The Economic Consequences of Oil Shocks - A Cross-Country Analysis*

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Abstract

We examine the economic consequences of oil shocks across a set of industrialized countries. First, we show that the underlying source of the oil price shift is crucial to determine the repercussions on the economy. For oil demand shocks driven by global economic activity and oil-specific demand shocks, all countries experience respectively a temporary increase and transitory decline of real GDP following the oil price increase. The effects of exogenous oil supply shocks are, however, very different across countries. Whereas net oil and energy-importing countries all face a permanent fall in economic activity, the impact is insignificant or even positive in net energy exporters. Second, the pass-through to inflation turns out to be considerably different across oil-importing countries and strongly depends on the existence of second-round effects of increasing wages. Third, we investigate how the dynamic effects have changed over time. We document a much less elastic oil demand curve since the mid-eighties, which seriously distorts comparisons over time. However, we demonstrate that countries which improved their net energy position the most over time, became relatively less vulnerable to oil shocks compared to other countries.

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1 Introduction

The interaction between oil and macroeconomic performance has received a lot of attention in the economic literature.[1] This interest dates back to the seventies. As can be seen in Figure 1, the seventies and early eighties were characterized by serious oil price fluctuations, and unfavorable oil supply shocks are frequently considered as the underlying source of worldwide macroeconomic volatility and stagflation during that period (see e.g. Blinder and Rudd 2008). The interest has been re-activated in more recent times and the possibility of a recurrence is an important subject in the current debate. Specifically, whereas the price of crude oil hovered around \$12 a barrel at the beginning of 1999, prices per barrel went up to \$133 by the middle of 2008 and felt back to \$39 in 2009. In this paper, we examine the macroeconomic effects of oil shocks across a set of industrialized countries that are structurally very diverse in terms of size, labor market characteristics and role of oil and other forms of energy in the economy: the United States (US), Euro area, Japan, United Kingdom (UK), Canada, Switzerland, Norway and Australia. We contribute to the ongoing debate by analyzing the interaction between oil and the macroeconomy from three different perspectives.

First, we assess the economic repercussions of several types of oil shocks. Many factors contributed to oil price fluctuations over time, and it is very likely that the ultimate consequences of oil price rises across countries are different and depend on the source of the oil price shift. Exogenous disruptions in the supply of oil that lead to higher oil prices are expected to result in depressed economic activity and rising inflation in oil-importing countries. Alternatively, oil prices can also rise because of increased demand for oil, which could be the result of increased economic activity or precautionary motives. The output situation could then be very different. In particular, in case of increased worldwide economic activity, these countries could be part of the boom or indirectly gain from trade with the rest of the world. Even if the oil demand shock is of a purely speculative nature, cross-country recycling effects of the income transfers to oil-exporting countries could be different from an exogenous oil supply shock, e.g. because of a different impact of the shock on global oil production. Recent studies by Kilian (2008a) and Peersman and Van Robays (2009a), henceforth PVR (2009a), have indeed shown that the effects are very different depending on the source of oil price shift for respectively the US and Euro area.

[1] Hamilton (1983) is the seminal academic contribution. For recent overviews, we refer to Hamilton (2009a) or Kilian (2008b).

The repercussions of oil shocks for oil-exporting countries are even less clear since rising oil prices should result in more oil revenues. Also countries that export other (non-oil) forms of energy could be influenced differently. Since prices of other sources of energy typically also rise at times of increasing oil prices, due to its substitutability, an oil-importing country that produces and exports other forms of energy could still benefit via an increased demand for other sources of energy. The latter is confirmed by PVR (2009b), who show that not only the role of oil but also other forms of energy in the economy are important to explain cross-country differences for the effects of oil supply shocks.

In the next section, we investigate how the cause of the oil price increase matters for the dynamic effects across countries. A distinction is made between exogenous disruptions in oil supply, oil demand shocks driven by global economic activity and oil-specific demand shocks which could be the result of speculative or precautionary motives in a structural VAR framework. We demonstrate considerably different consequences depending on the underlying source of oil price shift. After an unfavorable oil supply shock, oil and energy-importing countries face a permanent fall in economic activity, while the impact is insignificant or even positive in net energy-exporting countries. Inflationary effects are also less in the latter group, which can be explained by an appreciation of their exchange rates. On the other hand, the dynamic effects of oil demand shocks driven by global economic activity and oil-specific demand shocks turn out to be much more similar across countries. In particular, for all countries, we find a transitory increase in real GDP after a global activity shock, whereas output temporarily declines following an oil-specific demand shock. Cross-country differences in the magnitudes of the effects after both demand shocks are, however, not determined by the relevance of oil or energy for the domestic economy.

Second, we also examine the exact pass-through of oil shocks to inflation and economic activity. Since changes in monetary policy only affect inflation with a time lag, direct effects on the general price level through rising energy prices are inevitable over short horizons because energy prices are a component of the consumer price index. However, additional indirect inflationary effects may arise because higher energy input costs in the production process or second-round effects via higher wage demands are passed on to consumer prices by firms. These indirect effects are more delayed than the direct effects and can be influenced by monetary policy. It is therefore important to have a clear view on the whole transmission mechanism of an oil shock to inflation and the timing of the impact. PVR (2009a) find substantial differences in the pass-through between the US and Euro area. In particular, inflationary effects in the US are mainly driven by a strong direct impact of rising energy prices and indirect effects of higher production costs. In contrast, Euro area inflation reacts sluggishly and is much more driven by second-round effects of increasing wages.

Following PVR (2009a), we evaluate the importance of the individual channels for all the oil-importing countries in section 3. Whereas the direct effects of rising energy prices in the consumption basket are significant for all countries, additional indirect effects are very different, in particular the role of second-round effects. The latter are, for instance, very strong in the Euro area and Switzerland, rather mild in Japan and absent in the US. As a consequence, the speed and magnitude of the pass-through to consumer prices is also very different for these countries.

Finally, we investigate whether the effects of oil shocks have changed over time. On the one hand, the macroeconomic structure has changed, which can lead to a time-varying impact of oil disturbances. Prominent explanations for a reduced impact in more recent periods are a changed role and share of oil in the economy, improved monetary policy, more flexible labor markets, changes in the composition of automobile production and the overall importance of the automobile sector (see e.g. Edelstein and Kilian 2007, Bernanke 2006 or Blanchard and Gali 2007). On the other hand, the oil market itself has undergone substantial changes that can affect the interaction with the macroeconomy. Lee, Ni and Ratti (1995) and Ferderer (1996) argue that increased oil market volatility has led to a breakdown of the empirical relationship between oil prices and economic activity since the mid-eighties. Baumeister and Peersman (2008), henceforth BP (2008), document a considerably less elastic or steeper global oil demand curve over time. Accordingly, typical oil supply shocks are currently characterized by a much smaller impact on world oil production and a greater effect on oil prices compared to the 1970s and early 1980s, which can also bring about time-varying effects.

The steepening of the oil demand curve, as argued by BP (2008), seriously distorts empirical comparisons of the effects over time. By estimating the impact of exogenous oil supply shocks before and after the mid-eighties, we demonstrate in section 4 that the way of normalization is indeed crucial to conclude whether the effects have changed. In particular, when an oil supply shock is measured as a similar shift in oil prices (e.g. 10 percent rise), the impact on real GDP and inflation clearly becomes smaller over time, which is in line with the literature comparing the impact of oil price shocks over time (e.g. Edelstein and Kilian 2007, Herrera and Pesavento 2007 and Blanchard and Gali 2007). However, normalizing on a similar oil price increase considers a totally different underlying oil supply shock in a time-varying context. More specifically, such a comparison implicitly assumes a constant elasticity of oil demand over time, which is exactly rejected by the data. The shift of the oil supply curve to generate a similar oil price increase is much smaller in more recent periods compared to the 1970s and early 1980s, which has its consequences for assessing the dynamic effects. A smaller fall of oil production and hence also revenues for oil producing countries could, for instance, already result in a more subdued impact on worldwide exports. Conversely, when oil supply shocks are measured as a standardized change in oil production (e.g. a fall of 1 percent), several countries currently even face stronger long-run effects on real GDP and consumer prices. For exactly the same reason, also this experiment is biased. In particular, a similar shift in oil production has now a much greater impact on oil prices because of the less elastic oil demand curve and hence distorts the comparisons.[2] When a typical one standard deviation oil supply shock is considered, the impact in many countries has actually not dramatically changed over time. Whether the underlying magnitude of such an average oil shocks has changed can unfortunately not be identified.

