role. As Jeffery Frankel (2008) put it;

"Stocks of oil held in deposits underground dwarf those held in inventories aboveground, and the decision how much to produce is subject to the same calculations trading off interest rates against expected future appreciation that apply to inventories. (The classic reference is Hotelling´s Rule.) Apparently the Saudis have decided to leave theirs in the ground. "King Abdullah, the country´s ruler, put it more bluntly: I keep no secret from you that, when there were some new finds, I told them, No, leave it in the ground, with grace from God, our children need it" (Financial Times 19 May). I see the interest rate as part of the Saudis´ decision. Because the current rate of return on financial assets is abnormally low, they can do better by saving the oil for the future than by selling it today and investing the proceeds. Holding back production raises today´s oil price, to a point where the expected future return on oil has fallen to the same level as the interest rate. Hence the inverse effect of real interest rates on oil." (Monetary policy and commodity prices-Jeffrey Frankel, 29 May 2008, VOX[13])

[13] Research-based policy analysis and commentary from leading economists. http://voxeu.org/index.php?q=node/1178

Chapter 4: Literature review

Economists have long been intrigued by empirical evidence that suggests that oil price shocks may be closely related to macroeconomic performance. This observation is not new and dates back to the 1970s, a period that was characterized of growing dependence on imported oil, unpredicted disruptions in the supply of oil to the global market and poor macroeconomic performances among many countries in Europe, United States and Japan. Several studies have analyzed the link between oil prices and macroeconomic performance, usually implementing VAR methodology. In general, most of the studies conclude that the effects of oil prices on the economy are different among countries. This is especially true when analyzing the impact on oil importing and oil exporting countries. In addition to this, there are differences between developing, middle income and developed countries depending largely on how much the country in question is dependent on oil.

The earlier studies concentrate in general on the US market, which assesses the effects of oil price shocks on economic activity and the channels through which they are transmitted. The empirical findings of these pioneering researchers of the US market, Rasche and Tatom (1977, 1981), Darby (1982), Hamilton (1983), Burbidge and Harrison (1984), Santini (1985), and Gisser and Goodwin (1986) report a clear negative correlation between oil price shocks and real output.

Studies concerning non-US economies differ to a certain extent. For instance, Cundao and Perez de Garcia (2003) study 15 European countries by means of analyzing the impact of oil prices on inflation and industrial production indexes. The results they obtain are different depending on whether they used a world oil price index or national real prices. They conclude that the impact is higher when national oil prices are used which they assume is due to the role of exchange rates on macroeconomic variables. They also suggest that the increase in oil price during 1999 had greater impact on Europe than in US due to the weakness of the Euro. Moreover, they were unable to find any co-integrating long-run relationships between oil prices and economic activity except for Ireland and the United Kingdom. Therefore they suggest that the impact of oil shocks is limited to the short-run.

Jimenez-Rodriguez and Sanchez (2005) report that oil price shocks adversely affect UK output but favorably affect the Norwegian output. Similar to Jimenez-Rodriguez and Sanchez (2005), Mork, Olsen, and Mysen (1994) analyses the correlations between oil prices changes and the change in GDP. The results show a general pattern of negative correlations between GDP growth and real oil price increases for Canada and the UK but the estimated correlation for Norway is positive.

Berument, Ceylan and Dogan (2010) examines how oil price shocks affect the output growth of some MENA[14] countries that are considered as either net exporters or net importers of oil, but are too small to affect oil prices. They use VAR methodology and impose the restriction on the model that an individual country´s economic performance does not affect world oil prices as an identifying restriction. Their estimates suggest that oil price increases have a statistically significant and positive effect on the outputs of Algeria, Iran, Iraq, Kuwait, Libya, Oman, Qatar, Syria and the United Arab Emirates. However, oil price shocks did not appear to have a statistically significant effect on the outputs of Bahrain, Djibouti, Egypt, Israel, Jordan, Morocco and Tunisia. When they further decomposed positive oil shocks such as oil demand and oil supply for the latter set of countries, oil supply shocks were associated with lower output growth but the effect of oil demand shocks on output remain positive.

Another paper which not only analyzes the impact of oil prices on macroeconomic variables but also on financial variables such as stocks for a large set of countries, including both oil importing countries and oil exporting countries is provided by Lescaroux and Mignon (2008). Their results suggest that when Granger Causality exists, it generally runs from oil prices to the other considered variables in their study (GDP, unemployment, consumption, CPI, and share prices). Their analysis also indicates that there exists a strong Granger Causality running from oil prices to share prices, especially for oil exporting countries.

Moving forward and considering the relationship between oil prices and interest rates, some argues that the Fed´s monetary policy reaction to oil price shocks during the 1970s actually induced macroeconomic turbulence. As an example of this view, Bernanke, Gertler and Watson (1997) employ standard and modified VAR Systems. They find that an important part of the effect of oil price shocks on the economy does not result from the change in oil prices, per se, but from monetary policy reacting to increased inflation. Blanchard and Gali (2008) apply structural VAR techniques in order to evaluate the difference between the effects of oil price shocks on GDP growth and inflation in the 2000s and in the 1970s. They estimate multivariate VARs for the United States, France, Germany, United Kingdom, Italy and Japan and rolling bivariate VARs for a more detailed analysis of the United States. They found a significant difference for the effects between the two periods on both inflation and output which, they conclude, could be explained by a decrease in real wage rigidities, the increased credibility of monetary policy and the decrease in the share of oil consumption and production.

[14] MENA is the abbreviation of “Middle East and North Africa”.

Clarke and Terry (2009) conduct Bayesian estimates of a VAR, which allows for both coefficient drift and stochastic volatility, to examine the pass through of energy price inflation to core inflation in the United States. The estimates yield a pronounced reduction in the pass through from approximately 1975 onwards. Furthermore, they argue that this decline has been sustained through a recent period of markedly higher volatility of shocks to energy prices. They also conducted a reduced form and structural VAR and on the basis of that, they found out that monetary policy has been less responsive to energy price inflation since approximately 1985.

Kilian and Lewis (2009) modify the VAR model used by Bernanke, Gertler and Watson (1997). They find no evidence of systematic monetary policy response to oil price shocks after 1987, but that the finding is unlikely to be explained by reduced real wage rigidities. Furthermore, their results imply that there is no evidence that the Fed´s policy response to oil price shocks prior to 1987 was responsible for the substantial fluctuations in real output. They support the view of Bernanke, Gertler and Watson (1997) that instead of oil supply shocks, monetary policy is the primary explanation of the stagflation of the 1970s. However they do not apply a VAR or look at long term interest rates.

Most recently, Reicher and Utlaut (2010) examined the relationship between oil prices and long-term interest rates. They estimated a seven-variable-VAR for the U.S. economy on postwar data using long-run restrictions, taking changes in long-run interest rates and inflation expectations into account. They found a strong connection between oil prices and long-run nominal interest rates which has lasted through the entire postwar period. They find that a simple theoretical model of oil prices and monetary policy, where oil prices are flexible and other prices are sticky, in fact predicts a strong relationship if inflation and oil prices were driven by monetary policy. However, they conclude that the magnitude this relationship is still a bit of a puzzle, but this finding does call into question the identification techniques commonly used to identify oil shocks.

Another relationship that has been interesting to study is the oil price and exchange rate relationship. Zhou (1995) examined different source of real shocks in explaining the movements of real exchange rates for Finland, Japan and the U.S. for the period 1973 to 1993. Among many sources of real disturbance, such as oil prices, fiscal policy, and productivity shocks, oil prices were found to play a major role in explaining the movements in real exchange rate. Chaudhuri and Daniel (1998), investigate the long-run equilibrium real exchange rates and oil prices for 16 OECD countries and find that US dollar producer price exchange rates for most of the industrial countries and the real price of oil are cointegrated over the post-Bretton Woods period. Moreover, they find that the nonstationarity attributed to U.S. dollar real exchange rates over this period is due to the nonstationarity in the real price of oil.

Chen and Chen (2007) investigate the long-run relationship between real oil prices and real exchange rates by using a monthly panel of G7 countries for the period 1972:1 to 2005:10. Their results suggest that real oil prices may have been the dominant source of real exchange rate movements and that there is a link between real oil prices and real exchange rates. When they further examines the ability of real oil prices to forecast future real exchange returns, their panel predictive regression estimates suggests that real oil prices have significant forecasting power. The out-of-sample prediction performances showed greater predictability over longer horizons.

Chapter 5: Methodology

5.1 Source of data and information

In this study, quarterly data of industrial production index (henceforth "industrial production"), real effective exchange rate index[15] (henceforth "real exchange rate"), real long term interest rate (henceforth "real interest rate"), and inflation rate were obtained from Organization for Economic Cooperation and Development (OECD) database (Data from Main Economic Indicator). The oil price variable used in this study is World oil price which were obtained from International Financial Statistics (International Monetary Fund). Data used in "Peak theory" charts was obtained from BP Statistical Review 2011. The source of other data used for descriptive purposes (charts, tables etc) is shown below each chart and table in the text. The majority of articles regarding earlier studies on this subject were obtained from EconLit (Karlstad University, Library section on the internet), other articles were obtained by Google search.

5.2 The way the variables are used

The variables in this study were originally defined as followed: Oil price variable as nominal US dollars per barrel, Industrial production and real exchange rates as indexes while inflation rate and real interest rates as annual rates. As a first step, the oil price variable and real interest rate were converted into real terms (using US CPI for the oil price variable and the inflation rate for the respective country to convert the interest rates). As a second step, the variables oil price, industrial production and real exchange rates were transformed to natural logarithm.

The variables were then used in different ways depending on which analysis is conducted, for instance, to calculate correlations between oil price and real exchange rates the following return formula was used for:

$$\Delta y\ (quarterly\ change) = \ln(y_t) - \ln(y_{t-1}) \qquad [1]$$

The correlation coefficient between oil price changes and changes in industrial production were calculated using the following return formula:

$$\Delta y\ (annual\ change) = \ln(y_t) - \ln\ (y_{t-4}) \qquad [2]$$

The above specification gives us the annual change of the variables, i.e. change since same quarter of previous year. In addition, I used the forth lag of the oil variable when calculating the correlation coefficient between oil price change and the growth in industrial production. The reason for this

[15] Real effective exchange rate is the relative price level of one country, evaluated using baskets of goods and services of several major trading partners (Multilateral rate).

transformation is that according to the literature on this subject, the greatest effect of oil prices and economic activity is observed after one year; see for example Hamilton (2000), Cundao and Perez de Garcia (2003), Lescaroux and Mignon (2008), among others. It is however not true that the other variables considered in this study (real exchange rate, real interest rate and inflation rate) should share the same characteristics as industrial production, i.e. that the effect of oil prices would be observed after a year. The effect on these variables, if any, is likely to be observed straight away.

In this study, I also use a different specification of oil shock variable, the Net Oil Price Increase or NOPI specification, in order to determine the magnitude of the contribution to industrial production index. This specification has been widely used in the literature on this subject, see for example Hamilton (2003) or Cundao and Perez de Garcia (2003) among others. Hamilton (1996) argues that if one would like to measure how unsettling an increase in the price of crude oil is likely to be for the spending decision of consumers and firms, it is more appropriate to compare the current price with the price over the previous years rather than during the previous year alone. He thus proposes the following specification:

$$NOPI_t = \max\left[0, \ln(oil_t) - \ln(\max(oil_{t-4}, oil_{t-8}, oil_{t-12}, oil_{t-16}))\right] \quad [3]$$

5.3 Empirical Models

5.3.1 Correlations

As a first step of the empirical analysis, the correlation coefficients are calculated between the oil price variable and the other variables. These correlations are calculated for the full sample period; in the case of industrial production, *1966q1-2011q1*, in the case of real exchange rate, *1970q1-2011q1*, in the case of real interest rate, *1965q1-2011q1*, and in the case of inflation rate, *1966q1-2011q1.* The samples are then divided into two subsamples in order to investigate the correlations before and after 1986, i.e. before and after the oil price collapse in the mid 1980s. This part of the analysis is conducted for all countries for which data was available and for which there was enough data in the pre and post 1986 to calculate the correlations.

5.3.2 Oil shock´s contribution to industrial production

As a measure of oil price shock´s contribution to the growth of industrial production, I will adapt the nonlinear specification[16] used in Hamilton 2003 (equation 3.8) for each of the countries considered:

$$IPI_t = C + IPI_{t-1} + IPI_{t-2} + IPI_{t-3} + IPI_{t-4}$$
$$+ NOPI_{t-1} + NOPI_{t-2} + NOPI_{t-3} + NOPI_{t-4} \quad [4]$$

[16] The key result of that specification (equation 3.8 in Hamilton 2003) was a regression of quarterly GDP growth on a constant, 4 lags of GDP and 4 lags of the "net oil price increase NOPI".

This is basically a regression of real quarterly IPI growth on a constant, 4 lags IPI growth and 4 lags of the oil price measure NOPI. To calculate the size of the contribution, I calculate for each quarter in the episode the difference between the first quarter ahead forecast implied by the equation above, and what that first quarter ahead forecast would have been if the oil price measure NOPI had instead been equal to zero, and take this difference as a measure of the contribution of the oil shock to that quarter´s IPI growth. This part of the analysis is conducted for all countries for which data on industrial production were available from 1970.

Due to the unavailability of the data for some of the variables and countries considered in this study, further analysis (unit root tests, cointegration tests, impulse response analysis and variance decomposition analysis) will only include the countries; Australia, Belgium, Canada, France Germany, Italy, Netherlands, Switzerland, United Kingdom and United States. The time span is set to 1970q1-2011q1 except for Australia and United Kingdom for which real exchange rate were only available from 1972q1.

5.3.3 Unit Root tests

As a next step in the analysis, unit root tests are carried out in order to investigate the stationarity of the series considered. Here I will apply the traditional Phillips Peron test (PP), which is closely related to the Augmented Dickey Fuller test (ADF).

The Dickey Fuller test (DF) involves fitting the model:

$$y_t = \alpha + \rho y_{t-1} + \delta t + u_t \qquad [5]$$

by ordinary least squares (OLS), perhaps setting α=0 or δ=0. However, this regression is likely to be plagued by serial correlation. To take this into account, the augmented Dickey Fuller test (ADF) test instead fits the following model:

$$\Delta y_t = \alpha + \beta y_{t-1} + \delta t + \gamma_1 \Delta y_{t-1} + \gamma_2 \Delta y_{t-2} + \cdots + \gamma_k \Delta y_{t-k} + \epsilon_t \qquad [6]$$

Where k is the number of lags to include in the regression. Testing β=0 is equivalent to testing ρ=0, or equivalently, that y_t follows a unit root process. The Phillips Perron test involves fitting [6], and the results are used to calculate the test statistics. This test statistics can be viewed as Dickey Fuller statistics that have been made robust to serial correlation by using Newey-West heteroskedasticity- and autocorrelation-consistent covariance matrix estimator, Gujarati (2002).

The advantages of the PP test over the ADF are; the PP test is robust to general forms of heteroskedasticity in the error term and the user does not have to specify a lag length for the test regression. There is however problems associated with the PP test too. A well known weakness of the ADF and the PP tests is theirs potential confusion of structural breaks in the series as evidence of non-stationarity. In other words, they may fail to reject the null of unit root if the series have a structural break. It would mean, series that are found to be I(1), there may be a possibility that they are in fact stationary around the structural break(s), I(0), but are erroneously classified as I(1).[17] Also, the power of the test diminishes as deterministic terms are added to the regression. That is, tests that include a constant and trend in the regression have less power than tests that only include a constant in the regression. As a complement to the PP test, this study also applies the Zivot and Andrews (1992) test which takes into account that the series might contain structural breaks as for example the oil price shocks in the oil price series. Their procedure involves fitting the following model:

$$\Delta y_t = \alpha + \beta t + (\rho - 1) y_{t-1} + \gamma DU_t(\lambda) + \sum_{i=1}^{k} \theta_i \, \Delta y_{t-i} + u_t \qquad [7]$$

Where $DU(\lambda) = 1$ for $t > T\lambda$, and otherwise $DU = 0$; $\lambda = T_B/T$ represents the location where the structural break lies: T is the sample size and T_B is the date when the break occurred. In both tests, PP and Andrews Zivot, the null hypothesis is that the variable has a unit root. Rejection of the null hypothesis would mean that the series is stationary.

5.3.4 Cointegration tests

To investigate the long term links between oil price and the other variables considered in this study, I proceed with cointegration tests. Various tests have been suggested in the literature for this purposes, most of which are implemented in standard econometric packages and hence are easily available nowadays. Some well known examples include the residual-based Engle and Granger (1987), henceforth EG, or the system-based tests of Johansen (1988), henceforth J. Error-Correction-based tests have also been suggested by Boswijk (1994), henceforth Bo, and Banerjee et al. (1998), henceforth Bo, to name just few. Often one test rejects the null whereas another test does not, making it unclear how to interpret the outcomes of the tests.

In general, the p-values of different tests are typically not perfectly correlated, Gregory et al. (2004). Bayer and Hanck (2009), suggest that after running the above tests separately, one should test the underlying tests in combination in order to reach the right decision. Their combing tests have shown that when the underlying tests have similar power, the combined results are even more powerful than the best underlying test.[18] Instead of presenting the underlying tests

[17] Unit Roots, Structural Breaks and Cointegration Analysis: A Review of the Available Processes and Procedures and an Application. Workshop, Department of Banking and Finance Faculty of Business and Economics, Eastern Mediterranean University.

[18] They applied their tests to 159 data sets from published Cointegration studies and the result showed that in one third of all cases, single tests give conflicting results whereas the combining tests provided an unambiguous test decision.

and the combined tests here, the interested reader is advised to consult the paper of Bayer and Hanck (2009) where they explain the models in more detail. In all cases above, he null hypothesis is no cointegration, rejection of the null would mean that the variables are cointegrated, i.e. there is a long term relationship between the variables.

Just as the PP test fails to consider problems associated with structural breaks, the above cointegration tests also fails to consider the same problem when testing for cointegration between the variables. Gregory and Hansen (1996) developed a residual based test for cointegration that is valid against an alternative hypothesis that there may be one break in the cointegrating vector. They apply a similar approach by Zivot and Andrews (1992) and propose a two-stage estimation process of which the first step is to estimate:

$$y_{1t} = \alpha + \beta t + \gamma DU_t(\lambda) + \theta_t y_{2t} + u_t \quad [8]$$

The second step in the test is to test if u_t is I(0) or I(1) via the ADF or PP techniques. The motivation for this test is that there may be occasions in which the researcher may wish to test cointegration over some (fairly long) period of time, but then shifts to a new long-run relationship. The null hypothesis of this test is that there is no cointegration; rejection of the null would mean that the variables are cointegrated, i.e. there is a long term relationship between the variables.

5.3.5 Vector Autoregressions

To analyze the interactions between oil price and the other variables, an unrestricted Vector Autoregressive model (VAR) is estimated. This model allows a multivariate framework where each variable is dependent on its own lags but also on the lags of the other variables in the system. A simple two variable VAR model can be presented as the following:

$$Y_t = \alpha + \sum_{j=1}^{k} \beta_j Y_{t-j} + \sum_{j=1}^{k} \gamma_j X_{t-j} + u_{1t} \quad [9]$$

$$X_t = \alpha^* + \sum_{j=1}^{k} \theta_j Y_{t-j} + \sum_{j=1}^{k} \gamma_j X_{t-j} + u_{2t}$$

Where the u´s are the stochastic error terms, called impulses or innovations or shocks in the language of VAR. Before estimating the above equations, one has to decide on the maximum lag length, k. Including too many lagged terms will consume degree of freedom, and the possibility of including the multicollinearity problem. Including too few lags will lead to specification errors. One way of deciding how many lags to include in the model is to use a criterion like the Akaike or Schwarz and choose that model that gives the lowest values of these criteria, Gujarati (2002).

In our case, the VAR model will constitute of the following variables; industrial production, real oil price, real interest rate, inflation rate and real exchange rate, i.e. the system constitutes of five equations. For instance, the equation for industrial production equation has the following form:

$$Ip_t = \alpha_{10} + \alpha_{11}Ip_{t-1} + \cdots + \alpha_{1k}Ip_{t-k} + \beta_{11}r_{t-1} + \cdots + \beta_{1k}r_{t-k} + \gamma_{11}Oil_{t-1} + \cdots + \gamma_{1k}Oil_{t-k} + \delta_{11}Ex_{t-1} + \cdots + \delta_{1k}Ex_{t-k} + \theta_{11}Infl_{t-1} + \cdots + \theta_{1k}Infl_{t-k} \quad [10]$$

The choice of the ordering of the variables in the VAR model is also crucial for further analysis as impulse response and variance decomposition analysis (see below). In practice it is difficult to know which of the ordering is correct and one has often to consult earlier work on the subject. In this study, I will adapt a similar ordering[19] as suggested by Jimenez-Rodriguez and Sanchez (2004). The order of the variables is as follow: VAR (Industrial production, real oil price, inflation rate, real interest rate, and real exchange rate).

VAR has both advantages and drawbacks, Gujarati (2002).

The advantages:

- One does not have to worry about determining which variables are endogenous and which ones are exogenous; all variables in VAR are treated as endogenous.
- Estimation is simple; usual OLS can be applied to each equation in the system separately.
- Forecasts obtained from VAR are often better than those obtained from the more complex simultaneous-equation models.

The drawbacks:

- Unlike simultaneous-equation models, a VAR model is *a-theoretic* because it uses less prior information. In simultaneous-equation models, exclusion or inclusion of certain variables plays a crucial role in the identification of the model.
- VAR models are less suited for policy analysis.
- Difficulties in choosing the appropriate lag length.
- All the variables should be stationary, if not, we will have to transform the data (e.g., by first-differencing).
- Individual coefficients in the estimated VAR models are often difficult to interpret, practitioners of this technique often estimate the so called *impulse response function (IRF)*.

[19] They used the following order: VAR (real GDP, real oil price, inflation, short-term interest rate, long-term interest rate, real wage, and real effective exchange rate).

5.3.5.1 Granger Causality

Next, to investigate the short-term links between oil price and the other variables, I proceed with bivariate Granger causality test. Granger causality tests are usually performed in the context of vector autoregressions (VAR) or more specifically, individual equations within VAR systems. Individual equations in VARs are known as autoregressive distributed lag (ADL) relationships and may be represented as:

$$y_t = c + \sum_{i=1}^{p} a_i \, y_{t-i} + \sum_{i=1}^{p} b_i \, x_{t-i} + D_t + u_t, \qquad (t = 1, \dots, T) \qquad [11]$$

Where y_t and x_t respectively refer to the variables to be analyzed. D_t refer to other variables that need to be controlled for, if any. The null hypothesis is that x_t does not Granger-cause y_t amounts to testing whether $b_i = 0$ for $i = 1, \dots, p$. The rationale for conducting such a test is simple. If event X is seen as causing event Y, then event X should precede Y, Hamilton (1994).

5.3.5.2 Impulse response analysis

One interesting feature of VAR methodology is studying the so called impulse response function (IRF). The IRF traces out the response of the dependent variable in the VAR system to shocks in the error terms, such as the u´s in the [9] equations. Suppose u1 in the Y equation increases by a value of one standard deviation. Such a shock or change will change Y in the current as well as future periods. But since Y appears in the X equation, the change in u1 will also have an impact on X. Similarly, a change of one standard deviation in u2 of the X equation will have an impact on Y, Gujarati (2002). The IRF traces out the impact of such shocks for several periods in the future, in our case 16 quarters or 4 years.

5.3.5.3 Variance decomposition analysis

Another interesting feature of VAR methodology is to analyze the forecast-error variance decomposition (FEVD) which measures the fraction of the forecast-error variance of an endogenous variable that can be attributed to orthogonalized shocks to itself or to another endogenous variable in the model for b=1,2,… (b-step-ahead variance decomposition). In our case we want to analyze the contribution of variability due to an oil price shock to the other variables considered in this study (industrial production, long-term interest rate, real effective exchange rate and inflation rate). The b-step-ahead is set to 4 quarters or one year.

5.3.6 Hubbert peak theory

The Hubbert peak theory is based on the observation that the amount of oil under the ground in any region is finite, therefore the rate of discovery which initially increases quickly must at some time reach its maximum and then starts to decline. The theory is named after the American geophysicist

M. King Hubbert, who created a method of modeling the production curve given an assumed recovery volume. On the basis of his theory, in a paper[20] he presented to the American Petroleum institute in 1956, he correctly predicted that production of oil from conventional sources would peak in the U.S. around 1965-1970.

His predictions were dismissed at first; however in 1970 the U.S. produced 3.52 billion barrels and from that point and forward production started to decline just as Hubbert postulated. The accuracy of his prediction astonished oil executives. As production continued to decline in the 1980s and 1990s, the concept of peak production turned into a reality. Hubert used complex differential equations to model the production of oil based on the quantity of oil already produced in the country. A method which simplifies the calculation of the curve known as Hubbert Linearization will be used in this paper. This method uses simple mathematics to uncover the key features of the Hubbert Curve, which was developed first by Professor Kenneth Deffeyes[21]. Basically, the area under the curve represents all of the oil that will be produced from the country or the field in question. The peak of the curve represents the time period at which half of the available oil has been produced.

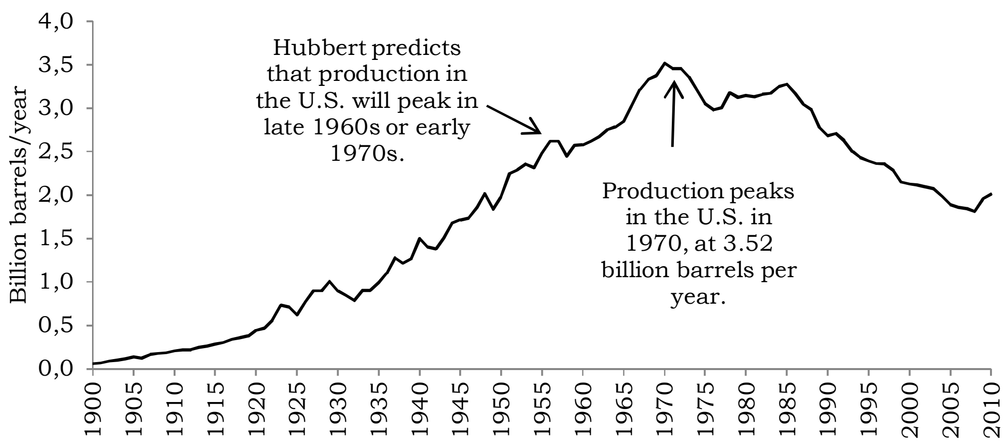

Figure 16. U.S. peak production and Hubbert´s prediction.

The Hubert peak theory makes it possible to estimate what percentage of oil has been produced and also predicts annual production volumes. The method is described in more detail in A12.

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[20] http://www.hubbertpeak.com/hubbert/1956/1956.pdf

[21] Kenneth S. Deffeyes is Professor Emeritus at Princeton University. Before joining the Princeton faculty in 1967, he conducted research at the Shell Oil research laboratory in Houston and taught at the University of Minnesota and Oregon State University. He is perhaps best known for his research in the area of Physical Geology. For more information visit: http://www.princeton.edu/hubbert/

Chapter 6: Empirical analysis

6.1 The macroeconomic relationship

6.1.1 Correlations

I start the analysis by examining the correlation coefficient between oil price and the other variables considered in this study. These are presented in Table 1 (A2). Before analyzing the results, the correlation coefficient is considered to be significant if it exceeds -/+ 0.30. The results for industrial production shows the expected negative sign for all countries and sub samples except for Switzerland in the second subsample (1986-11) and for Norway during the first subsample (1966-85) and during the full sample period (1966-11) which suggest that Norway´s industrial production was less responsive to oil price shocks during the first subsample compared to the other countries in the sample. Considering the countries with negative correlation coefficients, in the first subsample (1966-85), correlations were in the range -0.124 (Greece) to -0.664 (Luxembourg), while in the second subsample (1986-11) the coefficient is in the range -0.004 (Austria) to -0.401 (Australia). In general, the negative correlation coefficients for most of the countries in the sample are lower in magnitude for the period post 1986 which suggest that these countries industrial production is less responsive to oil price shocks post the mid 1980s.

The results for inflation rate show the expected positive sign for all countries in the first subsample (1966-85) except for Mexico. The positive correlation coefficient ranges from 0.008 (Norway) to 0.659 (Japan) in the first subsample (1966-85), while in the second subsample (1986-11) the coefficient is in the range -0.215 (Turkey) to 0.463 (United States). The correlation coefficient turned from being positive in the first sub sample to negative in the second sub sample for about half of the countries in the sample. The overall results indicate that the pass through effect from increasing oil prices to consumer prices is much lower today than in the 1970s. There are however some countries in the second subsample that still have high positive correlations (compared to the other countries in the sample) such as Belgium and the United States. This is explained by the higher weights' given to fuels and heating oil in constructing the CPI index for these countries.

The results for real exchange rates are mixed, reflecting if the country in question being net importer/exporter. Since oil price is nominated in USD, a weakening of the USD leads to increase in oil price. In fact it is widely believed that one of the contributing factors to the latest increase in oil prices (2002-2008) was due to the weakening of the US economy and the dollar value. This is demonstrated by the correlation coefficient for the US case in the second subsample (-0.345). On the other hand, the correlation coefficient for Canada and Norway is positive as one would expect, these two countries are key suppliers of oil among the OECD countries, so when oil price increases their currencies appreciates. Also, these two countries coefficients are lower during the first subsample (1970-86) which basically reflects these two countries share of world oil supply during this period. Australia´s coefficient is also high during the second subsample (1986-11), however not because the country is net exporter of oil but because the country is the third largest producer of gold in the world and gold prices have historically followed oil prices quite well.

Considering the result of the correlation between oil price and real interest rates, the majority of the countries show a negative correlation, although too low to be considered as significant. In the second sample, the United States stands out for having the most negative coefficient among the countries, -0.367. This clearly illustrates the mechanisms between these two variables discussed in chapter 3.3, i.e. high/low interest rates put downward/upward pressure on oil price through different channels. Also to note, that the coefficient for the US is smaller in the first subsample (1965-85) than the second sample (1986-11) which suggest that the impact have strengthen post 1986.

6.1.2 Oil shock´s contribution to industrial production

To illustrate the contribution of earlier oil price shocks to industrial production, I used the model described in chapter 5.3.2., which results are presented in Table 2 in A3. Although the model´s simplicity, the model did quite well in illustrating the magnitude of these shocks. As one would expect and following the discussion in chapter two, the contribution was larger during the first two shocks than during the shock in 1990 and 2008. During the first shock the negative contribution was ranging from -0.3 percent (United Kingdom) to -3.3 percent (Luxembourg), during the second shock -0.7 percent (Germany) to -3.0 percent (Luxembourg), during the third shock -0.1 (Finland and France) to -0.6(Greece), and during the latest shock -0.3 percent (Sweden) to -1.1 (Greece and Japan).

The model also predicted that the contribution to Norwegian industrial production is positive during all previous shocks. The result for Norway is also in line with the correlation coefficient provided in Table 1 in A2, i.e. during the first subsample (1966-85) the correlation coefficient was +0.154 while in the second subsample (1986-11) it turned to -0.155, compared to the contribution of +0.6 percent during the first shock and +0.2 percent during the latest shock. The results thus suggest that the positive impact on Norwegian industrial production was larger during the first two shocks compared to the one in 1990 and 2008.

6.1.3 Unit Root tests

To test the series for unit root, two different tests were used in this study. The first test is the traditional Phillips Peron test (PP) which is robust to general forms of heteroskedasticity in the error term. The second test is the Zivot and Andrews test (ZA) which takes into account that the series might contain structural breaks; this is likely to be the case since we are analyzing series with very long time span. The results of these tests are presented in Table 3-6 in A4. In both tests, the null hypothesis is that the variable has a unit root and a rejection of the null hypothesis would mean that the series are stationary. Considering the results provided by the PP test, the null hypothesis is not rejected for most variables and countries indicating that these variables are non-stationary in level form. Exceptions are represented by the industrial production for Belgium, Germany, Netherlands, by the inflation rate for Italy and by the real exchange rate for France and Switzerland which all appear to be stationary in levels (when considering the model with constant and trend). The null hypothesis is rejected for all variables and countries when expressed in first differences.

Allowing for breaks in both constant and trend, the results for the ZA test shows that the oil price variable is non-stationary in level form. Industrial production and real exchange rate are also non-stationary for all countries with the exception for the industrial production for France, Germany and the Netherlands and for the real exchange rate for Italy. The results for real interest rate and inflation rate suggest that for most countries, the variables are stationary in levels. In fact, the result for real interest rate and inflation rate did not change much using the model which only allows for break in the constant term, thus the result suggest that in general, real interest rate and inflation rate are stationary in levels but around the specified break. The null hypothesis is rejected for all variables and countries when expressed in first differences.

6.1.4 Cointegration tests

To investigate the long-term link between oil price and the other variables, I proceed with cointegration tests. Two variables are said to be cointegrated if they have a long-term, or equilibrium relationship between them. In this paper I test for cointegration using two tests; the first test is the Bayer and Hanck test which is a combined test of individual cointegration tests. The second test is the Gregory Hansen test which takes into account the possibility of structural breaks in the data. The null hypothesis of both tests are no cointegration, therefore, a rejection of the null hypothesis means that the two series are cointegrated. The results of these tests are presented in Table 7-8 in A5. Considering the results provided by the Bayer Hanck Test (the combined test for the individual tests); oil price and industrial production are cointegrated for Australia, Belgium, Germany, Italy and Switzerland. Cointegration is also found between oil price and real interest rate for Germany, Switzerland and United States. The result leads to the same conclusion when using both EG-J and EG-J-Ba-Bo.

In the case of oil price and inflation rate, the first test statistic (EG-J) does not reject the null hypothesis of no cointegration for all countries accept for Canada and Switzerland. The null is however rejected for Australia, Belgium, Canada, Germany, Switzerland and the United States when considering all underlying tests together (EG-J-Ba-Bo). Furthermore, there is not much evidence of cointegration between oil price and real exchange rate, the null hypothesis is rejected only for Switzerland and when using the test result that combines all four individual tests (EG-J-Ba-Bo).

Considering the results provided by Gregory-Hansen test, the variables are considered to be cointegrated if two or more of the statistics (ADF, Zt and Za) provided rejects the null of no cointegration. In the case of oil price and industrial production, cointegration exists only in the case of Germany. Similarly, in the case of oil price and real exchange rate the null hypothesis could not be rejected for all countries except for Italy. The results thus suggest that there is weak evidence of cointegration between both oil price and industrial production and between oil price and real exchange rate.

The null hypothesis is more frequently rejected in the case of oil price and real interest rate and oil price and inflation rate. Cointegration is found between oil price and real interest rate for all countries except for Australia and the Netherlands. In the case of oil price and inflation rate, the null hypothesis of no cointegration is rejected for Belgium, Canada, France, Italy, United Kingdom and the United States.

6.1.5 Selecting lag order for VAR model

To analyze the interactions between oil price and the other variables, an unrestricted Vector Autoregressive model (VAR) is estimated. The model was estimated according to the suggested ordering of the variables that were presented in chapter 5.3.5. Different lag order selection criterions are presented in Table 9, A6. As shown in the table, the suggested lag order differs among the different selection criterion, demonstrating the difficulties in general in choosing the right lag order. The lag order underlying the VAR model was chosen according to AIC criterion, which is commonly used. The lag order ranges from 2 (for Belgium, Canada and France) to 4 (for Australia and the Netherlands).

6.1.6 Granger causality

Considering the result of the Granger causality test which was applied in order to determine the direction of the causality between oil price and the other variables considered. The results of the test are presented in Table 10, in A7. Figures in bold indicates that the null hypothesis of no Granger causality is rejected at the 5% level. Considering the results for industrial production and inflation rate, the causality appears to run from oil price to these variables, although with some exception as shown in the case of Australia where causality runs from inflation rate to oil price and runs in the both direction in the case of Switzerland. Considering the results for real interest rate and real exchange rate, there is not enough evidence to conclude the direction of the causality. In the case of real interest rate, causality runs from oil price to real interest rate for Belgium, Italy and Switzerland, whereas it runs from real interest rate to oil price for Australia, Germany. In the case of real exchange rate, causality runs from oil price to real exchange rate for Netherlands, United Kingdom and the United States, and it runs from real exchange rate to oil price in the case for Australia. Furthermore, causality runs in the both direction for Germany.

6.1.7 Impulse response analysis

I continue the analysis by analyzing the results from the impulse response to assess the impact of a shock in real oil price on industrial production, real interest rates, real exchange rates and inflation rates. The results for the US are presented below in Figure 17-18; the results for the other countries are presented in A8 in Figures 21-25. In particular, the impulse response function traces over time the effects on a variable of an exogenous shock to another variable (the solid line). The dash line is the 95% confidence error bands for the IRFs which are provided to judge the statistical significance of the impulse response functions.

Considering industrial production, the impulse response functions indicates that an oil price shock is followed by declining industrial production where the biggest fall occurring in the third or fourth quarter after the shock excepts for Belgium where the biggest fall occurring in the fifth quarter. The contemporaneous affect[22] is zero for all countries as one would expect (industries do not react immediately to an oil price shock), also the effect tends to die out after 5-8 quarters from the shock. Moving forward and considering the results for real interest rate, the impulse response functions shows that the contemporaneous affect is negative and significant for Belgium, France, Italy, Switzerland and United States. The functions also shows that these rates start to increase following the shock, as seen in the case for Canada, France and the United States. The rates also increase for the other countries, however not immediately, but after 2-3 quarters.

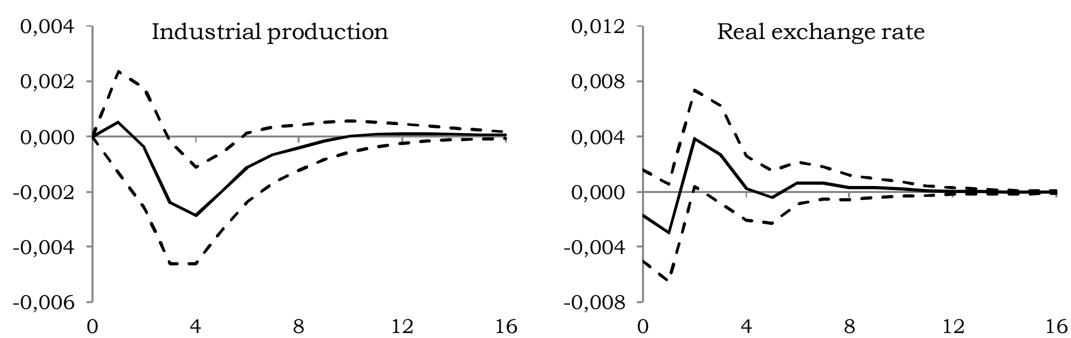

Figure 17. The figure presents the orthogonalised impulse-response function of Industrial production and Real exchange rate for United States.

[22] The immediate effect.

The effects on real exchange rates are different depending on whether the country in question is net oil importer/exporter. First we observe that the contemporaneous effect for France, Germany, Italy, Netherlands, Switzerland and the United States is negative however not significant. On the other hand the contemporaneous effect on the real exchange rate of Canada and Australia is positive and significant, and for the United Kingdom positive but not significant. These observations clearly demonstrate the terms of trades' shocks on these countries real exchange rates following an oil price shock, i.e. appreciation if terms of trade are improved and depreciation if terms of trade are worsen. Following the shock, the effect is positive and significant in the first quarter for United Kingdom and negative and significant in the second quarter for Germany. For all countries in the sample, the effect tends to die out after four to eight quarters following the shock.

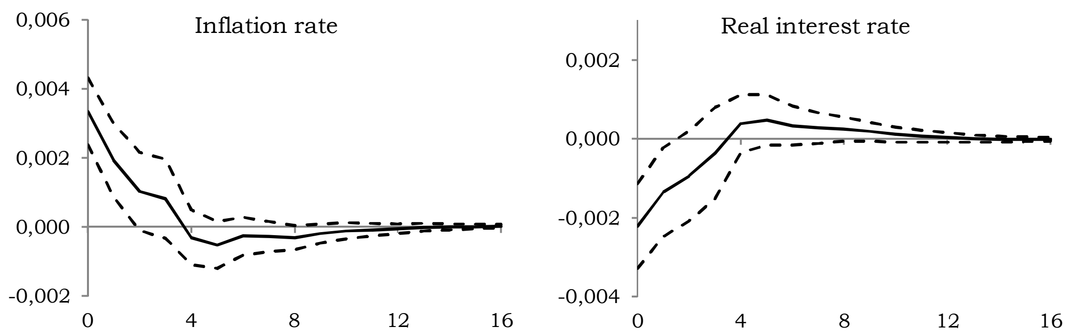

Figure 18. The figure presents the orthogonalised impulse-response function of inflation rate and real interest rate for United States.

The impulse response functions for the inflation rates shows that the contemporaneous affect is positive and significant for Belgium, Canada, France, Germany, Italy, Switzerland, United Kingdom and the United States. In the case of France, Germany, United Kingdom and the United States, the inflation rate declines gradually after the shock whereas for the rest of the countries the inflation rates tend to persist for 0-3 quarters (in the case of Belgium, Canada, Italy, Netherlands and Switzerland). In fact there is an increase in the inflation rate the following 1-2 quarter after the shock for Italy, Netherlands and Switzerland.

6.1.8 Variance decomposition analysis

In this section, I continue the analysis by analyzing the results from the forecast error variance decomposition (FEVDs) of industrial production, real interest rate, real exchange rate and inflation rate due to the oil price variable. Table 11, in A.9, presents the FEVDs for the countries considered. Each value in the table is in percentage form and shows how much of the unanticipated change in industrial production, real interest rate, real exchange rate and inflation rate are due to oil price shock. Also the table provides the t-values (in parentheses) of the computed FEVDs in order to judge for FEVDs significance.

The contribution of an oil price shock to the variability in industrial production varies from 1.3 percent (Canada) to 14.6 percent (United Kingdom). The FEVDs are significant for France, Germany and the United Kingdom. In the case of real interest rates the contribution varies from 2.4 percent (Germany) to 18.2 percent (Belgium) and the contributions are significant for Belgium, Italy, Netherlands and the United States. The FEVDs for real exchange rate shows that the contribution is in the range 0.6 percent (Italy) to 8.6 percent (Germany), and the FEVDs are significant for Australia and Germany. Finally the contribution to the variability in inflation rate ranges from 3.0 percent (Australia) to 35.4 percent (Belgium) and are significant for Belgium, Canada, France, Germany, Italy, Netherlands, Switzerland and the United States.

6.2 Oil Consumption and Economic growth

One important point in understanding short-run changes in the price of oil is the fact that income rather than price is the key determinant of the quantity of oil demanded by a country, Hamilton (2009). To see this, Figure 19 below plots the cumulative change in US real GDP (x-axis) against cumulative change in oil supplied to the US market (y-axis) for the period 1949-2007. One can observe that despite the large fluctuations in the price of oil during this period, oil consumption have followed GDP growth quiet well. Also evident, is that there is flattening in the slope over time and the downward adjustment in oil demand following the 1970s crises. The slope of 0.47 for the period 1985-97 could be attributed to the downward adjustment during the beginning of the 1980s; however, it is more likely that the flattening in the slope is due the fact that income elasticity declines as a country become more developed as illustrated by the slope of 1.04 (1961-73) compared to the slope of 1.22 (1949-61), i.e. the slope flattens before the OPEC embargo.

Figure 26-28 in A10, plots oil consumption against GDP for some of the other countries for the period 1965-2010. In addition to these countries, I have included the plots for China and India as they are considered as important oil consumer today. In general, oil consumption has followed GDP growth quiet well as in the US case discussed above. Also, the slope coefficient flattens for most of the countries post the 1980s, however to different extent reflecting each country´s share of oil consumed in relation to global oil supplied, the ability of each country to switch to alternative sources of energy and the development of the country. Another factor to bear in mind is that the country´s attitude towards oil consumption (whether to increase or decrease) is also dependent on what trading partners the country has. As an example, the Netherlands have substantially increased its share in oil consumption over the last 10 years, it might seem odd at first; however the

Netherlands main source of crude oil imports are from Russia, Norway and Saudi Arabia[23], all of which are not considered today as insecure importing partners.

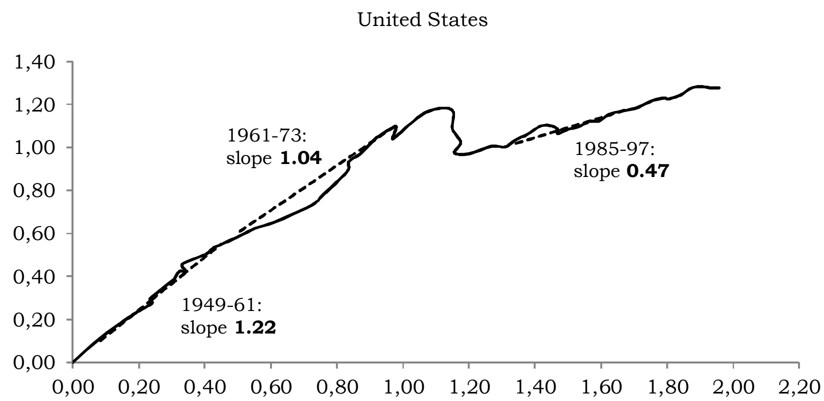

Figure 19. Cumulative change in US GDP (x-axis) against cumulative change in oil consumption in the US. Source: Hamilton (2009).

The Figures 29-30, presents countries for which no slope could be fitted for the period post 1980s. These countries were quick in switching from oil towards other substitutes after experiencing the shocks of the 1970s.

As a complement to these figures, the tables 12-13 in A11 (Countries Energy Mix), presents the average energy mix share used by these countries as of total primary energy demanded for different periods. Figures in bold indicates that the country in question has increased its share in the resource in question since previous period. In general, while countries have been efficiently decreasing their share in oil consumption, they have increased their consumption of another fossil fuel, namely Natural Gas. Gas is becoming increasingly important for most countries in their energy mix. As end of 2010, proven gas reserves in North, Central and South America amounted to 9.3 percent, in Europe and Eurasia 33.7 percent (of which 23.9 percent in Russia), in the Middle East 40.5 percent (of which 15.8 percent in Iran and 13.5 percent in Qatar), in Africa 7.9 percent, and in Asia Pacific 8.7 percent[24]. Clearly, Russia, Iran and Qatar are and going to be key suppliers of Gas in the short and long term. As the share of natural gas in global energy supply increases, it has begun to create risks factors of its own. Like oil, gas markets are subject to many disruptive geopolitical forces, including attempts to exercise monopoly power by Russia. After the discontinuance of Russian gas supplies to the Ukraine in the winter of 2005-06 and again in 2008-09, gas importing countries have begun to question that natural gas imports will prove more secure than oil. This have prompted

[23] http://ec.europa.eu/energy/energy_policy/doc/factsheets/mix/mix_nl_en.pdf
[24] BP Statistical Review 2011.

many consuming countries in Europe to seek diversification as means of mitigating away the potential risks of being heavily reliant on any single supplier.

By 2040, the internationally traded share of world natural gas demand is projected to rise to 48 percent, with Liquefied Natural Gas (LNG) shipments responsible for the majority of this growth. Most of that growth, in turn, is expected to come from the Middle East, Hartley and Medlock (2006). In other words, as European countries seek to diversify away from Russian natural gas, they expose their markets to Middle East geopolitical risks which further contribute to the similarities with oil markets.

Among the OECD countries that have the largest share of renewable source of energy are Denmark, Sweden, Finland, Portugal and Sweden, all having 4 percent and above. However this share is too small today to benefit these countries today, as seen from the table, these countries have no choice but to increase their share of natural gas in the short/medium term until their renewable sources are developed.

6.3 Depletion analysis

The Hubbert Curves in this paper are drawn using a very simple approach, namely Hubert linearization. There are other approaches one could use in order to get more accurate curves, see for example Laherrere (2000), who also points out some strengths and weaknesses with the Hubbert curve and. A simple Hubbert curve may be ideally applied only in the following cases:

- There should be large populations of fields: the production curve of a single oil field is generally asymmetrical. However when there is a large population of fields, such that the sum of a large number of asymmetrical distributions becomes symmetrical (normal) under the Central Limit Theorem of statistics.
- Exploration should follow a natural pattern unimpeded by political events or significant economic factors, as an example when OPEC cut production during the embargo in 1973.
- Where a single geological domain having a natural distribution of fields is considered, political boundaries should be avoided.

Bearing these constraints in mind we can continue to study the results of the curves presented in this paper. Starting with the US case (Figure 20, below), according to the model, oil production peak was reached in 1975 whereas actual production peaked in 1970. Ever since production has continued to decline, and in 2010 the US had produced 87 percent of its total expected output of 232 billion barrels. The Hubbert peaks for the other countries are presented in A12. Other countries that show a close pattern between actual production curves and predicted once are Norway and United

Kingdom. According to the model Norway´s oil production peak was reached in 2000 which is consistent with the year, 2000, when actual production peaked. In 2010, Norway had produced 83 percent of its total expected output of 30 billion barrels. For the United Kingdom, oil production peak was reached in 1994 according to the model; however actual peak occurred in 1999. In 2010, the United Kingdom had produced 87 percent of its total expected output of 31 billion barrels. The reason why the model failed in choosing the right year for which UK production peaked is because of the production disruption occurring prior to the peak as seen in the figure.

Another country which have been following this trend is Indonesia who for long time been a member of OPEC choose to voluntarily end its membership in 2008 when it became a net importer of oil. Actual production peak in Indonesia was reached in 1977, model peak was reached in 1990, and in 2010 the country had produced 83 percent of its total expected output of 26 billion barrels. Again the model failed in choosing the right year of the peak to constraints discussed above. As for the plots for the other countries, no clear conclusion could be drawn on whether these countries have reached their peak production or not. It is however important to give this area an attention since oil is likely not going to be available forever and the challenges will lie in the process of restructuring towards other substitutes.

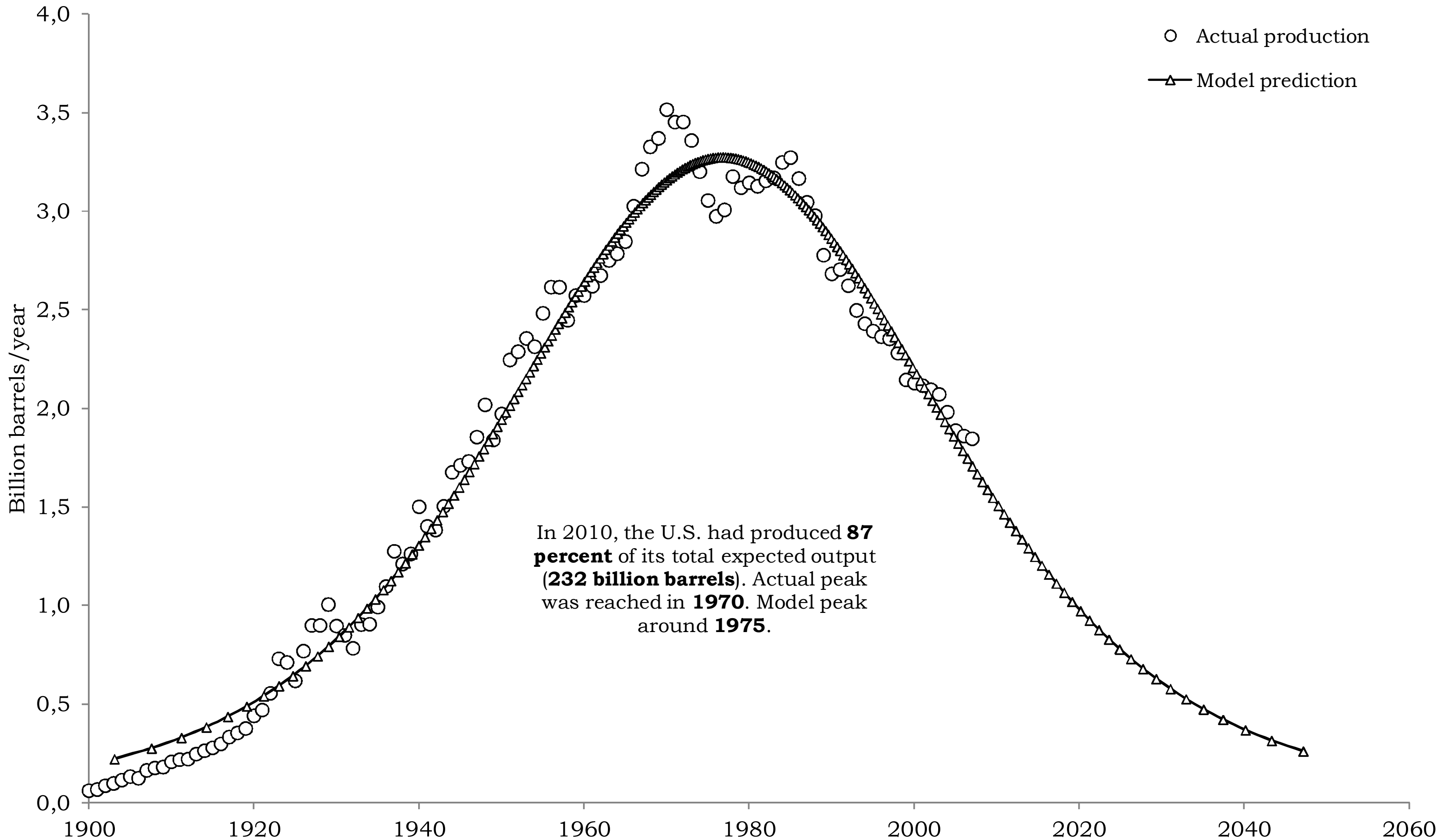

Figure 20. The Hubbert Curve for United States, author calculation. Based on data from BP Statistical Review 2011.

Chapter 7: Conclusions

This paper have analyzed the oil price-macro economy relationship by means of analyzing the impact of oil price on industrial production, the inflation rate, the real interest rate and the real exchange rate for a set of ten OECD countries using quarterly data for the period 1970q1-2011q1. The analysis was based on correlation analysis (for a larger set of countries), causality test, cointegration tests, impulse response analysis and variance decomposition analysis. In addition, this paper also applies unit root and cointegration techniques that accounts for structural breaks in the data which have received much attention lately in the area of econometrics.