The cross-country dimension of our analysis, however, should allow us to learn something about sources of time variation. Specifically, whilst all countries experienced a fall in oil intensity over time, the magnitudes have been very different. Some countries even switched from being a net oil-importing country to a net oil-exporting country over time (e.g. Canada and United Kingdom). Accordingly, we can evaluate the role of oil and other forms of energy for time-variation by comparing the *relative* changes over time between countries. This exercise does not suffer from a normalization problem, since the structural changes in the global oil market are the same for all countries. We show that a changed role of oil and other forms of energy over time is important to explain time-variation in the dynamic effects. In particular, countries that improved their net oil and energy dependence the most over time, also became much less vulnerable to oil supply shocks relative to other countries.

[2] This problem of comparability also carries over to shocks at the demand side of the oil market. BP (2009) show that also the short-run oil supply curve became much less elastic over time. As a consequence, also comparisons of normalized demand shocks are distorted.

2 The dynamic effects of different types of oil shocks

2.1 A benchmark structural VAR Model

Not every oil price increase is alike because the underlying source can differ. The oil price shocks of the seventies are, for instance, typically attributed to exogenous shortfalls in oil production, whereas the prolonged surge in oil prices that started in 1999 is commonly said to be mainly driven by shifts in the demand for oil (e.g. Hamilton 2003, 2009b). Barsky and Kilian (2004) argue that even the shocks of the seventies were partly demand driven. Knowing what drives an oil price increase can be important for understanding the impact on the economy. Indeed, Kilian (2008a) and PVR (2009a) show that the economic effects of oil shocks in the US and the Euro area significantly differ depending on the cause of the oil price shift. To properly assess the consequences of oil shocks, it is thus crucial to disentangle the oil price movements that are exogenously driven by supply from those that can be attributed to shifting demand. In our analysis, we therefore make an explicit distinction between oil supply shocks, oil-specific demand shocks and oil demand shocks caused by global economic activity. To do so, we rely on a structural vector autoregression (SVAR) framework that has the following general representation:

$$\begin{bmatrix} X_t \\ Y_{j,t} \end{bmatrix} = c + A(L) \begin{bmatrix} X_{t-1} \\ Y_{j,t-1} \end{bmatrix} + B \begin{bmatrix} \varepsilon_t^X \\ \varepsilon_{j,t}^Y \end{bmatrix}$$

The vector of endogenous variables can be divided into two groups. The first group X_t captures the supply and demand conditions in the oil market and includes world oil production (Q_{oil}), the nominal price of crude oil expressed in US dollars (P_{oil}) and a measure of world economic activity (Y_w). The other group of variables $Y_{j,t}$ is country-specific and contains real GDP (Y_j), consumer prices (P_j), nominal short term interest rate (i_j) and the nominal effective exchange rate (S_j) of country j. c is a matrix of constants and linear trends, $A(L)$ is a matrix polynomial in the lag operator L and B is the contemporaneous impact matrix of the vector of orthogonalized error terms ε_t^X and $\varepsilon_{j,t}^Y$. ε_t^X captures the structural shocks in the oil market and $\varepsilon_{j,t}^Y$ are shocks specific to country j. In this paper, we are only interested in the oil market shocks.

2.2 Identification of different types of oil shocks

In order to ensure identification of the underlying structural shocks in an SVAR model, a number of restrictions are required on the contemporaneous relationships between the variables. Kilian (2008a) disentangles oil supply shocks from demand shocks by assuming a vertical short-run oil supply curve in a monthly VAR, according to which shifts in the demand for oil do not have contemporaneous effects on the level of oil production. In addition, he assumes that economic activity is not immediately affected by oil-specific demand shocks. His identifying assumptions are, however, less appropriate for estimations with quarterly data such as real GDP. He therefore averages the monthly structural innovations over each quarter to estimate the impact on real GDP using a single-equation approach in a second step. To identify the structural innovations, we instead follow PVR (2009a) and BP (2009) by imposing the following more general sign restrictions:

Structural shocks	Q_{oil}	P_{oil}	Y_w	Y_j	P_j	i_j	S_j
1.Oil supply	< 0	> 0	≤ 0				
2.Oil demand driven by economic activity	> 0	> 0	> 0				
3.Oil-specific demand	> 0	> 0	≤ 0				

The restrictions are derived from a simple supply-demand scheme of the oil market. First, an oil supply shock is an exogenous shift of the oil supply curve and hence moves oil prices and oil production in opposite directions. Such shocks could, for instance, be the result of production disruptions caused by military conflicts or changes in the production quota's set by oil-exporting countries. Following an unfavorable oil supply shock, world industrial production will not increase.

Second, shocks on the demand side of the oil market will result in a shift of oil production and oil prices in the same direction, as demand-driven rises in oil prices are typically accommodated by increasing oil production in oil-exporting countries. Demand for oil can endogenously increase because of changes in macroeconomic activity that induce rising demand for commodities in general. Increasing demand from emerging economies like China is a good example. We define such a shock as an oil demand shock driven by economic activity. Accordingly, this shock is characterized by a positive co-movement between world economic activity, oil prices and oil production.

Finally, shifts in demand for oil that are not driven by economic activity are labeled oil-specific demand shocks. Fears concerning the availability of future supply of crude oil or an oil price increase based on speculative motives are natural examples. In contrast to the demand shock driven by economic activity, oil-specific demand shocks do not have a positive effect on global economic activity. The final impact could even be negative because of the associated oil price increase.

We impose the sign conditions to hold the first four quarters after the shocks to allow for sluggish responses. These conditions implemented in the global oil market are sufficient to uniquely disentangle the three types of shocks, and no zero restrictions on the contemporaneous relationships are needed. Since all individual country variables are not constrained in the estimations, the direction and magnitude of these responses are determined by the data. For full details about the estimation procedure, we refer to Peersman (2005) or PVR (2009b).

2.3 Economic consequences of oil shocks across countries

The results reported in this section are based on estimations of the benchmark VAR model over the sample period 1986Q1-2008Q1 with three lags.[3] Using a time-varying VAR framework, BP (2008) find a considerable break in the oil market dynamics in the first quarter of 1986, which remains stable thereafter (see also section 4). This date, closely related to the collapse of the OPEC cartel or the start of the Great Moderation, is also often selected for sample breaks in the oil literature and explains the choice of the starting point of the sample. Except for the interest rate, all variables are transformed to quarterly growth rates by taking the first difference of the natural logarithm.

Figures 2-4 summarize the estimated impulse response functions of the individual country macroeconomic variables to the different types of oil shocks, together with 84th and 16th percentiles error bands.[4] The responses have been accumulated and are shown in levels. For comparability, each oil shock has been normalized to a ten percent long-run increase in the nominal price of oil, which is close to the observed quarterly volatility of oil prices over the estimation period. The median responses for output and consumer prices at relevant horizons can also be found in Table 1.

[3] See PVR (2009b) for details about the data and a discussion of the specification and robustness.

[4] The estimated impulse responses of oil production and oil prices are shown in section 4.1, when we discuss the changes in the dynamics of the oil market over time.

2.3.1 Country characteristics

To conduct a cross-country comparison, Table 1 also contains some country-specific structural indicators of the role of oil and other forms of energy. All numbers are calculated as averages per unit of GDP. The role of oil is very different across the countries considered. The US, Euro area, Japan, Switzerland and Australia are net oil-importing countries, whereas the UK, Canada and Norway are net oil exporters. Imports of oil are considerably higher in the Euro area, Japan and the US compared to Switzerland and Australia. The latter country, as well as the US, also has a domestic oil producing sector that cannot be ignored. On the other hand, average oil exports in Norway are about 35 times as high as in Canada and the UK. Overall, Norway, US and Canada are the most oil-intensive economies.

The role of other forms of energy could also be relevant to interpret cross-country differences in the dynamic effects of crude oil price shocks. At times of increasing oil prices, the prices of other sources of energy, such as natural gas, typically also rise due to increased demand for these other energy products as well. This is clearly the case when the oil price shift is driven by increased worldwide economic activity since the demand for commodities in general rises. For exogenous oil supply and oil-specific demand shocks, the magnitude of this effect will obviously depend on the substitutability of oil with other sources of energy. Since prices of non-oil energy products tend to follow oil price movements, an oil-importing country that produces and exports other forms of energy could therefore still benefit from an unfavorable oil shock via increased demand for other sources of energy. Australia is a good example (see Table 1). Despite being an net importer of crude oil, Australia is a significant exporter of other energy goods. Conversely, whilst being an oil-exporting country, the UK is a net importer of non-oil energy. On the other hand, Canada and Norway are net exporters of both, and all other oil-importing countries (US, Euro area, Japan and Switzerland) also import other forms of energy.

2.3.2 Exogenous oil supply shocks

Figure 2 demonstrates that the economic consequences of an oil supply shock are very different for oil-importing and oil-exporting countries. Consider real GDP. All net oil and non-oil energy-importing countries (US, Euro area, Japan and Switzerland) experience a permanent fall in economic activity. The long-run magnitude is somewhat greater in

Japan compared to the other three countries (see Table 1). Moreover, output falls very sluggishly in the Euro area and Switzerland, whereas we observe an immediate decline in the US and Japan. This difference in shape will be further discussed in section 3, when we examine the oil transmission mechanism.

On the other hand, output permanently increases in the countries that export both oil and other forms of energy, i.e. Norway and Canada. Despite being a net oil-importing country, real GDP only temporarily falls in Australia. The latter, however, is a significant non-oil energy exporting country, which probably compensates for the negative oil price effect. Also the UK, which is an oil-exporting but non-oil energy-importing country, experiences only a transitory fall in activity. Overall, not only the role of oil but also that of other forms of energy is important for the dynamic effects of oil supply shocks on the economy.

The dependence on oil and non-oil energy products also seems to matter for the inflationary consequences. The exact pass-through and composition for energy-importing countries will be analyzed in section 3, but the estimates reported in Figure 2 already reveal a relatively strong impact on consumer prices for these countries except Japan, whereas inflationary pressures are negligible or even negative in energy-exporting countries. This different impact on consumer prices is probably driven by the response of the exchange rate. The exchange rate tends to appreciate in oil-exporting countries, which has a downward impact on inflation. The reaction of monetary policy to an oil supply shock is in line with the response of inflation. In particular, the interest rate reaction is rather tight in oil-importing countries, compared to a loosening in energy-exporting countries, as shown in the third column of Figure 2.

2.3.3 Global economic activity shocks

The effects of an oil demand shock driven by global economic activity are substantially different from exogenous oil supply shocks. Figure 3 shows that all countries are confronted with significant long-run inflationary effects and even a transitory increase of real GDP. Somewhat surprising, output in Japan, UK and Canada declines in the long run. When we compare the magnitudes of the maximum impact across countries (see Table 1), the temporary increase of output is rather similar, irrespective of the relevance of energy products. This is not a surprise since we are considering an oil price increase that is driven by a shift in worldwide economic activity. Output can even rise in oil-importing because the country itself is in a boom, or because it indirectly gains from trade with the rest of the world. Accordingly, other structural features probably determine the size of the effects. In particular, shocks that affect global economic activity could, for instance, be technology or aggregate demand shocks. Also the inflation differences are small between most countries. We only observe a stronger impact in Australia and Norway.

2.3.4 Oil-specific demand shocks

Also the dynamic effects of oil-specific demand shocks are very different from the two other sources of oil price shifts, as can be seen in Figure 4. In all countries, this shock is followed by a temporary, U-shaped, fall in real GDP with the peak mostly within the first year after the shock. The effects on consumer prices are on average much smaller compared to other types of oil shocks, and only significant in the US and UK. In the oil and energy exporting countries, the exchange rate does not significantly respond, in contrast to the appreciation after an oil supply shock. Comparing cross-country differences of the magnitudes of the effects on GDP and CPI (see Table 1) indicates that oil-importing and oil-exporting countries react in a similar way, i.e. the role of oil and energy in the economy again seems not to matter much. In sum, the underlying source of the oil price increase is crucial to determine the repercussions on the economy. In addition, the role of oil and other forms of energy in the economy, i.e. being an energy-importing or energy-exporting country, is only important for conventional oil supply shocks.

3 The pass-through to inflation and economic activity

Knowledge of the oil transmission mechanism is crucial to determine the appropriate policy reaction. First, the magnitude of the final effects on inflation and output depend on which channels are operative and on their relative strengths. Second, not only the magnitude but also the timing of impact is important for policy decisions. Given a lagged impact of monetary policy on headline inflation, direct effects of rising energy prices are unavoidable. However, if also indirect effects over longer horizons exist, there is a stabilization role for central banks. We focus on the impact of an oil supply shock that raises crude oil prices by 10 percent. Variance decompositions of the benchmark VARs indicate that disruptions in the supply of oil are still the most important driving force behind oil price fluctuations. The relative importance of supply and demand shocks to explain oil price volatility is approximately 50/50.[5] Furthermore, it is not straightforward to determine the precise transmission channels of oil price shifts driven by global economic activity since they could be correlated with domestic shocks, such as shocks to productivity or trade, which might impair the interpretation of the different channels. This difficulty carries over to an oil-specific demand shock since the estimated impact on inflation is only significantly positive in the US.

In the previous section, we already documented significant differences in the inflationary effects between oil-importing and oil-exporting countries after an exogenous oil supply shock. The latter group is actually not confronted with rising inflation, which can be explained by an appreciation of the nominal and real effective exchange rates. In this section, we further focus on the transmission mechanism in oil-importing countries. We apply a procedure to determine the relative importance of the different channels, proposed by PVR (2009a), which is only applicable for oil-importing countries. The ultimate impact on consumer prices and the speed of pass-through is very different across oil-importing countries. The impact of a 10 percent increase in oil prices is insignificant in Japan (0.10 percent), subdued in the US (0.35 percent), strong in the Euro area (0.58 percent), and very strong in Switzerland (0.88 percent). These figures were already reported in Table 1. Even more striking is the difference in the speed of adjustment. The exact shapes of the transmission to consumer prices are shown in the first row of Figure 5. Whilst the pass-through is still less than half after one year in the Euro area and Switzerland, the process is almost complete in the US and Japan over the same horizon.

To explain these remarkable differences, the ultimate pass-through to inflation needs to be decomposed into several effects. In particular, we consider a direct effect of oil shocks on the energy component of consumer prices, an indirect effect via rising production costs of non-energy goods and services, second-round effects of rising wages and an impact due to a fall in aggregate demand. The former three channels have a positive effect on inflation whilst the latter channel should reduce inflationary consequences. Since aggregate demand effects are part of the transmission mechanism to consumer prices, the pass-through to economic activity is also implicitly discussed. As already mentioned in section 2.3, the response of output is very sluggish in Switzerland and the Euro area, compared to a much

[5] More specifically, the contemporaneous contributions to oil price variability of an oil supply shock, an oil demand shock driven by global economic activity and an oil-specific demand shock are respectively 57, 27 and 16 percent.

quicker decline in Japan and the US.

In order to evaluate the relevance of the individual transmission channels, we extend our benchmark SVAR model of section 2. As we will explain below, all channels should affect several price measures or output components in a very different way. By examining the reaction of these variables in more detail, we can learn more about the transmission mechanism. Specifically, we re-estimate the benchmark SVARs for all countries by adding each time an additional variable of interest that captures a specific channel or effect (see PVR 2009a for details). The results of these estimates are summarized in Figure 5.

3.1 Direct effects

Since a consumer price index is calculated as a weighted average of prices of different types of goods and services of which energy goods is one, there will be a direct impact of an oil shock on inflation. To measure the relevance of this direct effect, we consider the impact of an oil supply shock on the energy component of CPI. The impulse response functions for a 10 percent oil price rise are displayed in the second row of Figure 5. Not surprisingly, there is a significant reaction of CPI-energy in all countries. The magnitude is respectively 2.7, 3.0, 1.4 and 4.0 percent for the US, Euro area, Japan and Switzerland. The relative stronger response in Switzerland is partly driven by a significant exchange rate depreciation. For the US and Japan, the impact on CPI-energy is already complete after 1-2 quarters, whilst it takes about one year in the Euro area and Switzerland.