The relationship between oil price and industrial production has weakened over time, which is in accordance with previous studies and with the discussion presented in chapter two. Furthermore, the biggest fall in industrial production following an oil price shock occurs with a lag of 3-4 quarters, as shown by the impulse response and the greatest variability due to oil price shock in industrial production is seen in France, Germany and the United Kingdom. The relationship between oil price and real exchange rate is negative if the country in question is net importer (Japan and United States) and positive if the country is net importer (Norway and Canada) and the magnitude of the impact depends on the share of each county´s net import/export of total world demand/supply as was shown by the correlations. The immediate effect of an oil price shock is appreciation (depreciation) of the currencies for net exporters (importers) reflecting the effects from terms of trades shocks on real exchange rates.

The immediate effect of an oil price shock on real interest rate is negative and increases following the shock whereas for inflation rate, the immediate impact is positive and decreases the following quarters after the shock. The IRFs for these two variables are mirrors of each other, indicating that an oil price shock passes through some of the price increase to other prices which in turn results in a rise in inflation rates. Real interest rates decrease by either decreasing nominal rates or by increasing inflation, so the negative shock on real interest rate is explained by the effect of rising inflation following the shock. Eventually, these rates start to increase as inflation rates decreases and the effect dies out after 4-8 quarters depending on the country in question.

This paper also applies alternative methods to test for unit root and cointegration, which takes into account for structural breaks in the data. The weakness of the PP test is clearly demonstrated in the case of inflation rates and real interest rates, where the test failed to reject the null hypothesis of a unit root, i.e. treating them as non-stationary, when they are in fact stationary around a structural break. The test results did not differ much for industrial production and real exchange rate.

Considering the results from the cointegration tests, individual tests and the combined test offered by Bayer Hanck show some signs of cointegration between oil price and industrial production. However, taking into account for structural breaks, the null hypothesis of no cointegration was not rejected for all countries except for Germany. The null hypothesis of no cointegration is frequently rejected for oil price and inflation rates and for oil price and real interest rates when taking account for structural breaks, in fact the results by Bayer Hanck also support the alternative hypothesis when oil price and inflation rate are considered. Furthermore, the alternative hypothesis of cointegration between oil price and real exchange rate could not be accepted for most of the countries and tests.

This paper have also discussed the importance of the terms oil scarcity, peak theory in order to give an answer to what alternatives source of energy are likely to be substitutable for oil in the short/long term. The result of the Hubbert curves[25] indicates that Australia, Indonesia, Mexico, Norway, United Kingdom, United States have already reached their oil production peaks and production in these countries have been declining on yearly basis ever since. In the short term, renewable source of energy are not likely to dominate OECD countries energy mix[26], instead, there is a general trend of increasing natural gas consumption among most OECD countries. As the share of natural gas in global energy increases, it has begun to create risk factors of its own. Like oil, gas markets are subject to many disruptive geopolitical forces, including attempts to exercise monopoly power by Russia. Consumer countries have begun to question that gas imports will prove to be more secure than oil imports. However, as European countries seek to diversify away from Russian natural gas, they will expose their markets to Middle East geopolitical risks as the majority of future gas is expected to be supplied by countries in the Middle East.

The term oil scarcity seems to be underestimated, and need more attention than it received so far and as discussed in chapter 2, Oil scarcity seems not to be reflected in the price of oil. In general it is expected that if oil prices were to rise, a substitute for the resource would be searched for and eventually found, but, if the price of oil do not reflect the scarcity of oil, then there is a risk that this search will be initiated too late. Scarcity may then pose a serious limitation to the economy before a substitute resource or technology has been found.

[25] The Hubbert curves presented in this paper are based on simple method known as Hubbert Linearization, more advanced method could be used in order to get more accurate results.

[26] The data shows however that Scandinavian countries are ahead of many other OECD countries in terms of renewable source of energy.

Suggestions for further studies; There are not many studies conducted on the gas market and its similarities to the oil markets. This paper has barely touched this area but points out the increasing interest among OECD countries for gas consumption. The oil price variable used in this paper was nominated in US dollars, one could extend the analysis and instead use oil price variables nominated in different exchange rates for the countries considered or use different specifications[27] of the oil price variable (as the NOPI specification described in this paper). Another interesting relationship to study is the relationship between gold price and oil price (as was seen in the case of Australia). Finally, this paper highlights the importance of oil scarcity; this area is likely to observe more attention in the near future as oil becomes scarcer. There are a variety of methods out there for calculating the Hubbert curves (the simplest one was used in this paper).

[27] Other specifications that could be used are for example oil price variable that only includes positive/negative changes.

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The World Bank- http://www.worldbank.org/

Appendices

A1. Data

The data used to analyze the relationship between oil prices and the other macroeconomic variables (Industrial production, real long-term interest rate ("real interest rate"), real effective exchange rate ("real exchange rate") and inflation rate) were obtained from *Organisation for Economic Co-operation and Development (OECD).* The countries for which correlations are calculated cover most OECD countries where data were available (see below). The unit root, cointegration and VAR analysis covers the countries: *Australia, Belgium, Canada, France, Germany, Italy, Netherlands, Switzerland, United Kingdom and United States.*

- *Real oil price:* World oil price, defined as the quarterly average nominal price was deflated by the U.S. quarterly CPI. *The two series cover the period: 1965q1-2011q1.*
- *Industrial Production: Total Industrial production index was used as an indicator of economic activity. <u>Length of the series:</u> Australia, Austria, Belgium, Canada, Finland, France, Germany, Greece, Italy, Japan, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland, United Kingdom and the United States cover the period 1965q1-2011q1. For Denmark, data was only available from 1974q1. For Hungary, Ireland, Mexico, New Zealand, Poland and Turkey from 1985q1.*
- *Exchange Rate:* Real Effective Exchange Rates was used in order to better reflect each individual country´s currency value relative to other currencies. The series are quarterly. *<u>Length of the series:</u> Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey and the United States cover the period 1970q1-2011q1. For Australia and United Kingdom the series was only available from 1972q1.*
- *Real Long* term interest rate: Long term (nominal) government bonds rate was converted into real term using the CPI of each country. The series are quarterly. *<u>Length of the series:</u> Australia, Belgium, Canada, France, Germany, Italy, Netherlands, Switzerland, United Kingdom and United States cover the period 1965q1-2011q1. For Ireland, New Zealand, Norway and Spain, the series was only available from 1986q1. For Denmark and Sweden from 1987q1, for Finland from 1988q1 and for Japan from 1989q1.*
- *Inflation rate:* The series are quarterly (annual rates). *<u>Length of the series:</u> Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden,*

Switzerland, Turkey, United Kingdom and United States cover the period 1965q1-2011q1. For Hungary, the series was only available from 1986q1.

Data used in "Peak theory" charts was obtained from BP *Statistical Review 2011. The source of other data used for descriptive purposes (diagrams, tables etc) is shown below each diagram and table in the text.*

A2. Correlations

	Industrial production			*Inflation rate*			*Real exchange rate*			*Real interest rate*		
Country	*1966-*	*1966-85*	*1986-11*	*1966-*	*1966-85*	*1986-11*	*1970-*	*1970-85*	*1986-11*	*1965-*	*1965-85*	*1986-11*
Australia	-0.417	-0.483	-0.401	0.286	0.354	0.020	0.222	0.047	0.354	-0.007	-0.088	0.074
Austria	-0.180	-0.439	-0.004	0.305	0.347	0.147	-0.107	-0.171	0.018	...	...	...
Belgium	-0.328	-0.613	-0.127	0.308	0.299	0.357	-0.015	-0.077	0.113	-0.162	-0.117	-0.210
Canada	-0.341	-0.445	-0.308	0.283	0.305	0.142	0.277	0.116	0.371	-0.094	-0.107	-0.086
Denmark	-0.161	-0.604	0.030	0.343	0.460	0.094	-0.137	-0.188	-0.074	...	...	0.120
Finland	-0.157	-0.212	-0.164	0.275	0.323	0.044	0.088	0.116	0.065	...	...	-0.008
France	-0.305	-0.482	-0.201	0.294	0.347	0.190	-0.099	-0.258	0.179	-0.156	-0.279	-0.030
Germany	-0.202	-0.414	-0.077	0.292	0.388	0.033	-0.014	-0.005	0.044	-0.080	-0.042	-0.117
Greece	-0.009	-0.124	-0.030	0.206	0.391	-0.246	0.135	0.216	0.067	...	...	...
Hungary	...	...	-0.108	...	...	-0.122	...	...	...	...	...	...
Iceland	...	...	...	0.009	0.023	-0.183	0.142	0.155	0.128	...	...	...
Ireland	...	...	-0.063	0.105	0.072	0.161	0.023	0.031	0.096	...	...	-0.001
Italy	-0.258	-0.354	-0.237	0.240	0.273	-0.133	-0.025	-0.025	0.029	-0.162	-0.222	-0.084
Japan	-0.335	-0.525	-0.304	0.480	0.659	-0.081	-0.193	-0.139	-0.204	...	...	-0.042
Luxembourg	-0.449	-0.664	-0.250	0.249	0.179	0.371	0.043	-0.112	0.232	...	...	...
Mexico	...	...	-0.158	-0.138	-0.171	-0.172	0.067	0.122	0.088	...	...	...
Netherlands	-0.321	-0.415	-0.310	0.220	0.250	-0.034	-0.057	-0.137	0.040	0.082	0.058	0.128
New Zealand	...	...	-0.258	0.127	0.114	-0.048	0.159	-0.036	0.233	...	...	-0.042
Norway	0.013	0.154	-0.155	0.076	0.008	-0.079	0.242	-0.035	0.439	...	...	-0.083
Poland	...	...	-0.141	...	...	...	...	...	...	...	...	...
Portugal	-0.174	-0.337	-0.133	0.186	0.220	-0.166	0.041	0.109	-0.017	...	...	...
Spain	-0.216	-0.281	-0.262	0.189	0.182	-0.054	0.094	0.172	0.079	...	...	-0.048
Sweden	-0.199	-0.219	-0.192	0.134	0.131	-0.045	0.106	-0.069	0.249	...	...	-0.053
Switzerland	-0.232	-0.516	0.023	0.360	0.439	0.147	-0.065	0.005	-0.149	-0.138	-0.031	-0.266
Turkey	...	...	-0.175	-0.064	0.142	-0.215	0.078	0.123	0.018	...	...	...
United Kingdom	-0.419	-0.521	-0.357	0.272	0.316	-0.064	0.181	0.097	0.212	-0.111	-0.163	-0.034
United States	-0.406	-0.509	-0.333	0.462	0.493	0.463	-0.123	0.045	-0.345	-0.296	-0.228	-0.367

Table 1. Correlations between oil price and industrial production, inflation rate, real exchange rate and real interest rate. The correlations between oil price and industrial production and oil price and inflation are based on annual changes, i.e. change since same quarter of previous year whereas the correlation between oil price and real exchange rate and between oil price and real interest rate are calculated using the change since previous quarter. In addition, in the case of industrial production, lag(4) of oil price change is used.

A3. Oil Shocks contribution to Industrial production

Oil Shocks contribution to Industrial production

	1974q1-1975q1			1979q2-1981q2			1990q3-1991q3			2007q4-2008q4		
Country	IPI	Cont.	No oil	IPI	Cont.	No oil	IPI	Cont.	No oil	IPI	Cont.	No oil
Australia	0,6	-2,5	3,1	2,7	-1,4	4,1	-2,4	-0,4	-1,9	1,6	-0,9	2,4
Austria	3,0	-1,6	4,5	3,3	-1,1	4,4	3,8	-0,2	4,0	2,2	-0,4	2,7
Belgium	1,4	-1,6	3,0	-0,3	-1,6	1,3	-2,3	-0,2	-2,1	-0,3	-0,4	0,1
Canada	1,1	-2,0	3,2	2,1	-0,9	3,0	-4,8	-0,3	-4,5	0,9	-0,7	1,6
Finland	3,5	-1,3	4,8	7,8	-1,4	9,2	-7,6	-0,1	-7,5	1,9	-0,4	2,2
France	0,1	-2,0	2,1	0,5	-1,5	2,0	0,4	-0,1	0,5	-2,0	-0,5	-1,5
Germany	-3,1	-1,1	-2,0	1,1	-0,7	1,8	4,3	-0,2	4,5	1,3	-0,3	1,6
Greece	-1,9	-2,5	0,6	1,6	-0,9	2,5	-1,9	-0,6	-1,3	2,1	-1,1	3,2
Italy	1,4	-2,0	3,4	4,0	-1,2	5,2	-1,4	-0,2	-1,2	-3,5	-0,6	-2,9
Japan	-7,3	-3,2	-4,1	4,1	-1,7	5,8	3,9	-0,5	4,4	-2,3	-1,1	-1,1
Luxembourg	-0,4	-3,3	2,8	-2,7	-3,0	0,3	0,5	0,1	0,4	-5,2	-0,8	-4,4
Netherlands	2,3	-2,8	5,1	0,4	-1,7	2,1	2,6	-0,2	2,8	2,7	-0,9	3,5
Norway	5,4	0,6	4,9	4,1	0,1	4,1	2,8	0,2	2,6	0,2	0,2	0,0
Portugal	0,6	-2,5	3,1	5,0	-1,2	6,2	4,2	-0,4	4,7	-3,9	-0,9	-3,0
Spain	5,3	-2,3	7,6	0,4	-0,9	1,2	-1,3	-0,3	-0,9	-6,3	-0,8	-5,5
Sweden	4,1	-0,9	5,0	2,2	-0,8	3,1	-1,3	-0,3	-0,9	-2,5	-0,3	-2,2
Switzerland	-3,1	-2,7	-0,4	2,4	-1,7	4,1	2,0	-0,2	2,2	3,0	-0,8	3,8
United Kingdom	-1,0	-0,3	-0,7	-3,5	-0,9	-2,6	-2,8	-0,2	-2,7	-2,5	0,0	-2,5
United States	-2,5	-2,2	-0,4	-0,6	-1,0	0,4	-0,8	-0,4	-0,4	-2,3	-0,7	-1,5

Table 2. Oil price shocks contribution to industrial production, using the model described in 5.3.2.

A4. Unit Root tests

Unit Root tests: Industrial production

	Phillips-Perron			Zivot-Andrews				
Country	*L(c)*	*L(c & t)*	*Fd*	*L(c)*	*Break*	*L(c & t)*	*Break*	*fd*
Australia	-1.512	-2.580	**-9.491**	-3.686	1987q1	-4.100	1999q3	**-10.121**
Belgium	-1.166	**-3.669**	**-10.735**	-4.751	1996q2	-4.925	1999q2	**-6.967**
Canada	-1.706	-1.946	**-6.004**	-3.600	2005q1	-4.804	1998q4	**-6.334**
France	-2.144	-2.797	**-7.923**	-4.318	2005q1	**-5.365**	2004q4	**-6.878**
Germany	-0.819	**-3.631**	**-8.246**	**-5.239**	**1992q3**	**-5.254**	1992q3	**-8.365**
Italy	-2.580	-2.154	**-9.880**	-2.962	2004q1	-4.551	2002q1	**-7.112**
Netherlands	-1.267	**-3.890**	**-12.919**	**-5.319**	**1981q1**	**-5.164**	1980q2	**-13.393**
Switzerland	0.085	-3.072	**-11.582**	-4.016	1980q2	-4.388	1984q3	**-7.176**
United Kingdom	-2.366	-1.567	**-10.992**	-2.446	1985q1	-3.442	1999q3	**-7.105**
United States	-1.175	-2.005	**-5.794**	-3.634	1993q4	-4.645	1996q2	**-6.074**
Oil	-2.293	-2.291	**-11.265**	-4.108	1986q1	-3.938	1997q1	**-10.044**

Table 3. Unit root test for industrial production. In bold, the null hypothesis is rejected at 5%.

Unit Root tests: Real interest rate

	Phillips-Perron			Zivot-Andrews				
Country	*L(c)*	*L(c & t)*	*Fd*	*L(c)*	*Break*	*L(c & t)*	*Break*	*fd*
Australia	-2.368	-2.308	**-11.243**	**-5.114**	1980q2	**-7.185**	1983q2	**-8.713**
Belgium	-2.108	-2.064	**-7.962**	-4.202	1978q2	**-5.483**	1983q4	**-9.001**
Canada	-2.215	-2.119	**-9.992**	**-5.110**	1981q2	**-6.420**	1983q1	**-9.050**
France	-1.893	-1.826	**-8.132**	-4.398	1982q3	**-5.506**	1982q3	**-9.362**
Germany	-2.640	-2.945	**-10.256**	**-4.988**	1982q1	**-5.630**	1983q2	**-8.395**
Italy	-2.127	-2.374	**-7.863**	**-5.561**	1980q4	**-6.114**	1988q2	**-10.389**
Netherlands	-2.124	-2.062	**-11.704**	-2.993	1980q4	-3.964	1982q3	**-8.820**
Switzerland	**-3.267**	-3.355	**-9.439**	-4.599	1983q1	-5.018	1978q2	**-9.290**
United Kingdom	-2.843	-2.787	**-8.204**	**-6.539**	1980q3	**-6.522**	1980q3	**-8.518**
United States	-2.500	-2.485	**-9.534**	-6.157	1980q3	-6.140	1980q3	**-7.392**
Oil	-2.293	-2.291	**-11.265**	-4.108	1986q1	-3.938	1997q1	**-10.044**

Table 4. Unit root test for real interest rate. In bold, the null hypothesis is rejected at 5%.

Phillips-Perron	*1 % Critical Value*	*5 % Critical Value*	*10 % Critical Value*
Constant	*-3.491*	*-2.886*	*-2.576*
Constant & trend	*-4.021*	*-3.443*	*-3.143*
No Constant	*-2.593*	*-1.950*	*-1.614*

Zivot-Andrews	*1 % Critical Value*	*5 % Critical Value*
Constant	*-5.43*	*-4.80*
Constant & trend	*-5.57*	*-5.08*
No constant	*-4.93*	*-4.42*

Unit Root tests: Inflation rate

	Phillips-Perron			*Zivot-Andrews*				
Country	*L(c)*	*L(c & t)*	*Fd*	*L(c)*	*Break*	*L(c & t)*	*Break*	*fd*
Australia	-2.009	-3.364	**-10.302**	**-7.378**	2000q1	**-8.320**	1991q1	**-8.052**
Belgium	-2.111	-2.974	**-7.098**	**-5.260**	1984q3	**-5.496**	1985q3	**-8.371**
Canada	-1.656	-3.000	**-8.859**	**-5.461**	1983q1	**-5.486**	1982q3	**-8.244**
France	-1.270	-2.577	**-7.117**	**-5.786**	1984q1	**-5.526**	1984q1	**-9.131**
Germany	-2.214	-2.704	**-9.580**	-4.309	1982q1	-4.416	1988q4	**-7.282**
Italy	-1.560	**-3.618**	**-6.942**	**-6.337**	1983q3	**-6.359**	1983q3	**-11.185**
Netherlands	-1.951	-2.130	**-10.358**	**-4.827**	1982q2	**-5.764**	1989q2	**-6.764**
Switzerland	-2.438	-3.040	**-8.984**	-4.243	1989q1	**-5.690**	1979q1	**-7.325**
United Kingdom	-1.952	-2.935	**-7.424**	**-5.807**	1982q1	**-5.748**	1980q3	**-8.393**
United States	-2.212	-3.337	**-8.298**	-6.359	1981q4	**-6.927**	1981q4	**-7.786**
Oil	-2.293	-2.291	**-11.265**	-4.108	1986q1	-3.938	1997q1	**-10.044**

Table 5. Unit root test for inflation rate. In bold, the null hypothesis is rejected at 5%.

Unit Root tests: Real exchange rate

	Phillips-Perron			*Zivot-Andrews*				
Country	*L(c)*	*L(c & t)*	*Fd*	*L(c)*	*Break*	*L(c & t)*	*Break*	*fd*
Australia	-1.645	-1.266	**-10.723**	-3.803	2002q4	-4.556	2002q4	**-7.053**
Belgium	-1.924	-1.930	**-9.106**	-4.236	1980q4	-4.055	1979q2	**-9.285**
Canada	-1.696	-1.095	**-8.528**	-3.259	2004q3	-3.471	1997q4	**-6.398**
France	-2.796	**-3.602**	**-9.753**	**-4.905**	1982q3	-4.947	1999q1	**-6.957**
Germany	-2.378	-2.816	**-10.090**	**-4.800**	1991q3	-4.940	1991q3	**-5.607**
Italy	-2.378	-2.524	**-9.070**	**-6.331**	1992q4	**-6.806**	1992q4	**-6.545**
Netherlands	-2.689	-2.729	**-9.997**	-4.392	2002q2	-4.058	2002q2	**-10.023**
Switzerland	**-3.309**	**-3.717**	**-9.341**	**-4.976**	1996q4	-4.693	1996q4	**-9.758**
United Kingdom	-2.450	-2.418	**-10.182**	-3.882	1979q1	-3.710	1979q1	**-10.388**
United States	-2.103	-2.126	**-9.406**	-2.882	1985q4	-3.842	1985q4	**-6.035**
Oil	-2.293	-2.291	**-11.265**	-4.108	1986q1	-3.938	1997q1	**-10.044**

Table 6. Unit root test for real exchange rate. In bold, the null hypothesis is rejected at 5%.

Phillips-Perron	*1 % Critical Value*	*5 % Critical Value*	*10 % Critical Value*
Constant	*-3.491*	*-2.886*	*-2.576*
Constant & trend	*-4.021*	*-3.443*	*-3.143*
No Constant	*-2.593*	*-1.950*	*-1.614*

Zivot-Andrews	*1 % Critical Value*	*5 % Critical Value*
Constant	*-5.43*	*-4.80*
Constant & trend	*-5.57*	*-5.08*
No constant	*-4.93*	*-4.42*

A5. Cointegration tests

Tests for Cointegration: Oil price and Industrial production

	Underlying Tests								Bayer Hanck Test		Gregory-Hansen Test					
Country	*EG*	*p-value*	*J*	*p-value*	*Ba*	*p-value*	*Bo*	*p-value*	*EG-J*	*EG-J-Ba-Bo*	*ADF*	*Break*	*Zt*	*Break*	*Za*	*Break*
Australia	-3.429	0.113	**21.032**	0.020	**-4.090**	0.016	**18.667**	0.011	**12.130**	**29.341**	-5.31	1999q3	**-5.95**	1999q3	-42.74	1999q3
Belgium	-3.609	0.074	**20.840**	0.022	**-4.477**	0.004	**21.665**	0.004	**12.824**	**34.874**	-4.85	1997q1	-5.04	2000q1	-38.27	2000q1
Canada	-2.657	0.425	10.044	0.517	-2.472	0.447	7.865	0.376	3.027	6.592	-4.68	1998q4	-5.48	2000q2	-30.44	2000q2
France	-2.868	0.317	11.535	0.373	-2.658	0.356	8.628	0.309	4.264	8.673	-5.53	1999q3	**-6.03**	2000q1	-37.61	2000q1
Germany	**-4.470**	0.006	**21.931**	0.015	**-4.759**	0.002	**22.708**	0.002	**18.604**	**43.544**	**-6.10**	1986q1	**-5.55**	1987q1	-34.59	1987q1
Italy	-3.479	0.101	**23.065**	0.010	-3.264	0.129	**15.434**	0.036	**13.769**	**24.518**	-5.27	2002q1	-5.18	2001q1	-39.40	2001q1
Netherlands	-3.081	0.224	14.429	0.175	-3.239	0.135	13.883	0.062	6.473	16.020	-5.46	1981q2	-5.38	1981q3	-47.51	1981q3
Switzerland	-3.383	0.125	**20.255**	0.027	**-4.046**	0.018	**16.374**	0.026	**11.341**	**26.645**	-4.69	1986q2	-4.43	1985q3	-32.85	1985q3
United Kingdom	-2.827	0.337	17.399	0.070	-2.703	0.334	10.986	0.158	7.473	13.357	-4.64	1981q1	**-6.44**	2002q2	-41.24	2002q2
United States	-2.582	0.466	7.445	0.791	-2.396	0.486	7.407	0.419	1.992	5.172	-4.76	1997q2	-5.23	1997q1	-35.31	1997q1

Tests for Cointegration: Oil price and Real interest rate

	Underlying Tests								Bayer Hanck Test		Gregory-Hansen Test					
Country	*EG*	*p-value*	*J*	*p-value*	*Ba*	*p-value*	*Bo*	*p-value*	*EG-J*	*EG-J-Ba-Bo*	*ADF*	*Break*	*Zt*	*Break*	*Za*	*Break*
Australia	-2.703	0.401	14.474	0.172	-3.133	0.166	12.393	0.101	5.336	13.496	**-6.26**	1986q4	-5.42	1979q3	-45.14	1979q3
Belgium	-2.333	0.604	15.574	0.124	-3.656	0.053	**15.302**	0.037	5.175	17.597	**-6.21**	1978q2	**-6.41**	1979q1	-57.76	1979q1
Canada	-2.377	0.580	15.934	0.111	-2.592	0.387	9.359	0.254	5.470	10.105	**-6.42**	1982q1	**-6.37**	1985q2	-55.14	1985q2
France	-2.014	0.761	12.379	0.305	-2.126	0.621	10.034	0.209	2.919	7.001	**-7.45**	1986q2	**-6.69**	1984q3	**-61.09**	1984q3
Germany	-3.733	0.054	**20.762**	0.022	**-3.864**	0.030	**14.937**	0.042	**13.370**	**26.647**	**-6.41**	1989q1	**-6.24**	1988q1	-48.69	1988q1
Italy	-2.459	0.535	14.944	0.150	-3.167	0.155	14.432	0.051	5.037	14.690	**-6.65**	1982q1	**-6.37**	1982q2	-50.72	1982q2
Netherlands	-2.360	0.589	12.576	0.290	-2.885	0.255	8.381	0.329	3.532	8.478	**-6.22**	1989q2	-5.24	1988q3	-41.88	1988q3
Switzerland	**-4.045**	0.023	**21.388**	0.018	**-4.314**	0.007	**19.016**	0.010	**15.475**	**34.367**	**-6.38**	1978q1	**-6.38**	1977q4	-54.57	1977q4
United Kingdom	-3.184	0.185	12.632	0.285	-3.195	0.147	10.231	0.197	5.873	12.940	**-7.35**	1982q1	**-6.99**	1981q4	**-63.09**	1981q4
United States	-2.712	0.396	**26.910**	0.002	**-4.496**	0.004	**28.496**	0.000	**13.831**	**41.859**	**-5.76**	1984q4	**-6.26**	1985q2	**-58.79**	1985q2

Table 7. Cointegration test for oil price and industrial production and oil price and real interest rate. In bold the null hypothesis is rejected at 5%. Critical values for EG-J at 1, 5 and 10% are 17.289, 11.269 and 8.686 respectively. For EG-J-Ba-Bo at 1, 5 and 10% are 34.334, 22.215 and 17.187 respectively. The critical values for Gregory-Hansen are; ADF and Zt at 1, 5 and 10% are -6.02, -5.50 and -5.24 respectively, Za at 1, 5 and 10% are -69.37, -58.58 and -53.31 respectively.