If only direct effects are relevant, the prices of non-energy goods and services should however not be influenced by the oil shock. The latter can be evaluated by looking at the impact on core-CPI, which explicitly excludes energy prices. These estimated responses are shown in the third row of Figure 5 and reveal that also significant indirect inflationary effects are present in the US, Euro area and Switzerland. The long-run magnitudes of these indirect effects are respectively 0.14, 0.36 and 0.53 percent. In addition, the speed of transmission to core inflation is very different. The latter starts to rise relatively quickly in the US, whilst the pass-through is very sluggish in the Euro area and Switzerland. These differences are carried on to the shapes and magnitudes of the ultimate effects on headline inflation. For Japan, we do not find additional indirect effects, i.e. the response of core CPI is insignificant.

3.2 Cost effects

Increased oil prices imply higher production costs for firms, who will attempt to pass these on to their selling prices. Hence, also consumer prices of non-energy goods start to rise. In contrast to the direct effects, this cost effect has an influence on core inflation. However, given the fact that the GDP deflator is the price of domestic value added, both the direct and the cost effects of oil as an input factor in the domestic production function should not affect the GDP deflator in pure oil-importing countries. In particular, without domestic oil production, these effects will only result in a shift of the import deflator.[6] The latter contains not only the import of crude oil, but also the price of final goods or other foreign commodities which could be directly or indirectly affected by oil price shifts which could also be considered as a cost effect from a domestic point of view. For Switzerland, this effect is aggravated by an estimated significant depreciation of the exchange rate.

Impulse responses for the GDP and import deflators can be found in respectively the fourth and fifth row of Figure 5. Whereas import prices increase significantly, there is no reaction of the US GDP deflator to an oil supply shock, despite being an oil-producing country. Consequently, the rise of US core inflation can be fully attributed to a cost effect. Also in Japan, an oil supply shock does not affect the GDP deflator in the long run. We even find a temporary fall in the short run. Given the insignificant reaction of core inflation, the latter implies only a limited transitory cost effect in Japan.

The situation in the Euro area and Switzerland is totally different. They experience a significant rise in the GDP deflator after an unfavorable oil supply shock. Given the reaction of the import deflator, which combines direct and cost effects, the existence of a cost effect in both countries cannot be excluded.[7] However, the shape and magnitudes of the responses reveal that the bulk of the reaction of core inflation should be explained by

[6] This proposition relies on the standard assumption of separability between oil and other production factors in order to ensure the existence of a value-added production function (see Barsky and Kilian 2004 or Rotemberg and Woodford 1996 for a formal exposition of a production function with foreign commodity import and domestic value added). The situation is slightly different for the US, which is also an oil producer. In addition, to the extent that the prices of non-oil energy products rise that are produced within the country, the GDP deflator could also rise.

[7] The response of the import deflator in the Euro area should be interpreted with caution. This series, which is obtained from the AWM dataset, is an aggregate of import prices of all individual member countries. As a result, higher export prices of one member country, for instance due to second-round effects, will result in higher import prices for the other member countries and hence an increase of the aggregate import deflator.

the reaction of the GDP deflator. This striking contrast with the US and Japan will be further examined in the next section.

3.3 Second-round effects

An unfavorable oil supply shock could increase the GDP deflator via positive second-round effects and decrease it via negative demand effects. The demand channel will be analyzed in the next section. Second-round effects could be triggered if employees successfully realize higher nominal wages in the wage bargaining process to maintain their purchasing power after the rise of energy prices. As a result, the costs of firms increase. If firms decide to pass on the higher wage costs to output prices, there is an upward impact on prices of goods and services contained in the non-energy component of CPI. In contrast to direct and cost effects, rising wages also affect the GDP deflator. Moreover, whilst direct and cost effects only result in a permanent shift of the price level, second-round effects could lead to a self-sustaining spiral of increasing wages and prices which results in a more persistent impact on inflation. Note that second-round effects could also be triggered when price-setters increase the mark-up of prices above costs because of higher inflation expectations.

The relevance of second-round effects in oil-importing countries can be evaluated by examining the reaction of respectively (nominal) total labor costs per employee, real consumer wages and the producer price-wage ratio. The latter variable can be considered as the inverse of real producer wages, or alternatively as the sum of profits and net indirect taxes. The impulse responses can be found the last three rows of Figure 5. Strikingly, the existence of second-round effects is very different across countries and seems to be key to explain the cross-country asymmetries of the ultimate impact of an oil supply shock on inflation. Since nominal wages do not rise and also the price-wage ratio remains constant, second-round effects are not present in the US. Given the rise in overall consumer prices, this implies that the loss of purchasing power is entirely borne by employees. The corresponding significant fall in real consumer wages is shown in the last row of Figure 5.

The situation is different in Japan. Whereas the GDP deflator also remains constant in the long run, nominal wages do slightly rise after an unfavorable oil supply shock and workers succeed more or less in maintaining their purchasing power. In contrast to the US, producers suffer the loss in purchasing power, i.e. we observe a significant fall in the price-wage ratio that compensates for the wage increase. The latter signals the presence of significant demand effects, having a negative influence of inflation.[8]

Also in the Euro area, employees seem to be able to transfer the loss in purchasing power to producers, i.e. real consumer wages remain constant in the long run and there is a significant fall in the price-wage ratio. The latter indicates that demand effects are also present in the Euro area, which limit the transmission to headline inflation. However, in contrast to Japan, the fall in the price-wage ratio only partially offsets rising labor costs. Accordingly, rising labor costs and second-round effects also result in higher producer and consumer prices. The latter is reflected in the significant rise of the GDP deflator. As is the case in the Euro area, a significant increase in nominal wages in Switzerland trigger second-round effects that explain the rise of the GDP deflator. Although in the short-run the loss in purchasing power is however borne by the employees in Switzerland, they manage to keep their real wages constant in the long-run.[9]

3.4 Demand effects

A final transmission channel of an unfavorable oil shock to inflation, which also influences the GDP deflator, is the impact of a reduction in aggregate demand. On the one hand, an increase in costs and prices will result in lower demand and economic activity, which is captured by a shift of the aggregate supply curve along a downward sloping aggregate demand curve. To limit the fall in production, firms could react by decreasing profit margins or negotiate lower wages for its employees. The pass-through to inflation is then incomplete and will depend, among others, on the elasticity of aggregate demand. On the other hand, an oil shock could also trigger an independent reduction of aggregate demand, which is reflected by an accompanying shift of the aggregate demand curve. These additional demand-side effects further reduce economic activity and have a negative

[8] The absence of a GDP deflator reaction to an oil supply shock in the US, however, does not imply that there are no (negative) demand effects. First, since the US is also an oil-producing country, the constant price-wage ratio could cover positive cost effects compensated by negative demand effects. Second, it is perfectly possible that a reduction in aggregate demand is transmitted to the labour market. A fall in labour demand and accompanying rise in unemployment reduces bargaining power of employees which could impede nominal wages to move up. PVR(2009a) show that this is exactely what happens.

[9] Since quarterly data on nominal total labour costs are not available for Switzerland, we interpolated annual nominal wages based on variations in unit labour costs corrected for changes in GDP.

impact on inflation.[10]

For oil-importing countries, an increase in oil and energy prices erodes the disposable income of consumers. Given a relatively small elasticity of oil and energy demand, this income effect depresses the demand for other domestically produced goods. In addition, consumers may decide to increase their overall precautionary savings because of a greater perceived likelihood of future income loss, which also results in a reduction of private spending. Furthermore, if uncertainty increases about future availability of oil and its price, it could be more optimal to postpone irreversible purchases of investment and consumption goods that are complementary to energy. In particular, Bernanke (1983) shows that increased uncertainty about the future price of irreversible investments raises the option value associated with waiting to invest, which will lead to less investment and durable consumption expenditures. Finally, aggregate demand could also fall if the central bank tightens policy in response to the inflation induced by the oil price shock. All these independent demand side effects should reduce the ultimate pass-through of an oil supply shock to consumer prices.

To learn more about the existence of demand effects, Figure 6 shows the impulse responses of respectively real GDP, private consumption, investment, exports, government spending and the nominal interest rate. The results are again very different across countries. In the US, there is an immediate fall in private consumption with a shape that is strongly correlated with the response of real GDP. This pattern is consistent with the existence of an income and precautionary savings effect. It is not very likely that a monetary policy effect is present in the US. On the one hand, we hardly find an increase of the nominal interest rate and certainly not the real interest rate. On the other hand, the investment reaction, which should capture the main channel of monetary transmission, is only marginally significant. The rather insignificant response of investment also indicates that the uncertainty effect, and the associated postponement of irreversible investment, is

[10] Oil shocks could also result in a changed composition of aggregate demand, for example a shift from energy-intensive to energy-efficient goods, which will also lower economic activity (Davis and Haltiwanger 2001). This change could cause a reallocation of capital and labour from the energy-intensive to the energy-efficient sector. In the presence of frictions in capital and labour markets, these reallocations will be costly in the short-run, and can lead to a substantial reduction in economic activity. In contrast to the other demand effects, this allocative effect is not necessarily accompanied by a shift in the aggregate demand curve, and the impact on inflation is less clear. For a more detailed exposition of the demand side effects and an overview of the empirical literature, we refer to Kilian (2008b).

negligible. We also notice a significant fall in US government spending and export.

The composition of the demand-side effects is totally different in the Euro area and Switzerland. Private consumption only declines very sluggishly, which is not in line with an income or precautionary savings effect for which a relatively quick response is expected. For the Euro area, this is actually not surprising given the insignificant reaction of real consumer wages, i.e. there is no fall of disposable income. Also in Switzerland the purchasing power remains constant in the long-run. In addition, there is a considerable decline of investment in the Euro area and Switzerland that only starts accelerating with a delay. This pattern of consumption and investment indicates that another effect is at play. More specifically, due to the inflationary effects caused by the oil shock and the existence of harmful second-round effects in these two countries, a monetary tightening is required. The latter is captured by the significant estimated interest rate increase in both areas. This monetary policy effect also explains the different speed of pass-through to real GDP. Given lags in the monetary transmission mechanism, consumption, investment and therefore also real GDP only start to fall with a delay. Especially the much stronger decline in investment is a feature which characterizes the presence of monetary policy effects. The lack of an interest rate reaction in Japan, combined with the absence of a loss in purchasing power for consumers, results in an insignificant reaction of private consumption and investment. Hence, demand effects are only reflected in a significant fall of the price-wage ratio reported in section 3.3.

4 Time-varying effects of oil supply shocks

The way the economy experiences oil shocks appears to have changed fundamentally over time. Since the two large oil shocks in the 1970s, oil price increases were associated with higher inflation and lower economic growth. A remarkable feature of the recent, prolonged surge in oil prices however, is the relatively mild impact it seems to exert on real economic activity and the price level. Instabilities over time in the oil-macro relationship have been widely documented in the literature.[11] On the one hand, the macroeconomic structure has changed over time which can create time-varying effects of oil shocks. Prominent explanations discussed in the literature are improved monetary policy (e.g. Bernanke et

[11] Structural breaks in the relationship between oil prices and the macroeconomy were initially documented by Mork (1989) and Hooker (1996, 2002).

al. 1997 or Blanchard and Gali 2007), more flexible labor markets (Blanchard and Gali 2007), changes in the composition of automobile production and the overall importance of the US automobile sector (Edelstein and Kilian 2007), and variations in the role and share of oil in the economy (e.g. Bernanke 2006 or Blanchard and Gali 2007).[12] On the other hand, also the oil market itself has undergone substantial changes. For instance, the transition from a regime of administered oil prices to a system of direct trading in the spot market and the collapse of OPEC in late 1985 were accompanied by a dramatic rise in oil price volatility. Lee, Ni and Ratti (1995) and Ferderer (1996) argue that this increased oil market volatility has led to a breakdown of the relationship between oil prices and economic activity.

For the US economy, Edelstein and Kilian (2007), Herrera and Pesavento (2007) and Blanchard and Gali (2007) indeed find a reduced impact of oil price shocks on real GDP and inflation over time. BP (2008), however, have shown that such comparisons over time are seriously distorted since the global oil market has been characterized by another remarkable structural change since the mid-eighties. In the next subsections, we further document this structural change and the consequences for our analysis.

4.1 Structural change in the oil market

In order to explore how the interaction between oil shocks and the macroeconomy has evolved over time, BP (2008) estimate a multivariate time-varying parameters Bayesian vector autoregression (TVP-BVAR) with stochastic volatility for the period 1970Q1-2008Q1. The time-varying coefficients are meant to capture smooth transitions in the propagation mechanism of oil shocks, while the stochastic volatility component models changes in the magnitude of structural shocks and their immediate impact.[13] They document a considerably less elastic or steeper oil demand curve over time. The top-panel of Figure 7 shows their estimated slope of the oil demand curve at each point in time with 84th and 16th percentiles confidence bands.[14] Whereas the elasticity fluctuated between

[12] Other arguments for changing (but not necessary reduced) macroeconomic effects of oil shocks that have been put forward are time-varying mark-ups of firms (Rotemberg and Woodford 1996) and changes in firms' capacity utilization (Finn 2000).

[13] This approach has frequently been used in the so-called "Great Moderation" literature, see e.g. Cogley and Sargent (2002) or Primiceri (2005).

[14] The figure contains the elasticity of oil demand to a 10% increase in the real price of crude oil $\left(\frac{\frac{\Delta Q}{Q}}{\frac{\Delta P}{P}}\right)$, measured four quarters after the increase. The exact horizon of the elasticity does not matter for the

-5% and -15% in the seventies and early eighties, the fall in oil demand after a 10 percent increase in oil prices is hardly -1% to -2% since the mid-eighties.

The steepening of the global oil demand curve seriously complicates comparisons of the dynamic effects of oil supply shocks over time. For instance, a comparison that is based on a similar change in crude oil prices (e.g. a 10 percent rise) implicitly assumes a constant elasticity of oil demand over time, which is exactly rejected by the data. Hence, this experiment compares the impact of a totally different underlying oil supply shock. The bottom panel of Figure 7 illustrates that the shift of the oil supply curve to generate a similar oil price increase is clearly different for a steep or flat slope of the oil demand curve. For exactly the same reason, measuring an exogenous oil supply shock as a similar shift in world oil production over time (e.g. a production shortfall of 1 percent) is a biased experiment since the accompanying oil price increase will be very different. On the other hand, the impact of an "average" (e.g. one standard deviation) oil supply shock can be compared. However, also the magnitude of an average shock could have changed over time, which can influence the outcome. Whether the size of a typical oil supply shocks has changed can, unfortunately, not be identified.[15] This problem of comparability also carries over to shocks at the demand side of the oil market. BP (2009) show that also the short-run oil supply curve became much less elastic over time. Accordingly, also comparisons of normalized demand shocks are biased since a constant slope of the oil supply curve is assumed. In the next section, we demonstrate the consequences of this structural change to draw conclusions about time variation.

4.2 Has the impact changed over time?

The results of BP (2008) presented in Figure 7 clearly show a break in the slope of the oil demand curve in the first quarter of 1986. Therefore, we now estimate and compare the dynamic effects of oil supply shocks using our benchmark SVAR model of section 2.1 for two different sample periods, i.e. 1970Q1-1985Q4 (henceforth 'the seventies') and 1986Q1-2008Q1 (henceforth 'the nineties'). The latter period is actually also the one reported in

conclusions.

[15] This is a standard problem when VAR results are compared across different samples. Only the contemporaneous impact of a shock on a number of variables can be measured. Consequently, it is not possible to know exactly whether the shock itself (volatility) has changed or the immediate reaction to this shock (economic structure).

the previous sections. The top row of Figure 8 contains the impulse responses for global oil production and the oil price following a typical one standard deviation oil supply shock. Dotted black lines and full red lines are respectively the estimates for the seventies and the nineties. An average unfavorable oil supply shock in the nineties is characterized by a much smaller fall in oil production and a larger effect on the price of crude oil relative to the seventies. The corresponding estimated slope of the oil demand curve can be found in the last column of the top row, which confirms the considerable steepening over time.