Tests for Cointegration: Oil price and Inflation rate

	Underlying Tests								Bayer Hanck Test		Gregory-Hansen Test					
Country	*EG*	*p-value*	*J*	*p-value*	*Ba*	*p-value*	*Bo*	*p-value*	*EG-J*	*EG-J-Ba-Bo*	*ADF*	*Break*	*Zt*	*Break*	*Za*	*Break*
Australia	**-3.837**	0.041	15.698	0.119	**-3.739**	0.042	**15.643**	0.033	10.596	**23.701**	**-6.74**	1991q2	-4.84	1979q1	-39.21	1979q1
Belgium	-3.317	0.143	17.417	0.070	**-4.106**	0.015	**17.636**	0.016	9.199	**25.720**	**-5.60**	1980q4	**-5.74**	1979q1	-48.95	1979q1
Canada	**-3.998**	0.027	**22.906**	0.010	**-4.508**	0.004	**22.793**	0.002	**16.310**	**39.417**	**-5.56**	1983q4	**-5.67**	1983q4	-44.25	1983q4
France	-3.153	0.196	12.635	0.285	-3.032	0.200	11.934	0.118	5.763	13.247	**-6.19**	1984q4	**-6.42**	1985q1	-57.02	1985q1
Germany	-3.556	0.084	14.903	0.152	**-3.902**	0.027	**15.243**	0.038	8.708	**22.395**	-4.74	1989q4	-5.22	1990q1	-33.07	1990q1
Italy	**-3.774**	0.049	12.743	0.278	-3.252	0.132	12.517	0.098	8.567	17.259	**-8.23**	1987q3	**-6.61**	1986q1	**-58.64**	1986q1
Netherlands	-2.894	0.305	13.804	0.208	**-3.685**	0.049	13.958	0.060	5.504	17.136	-5.26	1989q2	-5.17	1989q1	-34.85	1989q1
Switzerland	**-3.982**	0.028	18.157	0.055	**-4.242**	0.010	**18.705**	0.011	**12.887**	**31.140**	-4.74	1979q2	-4.71	1978q3	-33.66	1978q3
United Kingdom	-3.449	0.108	12.268	0.313	-3.453	0.086	12.365	0.102	6.767	16.224	**-6.19**	1984q2	**-6.09**	1984q2	-54.46	1984q2
United States	-3.217	0.174	**18.207**	0.055	-3.664	0.052	**18.571**	0.011	9.293	**24.099**	**-5.73**	1986q2	**-5.72**	1986q1	-50.13	1986q1

Tests for Cointegration: Oil price and Real exchange rate

	Underlying Tests								Bayer Hanck Test		Gregory-Hansen Test					
Country	*EG*	*p-value*	*J*	*p-value*	*Ba*	*p-value*	*Bo*	*p-value*	*EG-J*	*EG-J-Ba-Bo*	*ADF*	*Break*	*Zt*	*Break*	*Za*	*Break*
Australia	-2.845	0.328	13.693	0.215	-1.250	0.914	1.724	0.958	5.294	5.557	-4.94	1977q4	-4.77	1980q4	-36.65	1980q4
Belgium	-2.475	0.526	12.396	0.303	-2.099	0.634	5.403	0.638	3.666	5.473	-3.79	1980q1	-4.08	1980q2	-27.38	1980q2
Canada	-2.139	0.704	10.501	0.471	-1.932	0.710	4.246	0.766	2.205	3.420	-4.82	1987q3	-4.81	1987q3	-38.03	1987q3
France	-3.674	0.063	14.880	0.153	-3.554	0.068	12.823	0.088	9.278	19.495	-5.22	1986q2	-5.35	1985q3	-38.97	1985q3
Germany	-3.459	0.105	12.730	0.279	-3.300	0.120	12.515	0.098	7.052	15.934	-5.15	1991q3	-4.78	1991q2	-27.37	1991q2
Italy	-2.512	0.505	8.478	0.684	-2.556	0.404	7.891	0.373	2.121	5.904	**-5.73**	1993q2	**-5.67**	1993q1	-46.76	1993q1
Netherlands	-3.652	0.066	18.144	0.056	-2.698	0.336	9.155	0.268	11.176	15.982	-4.99	1979q2	-4.85	1979q4	-30.39	1979q4
Switzerland	-3.646	0.067	17.893	0.060	**-3.965**	0.023	**15.757**	0.032	10.998	**25.386**	-5.45	1997q2	-5.34	1979q3	-40.12	1979q3
United Kingdom	-2.854	0.324	8.422	0.690	-2.669	0.350	7.128	0.447	2.993	6.697	-4.11	1998q2	-4.41	1998q2	-25.60	1998q2
United States	-2.459	0.535	6.489	0.874	-2.449	0.459	6.283	0.538	1.517	4.310	-3.92	1986q1	-4.18	1986q2	-29.36	1986q2

Table 8. Cointegration test for oil price and inflation rate and oil price and real exchange rate. In bold the null hypothesis is rejected at 5%. Critical values for EG-J at 1, 5 and 10% are 17.289, 11.269 and 8.686 respectively. For EG-J-Ba-Bo at 1, 5 and 10% are 34.334, 22.215 and 17.187 respectively. The critical values for Gregory-Hansen are; ADF and Zt at 1, 5 and 10% are -6.02, -5.50 and -5.24 respectively, Za at 1, 5 and 10% are -69.37, -58.58 and -53.31 respectively.

A6. Lag order selection criteria

Selection order criteria

Country	*LR*	*FPE*	*AIC*	*HQIC*	*SBIC*
Australia	4	4	**4**	1	1
Belgium	4	2	**2**	2	2
Canada	3	2	**2**	2	2
France	3	2	**2**	2	2
Germany	4	3	**3**	2	2
Italy	3	3	**3**	2	2
Netherlands	4	4	**4**	1	1
Switzerland	4	3	**3**	2	1
United Kingdom	3	3	**3**	2	1
United States	4	3	**3**	2	2

Table 9. The table presents different lag order selection criteria for the underlying VAR model. LR-likelihood-ratio test, FPE-final prediction error, AIC-Akaike´s information criterion, HQIC-Hannan and Quinn information criterion and SBIC-Schwarz´s Bayesian information criterion. The VAR model chosen in this study is according to the lag order provided by AIC.

A7. Granger Causality

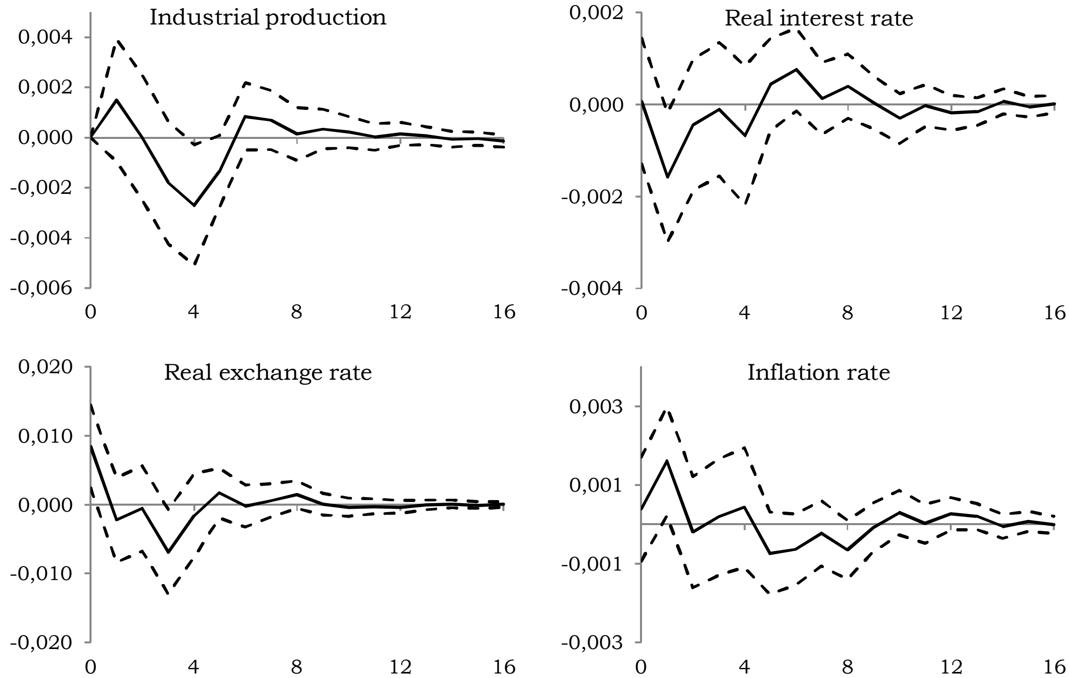
Granger Causality test

Country	*Oil→IP*	*IP→Oil*	*Oil→r*	*r →Oil*	*Oil→REER*	*REER→Oil*	*Oil→Infl*	*Infl→Oil*
Australia	1.395	.953	1.939	**2.905**	2.409	**3.390**	1.444	**3.762**
Belgium	**3.988**	.214	**7.010**	.809	1.445	.119	**7.472**	.491
Canada	.296	1.250	.660	.806	.707	1.695	**3.596**	.413
France	2.072	.124	.531	.432	1.425	.003	.533	1.138
Germany	**3.453**	.102	.359	**2.991**	**7.521**	**6.444**	.076	2.305
Italy	**3.707**	2.330	**3.715**	.258	.542	1.176	**6.147**	.085
Netherlands	**4.075**	.679	1.816	1.285	**3.145**	1.157	1.837	1.372
Switzerland	.582	.196	**5.470**	1.001	1.160	.400	**4.011**	**3.089**
United Kingdom	**8.666**	.824	.887	1.906	**2.997**	1.323	1.449	2.377
United States	1.389	1.917	1.424	.892	**5.128**	.273	**2.807**	2.069

Table 10. The table presents the F-values from the Granger Causality test. The null hypothesis is that variable 1 does not granger cause variable 2 (variable 1→variable 2). In bold, the null hypothesis is rejected at 5% level.

A8. Impulse Response

Australia



Belgium

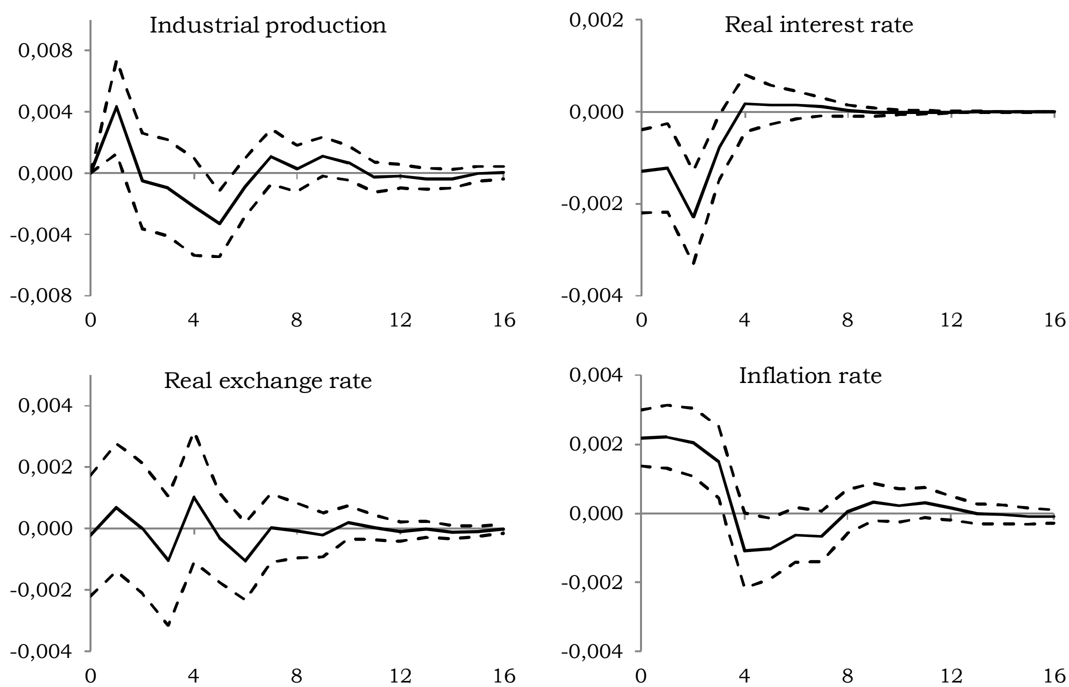
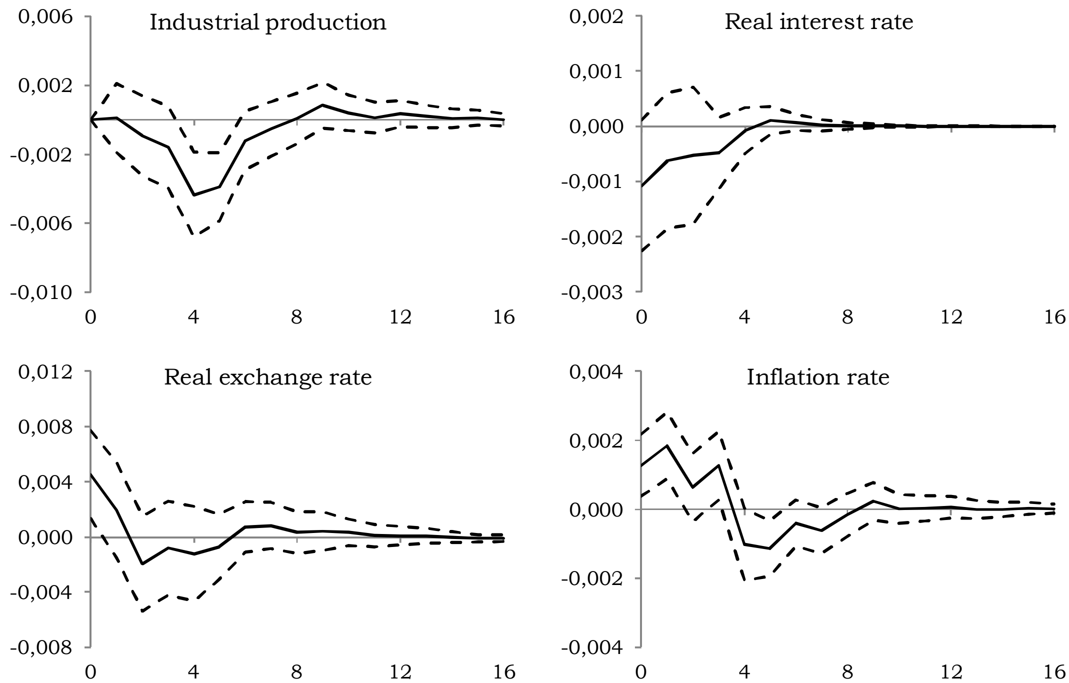


Figure 21. The figure presents the orthogonalised impulse-response function of Industrial production, real interest rate, Real exchange rate and Inflation rate to a one-standard-deviation oil price innovation for Australia and Belgium.

Canada



France

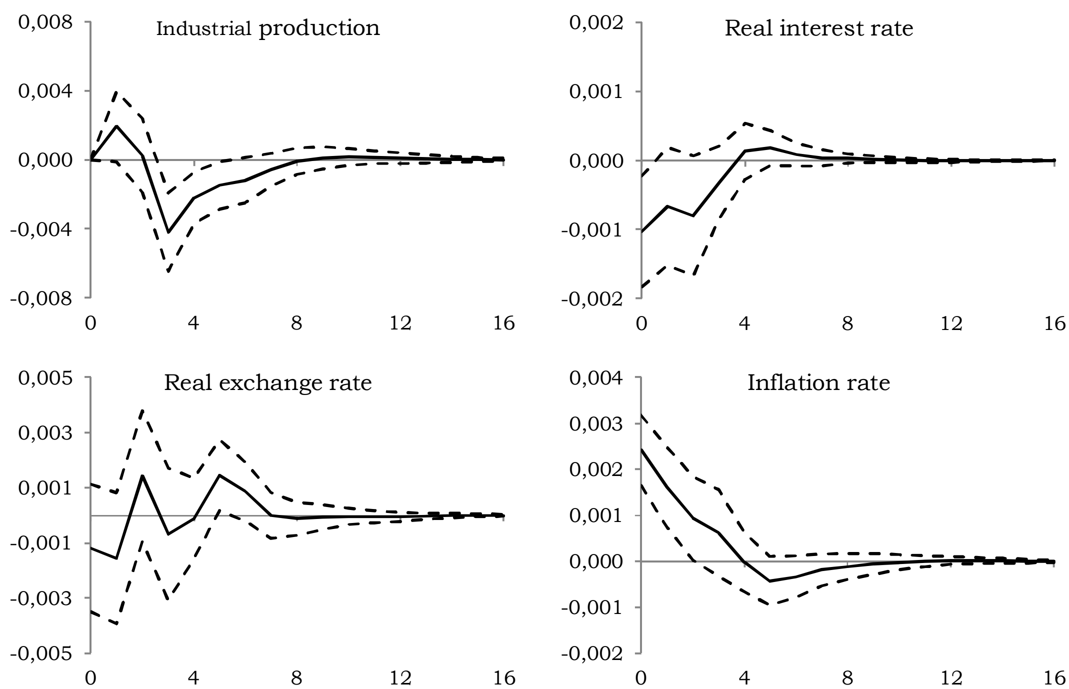
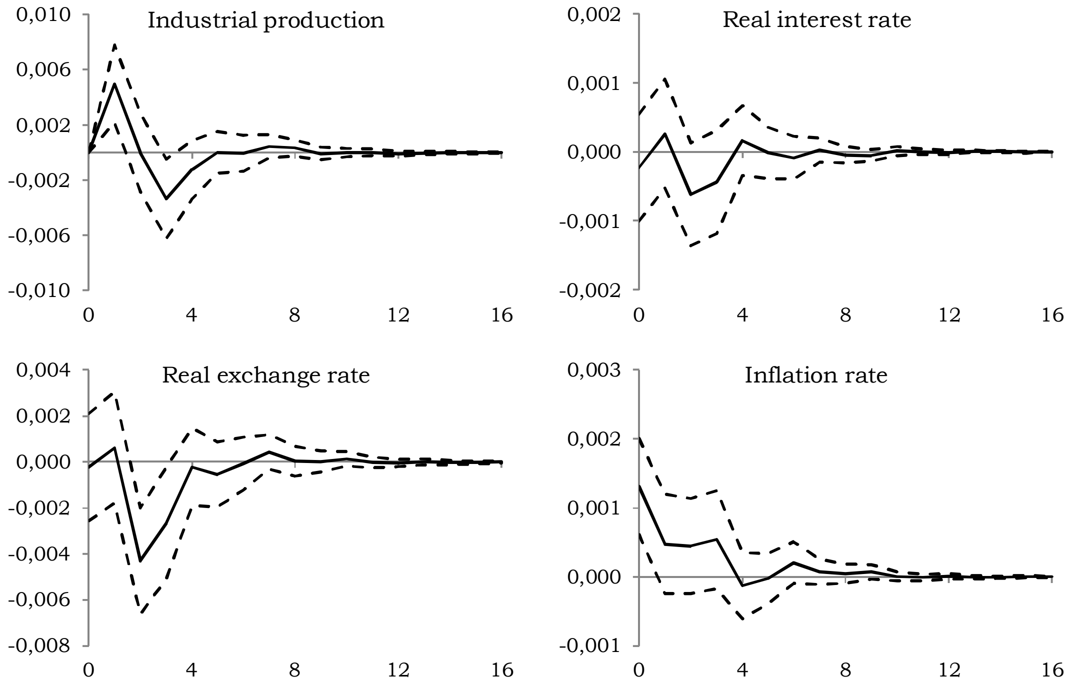


Figure 22. The figure presents the orthogonalised impulse-response function of Industrial production, real interest rate, Real exchange rate and Inflation rate to a one-standard-deviation oil price innovation for Canada and France.

<u>Germany</u>



<u>Italy</u>

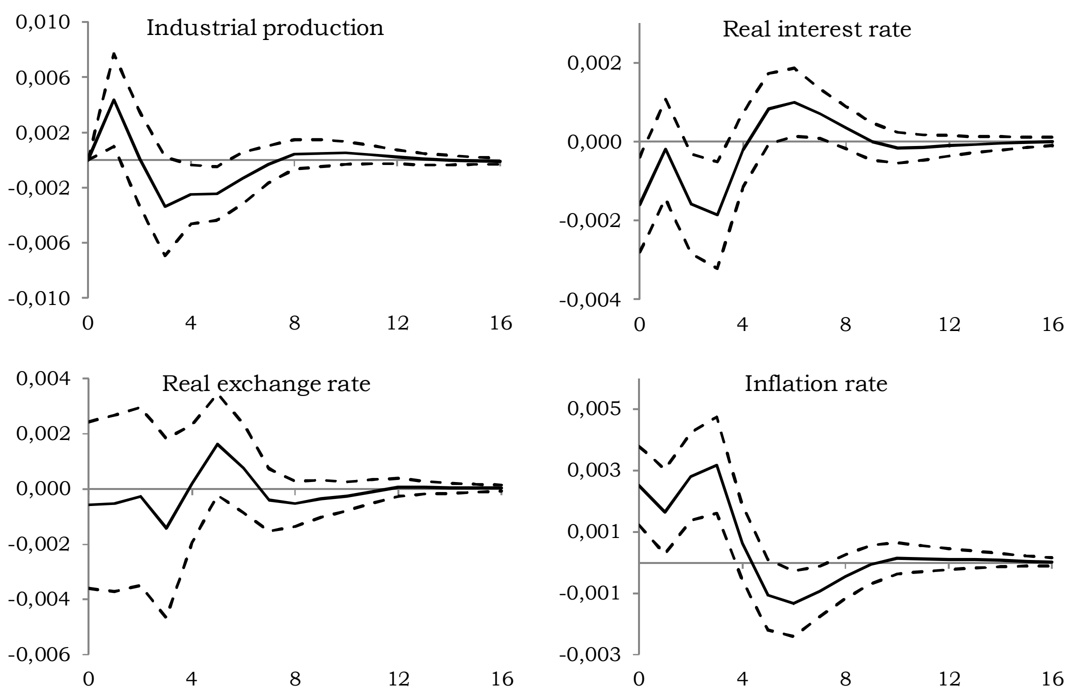
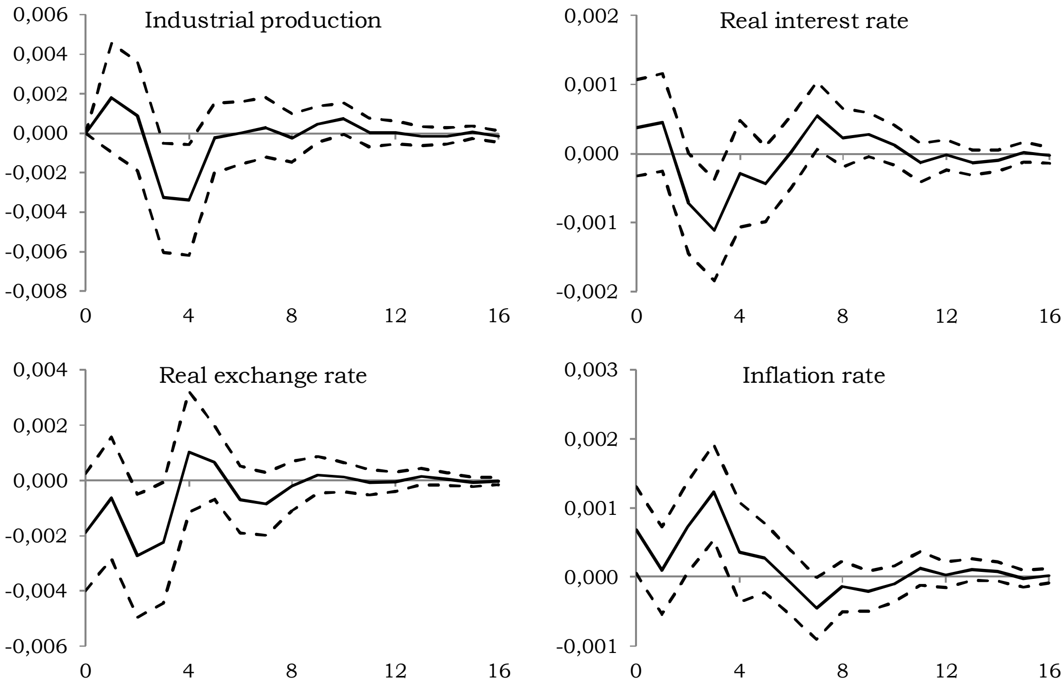


Figure 23. The figure presents the orthogonalised impulse-response function of Industrial production, real interest rate, Real exchange rate and Inflation rate to a one-standard-deviation oil price innovation for Germany and Italy.

Netherlands



Switzerland

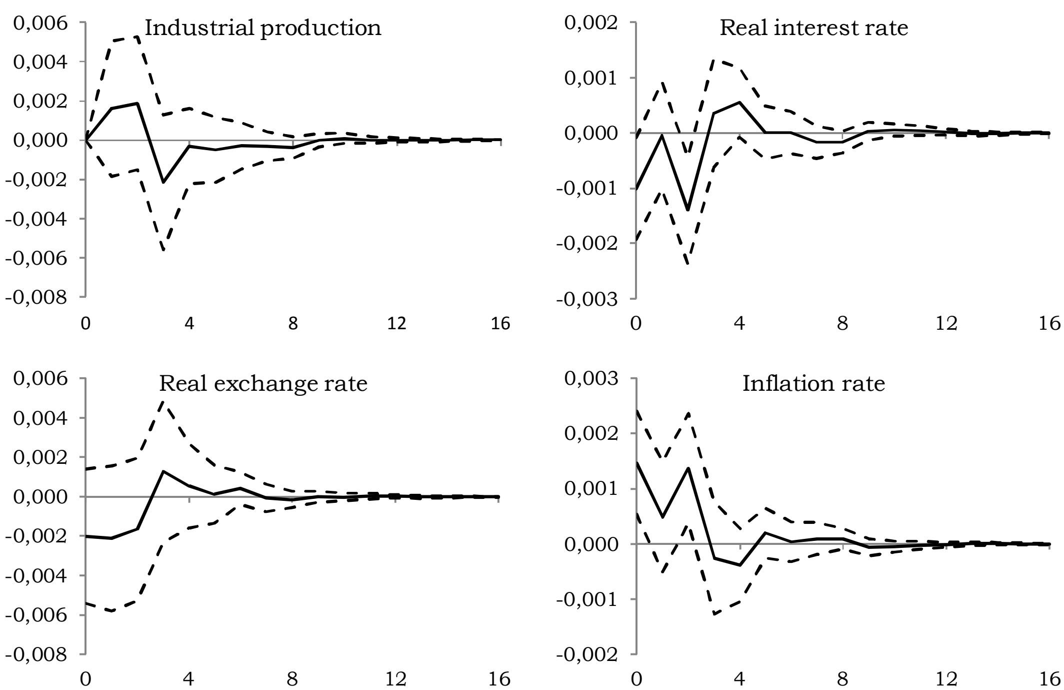


Figure 24. The figure presents the orthogonalised impulse-response function of Industrial production, real interest rate, Real exchange rate and Inflation rate to a one-standard-deviation oil price innovation for Netherlands and Switzerland.

United Kingdom

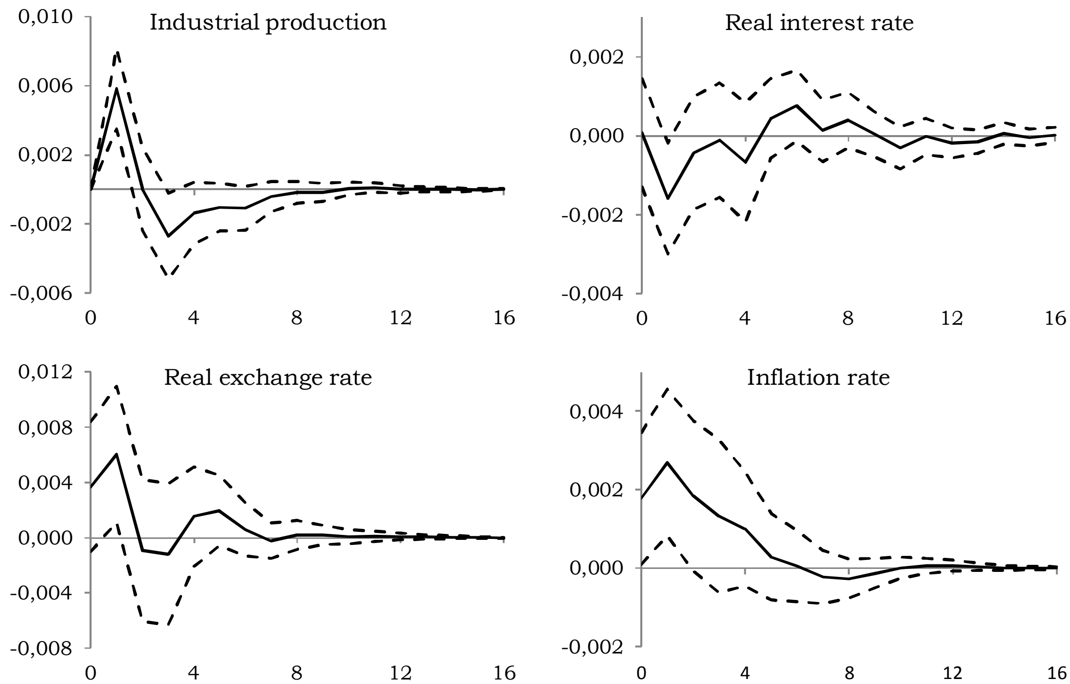


Figure 25. The figure presents the orthogonalised impulse-response function of Industrial production, real interest rate, Real exchange rate and Inflation rate to a one-standard-deviation oil price innovation for United Kingdom .

A9. Variance decomposition

Country	*IP*	*r*	*REER*	*Infl*
Australia	0,021	0,029	**0,074**	0,030
	(0,96)	(1,14)	(2,04)	(1,17)
Belgium	0,050	**0,182**	0,011	**0,354**
	(1,56)	(2,85)	(0,68)	(4,47)
Canada	0,013	0,030	0,054	**0,154**
	(0,65)	(1,14)	(1,54)	(2,57)
France	**0,090**	0,063	0,025	**0,236**
	(2,33)	(1,60)	(1,10)	(3,62)
Germany	**0,083**	0,024	**0,086**	**0,094**
	(2,28)	(1,08)	(2,11)	(2,04)
Italy	0,051	**0,100**	0,006	**0,225**
	(1,83)	(2,08)	(0,47)	(3,37)
Netherlands	0,041	**0,082**	0,073	**0,109**
	(1,41)	(2,08)	(1,65)	(2,14)
Switzerland	0,019	0,069	0,022	**0,091**
	(1,00)	(1,95)	(0,90)	(2,10)
United Kingdom	**0,146**	0,044	0,046	0,094
	(3,02)	(1,19)	(1,41)	(1,67)
United States	0,059	**0,123**	0,059	**0,264**
	(1,53)	(2,51)	(1,70)	(4,32)

Table 11. This table presents the results of the estimated variance decomposition at the 4-period horizon (one year).

A10. Oil Consumption and Economic growth

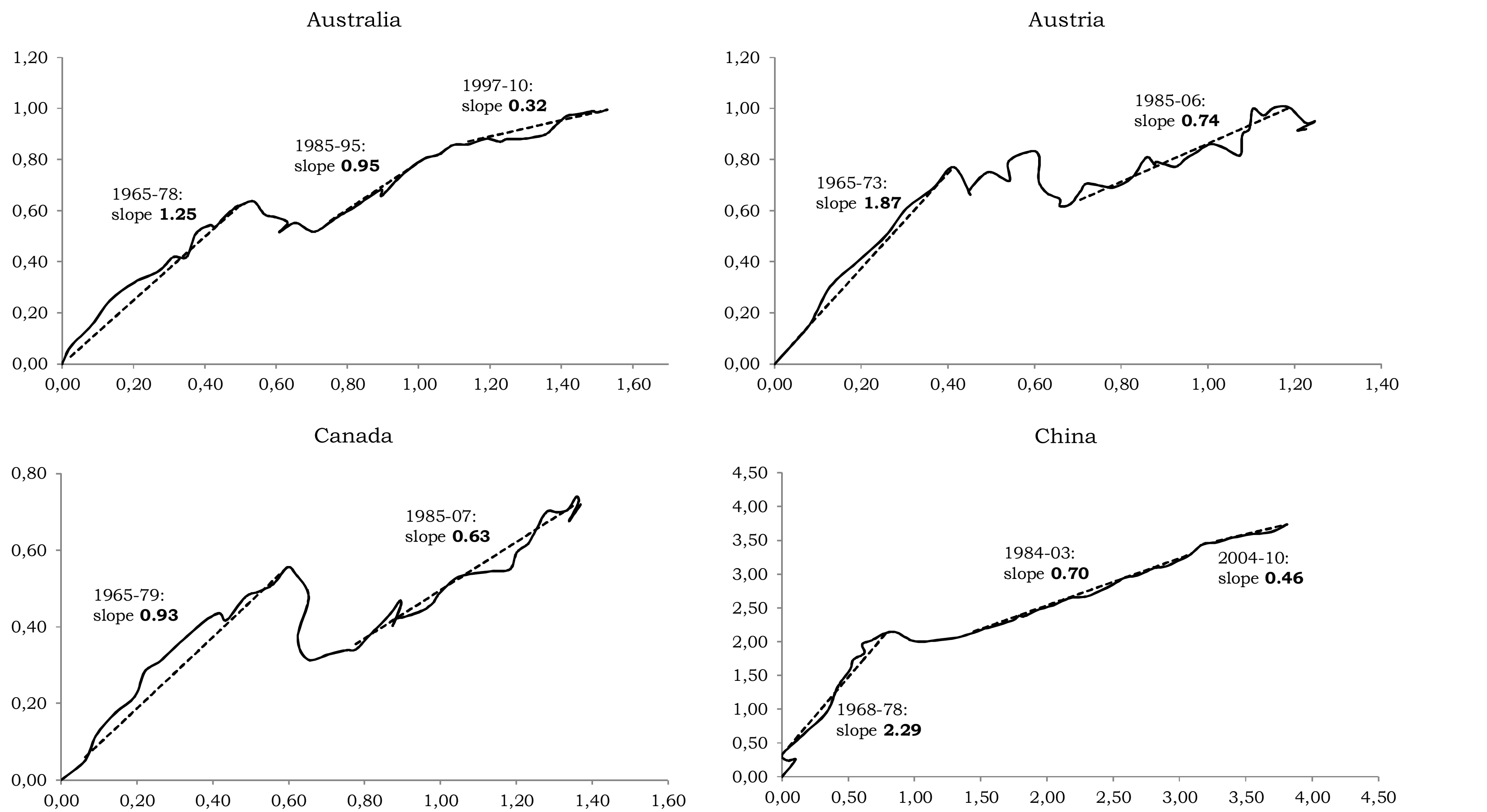


Figure 26. X-axis: cumulative change in natural logarithm of the country´s GDP in 2000s dollars between 1965 and the year for which a given data point is plotted, source: World Bank. Y-axis: cumulative change in natural logarithm of oil supplied to the country´s market between 1965 and the year for which a given data point is plotted, source BP Statistical Review 2011.

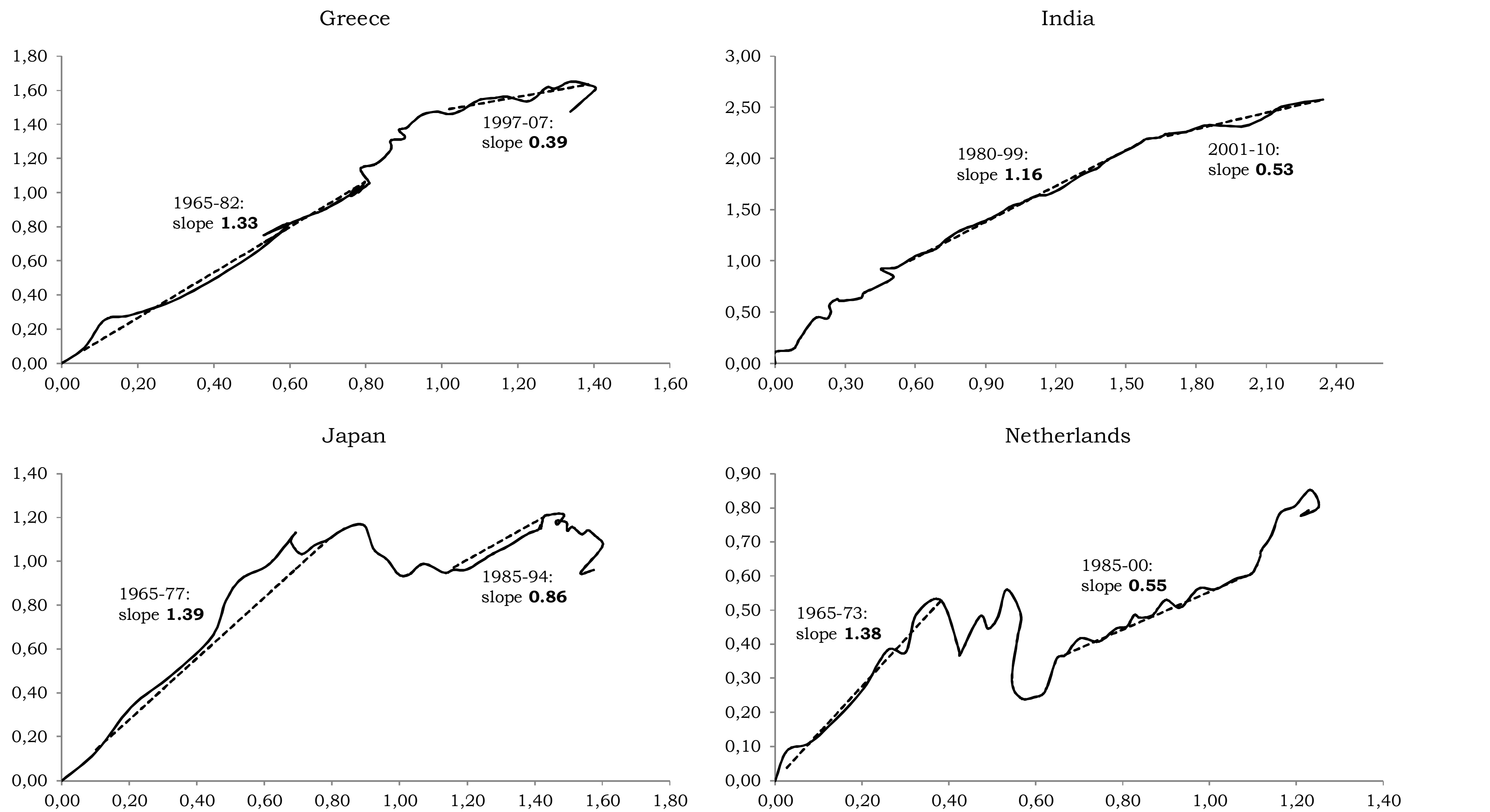


Figure 27. X-axis: cumulative change in natural logarithm of the country´s GDP in 2000s dollars between 1965 and the year for which a given data point is plotted, source: World Bank. Y-axis: cumulative change in natural logarithm of oil supplied to the country´s market between 1965 and the year for which a given data point is plotted, source BP Statistical Review 2011.

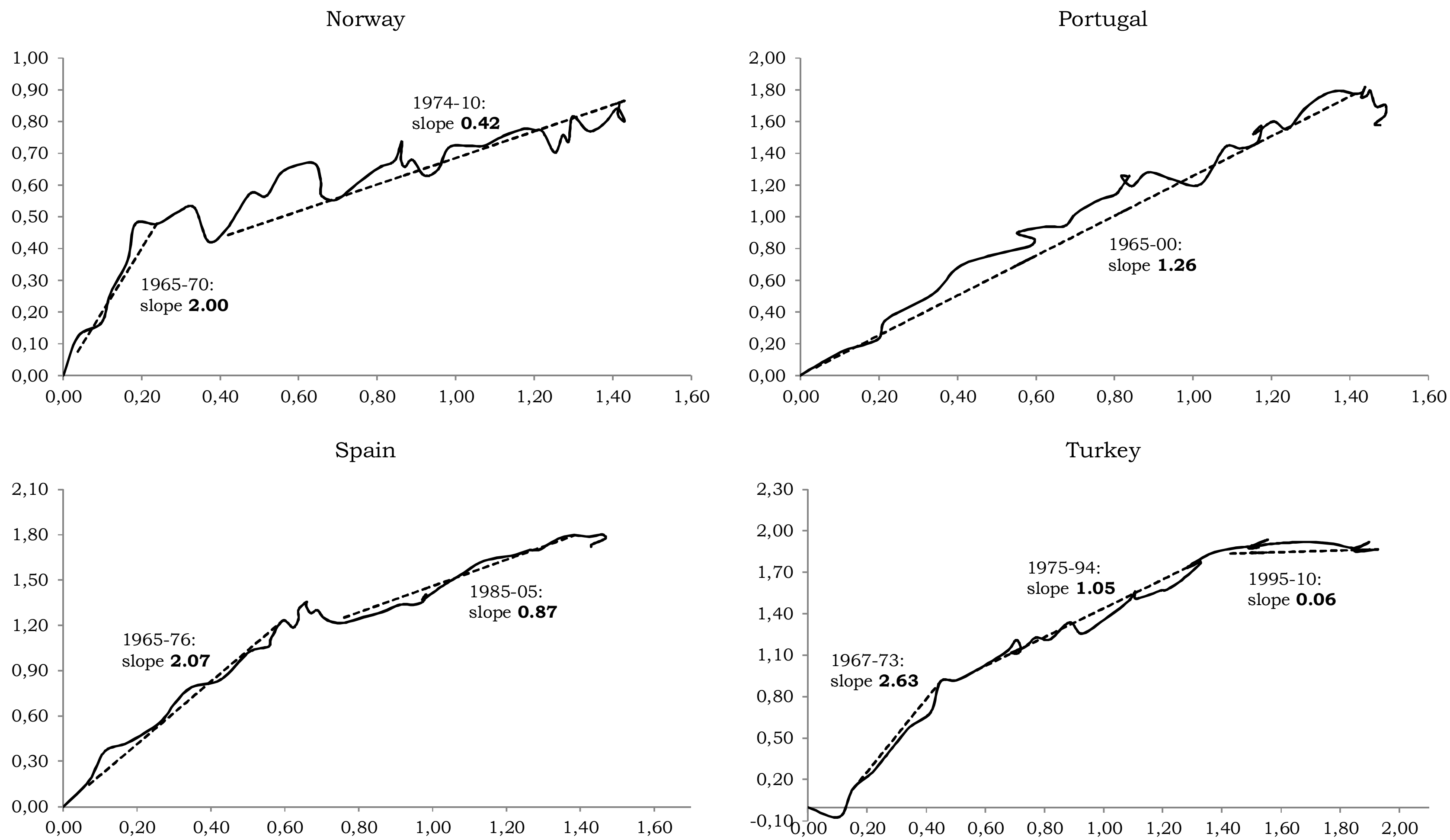


Figure 28. X-axis: cumulative change in natural logarithm of the country´s GDP in 2000s dollars between 1965 and the year for which a given data point is plotted, source: World Bank. Y-axis: cumulative change in natural logarithm of oil supplied to the country´s market between 1965 and the year for which a given data point is plotted, source BP Statistical Review 2011.

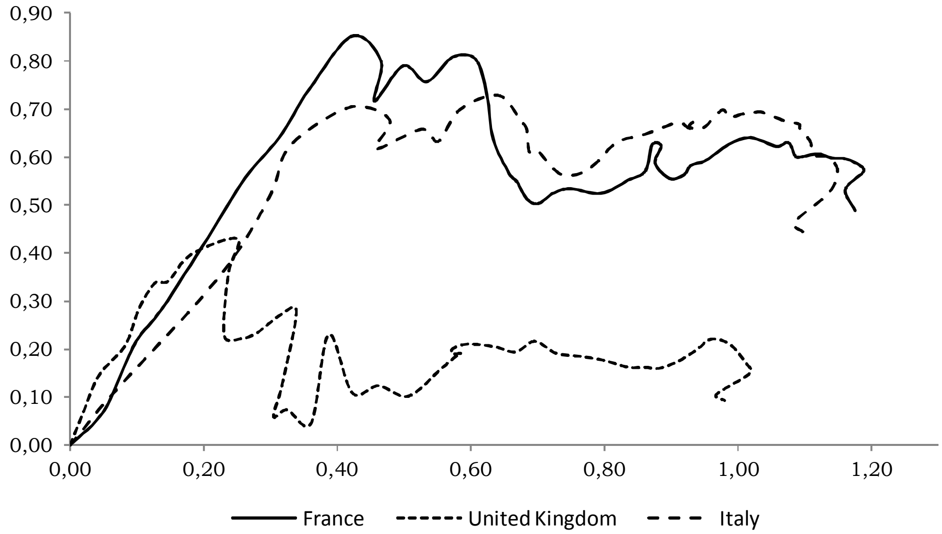


Figure 29. X-axis: cumulative change in natural logarithm of the country´s GDP in 2000s dollars between 1965 and the year for which a given data point is plotted, source: World Bank. Y-axis: cumulative change in natural logarithm of oil supplied to the country´s market between 1965 and the year for which a given data point is plotted, source BP Statistical Review 2011.

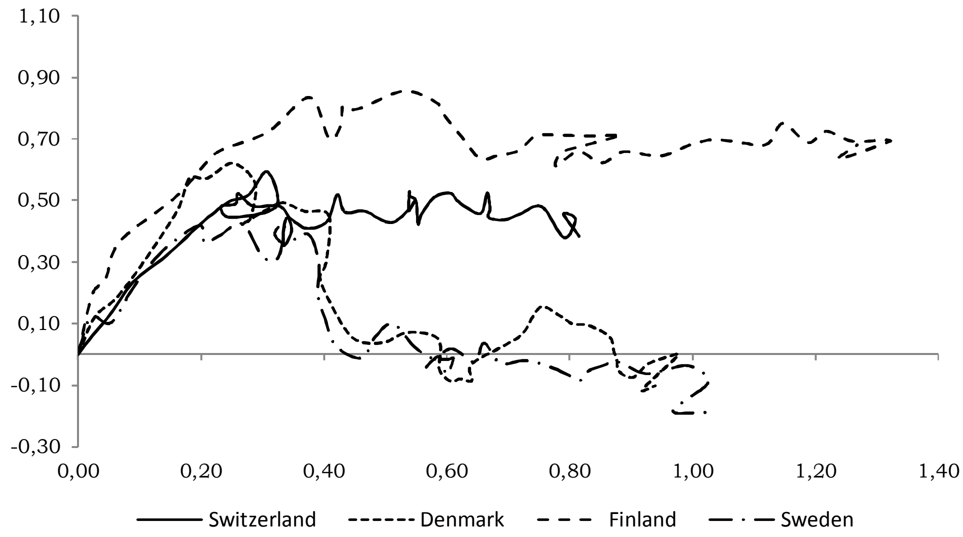


Figure 30. X-axis: cumulative change in natural logarithm of the country´s GDP in 2000s dollars between 1965 and the year for which a given data point is plotted, source: World Bank. Y-axis: cumulative change in natural logarithm of oil supplied to the country´s market between 1965 and the year for which a given data point is plotted, source BP Statistical Review 2011.

A11. Countries Energy Mix

Australia	Oil	Gas	Coal	Nuclear	Hydro	Renew.	Austria	Oil	Gas	Coal	Nuclear	Hydro	Renew.	Canada	Oil	Gas	Coal	Nuclear	Hydro	Renew.
1965-72	0,52	0,02	0,41	..	0,05	..	1965-72	0,43	0,12	0,22	..	0,22	..	1965-72	0,46	0,20	0,11	0,00	0,23	..
1973-80	0,48	**0,11**	0,36	..	**0,05**	..	1973-80	**0,47**	**0,17**	0,13	..	0,22	..	1973-80	0,43	**0,22**	0,09	**0,03**	**0,23**	..
1981-89	0,39	**0,17**	**0,40**	..	0,04	..	1981-89	0,40	**0,18**	**0,13**	..	**0,28**	..	1981-89	0,33	**0,22**	**0,11**	**0,06**	**0,28**	..
1990-99	0,36	**0,17**	**0,43**	..	0,04	**0,00**	1990-99	0,39	**0,23**	0,10	..	0,27	**0,01**	1990-99	0,30	**0,26**	0,10	**0,07**	0,27	**0,00**
2000-10	0,34	**0,19**	**0,43**	..	0,03	**0,01**	2000-10	**0,40**	**0,25**	0,08	..	0,24	**0,03**	2000-10	**0,31**	**0,27**	0,10	0,06	0,26	**0,01**
China	Oil	Gas	Coal	Nuclear	Hydro	Renew.	Denmark	Oil	Gas	Coal	Nuclear	Hydro	Renew.	Finland	Oil	Gas	Coal	Nuclear	Hydro	Renew.
1965-72	0,13	0,01	0,83	..	0,03	..	1965-72	0,88	..	0,12	..	0,00	..	1965-72	0,66	..	0,16	..	0,18	..
1973-80	**0,22**	**0,03**	0,72	..	0,03	..	1973-80	0,83	..	**0,17**	..	0,00	..	1973-80	**0,67**	**0,03**	0,14	**0,03**	0,13	..
1981-89	0,18	0,02	**0,76**	..	**0,04**	..	1981-89	0,60	**0,04**	**0,36**	..	**0,00**	..	1981-89	0,50	**0,04**	0,13	**0,19**	**0,14**	..
1990-99	**0,19**	0,02	0,75	**0,00**	**0,04**	**0,00**	1990-99	0,49	**0,15**	0,33	..	0,00	**0,02**	1990-99	0,41	**0,11**	**0,14**	0,18	0,11	**0,06**
2000-10	**0,20**	**0,03**	0,71	**0,01**	**0,06**	**0,00**	2000-10	0,46	**0,22**	0,22	..	**0,00**	**0,10**	2000-10	0,37	**0,12**	**0,15**	**0,18**	0,10	**0,07**
France	Oil	Gas	Coal	Nuclear	Hydro	Renew.	Greece	Oil	Gas	Coal	Nuclear	Hydro	Renew.	India	Oil	Gas	Coal	Nuclear	Hydro	Renew.
1965-72	0,57	0,06	0,29	0,01	0,08	..	1965-72	0,67	..	0,28	..	0,05	..	1965-72	0,28	0,01	0,61	0,00	0,10	..
1973-80	**0,63**	**0,11**	0,16	**0,03**	0,07	..	1973-80	0,63	..	**0,33**	..	0,04	..	1973-80	**0,30**	**0,01**	0,57	**0,01**	**0,11**	..
1981-89	0,45	**0,12**	0,11	**0,24**	**0,08**	..	1981-89	**0,66**	**0,00**	0,30	..	0,04	..	1981-89	**0,31**	**0,03**	0,56	**0,01**	0,09	..
1990-99	0,39	**0,13**	0,07	**0,35**	0,06	**0,00**	1990-99	0,65	**0,01**	**0,31**	..	0,03	..	1990-99	**0,32**	**0,07**	0,52	**0,01**	0,07	**0,00**
2000-10	0,36	**0,15**	0,05	**0,38**	0,05	**0,01**	2000-10	0,62	**0,08**	0,26	..	**0,03**	**0,01**	2000-10	**0,33**	**0,09**	0,51	**0,01**	0,06	**0,01**
Italy	Oil	Gas	Coal	Nuclear	Hydro	Renew.	Japan	Oil	Gas	Coal	Nuclear	Hydro	Renew.	Netherland	Oil	Gas	Coal	Nuclear	Hydro	Renew.
1965-72	0,71	0,10	0,09	0,01	0,10	..	1965-72	0,67	0,01	0,24	0,00	0,08	..	1965-72	0,66	0,19	0,15	0,00	..	..
1973-80	**0,71**	**0,14**	0,07	0,01	0,07	..	1973-80	**0,74**	**0,03**	0,15	**0,03**	0,05	..	1973-80	0,52	**0,43**	0,04	**0,01**	..	..
1981-89	0,63	**0,20**	**0,10**	**0,01**	0,06	..	1981-89	0,59	**0,09**	**0,19**	**0,09**	0,05	..	1981-89	0,46	**0,44**	**0,09**	**0,01**	..	..
1990-99	0,58	**0,28**	0,07	..	0,06	**0,01**	1990-99	0,54	**0,11**	0,18	**0,13**	0,04	**0,01**	1990-99	0,46	0,42	**0,11**	0,01	..	**0,00**
2000-10	0,48	**0,36**	0,09	..	0,05	**0,02**	2000-10	0,46	**0,14**	**0,22**	**0,13**	0,04	**0,01**	2000-10	**0,51**	0,38	0,09	0,01	..	**0,02**

Table 12. Average energy mix share. Source BP Statistical Review 2011.