The consequences of this structural change in the oil market for comparisons over time are illustrated for US real GDP and consumer prices in respectively the second and third row of Figure 8.[16] In particular, the way of normalization becomes very important. Consider, for instance, the effect of an oil supply shock which raises the price of crude oil by 10 percent. Such a shock has a more muted impact on economic activity and inflation in more recent times compared to the seventies. This finding complies very well with the general perception and the empirical evidence on time-varying effects of oil price shocks discussed above. This experiment, however, is biased since a constant slope of the oil demand curve across both sample periods should be assumed, which is clearly not the case. Specifically, a 10 percent rise in oil prices is currently generated by an oil production shortfall of less than 1 percent. To elicit the same oil price movement in the seventies, a decline in oil supply of around 3 percent was required. Despite the assertion by Blanchard and Gali (2007) that "what matters [...] to any given country is not the level of global oil production, but the price at which firms and households can purchase oil" (p.17), it is the volume of oil which is the input factor of the production process. For instance, the impact on revenues for oil-exporting countries and corresponding income recycling effects via trade depend on the amount of oil production.[17]

As an alternative, we could consider a 1 percent innovation in oil production. Oil supply shocks have frequently been viewed as physical disruptions in the production of crude oil due to deliberate decisions by OPEC aimed at achieving a certain price level, or as destruction of oil facilities in the wake of war activities. Figure 8 shows that the

[16] Results for other countries and variables are available upon request. However, since the structural change in the oil market is the same for all countries, the general message of a distorted comparison over time is not altered.

[17] The issue whether oil prices or quantities matter in a world production function can be compared with employment and wages. Also the amount of employment is more relevant for economic activity than the wage level, since the latter is only a transfer from employers to employees.

accumulated loss in US real GDP growth is about twice as large in the nineties compared to earlier times and the response of consumer prices is much more pronounced. This finding is not surprising since a similar reduction in oil production triggers a substantially larger oil price increase in the recent sample period due to the much less elastic oil demand curve. More specifically, oil prices increased with 23.9 percent to a 1 percent shortfall in world oil production in the nineties, whilst this was only 3.2 percent in the seventies. Normalizing on the quantity variable to make intertemporal comparisons is therefore also problematic, particularly since a typical (one standard deviation) shift of oil supply in the nineties is characterized by a change in world oil production that is only one fifth of an average shift in the seventies. Given the indistinguishability of volatility and immediate impact of a structural shock in an SVAR, it is not possible to identify whether these smaller changes in oil production are only the result of a steeper oil demand curve, or also the consequence of smaller shifts in the underlying supply curve over time.[18]

When we consider the dynamic effects of a typical one standard deviation oil supply shock, Figure 8 shows that the impact on US macroeconomic aggregates has been rather similar over time, which is consistent with the results of BP (2008).[19] If the effects of average supply shocks in the US have not dramatically changed over time, it is surprising that the perceived consequences of current oil shocks are so different from those in the seventies. To explain this, BP (2008) demonstrate that oil supply shocks made only a limited contribution to the Great Inflation. Alternative factors, such as loose monetary policy, were much more relevant, which is in line with the propositions made by Barsky and Kilian (2004). In addition, the role of oil supply shocks to the recessions of 1974/75, early 1980s and 1990s, was significant but certainly not exclusive, which implies that also other shocks were at play. Unfavorable oil supply disturbances, however, also significantly reduced real activity around 1999, which made the ongoing boom more subdued. As a consequence, the exact timing of the oil shocks could have influenced the general perception that oil supply shocks had stronger economic consequences in the seventies compared to more recent times.[20] Furthermore, BP (2008) show that the most recent oil price surges are more demand driven. Since economic consequences are very different for shocks at the

[18]Note that, in case of a vertical oil supply curve, the observed decrease in oil production changes would be fully driven by decreased oil supply volatility.

[19]This is not the case for all countries in our analysis, in particular the energy-exporting countries.

[20]Hamilton (2009b) argues for instance that oil price changes also made a relevant contribution to the US recession between 2007Q4 and 2008Q3.

demand side of the oil market, for instance oil demand shocks driven by global economic activity, the perceived effects of oil price movements could also have changed.

4.3 Cross-country differences over time

In the previous section, we have shown that comparisons of the dynamic effects of oil supply shocks over time are distorted. To learn more about time variation and avoid the normalization problem, however, the cross-country dimension of our analysis can be explored. Specifically, PVR (2009b) argue that if a reduced dependency on crude oil and other forms of energy has resulted in a more subdued responsiveness to oil shocks, the change over time should be bigger for countries that improved their net energy position or oil intensity of the economy the most. Table 2 shows the role of oil and total energy for the periods 1970-1985, 1986-2008, and the change between both periods. Whilst all countries experienced a noticeable fall in total energy intensity of the economy and an improvement in net oil and energy dependence, the cross-country differences are substantial. Some countries, i.e. Canada and the UK, even switched from being oil-importing countries in the seventies to net exporters in more recent periods. Even within the group of oil and energy-importing countries, the changes are very different over time. The Euro area and Japan significantly improved their oil dependences, whereas the dependence on import of oil hardly improved for the US and Switzerland. Since the structural changes in the global oil market are the same for all countries, comparing relative changes between countries does not suffer from a normalization problem.

To evaluate whether a changed role of oil and other forms of energy in the economy is important to explain time variation, Figure 9 presents the impact of an oil supply shock, normalized to a 10 percent increase of oil prices, on real GDP and consumer prices in all individual countries for respectively the 1970-1985 and 1986-2008 periods.[21] The differences between both periods based on the median impulse responses are also reported in Table 2. Normalizing on oil prices, the ultimate output consequences have indeed reduced over time for all countries, which is in line with the above reported evidence for the US. The degree of the improvement, however, is very different across countries. All countries that are currently net exporters of energy, i.e. Norway, Canada, Australia and the UK, made the largest improvement over time. Whilst their output effects were more or less

[21] Since we only compare the relative cross-country differences over time, it does not matter whether we normalize on oil prices or oil production.

equally severe as in the other countries in the seventies, the impact in these four countries became insignificant or even positive in more recent times. These countries are also exactly the ones that increased their net energy position the most between both periods. Even among the energy-importing countries, we notice a reduction in the output effects which is somewhat lower in Switzerland and the US, two countries that hardly improved their net energy dependence over time.[22] Overall, the results support the hypothesis that the role and share of oil and other forms of energy matters to explain different output effects of oil supply shocks over time. Also for inflation, we find a stronger reduction in the effects for countries that improved their net energy position the most over time.

5 Conclusions

In this paper, we have analyzed the effects of oil shocks on a set of industrialized countries that are very diverse with respect to the role of oil and energy in their economy. By approaching this analysis from three different perspectives, several results are found that are worth mentioning. First, the economic consequences of an oil price increase crucially depend on the underlying source of the oil price shift in all countries, which is in line with the results of Kilian (2008a) and PVR (2009a) for respectively the US and the Euro area. More specifically, after an oil demand shock driven by changing economic activity, output temporary increases and inflation strongly rises. This is in contrast to an oil-specific demand shock, after which economic activity temporarily declines and inflationary effects are mostly insignificant. Following both types of oil demand shocks, the degree of dependency on oil and energy is not important for explaining cross-country differences in the economic effects. Conversely, being a net oil or energy exporting country does matter after exogenous oil supply shocks. We find that the net oil and energy-importing countries (US, Euro area, Japan and Switzerland) all face a permanent fall in economic activity and a significant rise in inflation, whereas the long-run output response in the oil and energy exporting countries (Canada, Australia, UK and Norway) is insignificant or even positive.

[22] Note that, if we only consider the long-run impact on economic activity, Japan is the country with the smallest improvement. This result is, however, mainly driven by a changed shape of the effects. Considering the maximum impact on output, the estimated improvement would be 1.22, which is even similar as the energy-exporting countries. Also for Switzerland the shape changed somewhat over time but, taking this into account would still result in a change over time that is lower than all other countries except the US, i.e. 0.75.

The inflationary effects in the exporting countries are limited, probably because of the appreciation of the effective exchange rates after an oil supply shock.

Second, the pass-trough of an oil supply shock to inflation is considerably different between the energy-importing countries. The direct effects of an oil supply shock to inflation are strong and significant in all countries. The cross-country differences in the effects on inflation, however, are mainly due to differences in the indirect effects. In turn, these are strongly determined by the existence of second-round effects. In the Euro area and Switzerland, the GDP deflator as well as nominal wages strongly increase and explain the relatively strong response of inflation. Conversely, the GDP deflator does not react in the US and in Japan in the long-run. In the US, second-round effects are not present since nominal wages and mark-ups do not change, whilst the slight increase of the wage in Japan is completely compensated by a decrease in producers' profit margins. Also demand and output effects are different across countries. In the US, an income and the precautionary savings effect is important to explain an immediate fall in GDP, while a delayed decrease in economic activity in the Euro area and Switzerland can be attributed to monetary policy that tightens its interest rate to halt second-round effects.