Norway	Oil	Gas	Coal	Nuclear	Hydro	Renew.
1965-72	0,33	..	0,05	..	0,62	..
1973-80	0,32	**0,01**	0,02	..	0,65	..
1981-89	0,26	**0,04**	0,01	..	**0,69**	..
1990-99	0,25	**0,07**	**0,01**	..	0,67	**0,00**
2000-10	0,23	**0,09**	0,01	..	0,66	**0,00**

Portugal	Oil	Gas	Coal	Nuclear	Hydro	Renew.
1965-72	0,68	..	0,10	..	0,23	..
1973-80	**0,75**	..	0,05	..	0,20	..
1981-89	0,74	..	**0,09**	..	0,17	..
1990-99	0,68	**0,01**	**0,18**	..	0,12	**0,01**
2000-10	0,58	**0,13**	0,14	..	0,10	**0,05**

Spain	Oil	Gas	Coal	Nuclear	Hydro	Renew.
1965-72	0,61	0,00	0,22	0,01	0,17	..
1973-80	**0,69**	**0,02**	0,15	**0,02**	0,11	..
1981-89	0,58	**0,03**	**0,23**	**0,08**	0,08	..
1990-99	0,55	**0,08**	0,18	**0,12**	0,06	**0,00**
2000-10	0,52	**0,17**	0,12	0,09	0,05	**0,04**

Sweden	Oil	Gas	Coal	Nuclear	Hydro	Renew.
1965-72	0,67	..	0,04	0,00	0,30	..
1973-80	0,60	..	**0,04**	**0,08**	0,29	..
1981-89	0,39	**0,00**	**0,05**	**0,25**	**0,31**	..
1990-99	0,33	**0,01**	0,04	**0,31**	0,30	**0,01**
2000-10	0,31	**0,02**	0,04	0,29	**0,30**	**0,04**

Switzerland	Oil	Gas	Coal	Nuclear	Hydro	Renew.
1965-72	0,60	0,00	0,04	0,01	0,35	..
1973-80	0,58	**0,02**	0,01	**0,08**	0,30	..
1981-89	0,47	**0,05**	**0,01**	**0,17**	0,30	..
1990-99	0,45	**0,07**	0,01	**0,19**	0,27	**0,01**
2000-10	0,42	**0,09**	0,00	**0,21**	**0,27**	**0,01**

Turkey	Oil	Gas	Coal	Nuclear	Hydro	Renew.
1965-72	0,59	..	0,36	..	0,06	..
1973-80	**0,67**	..	0,26	..	**0,08**	..
1981-89	0,54	**0,01**	**0,34**	..	**0,10**	..
1990-99	0,45	**0,10**	0,33	..	**0,12**	**0,00**
2000-10	0,34	**0,26**	0,30	..	0,09	**0,00**

United Kingdom	Oil	Gas	Coal	Nuclear	Hydro	Renew.
1965-72	0,45	0,04	0,48	0,03	0,00	..
1973-80	**0,45**	**0,16**	0,35	**0,04**	0,00	..
1981-89	0,39	**0,22**	0,32	**0,06**	**0,01**	..
1990-99	0,38	**0,29**	0,23	**0,09**	0,00	**0,00**
2000-10	0,36	**0,38**	0,16	0,08	0,00	**0,01**

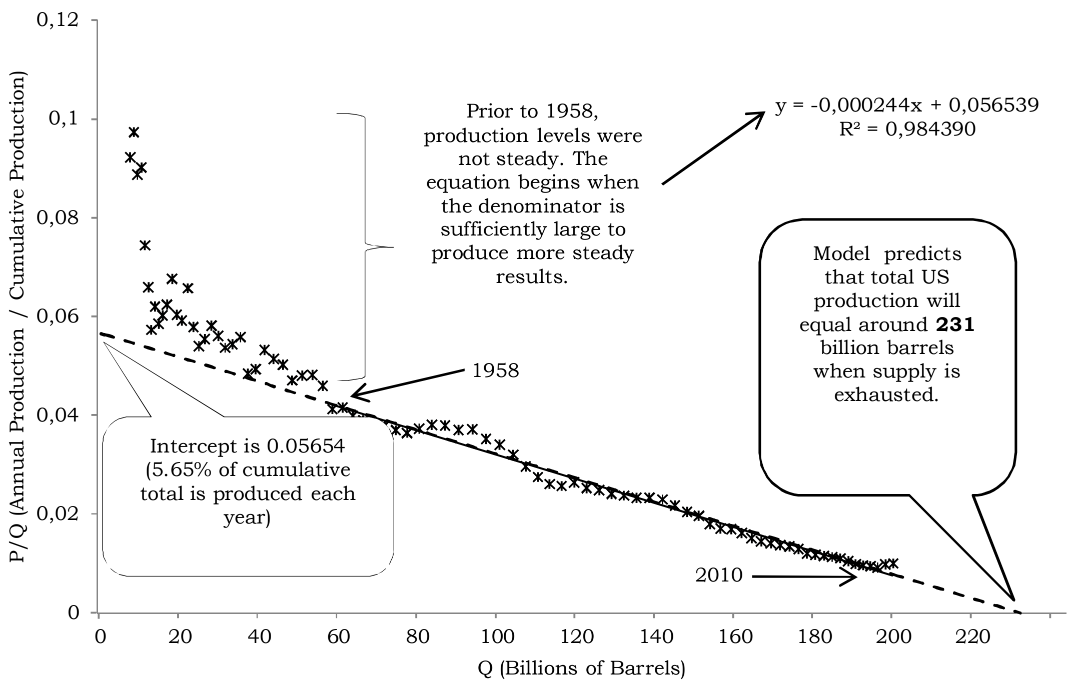
United States	Oil	Gas	Coal	Nuclear	Hydro	Renew.
1965-72	0,43	0,33	0,20	0,00	0,04	..
1973-80	**0,46**	0,29	0,19	**0,03**	0,04	..
1981-89	0,41	0,26	**0,24**	**0,05**	**0,04**	..
1990-99	0,38	**0,26**	**0,24**	**0,07**	0,03	**0,01**
2000-10	**0,39**	0,25	0,24	**0,08**	0,03	**0,01**

Table 13. Average energy mix share. Source BP Statistical Review 2011.

A12. Hubbert Linearization

Hubbert´s curve is the first derivative of a logistic function. The most important piece of information that one needs to know in order to construct the curve is the total amount of oil in place. Because of the complexity in Hubbert´s analysis, it is easier to use linearization to estimate the total oil in place. One way to estimate the total oil in place is to use Linearization method, and the only variable needed is production data (annual production). The first step is to plot the production data (P) as a fraction of cumulative production (Q) on the vertical (y) axis. Cumulative production (Q) is placed on the horizontal (x) axis.

As the chart below shows for the U.S. case, the relationship between P/Q and Q becomes linear as production matures. This linear relationship follows the simple *y = mx + b* equation for graphing a line in plane. Hubbert´s logistic differential equation has a linear property and we can exploit this relationship with the linear representation of P/Q versus Q.



After the denominator Q becomes sufficiently large, P/Q begins to decline linearly. In the U.S. case this begins in 1958 and continues to 2010. A simple linear regression for these points yields the important *y = mx + b* equation we need to build our logistic representation of production. In this case, the regression yields the following equation: *y = -0.000244x + 0.056539*. Plotting the line represented by the regression equation gives the x and y intercepts. The x intercept is crucial. The y axis represents the total quantity of oil produced (Q). The intercept is an estimate of the total oil that will be produced (Q_f). In the U.S. case, the model predicts that total production will equal around 231 billion barrels when supply is exhausted.

The slope in the regression equation is also important. It represents the annual production as a fraction of cumulative production. This completes the set of variables needed to form a production function. The table below shows the translation of the *y = mx + b* equation to the oil production variables.

Variable	***Definition***
P	*Annual Production*
Q	*Cumulative Production to Date*
Q_f	*Total Oil in Place*
Y	P/Q
m	$-a/Q_f$
x	Q
b	a

The following algebraic manipulation yields an equation for annual production: $P = Qa(1 - \frac{Q}{Q_f})$

$P/_Q = \left(\frac{-a}{Q_f}\right)Q + a$ (Substituting the production variables into *y = mx + b* equation)

$P/_Q = \frac{-aQ}{Q_f} + a$ (Simplify the right-hand side of the equation)

$P = \frac{-aQ^2}{Q_f} + aQ$ (Multiply both sides by Q to isolate production on the left)

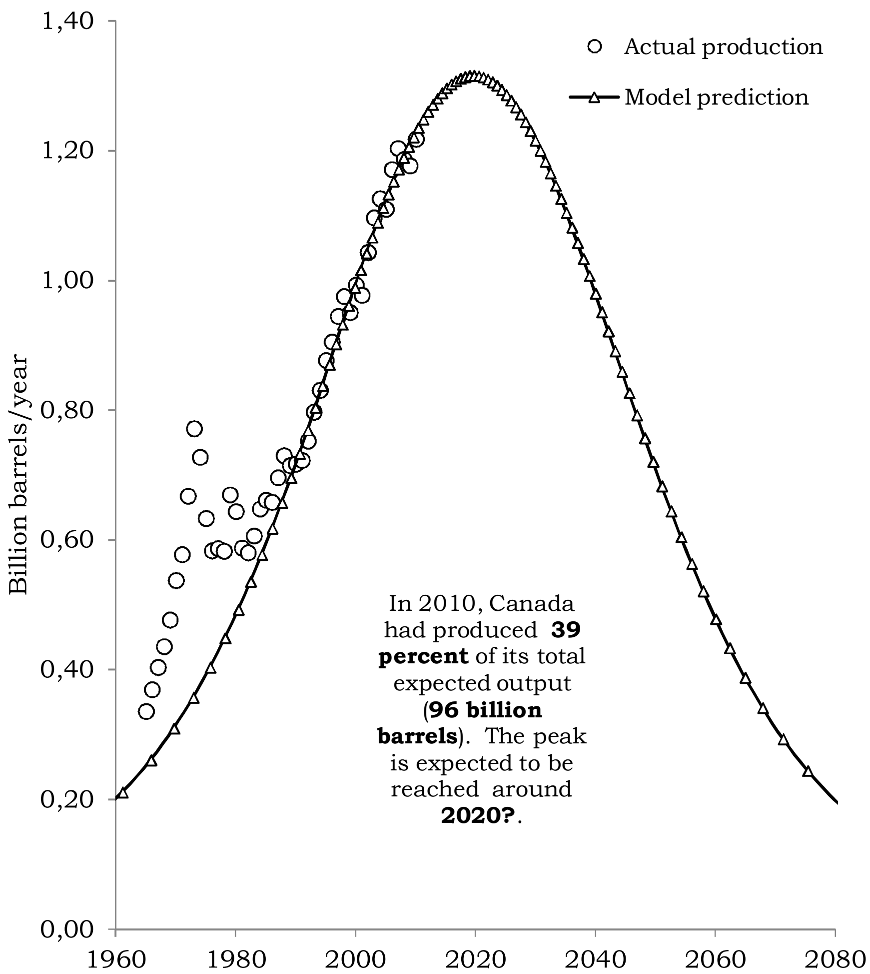
$P = aQ - \frac{aQ^2}{Q_f}$ (Rearrange the right side to remove the negative)

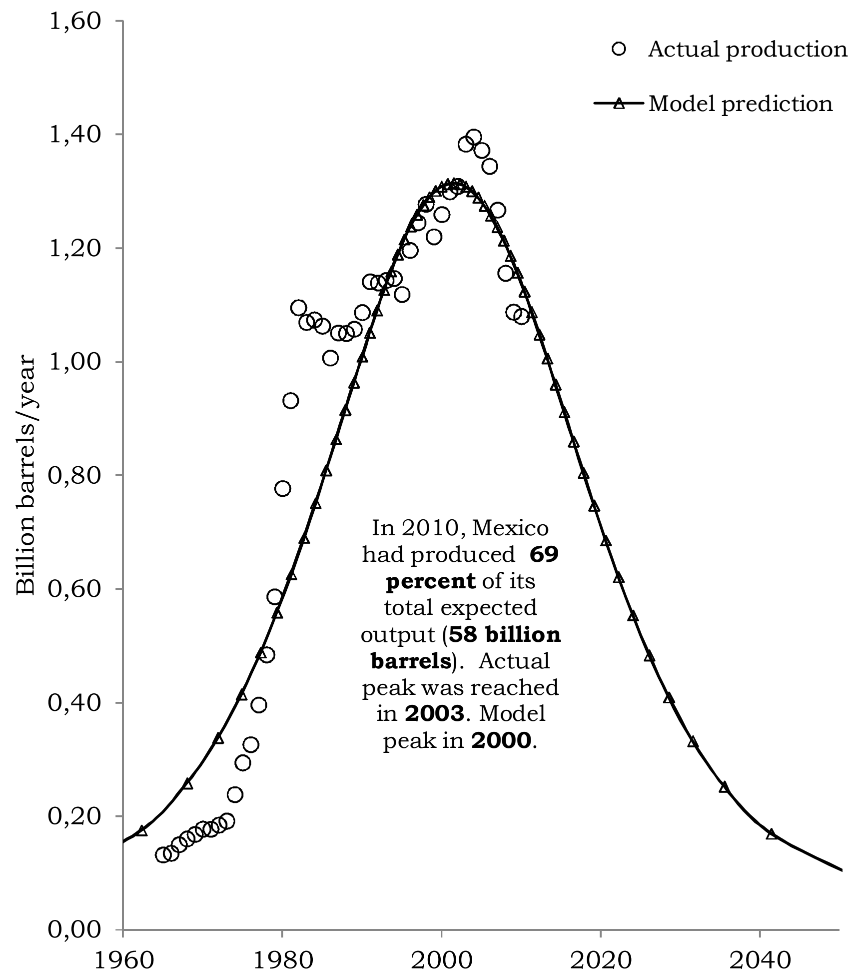
$P = aQ\left(1 - \frac{Q}{Q_f}\right)$ (Factor out aQ from the right-hand side equation)

The inverse of this equation gives a measure of time: years per billion barrels. To complete the linearization process and build a Hubbert curve, plot the projected production and this inverse value in 1 billion barrel increments of cumulative oil production. To add actual years to the plot, look at the actual cumulative production (Q) and match it to the corresponding value in the model. Then, subtract or add 1/P for values above and below the target year respectively. An example of this is shown below where the target year is 1983:

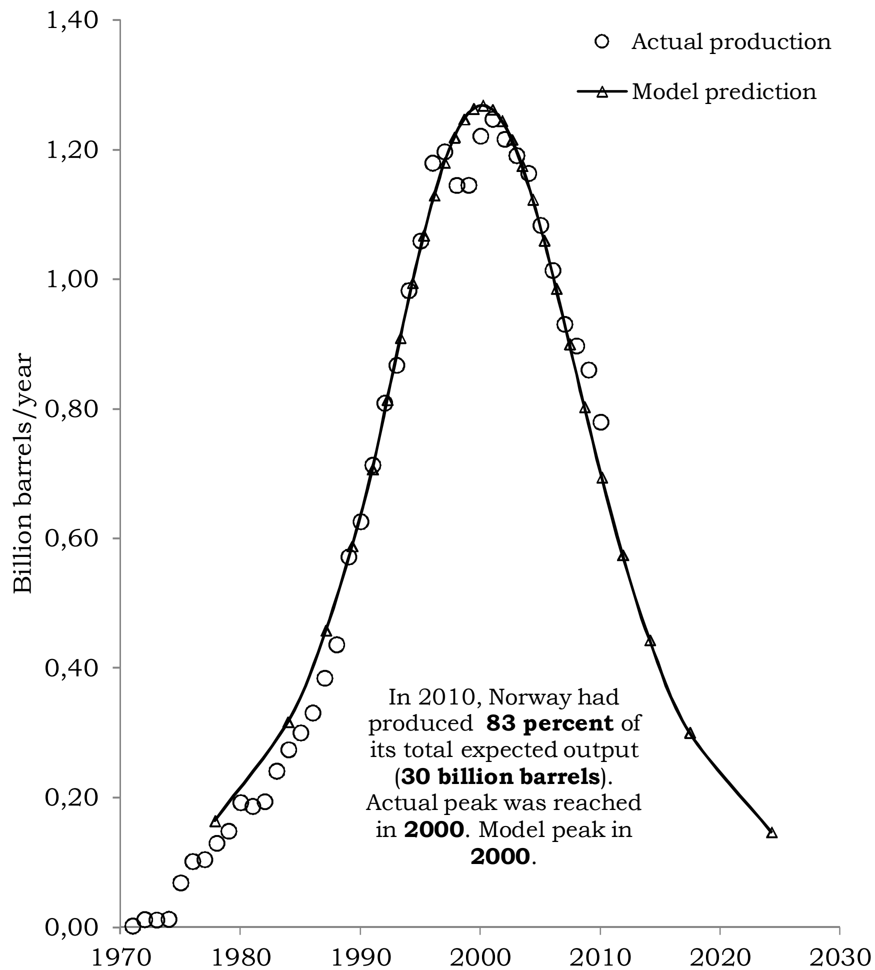
$Q\ (Billions\ of\ Barrels)$	$Predicted\ Annual\ Production$	$1/P$	$Year$
133	3.20	0.31	1982.06
134	3.19	0.31	1982.37
135	3.19	0.31	1982.69
136	3.18	0.31	**1983.00**
137	3.17	0.32	1983.32
138	3.16	0.32	1983.63

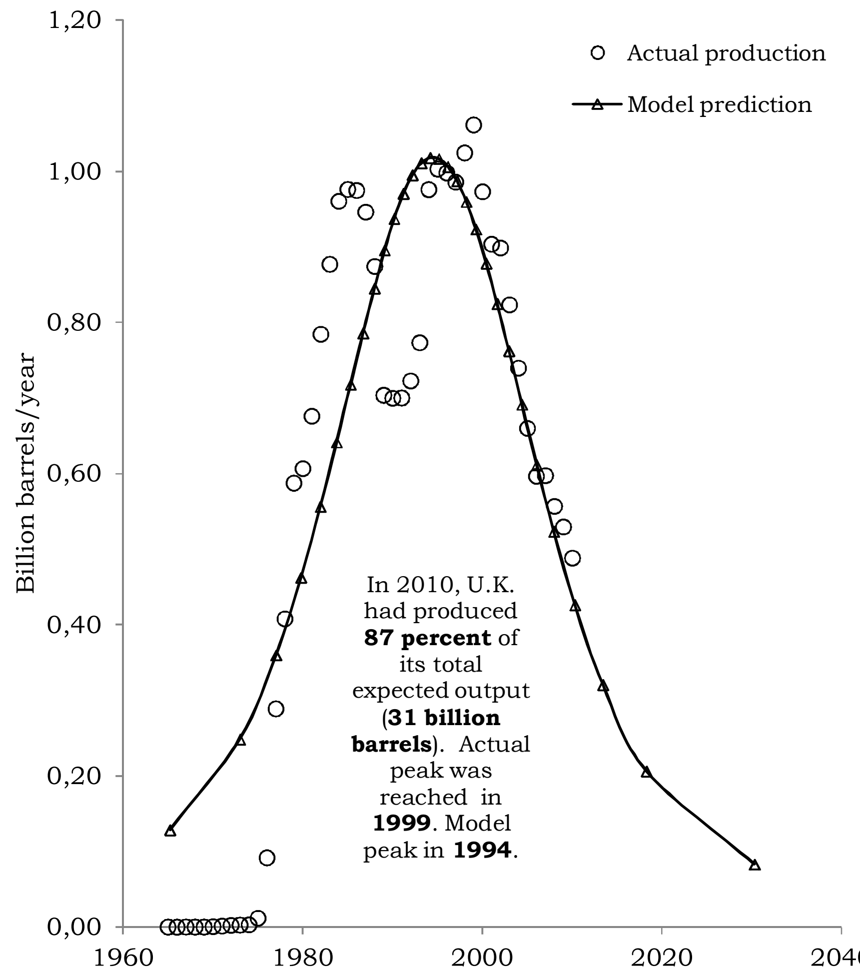
Hubbert Curve: Canada and Mexico



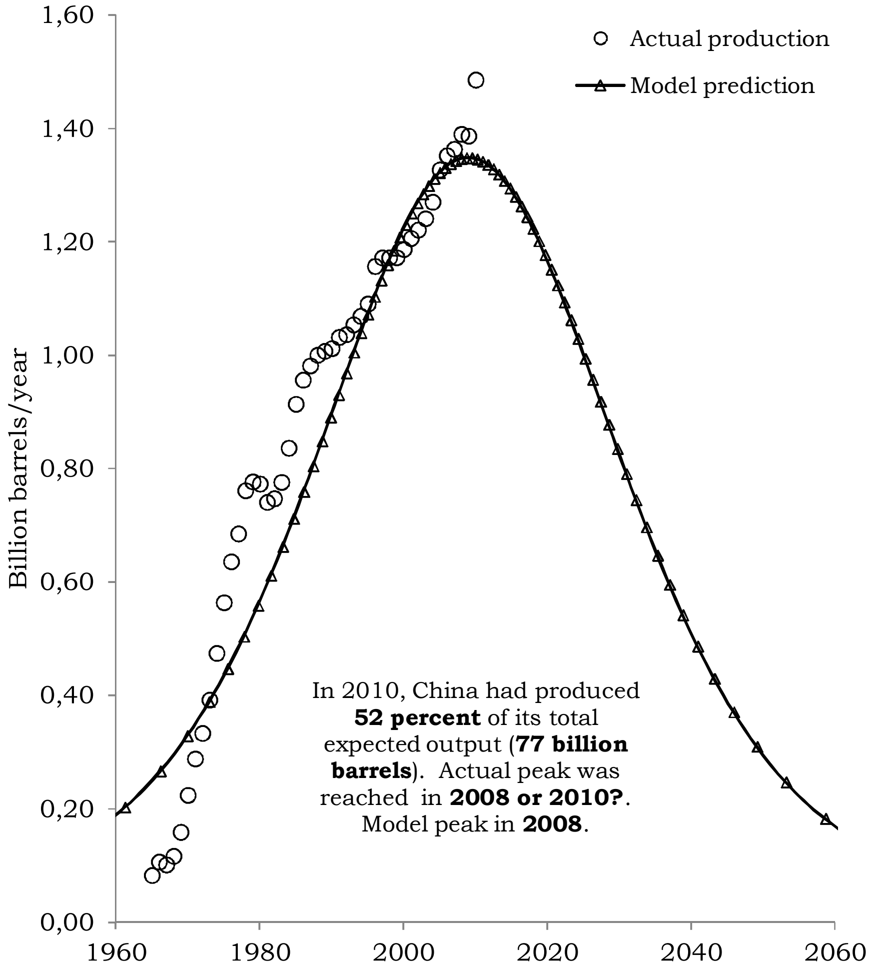


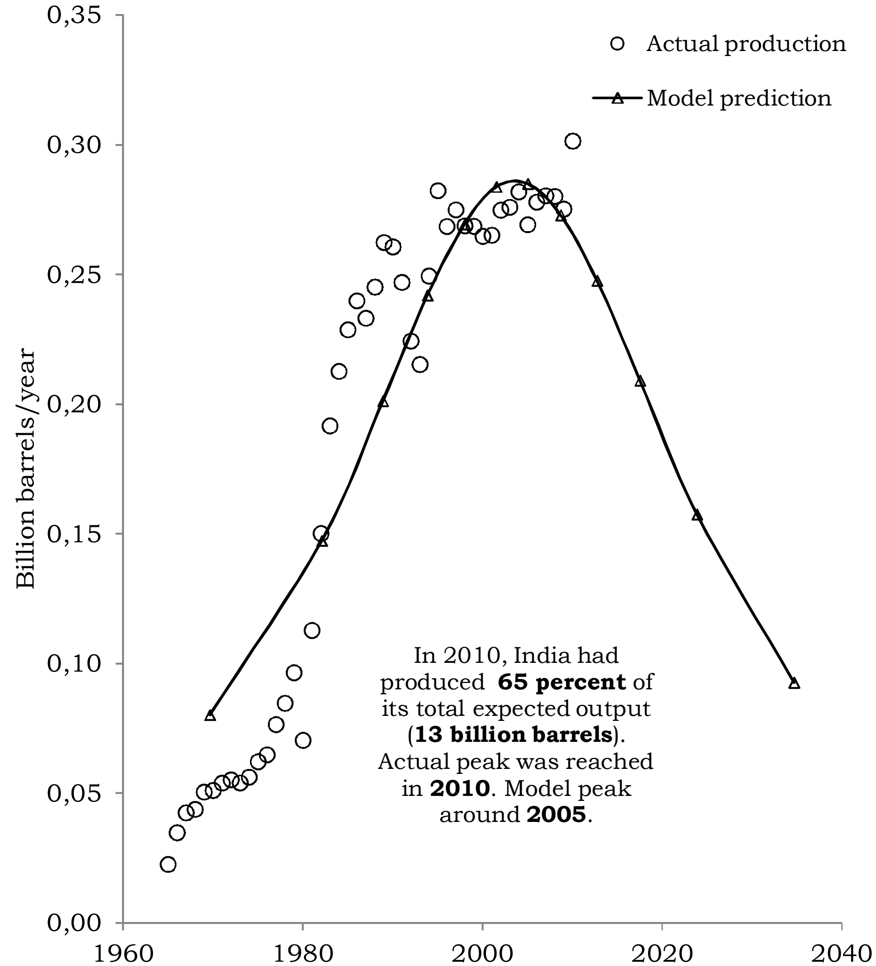
Hubbert Curve: Norway and UK



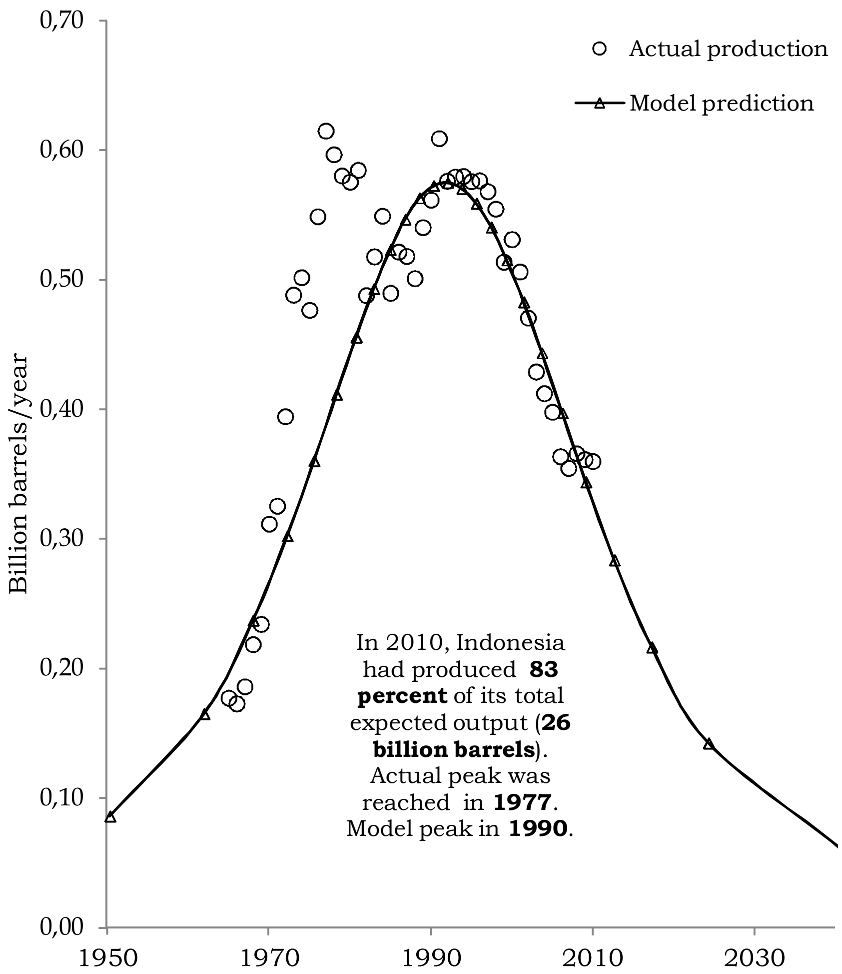


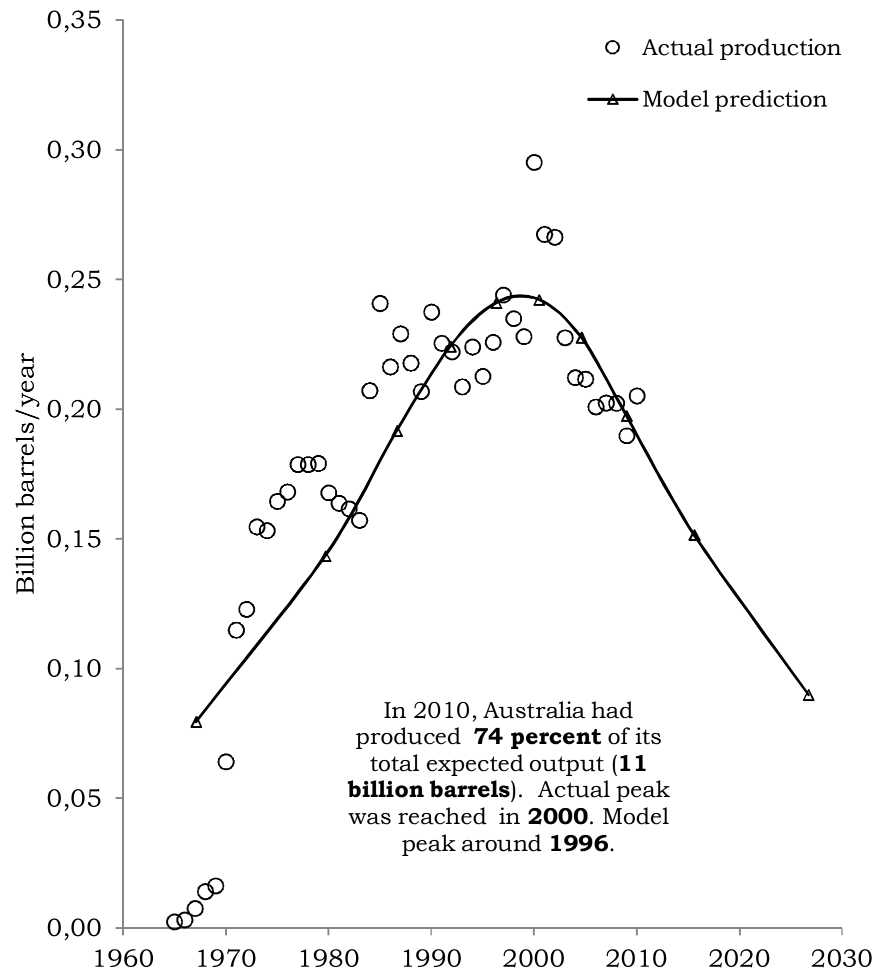
Hubbert Curve: China and India



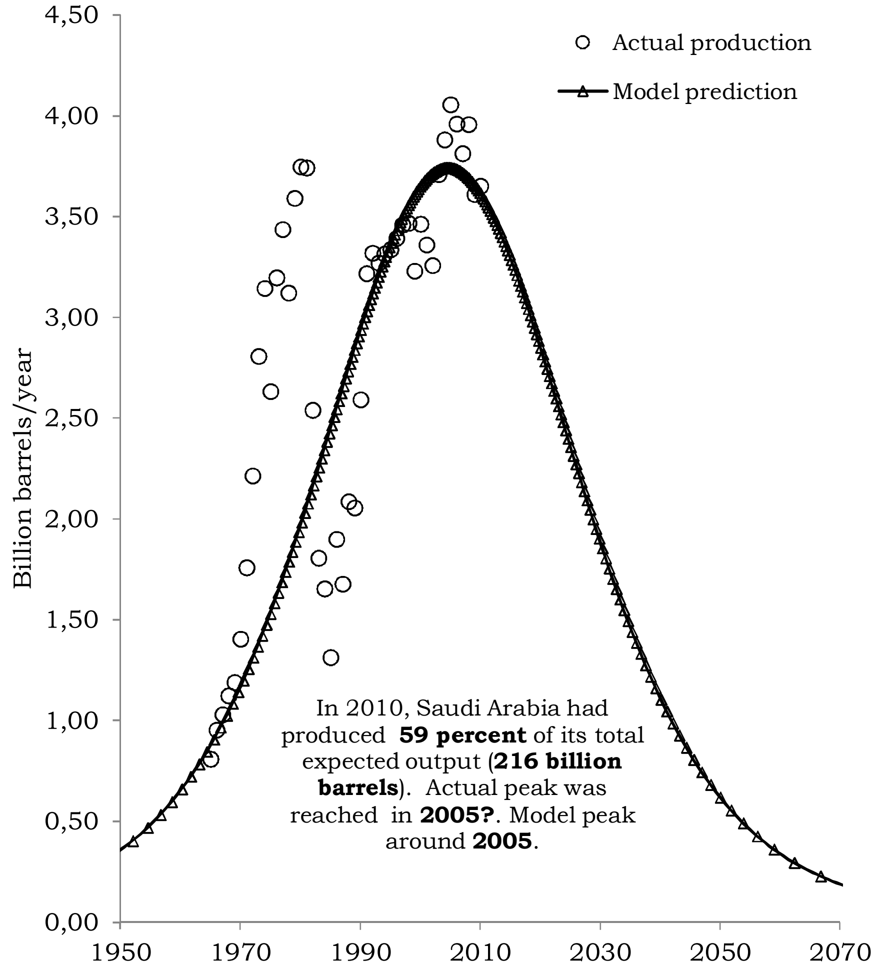


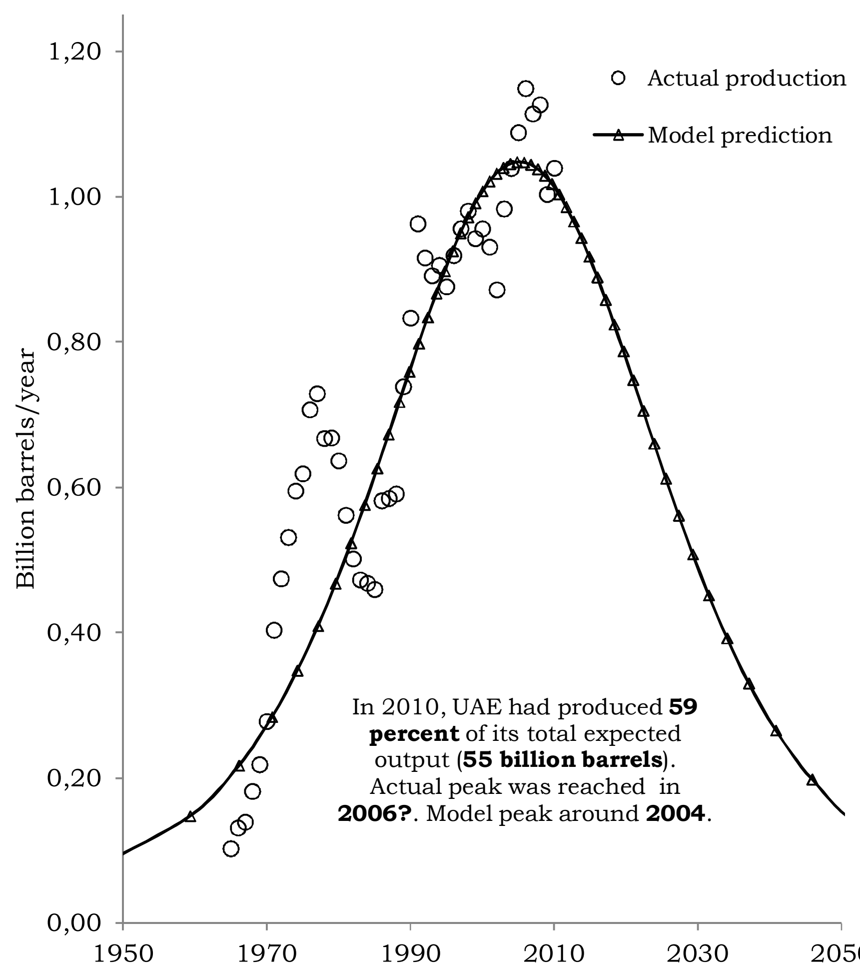
Hubbert Curve: Indonesia and Australia



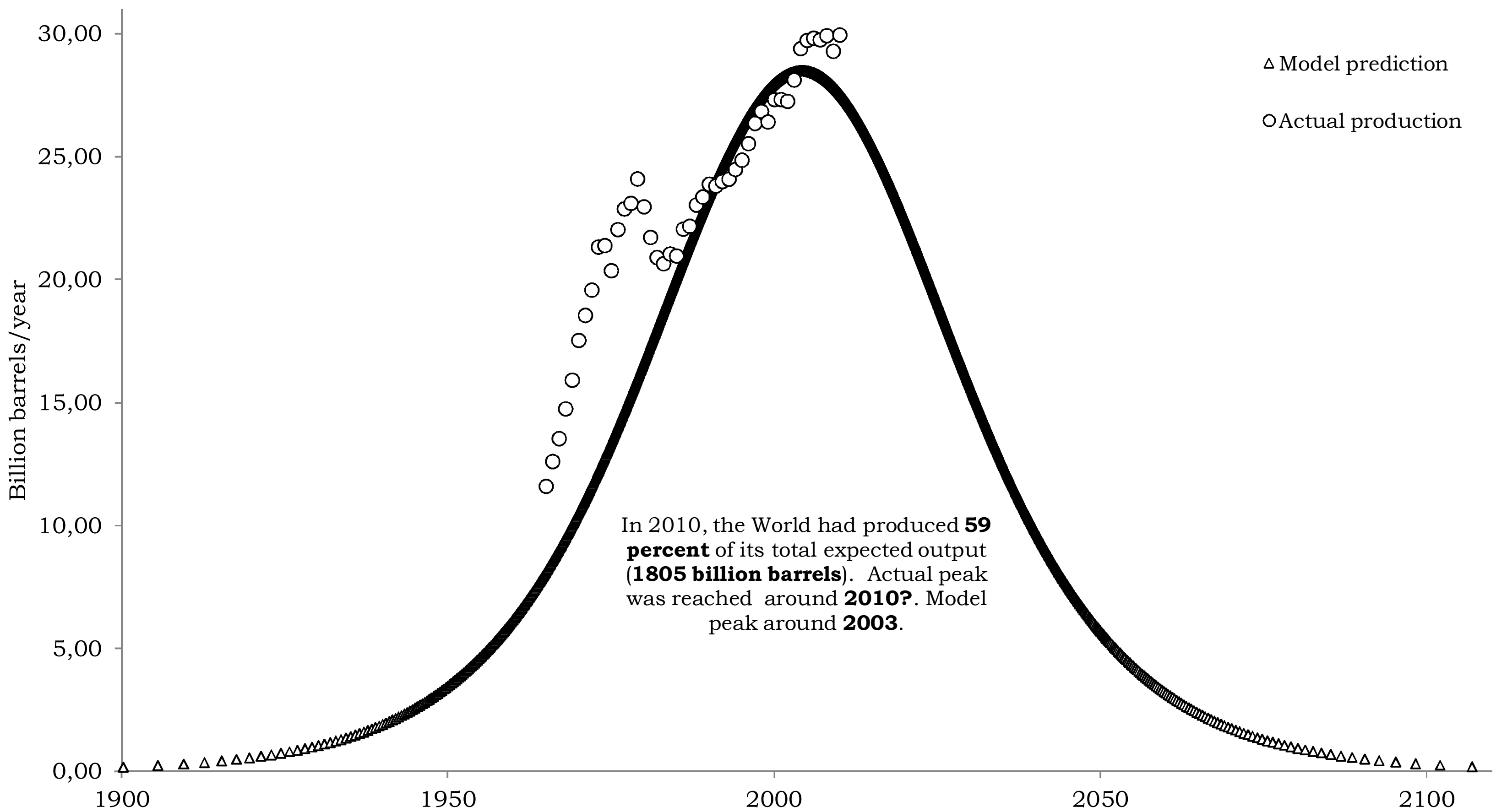


Hubbert Curve: Saudi Arabia and UAE





Hubbert Curve: World



A13. Some geopolitical and other aspects

Pre 1973- The fall of Bretton Woods

In the 1950s and 1960s, almost every currency in the world was anchored to the U.S. dollar and the dollar in turn was anchored to gold ($35 per ounce). In the late 1960s, the United States was running balance of payments deficits and trade deficits following the costs of the Vietnam War and increased domestic spending which accelerated inflation. The effect of the expansionary monetary policy in the United States, and the associated rise in inflation was a depreciation of the dollar´s real exchange rate, or a real appreciation of other countries currencies. Other countries tried to resist this appreciation pressures by buying dollars. The dollar reserves for those countries accumulated and inflationary pressures grew as those countries supplied more of their own currencies to the foreign exchange markets in order to keep their currencies pegged to the dollar at the fixed rates. Therefore, they accused the U.S. of "exporting" inflation, Hammes and Wills (2005).

When those countries started to redeem their dollar reserves for gold, it became clear that the United States could no longer hold the gold price of $35 per ounce. In order to slow the outflow of gold, the United States suspended its obligation to buy dollars from foreign central banks at $35 per ounce and on August 7 1971, Richard Nixon closed the "gold window". With the "floating" of gold, the world moved from a fixed to a flexible exchange rate system as more countries stopped interventions in the foreign exchange market once the United States stopped buying dollars with gold, Hammes and Wills (2005). Gold price was initially revalued to $38, by the end of the 1970s it had risen to more than $450, i.e. an increase of 1084 percent in a decade (Figure 31).

The value of the dollar declined on average 20 percent against major currencies (Figure 13) during the period 1971-1973. Given that oil contracts were in US dollars, the declining value of the dollar meant less revenue for OPEC per unit (barrel) sold to most western countries. To give a glimpse of OPECs loss during this period, one can think of oil priced in gold (T.Ounce/barrel). From figure 32, we can observe that 4 months before the closing of the "gold window" one barrel equaled 0.07 T.Ounce of gold, that is to say, to buy 1 T.Ounce of gold, OPEC had to pay approximately 14 barrels of oil. By October 1972 (one year before OPEC embargo), OPEC had to pay 25 barrels per T.Ounce of gold. The decline in "real" price of oil and the general worldwide inflation did not go unnoticed by OPEC member countries.

In response to the declining value of the dollar, OPEC member countries agreed (the Tehran Agreement of 1971) on an 8.25 percent increase in the price of oil which corresponded to the rise of 8.57 percent in the price of gold vis-á-vis the US dollar. At the same meeting they also agreed on that the future price of oil would be adjusted on a quarterly basis in line with an index based on the movements of nine major industrialized nations[28] vis-á-vis the US dollar, Ahrari (1986). Yet, by July 1973, nearly 40 barrels was required to buy 1 T.Ounce of gold. This automatic indexing was abandoned short after October 1973.

[28] Britain, France, West Germany, Italy, Japan, Belgium, Holland, Sweden and Switzerland.

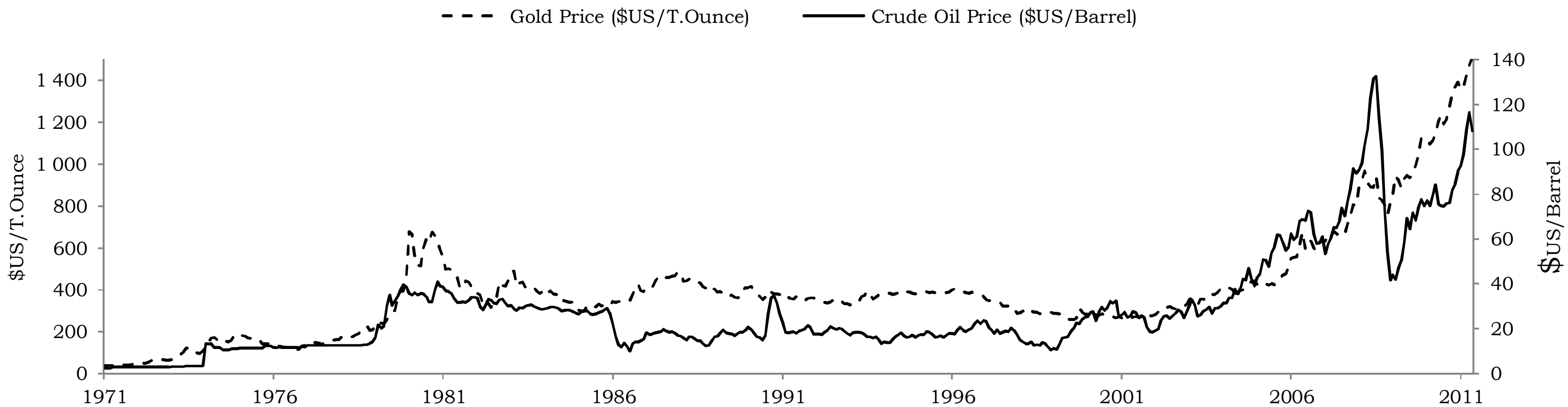


Figure 32. Dollar prices of gold and oil 1971 January- 2011 May. Source: International Financial Statistics (world oil price) and IHS Global Insight (Gold Price).

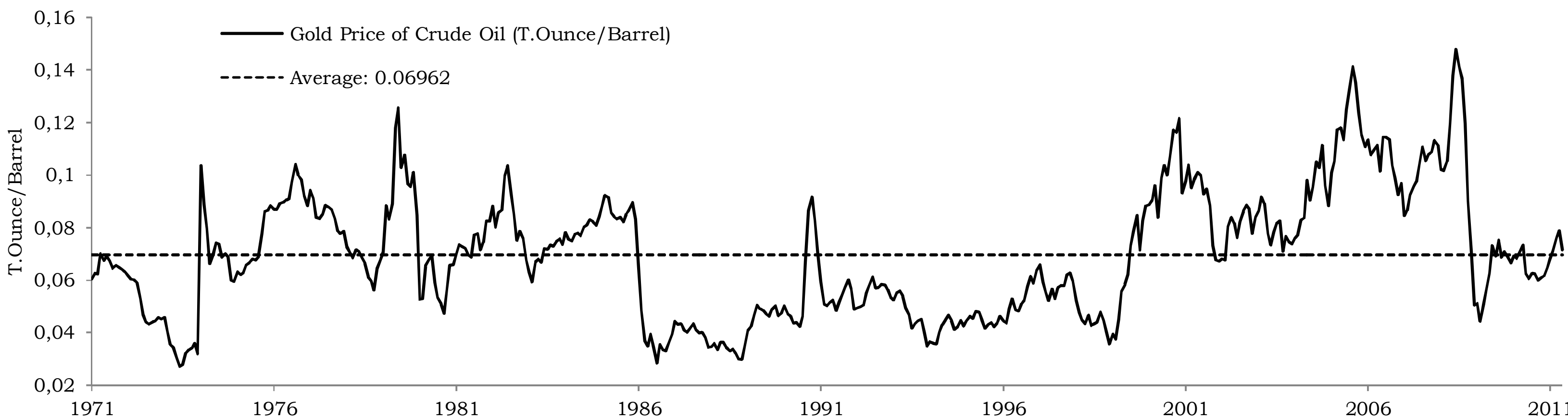


Figure 31. Gold price of crude oil 1971 January- 2011 May (troy ounces/barrel). Source: International Financial Statistics (world oil price) and HIS Global Insight (Gold Price).

1973-1974: The October War and the Oil Embargo

By 1973, the Bretton Woods monetary system was dead. The October War was part of the Arab-Israel conflict which was ongoing from 1948 when the state of Israel was formed. It was the fourth Arab-Israeli War which was led by Egypt and Syria and started with a surprising attack on Israel on Yom Kippur the holiest day in Judaism, which coincided with the Muslim holy month of Ramadan. The war was fought from October 6 to October 25 in 1973. In response to the U.S. decision to resupply the Israeli military, the OPEC plus other Arab countries announced on October 16 that they would cut supply of oil by 5%

"Until the Israeli forces are completely evacuated from all the Arab territories occupied

In the June 1967 war and the legitimate rights of the Palestinian people are restored."[29]

Below in figure 33, I have plotted the change in production from OPEC, non-OPEC and World during the months post the October War and the oil embargo as percentage of total world production prior to this event. As we can see from the Figure, the increase in non-OPEC production was rather minor during this crisis as will be compared to later crisis below. The immediate effect of the embargo was that oil price climbed from an average of $3.00 per barrel prior to the embargo to $12.00 per barrel in October. This increase in price had a dramatic effect on oil exporting countries in the Middle East who had long been dominated by industrial powers who now seen to have acquired the power to control price over a vital commodity.

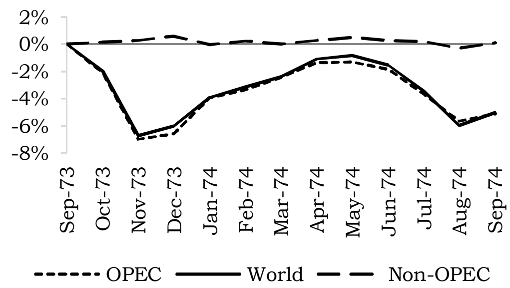


Figure 33. Supply disruption during OPECs embargo. Source: BP statistical review 2011.

This power, to control oil prices and supply became to be known as the "oil weapon" used by Arab countries to select industrialized countries as a tool to put pressure on Israel during the October War, Licklider (1988). For the U.S. case, the embargo threatened its energy security as being the largest oil consuming country in the world. The embargo left many U.S. oil producers searching for new ways to develop expensive oil. The major problems these producers were facing was that; finding oil and developing new oil fields usually require a time lag of 5 to 10 years between the planning process and production, Ikenberry (1986). Another factor that exacerbated the crisis was U.S. price controls which were intended to promote oil explorations through limiting the price of old oil that already been discovered while allowing newly discovered oil to be sold at higher price, Helbling and Turley (1975). This rule also discouraged alternative energies from being developed. The rule had been intended to promote oil exploration. The scarcity of oil was dealt by the rationing of gasoline (which occurred also in many other European countries), with motorist facing long lines at gas stations Fraum (2000).

Japan on the other hand was quick on taking advantage of the embargo. The auto makers in Japan also took advantage of the embargo when realizing the increase in fuel prices

[29] Quotation taken from OPEC ministers´ press release reported by Al-Sowayegh (1984, p. 129)

in the U.S. They started to produce small, more fuel efficient models, which they in turn sold to the U.S. market as an alternative to American "gas-guzzling" cars of that time. This in turn led to a drop in American auto sales that lasted into the 1980s.

The effects of the embargo on Europe were not uniform. Netherlands faced a complete embargo, United Kingdom and France was not much affected (having refused to allow the Americans to use their airfields and embargoed arms and supplies to both Arabs and Israelis), while other faced only partial cutbacks. For instance, the United Kingdom, Germany, Italy, Switzerland and Norway banned flying, driving and boating on Sundays. Sweden rationed its gasoline and heating oil. The Netherlands imposed prison sentences for those who used more than their given ratio of electricity use Fraum (2000).

The sudden ability of OPEC to exercise power in 1973 cannot be explained on the basis of Arab nationalism alone or the "oil weapon". Other factors need to be considered in order to understand this "sudden ability". The global supply and demand for oil were very important contributing factors. In the background, there was increase in demand for energy as the world economy reintegrated and enjoyed one of its longest periods of economic growth after World War II. Increase in demand initially prompted regulators in the U.S., such as Texas Rail Commission, to eliminate all restrictions on productions. As Texas was producing the maximum that it possibly could produce from its field, no excess capacity remained as backup to be brought to the market in case of supply shortage emergency. This in turn eliminated the U.S. role as being a stabilizing force in global oil market. The other factor was the trend toward nationalization of oil resources and the loss of market power of large multinational oil companies, generally known as the "seven sisters" which gave OPEC an oligopolistic power to determine oil prices directly, El-Gamal and M. Jaffe (2010).

Using the "oil weapon" to put pressure on the U.S. and the West could off course be considered as a nationalistic aspect. However, it is not clear whether these political considerations could have dominated the oil exporting countries´ economic self interest. In early 1974, Secretary of State Henry Kissinger announced after a series of discussions with oil exporting Arab countries that the use of petroleum as a weapon to influence the outcome of the Arab-Israeli conflict had little merit in reality[30]. In fact, some supply disruptions unrelated to the conflict appear to have contributed significantly to the oil shock of 1973-74[31]. Meanwhile, Saudi Arabia was secretly selling oil to the U.S. military to help fuel America´s operations for the Vietnam War, even as it was publicly announcing its oil sale boycott of America in solidarity to the Arab cause, Bronson (2006).

[30] Department of State, Bulletin 70, no. 1806, 14 February 1974, p. 109- cited in El-Gamal and M. Jaffe (2010, p. 26).

[31] Testimony of the Chief Reservoir Engineer of Socal before the Church Committee, cited in Arhnacarry , p. "The Petroleum Crisis, Saudi Arabia and U.S. Foreign Policy," Energy Information Services 3, 14 April 1981, p.3, suggests that technical problems in the Shedgum section of the Ghawar field was a significant cause of supply disruptions.

Summary

- OPEC announces on October 6 1973 a production cut of 5 percent and impose embargo on countries supporting Israel during October War.
- Oil price rose from $3.42 in September 1973 to $13.43 in January 1974, a 293 percent increase.
- The OPEC embargo knocked 7.0 percent of world production prior to embargo. (September 1973-November 1973)
- Price controls exacerbated the crises.
- The effect on Europe was not uniform.
- Other background factors need to be considered such as the increasing demand for energy after World War II, elimination of restriction on production (Texas Rail Commission), the lost in market power of big multinational oil companies, the power of "oil-weapon" and the U.S. and Saudi Arabia´s thick foreign relations in order to understand the full scale of the 1973-74 crisis.

1979: The Iranian Revolution

The second oil crisis, the crisis of 1979, occurred in the wake of the Iranian Revolution. Massive protests on the Shah of Iran and his western democratic vision of Iran resulted his fall in the early 1979. These protests severely disrupted the supply of Iranian oil, with production being greatly decreased and exports suspended. In September 1978, Iran produced 6.1 million barrels per day, by January 1979 production was down to 0.73 million barrels per day. Oil exports were later resumed under the new regime; however production was only 75 percent of that produced prior to the fall of the Shah which further pushed prices up. To compensate for the shortfall, Saudi Arabia and other OPEC members increased their production and the overall loss in world production was about 4 percent. Below in Figure 34, I have plotted the change in production from Iran, OPEC, non-OPEC and World during the months post the Iranian Revolution as percentage of total world production prior to the Revolution.

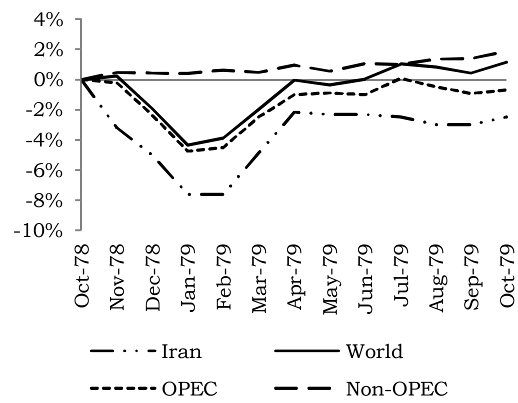


Figure 34. Supply disruptions during The Iranian Revolution. Source: BP statistical Review 2011.

At the same time, the panic in the U.S. was widespread. In April 1979, President Jimmy Carter began a phased deregulation of oil prices. At the time, average oil price was $15.85 per barrel. Deregulating domestic oil price controls allowed U.S. oil output to rise sharply from the Prudhoe Bay fields, although oil imports fell sharply. Long lines once again appeared at gas stations, just as they did in 1973. In November 1979, a group of Iranian students stormed the U.S. Embassy in Tehran demanding the return of Iran´s deposed leader, The Shah, who was receiving treatment for his cancer in the U.S. This action resulted in that President Jimmy Carter ordering a complete embargo on Iranian oil which further pushed oil prices up[32].

[32] http://www.history.com/this-day-in-history/iranian-students-storm-us-embassy-in-tehran-leading-to-oil-embargo

Summary

- The Iranian Revolution leads to the fall of the Shah and the Shah flees the country at end of 1979.
- Oil price rose from $14.05 in December 1978 to $39.7 in November 1979, a 183 percent increase.
- The Iranian Revolution knocked 8.6 percent of world production prior to the Revolution (September 1978-January 1979).
- A group of Iranian students storms the U.S. Embassy in Tehran leading to a U.S. embargo on imports from Iran.
- President Jimmy Carter begins a phase of deregulation of oil prices in the U.S.