Finally, we find that countries that have improved their net energy position the most over time became relatively less vulnerable to oil supply shocks. By exploring the cross-country dimension, we have avoided a normalization problem that is inherent in comparing time-varying effects of oil supply shocks. This comparability problem arises because the oil demand curve has become much less elastic since the mid eighties. Accordingly, considering a similar oil price increase over time, or a similar oil production distortion, implies a bias in estimating time-varying effects of oil shocks since a totally different underlying shift in the oil supply curve is evaluated.

Not only the dependence on oil and other energy products is relevant for explaining time-varying effects of oil shocks, but also changes in monetary policy credibility and labor market characteristics could play an important role. Analyzing the relevance of these structural changes is however a suggestion for future research. Another interesting question, certainly after observing the substantial decline in oil prices that followed the financial crisis in mid 2008, is whether the inflationary effects of oil shocks are symmetric. We have assumed symmetry in all our estimations, which is for example not necessarily true in the case of downward rigidity of nominal wages.

References

[1] Barsky, R.B. and L. Kilian (2004), "Oil and the Macroeconomy Since the 1970s", *Journal of Economic Perspectives*, 18(4), p 115-134.

[2] Baumeister, C. and G. Peersman (2008), "Time-Varying Effects of Oil Supply Shocks on the US Economy", *mimeo*, Ghent University.

[3] Baumeister, C. and G. Peersman (2009), "Sources of the crude oil market volatility puzzle", *mimeo*, Ghent University.

[4] Bernanke, B.S. (1983), "Irreversibility, Uncertainty and Cyclical Investment", *Quarterly Journal of Economics*, 97(1), p 86-106.

[5] Bernanke, B.S., M. Gertler, and M. Watson (1997), "Systematic Monetary Policy and the Effect of Oil Price Shocks", *Brookings Papers on Economic Activity*, 1, p 91-157.

[6] Bernanke, B.S. (2006), "Energy and the Economy", speech to the Economic Club of Chicago, June 15.

[7] Blanchard, O.J. and J. Galí (2007), "The Macroeconomic Effects of Oil Price Shocks: Why are the 2000s so different from the 1970s?", *NBER Working Paper 13368*.

[8] Blinder, A.S. and J.B. Rudd (2008), "The Supply-Shock Explanation of the Great Stagflation Revisited", *NBER Working Paper 14563*.

[9] Cogley, T. and T.J. Sargent (2002), "Evolving Post-WWII U.S. Inflation Dynamics", in: *NBER Macroeconomics Annual 2001*, B.S. Bernanke and K. Rogoff (eds.), MIT Press, Cambridge, MA, p 331-347.

[10] Davis, S.J. and J. Haltiwanger (2001), "Sectoral Job Creation and Destruction Responses to Oil Price Changes", *Journal of Monetary Economics*, 48(3), p 465-512.

[11] Edelstein, P. and L. Kilian (2007), "Retail Energy Prices and Consumer Expenditures", *mimeo*, Department of Economics, University of Michigan.

[12] Ferderer, J.P. (1996), "Oil Price Volatility and the Macroeconomy", *Journal of Macroeconomics*, 18(1), p 1-26.

[13] Finn, M.G. (2000), "Perfect Competition and the Effects of Energy Price Increases on Economic Activity", *Journal of Money, Credit, and Banking*, 32(3), Part 1, p 400-416.

[14] Hamilton, J.D. (1983), "Oil and the Macroeconomy Since World War II", *Journal of Political Economy*, 91(2), p 228-248.

[15] Hamilton, J.D. (2003), "What is an Oil Shock?", *Journal of Econometrics*, 113, p 363-398.

[16] Hamilton, J.D. (2009a), "Understanding Crude Oil Prices", *Energy Journal*, 30(2), p 179-206.

[17] Hamilton, J.D. (2009b), "Causes and Consequences of the Oil Shock of 2007-2008", *Brookings Papers,* forthcoming.

[18] Herrera, A.M. and E. Pesavento (2007), "Oil Price Shocks, Systematic Monetary Policy and the 'Great Moderation'", *Macroeconomic Dynamics*, 13(1), p 107-137.

[19] Hooker, M.A. (1996), "What Happened to the Oil Price–Macroeconomy Relationship?", *Journal of Monetary Economics*, 38(2), p 195-213.

[20] Hooker, M.A. (2002), "Are Oil Shocks Inflationary? Asymmetric and Nonlinear Specifications versus Changes in Regime", *Journal of Money, Credit, and Banking*, 34(2), p 540-561.

[21] Kilian, L. (2008a), "Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market", *American Economic Review*, forthcoming.

[22] Kilian, L. (2008b), "The Economic Effects of Energy Price Shocks", *Journal of Economic Literature*, 46(6), p 871-909

[23] Lee, K., S. Ni, and R.A. Ratti (1995), "Oil Shocks and the Macroeconomy: The Role of Price Variability", *The Energy Journal*, 16(4), p 39-56.

[24] Mork, K. (1989), "Oil and the Macroeconomy When Prices Go Up and Down: An Extension of Hamilton's Results", *Journal of Political Economy*, 97(3), p 740-744.

[25] Peersman, G. (2005), "What Caused the Early Millennium Slowdown? Evidence Based on Vector Autoregressions", *Journal of Applied Econometrics*, 20, p 185-207.

[26] Peersman, G. and I. Van Robays (2009a), "Oil and the Euro Area Economy", *Economic Policy*, forthcoming.

[27] Peersman, G. and I. Van Robays (2009b), "Cross-Country Differences in the Effects of Oil Shocks", *mimeo*, Ghent University.

[28] Primiceri, G.E. (2005), "Time Varying Structural Vector Autoregressions and Monetary Policy", *Review of Economic Studies*, 72(3), p 821-852.

[29] Rotemberg, J.J. and M. Woodford (1996), "Imperfect Competition and the Effects of Energy Price Increases on Economic Activity", *Journal of Money, Credit, and Banking*, 28(4), Part1, p 549-577.

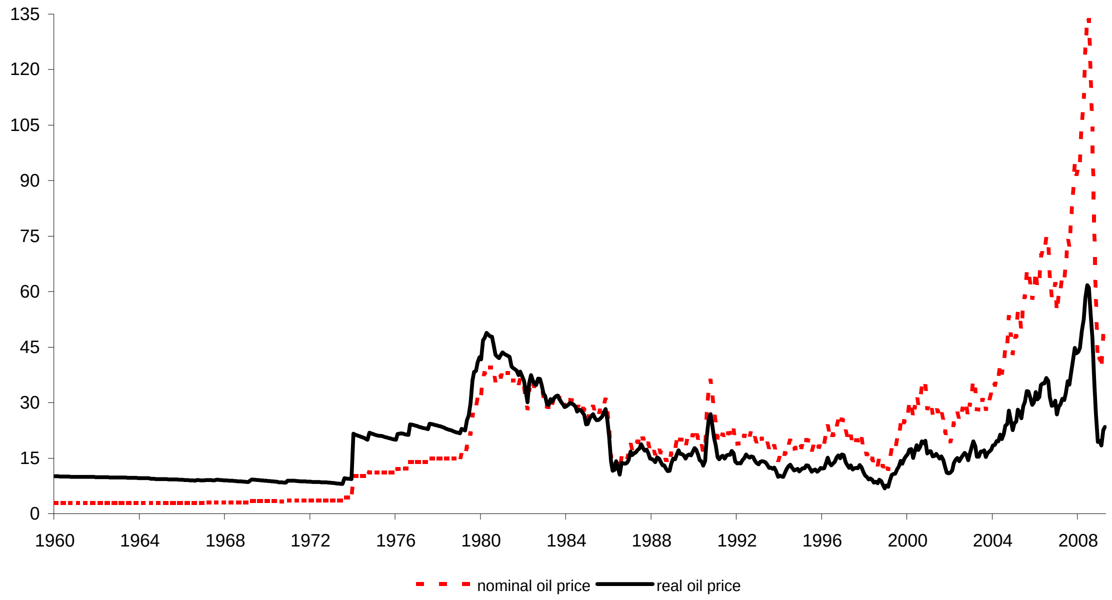


Figure 1. Evolution of nominal and real price of crude oil
Notes: oil price is the monthly average price of West Texas Intermediate, real oil prices are deflated using US monthly CPI, 1982-84=100