1980: Iraq-Iran war

During the 1970s, the Bathist team of Hasan Al-Bakr and Saddam Hussein navigated a series of challenges from without: Syria to the West and Iran to the East, as well as from within: Kurdish independence movements in the North and Shiite political dissent in the south. Those challenges were navigated through a series of diplomatic moves (such as the treaty with Iran in 1975), military threats (such as amassing troops on the Syrian border), and direct persecution of Kurds in the North and Shiites in the South. According to one report, Iraq spent 40 percent of its massive petrodollar inflows during that period on weaponry, Tripp (2000) and Pollack (2004).

However, the greatest challenge to the Bathist regime was posed by the success of the Iranian revolution (in establishing a religious Shiite state to its east). The direct and inspirational support from the revolution in Iran emboldened the Iraqi Shiites which prompted Saddam Hussein to expel tens of thousands of Iraqi Shiites that were considered by the regime to be "Iranian Shiites". Shortly thereafter, Saddam Hussein started the first of two disastrous wars by invading Iran in 1980.

What Saddam Hussein had envisioned as a minor exercise of power turned into a devastating eight year long war, as Iran sought to reassert its presence and to defend the success of its revolution. Several attacks between Iran and Iraq on each others´ cities and oil resources eventually tipped the scales in Iraq´s favor, as Western powers (especially the U.S.) moved into the region to protect oil supplies. Below in Figure 35, we can see the supply disruptions due to the Iraq-Iran War.

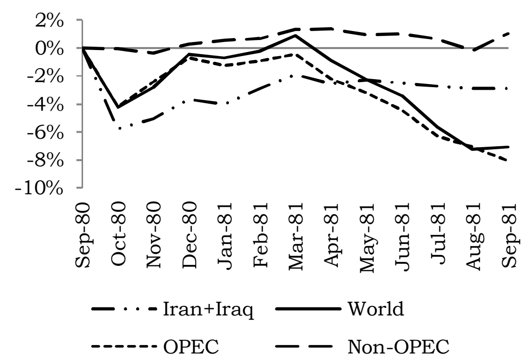


Figure 35. Supply disruptions during Iraq-Iran War. Source: BP statistical Review 2011.

In September 1980 Iraq and Iran were producing 4.0 million barrels per day (1.2 million from Iran and 2.8 million from Iraq), by October 1980, the same figure was down to 0.7 million barrels per day (0.5 million from Iran and 0.2 million from Iraq).

Financial support from Saudi Arabia and Kuwait, and military support from both the Soviet Union and the U.S., eventually forced a cease fire on Iran in 1988. At the beginning of the war, Iraq held a clear advantage in armor, while both countries were roughly equal regarding artillery. The gap started too widened as the war went on (Table 14).

Iran started with a stronger air force, but over time, the balance shifted towards favoring Iraq.

Imbalance of Power (1980-87)	Iraq	Iran
Tanks in 1980	2700	1740
Tanks in 1987	4500+	1000
Fighter Aircraft in 1980	332	445
Fighter Aircraft in 1987	500+	65
Helicopters in 1980	40	500
Helicopters in 1987	150	60
Artillery in 1980	1000	1000+
Artillery in 1987	4000+	1000+

Table 14. Military strength of Iraq and Iran during the War. Source: "The Arming, and Disarming, of Iran's Revolution," The Economist, International Edition, 19 September 1987, 56-57.

The Iraqi economy was devastated from the long war, which exhausted the bulk of its Dollar reserves accumulated during the 1970s, and shackled it with a debt repayment that consumed 50 percent of its oil revenues in 1990[33]. Total estimated debt to other countries was $130 billion, of which $21 billion was borrowed from the Paris Club[34] and the larger portion of the debt was borrowed from neighboring Arab countries[35].

Summary

- Saddam Hussein sees an opportunity after the Iranian Revolution to attack the weak neighboring country Iran after its Revolution, with the vision of making Iraq a super power in the region. The war lasted from September 1980 to August 1988.
- Oil price rose from $31.88 in August 1980 to $40.97 in November 1980, a 29 percent increase.
- The war knocked 7.2 percent of world production prior to the war (July 1980-October 1980).
- Many countries were supporting both Iraq and Iran through the war period, though the support favored Iraq.
- Iraq ends up with a $130 billion debt for financing the war.

The Price Collapse of 1980s

In the early 1980 there was a serious surplus of crude oil caused by falling demand following the crisis in 1973 and 1979. World oil price was peaking at $40.97 per barrel (nominal terms) in November 1980. From that peak, price started to decline gradually and in the first half of 1986 price fell from $26.75 per barrel in December 1985 to $9.88 per barrel in July 1986. The surplus of oil began in the early 1980s as a result of slowed economic activity in industrial countries and the energy conservation spurred by high fuel prices[36]. Figure 36 presents oil consumption in Europe, Japan and the United States and production of OPEC, non-OPEC and Former Soviet Union (Figure 37) during the period 1965 to 1990.

[33] Foreign currency reserves fell from $30 billion in 1980 to $3 billion in 1983. In 1983 Iraq´s debt had reached $25 billion (ibid., p. 235). More accurate data on Iraq´s economy and finances under the Bathist rule are not available, because they were treated as state secrets, (ibid. p. 214).
[34] This debt was originated from Japan, Russia, France, Germany, United States, Italy and the United Kingdom.
[35] The large portion of the debt was from Kuwait, Saudi Arabia, Qatar, UAE and Jordan.

[36] Oil Glut, Price Cuts: How Long Will They Last?". **89**. U.S. News & World Report. 1980-08-18. p. 44.

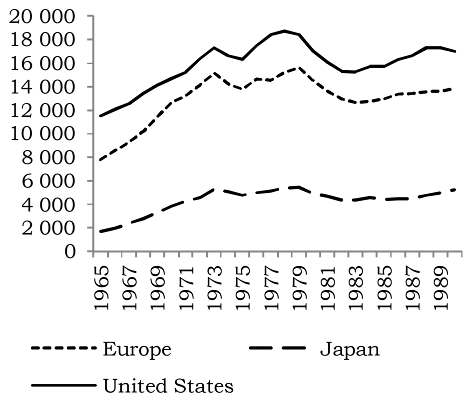


Figure 36. Oil Consumption, thousand barrels per day. Source: BP statistical Review 2011.

Consumption had fallen with 17 percent, 19 percent and 15 percent from 1979 to 1985 for Europe, Japan and United States respectively. This falling demand in combination with overproduction from non-OPEC (Figure 37) caused the six-year long decline in oil prices[37].

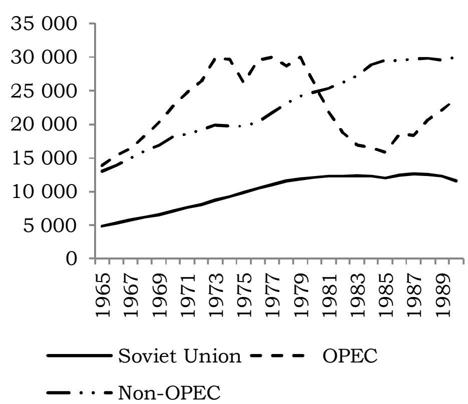


Figure 37. Oil Production, thousand barrels per day. Source: BP statistical Review 2011.

The remove of market controls from petroleum products in the late 1970s, which allowed the free market to adjust oil prices in the United States, encouraged oil producers in the United States to increase production. The United States Oil Windfall profits tax[38] was lowered in August 1981 and removed in 1988, ending disincentives to oil producers in the United States[39]. The United States import of crude oil fell from 46.5 percent in 1977 to 28 percent in 1982 and 1983 due to lower consumption. The reliance on Middle East source dwindled even further as United Kingdom, Mexico Nigeria and Norway joined Canada in the forefront of American suppliers[40].

From 1979 to 1986, OPEC decreased its production several times in an attempt to keep oil prices high. OPEC production fell from 30 million bpd in 1979 to 15.9 million bpd in 1985, i.e. a decrease with approximately 50 percent. However, OPEC failed to hold on to its preeminent position and by 1981 its production was surpassed by Non-OPEC production. OPEC share of total world production fell from 51 percent in the mid 1970s to 28 percent in 1985. OPEC´s membership began to have divided opinions over what actions to take. In September 1985, Saudi Arabia tried to gain market share by increasing production, creating a "huge surplus that angered many of its colleagues in OPEC"[41].

The impact of the oil collapse in 1986 benefited oil consuming countries as the United States, Japan, Europe and Third World nations, but represented a serious loss in revenues for oil producing countries in northern Europe, the Former Soviet Union and OPEC. Former Soviet Union production was increasing up to the end of

37 http://www.nytimes.com/2008/03/03/business/worldbusiness/03cnd-oil.html?hp

38 A windfall profits tax is a higher tax rate on profits that ensue from a sudden windfall gain (unexpected gain) to a particular company or industry.

39 Edward Weiner (1999). Urban Transportation Planning in the United States An Historical Overview

40 http://www.nytimes.com/1989/12/30/business/worrying-anew-over-oil-imports.html

41 http://www.time.com/time/printout/0,8816,961087,00.html

the 1970s; in 1978 Former Soviet Union was the largest producing country in the world, producing 11.0 million bpd. A third of that oil was exported, and mainly to capitalist countries, since socialist countries were unable to pay in hard currency and preferred to make payment in goods. However, the price collapse in the mid 1980s led to the fall of the Union a few years later.

It should be noted that the Former Soviet Union have historically profited from the earlier crises in the Middle East region. The Middle East crisis made Siberian oil fields the main source of Russian oil. They allowed the country to raise its production so drastically from the level of 3.1 million bpd in 1960. In 1973, Soviet leader Leonid Brezhnev who understood that an Arab-Israeli conflict would promise a huge influx of petrodollars suggested to United States president Richard Nixon that they cooperate in developing Western Siberian oil fields. The Soviets proposed a project under which the United States would invest $10 billion in the course of 25 years (that is, in 1998) it would get its investment back in oil and gas. The United States could off course not foresee the sharp fall in oil price and the consequent of it i.e. the fall of the Soviet Union, so the American passed that offer since they were not sure that there really were reserves of that magnitude that could be profitably accessed in Siberia. They also doubted that it would be technically possible to bring Siberian oil and gas to the American market. Soaring oil prices made Siberian oil production quite profitable, and Japan willingly provided the Soviet Union with a $100 million credit for developing production[42].

Summary

- Surplus of oil in world market caused by falling demand due to the earlier crisis in 1973 and 1979. Consumption falls with 17 percent, 19 percent and 15 percent from 1979 to 1985 for Europe, Japan and United States respectively.
- OPEC tries to keep oil prices high by reducing its production, though oil prices continued to decline in the first half of the 1980s. The largest decline in price was seen from December 1985 ($26.75) to July 1986 ($9.88), a fall with 63 percent.
- OPEC share of total world production falls from 51 percent in the mid 1970s to 28 percent in 1985.
- Non-OPEC production increase due to deregulation of oil prices of 1979 and by lowering the Windfall profits tax.
- The beneficiary of the price collapse was countries in Europe, Japan, United States and Third world nations. The collapse represents a serious loss in revenues for oil producing countries in northern Europe, the Former Soviet Union and OPEC. This price collapse played a major part in the fall of the Soviet Union.

1990: Iraq´s invasion of Kuwait

The 1990 oil price shock was in response to the Iraqi invasion of Kuwait on August 2, 1990. This was the second disastrous gamble by Saddam Hussein. Iraq had tried repeatedly to appeal for economic help from Saudi Arabia and Kuwait, in the forms of forgiveness of Iraq´s 40 billion debt, used to finance the war with Iran, and reduction in their oil supplies to boost Iraq´s oil revenues and finance reconstruction. When Saddam´s appeals were repeatedly refused, he decided to take by force what he considered to be his rightful claim for fighting an eight year war on behalf of the

[42] Charles Ganske. The Long War in the Middle East and Russian Oil. http://www.russiablog.org/2006/08/kommersant_mideast_war_means_m.php

other Gulf States, which were equally wary of Iran and potential regional Shiites revival.

On August 2 1990 Saddam Hussein invaded Kuwait, in the belief that he could dictate his terms to Kuwait and Saudi Arabia, by force and through the threat of force, respectively. Saudi Arabia sought the help of the U.S., which led an international coalition in a swift war to liberate Kuwait. For Saudi Arabia, the massive financial cost of the war combined with low oil prices to exacerbate the Kingdom´s economic problems. The price of crude oil rose from $16.81 in July 1990 to $33.62 in September 1990, though the price was back to about the same level as before the invasion in February 1991, $18.53.

Production for these two countries fell from 5.3 million barrels per day in July 1990 to 0.5 million barrels per day in December 1990. The reason why this shortage of supply didn't affect prices much was that, other OPEC countries and non-OPEC countries was relatively quick on compensating for this shortage. Saudi Arabia for example, increased its production from 5.4 million barrels per day in August 1990 to 8.5 million barrels per day in December 1990 which is about 65 percent of the shortage caused by the invasion. Iraq reached its normal production levels first at the end of 1998; largely because the sanctions it was imposed on it after the invasion of Kuwait and technical problems with oil fields, pipelines, and other oil infrastructure. Iraq also claimed that oil production capacity expansion was constrained by refusal of the United Nations to provide Iraq with all the oil industry equipment it has requested during that period. Figure 38 presents the supply disruptions due to Iraq´s invasion of Kuwait.

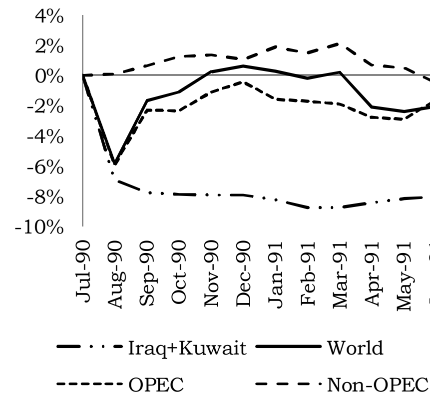


Figure 38. Supply disruptions during Iraq´s invasion of Kuwait. Source: BP statistical Review 2011.

Summary

- Iraq accuses Kuwait of overproducing oil and lowering profits for Iraq, especially when Iraq was in a financial stress after the Iraq-Iran war which leads to the invasion of Kuwait on August 1990.
- Oil price rose from $16.81 in July 1990 to $34.85 in October 1990, a 107 percent increase.
- The invasion knocked 7.8 percent of world production prior to the war (July 1990-September 1990).
- The crisis is short-lived, largely because Saudi Arabia increases its production from 5.4 million bpd in July 1990 to 8.4 million bpd in December 1990 accounting for 57 percent of the shortage caused by the invasion.

The oil price shock of 2008

What caused the oil price to peak in July 2008? Previous crisis were related to shortage in supply or "Supply shocks" caused generally by turmoil in the Middle East. The 2008 crisis had however different causes. Oil price started to gradually increase after the beginning of 2000. Some geo-political events could have explained the short-term effects such as North Korean missile tests[43], the 2006 conflict between Israel and Lebanon[44],

[43] http://edition.cnn.com/2006/BUSINESS/07/05/oil.price/index.html
[44] http://news.bbc.co.uk/2/hi/business/7083015.stm

worries over Iranian nuclear plans in 2006[45], the Hurricane Katrina[46] and some other factors[47]. However by 2008, such pressures appeared to have an insignificant impact on oil prices given the onset of the global recession[48]. The 2008 recession caused demand for oil to shrink in late 2008, with oil prices falling from July 2008 to December 2008.

According to Hamilton (2008), the big story has been not a dramatic reduction in supply (as previous crisis) but a failure of production to increase between 2005 and 2007 (Figure 39 below). For many years, Saudi Arabia has been the most important producer of crude oil. Saudi Arabia has also followed a strategy of adjusting production in an effort to stabilize prices. For example the decision to increase production the following months of the Invasion of Kuwait was a reason why that oil price shock was so short lived.

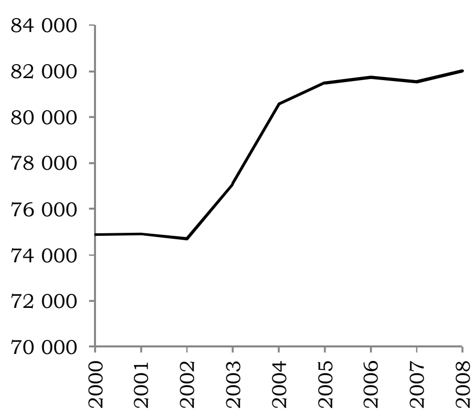


Figure 39. World Oil Production, thousand barrels per day. Source: BP statistical Review 2011.

Because the Saudis had historically used their excess to compensate for shortage caused by other countries in the region, many analysts had assumed that they would continue to do the same in response to longer run pressure of growing world demand. As an example, which James D. Hamilton mentions in his paper, the International Energy Agency was projecting in their 2007 World Energy Outlook that the Saudis would be pumping 12 million bpd by 2010 when Saudis production amounted to only 10 million bpd according to the latest BP Statistical Review of World Energy June 2011. Actually, Saudi Arabia decreased its production from the level in 2005, 11.1 million barrels per day. A large part of the stagnation in world production during 2005-2007 was due to Saudi Arabia not increasing its production. The other factor that made price to increase as it did during this period was the increasing Chinese demand for oil (Figure 40).

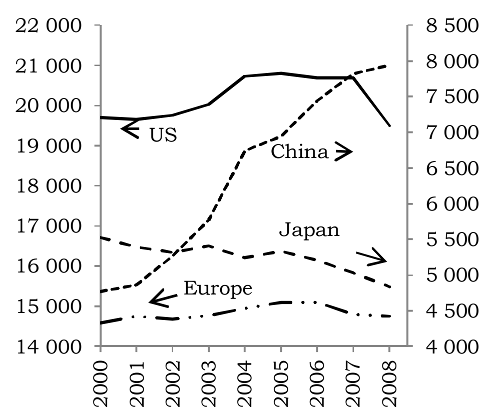


Figure 40. US, Europe, Japan and China Oil Consumption, thousand barrels per day. Source: BP statistical Review 2011.

Militarism and unproductive use of capital and labor

Countries in the Middle East have generally not prioritized investment in human capital or productive capacity and the majority of investments have been in areas that matter to the

45 http://news.bbc.co.uk/2/hi/business/4684844.stm
46 http://fpc.state.gov/documents/organization/53572.pdf
47 http://www.slate.com/id/2181282/
48 http://news.sky.com/skynews/Home/Business/Oil-Prices-Fall-To-Four-month-Lows-Despite-Production-In-Gulf-of-Mexico-Shut-Due-To-Hurricane-Gustav/Article/200809115091229?lpos=Business_3&lid=ARTICLE_15091229_Oil%2BPrices%2BFall%2BTo%2BFour-month%2BLows%2BDespite%2BProduction%2BIn%2BGulf%2Bof%2BMexico%2BShut%2BDue%2BTo%2BHurricane%2BGustav

state. This is particularly true in the case of military expenditure, which protects the ruling elites from external threats as well as internal challenges by appeasing military leaders who could mount a coup. In the case of the oil rich Gulf States, the war between Iraq and Iran wasted a large portion of their oil revenues on both financing the war and financing reconstruction following war related capital destruction. As we can see from Figure 41 below, military expenditures in Saudi Arabia and Kuwait were high as percentage of those countries´ GDP, even if we exclude the years 1990 and 1991.

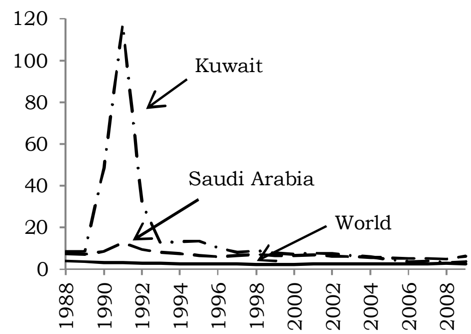


Figure 41. Military expenditures as a percentage of GDP Source: World Bank, World development Indicators.

More importantly, Figure 42 shows the disproportionate allocation of human capital to the military. This contributed further to the lack of long term absorptive capacity in productive segments of the economy, by discouraging long term investment.

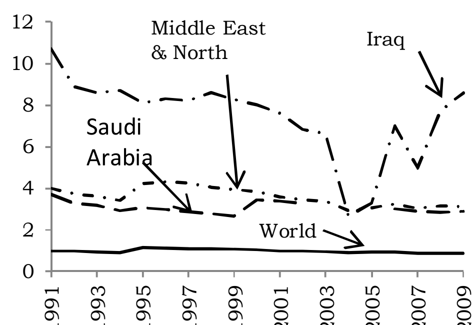


Figure42. Military personnel as a percentage of total labor force. Source: World Bank, World development Indicators.

Strategic restraint of Capacity Expansion

The Asian recovery and its economic growth dramatically increased the demand for oil into the mid 1990s. It is worth mentioning the similarities between the mid 1990s economic conditions and the conditions leading to the 1970s crisis. First, in terms of increased oil demand[49]. Second, the inability of production capacity to keep in pace with demand growth[50]. There are two main reasons for limited capacity; the first is mismanagement of petrodollar revenues, through subsidies and other distortions, which prevented sufficient investment in maintaining existing fields and exploring for new ones. The second is OPEC´s restraint in expanding production capacity in response to price increases and forecasts of higher demand, El-Gamal and M. Jaffe (2010).

Production capacity growth can be attained by redirecting some of revenues from oil export to exploration and development, or by reopening some capital poor markets to foreign investment by international oil companies. Foreign direct investment flows to the oil sectors of OPEC countries slowed in this decade for two reasons. First, domestic political oppositions to foreign involvement in the oil sector, especially following the Iraq war in 2003. The second reason was that renewed petrodollar riches made OPEC countries financially self-sufficient, therefore discouraging further foreign direct investment in the oil sector. In the meantime, fear of another episode of low oil prices and a declining spirit of cooperation with the

[49] Oil demand outside the Soviet bloc grew by 21 million barrels a day between 1960 and 1970. Similarly, global oil demand grew by 12 million barrels per day between 1996 and 2006.

[50] The United States surplus capacity of 4 million barrels per day in the 1960s had virtually vanished by 1973, and OPEC´s spare capacity was cut in half, from 3-4 million barrels per day to 1.5 million barrels per day. OPEC spare capacity has returned close to 1.5 million barrels per day, representing less than 2 percent of total global demand.

United States in light of Middle East geopolitical developments have prompted OPEC to adopt a policy of defending higher oil prices by limiting capacity expansion, El-Gamal and M. Jaffe (2010).

Year	Capacity	Sales	Spare Cap
1979	38.76	34.01	4.75
1983	31.75	16.65	15.1
1990	27.60	22.20	5.40
1997	30.34	27.59	2.75
1998	30.55	25.85	4.70
2000	30.44	30.04	0.40
2001	31.38	28.23	3.15
2005	30.57	29.87	0.70

Table 15. OPEC Production Capacity and Sales (in mm b/d). Source: Energy Intelligence Group and Baker Institute.

Table 15 illustrates the relatively stable total OPEC capacity, which resulted in reduction of spare capacity from 5 million barrels per day in 1998 to merely 0.7 million barrels per day in 2005. In recent years, Saudi Arabia has invested $10-15 billion only to maintain spare capacity of 1 to 1.5 million barrels per day, in the face of declining output capacity at some of its mature fields. However, the Kingdom resisted calls from OECD countries to expand its output quickly to 15 million barrels per day in order to meet the expected rise in oil demand, El-Gamal and M. Jaffe (2010).

Economic Sanctions and the "War on Terror"

Throughout the 1980s and into the 1990s, economic sanctions became the hallmark of the United States and international response to the rise of military conflict and state sponsored terrorism. This paradigm seemed to become a fixture of U.S. foreign policy in later years, as one author suggested: "Negative economic tools… will be a crucial component of America´s more activist foreign policy agenda. They will continue to play a key role in combating terrorism", O´Sullivan (2003). Economic sanctions have become a multipurpose tool for containing threats and regime change[51]. On August 6, 1990, after Iraq´s invasion of Kuwait, the United Nations Security Council passed a resolution imposing a multilateral trade embargo against Iraq, with exception only for humanitarian assistance. The sanctions on Iraq were extended and escalated until the U.S. invasion in 2003, preventing not only new investments in Iraq´s oil industry, but even basic repairs and improvements.[52]

These economic sanctions during the 1990s did little to stem the tide of terrorist financing or weaken the target regimes, which in fact profited from smuggling activities. Instead, the sanctions caused slower investment in the oil fields of Iraq, Iran, and Libya, which later resulted in shortages when global economic demand reached new heights 2003-2008. Therefore, because of those sanctions, OPEC was unable to reach the planned production capacity targets that it had set for the mid-1990s, see also O´Sullivan (2003) who provides a good survey of the effects of various sanctions. OPEC´s ability to exercise market power after the price collapse of 1998 was in large part made possible precisely by this lack of excess capacity caused by sanctions, El-Gamal and M. Jaffe (2010).

September 11 and the "war on terror" brought new momentum to the U.S. national concerns about the link between terrorism and the proliferation of weapons of mass

[51] Earlier sanctions included an import ban on Iran and the freezing of $12 billion in Iranian assets in November 1979 following the Iranian seizure of the U.S. embassy in Tehran. A month later in that same year, Libya were put on the State Department´s list of state sponsors of terrorism and the U.S. issued a ban of exports of dual-use technologies to the country.

[52] www.bakerinstitute.org

destruction to the Middle East. Infamously, George Bush´s call to arms against an "Axis of Evil" of Iraq, Iran, and North Korea in his January 2002 State of the Union[53] addresses tied those countries to the threat of terrorism

> *"States like these, and their terrorist allies, constitutes an axis of evil, arming to threaten the peace of the world. By seeking weapons of mass destruction, these regimes (Iraq, Iran, North Korea) pose a grave and growing danger. They could provide these arms to terrorists, giving them the means to match their hatred. They could attack our allies or attempt to blackmail the United States…"*

Within this framework, the U.S. administration´s continued conflict with Iran over Tehran´s nuclear program has contributed to volatility in oil markets. This has also led to that some Iranian leaders again to invoke the 1973 memories of an "oil weapon". Iran threatened to cut its oil exports to the west if U.S. led coalition imposed further sanctions. For instance, Iranian Supreme Leader Ayatollah Ali Khamenei in June 2006 warned the United States that Washington "should know that the slightest misbehavior on your part would endanger the entire region´s energy security. … You are not capable of guaranteeing energy security in the region"[54]. The response to this by Saudi Arabia was increasing its investments in upstream oil production capability in order to be able to replace any lost Iranian exports[55].

The possibility of an escalation in the U.S. conflict with Iran over its nuclear program remains a wild card in oil price trends. Some analyst has argued that the widening U.S. presence in the Gulf has increased those risks. Thus in the short term the U.S. presence did contribute to higher energy prices through increased geopolitical risk premium and slower capacity building. Also, petrodollars flows to the region have ignited a new arms race that contributed to price escalation during 2003-08. The increasing U.S. debt, due in part to financing the Iraq war and in part to feedback through higher oil import costs, also contributed to the declining Dollar, which in turn fed the spiral of rising Dollar-denominated oil prices and continued the downward pressure on the Dollar, El-Gamal and M. Jaffe (2010).

[53] Bush State of the Union address: www.whitehouse.gov/news/releases/2002/01/20020129-11.html

[54] CNN, Iran Warns U.S. on Oil Shipments", June 4, 2006, www.cnn.com2006WORLDmeast0604us.Iran

[55] See "Saudi Aramco: National Flagship with International Responsibilities," at www.rice.eduenergy.