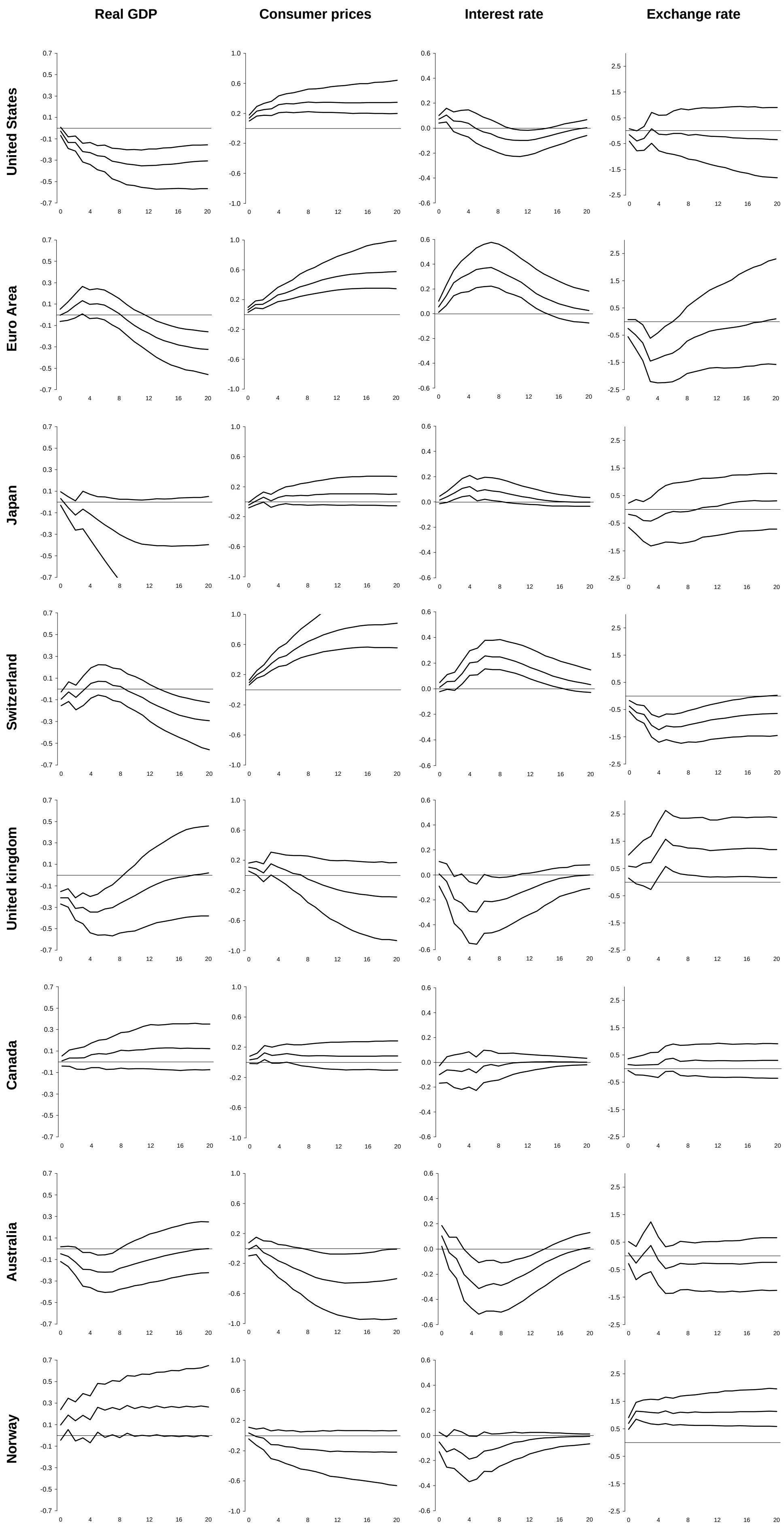


Figure 2. Impact of oil supply shock

Notes: figures are median impulse responses to a 10 percent long-run rise in oil prices, together with the 16th and 84th percentile error bands, horizon is quarterly

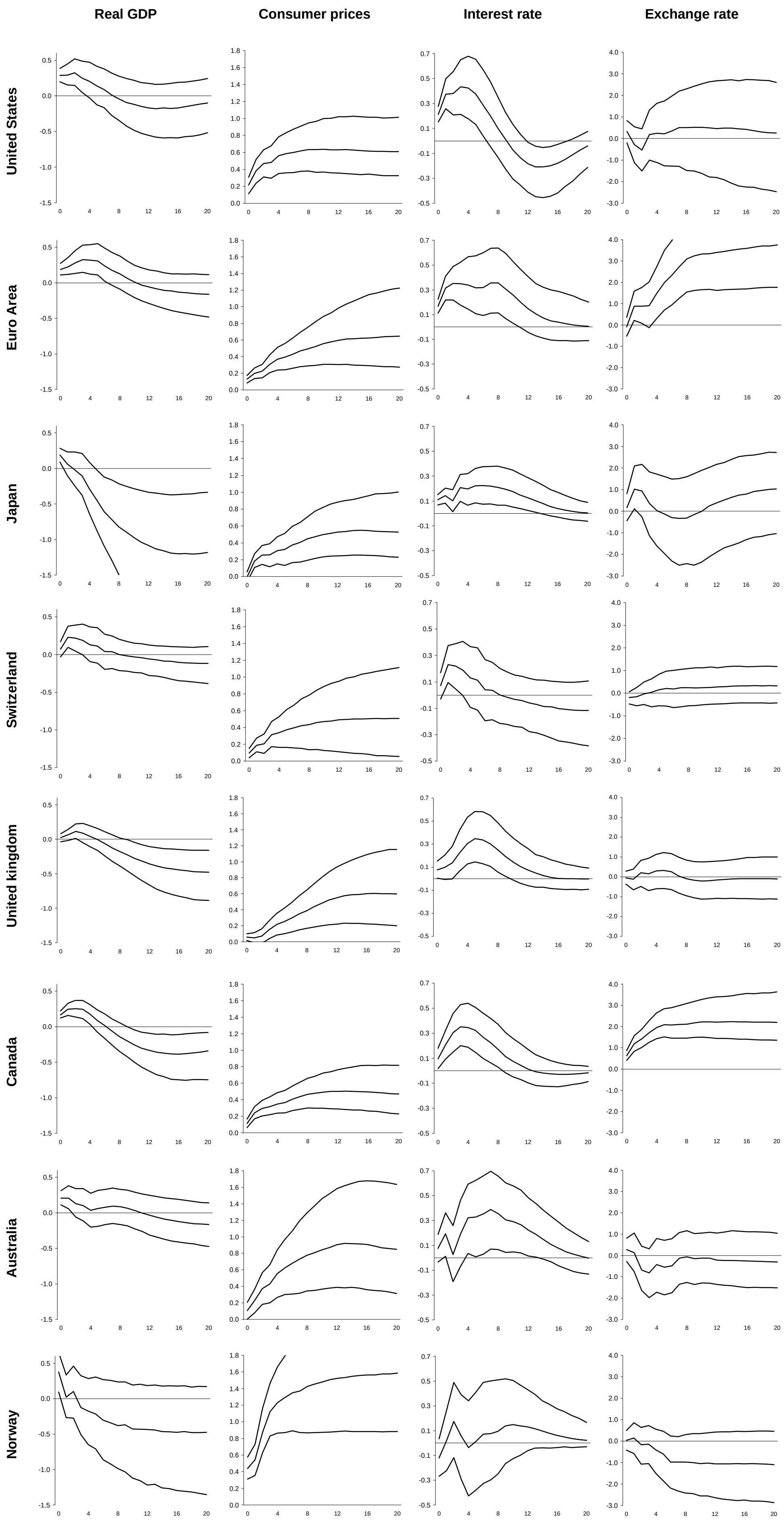


Figure 3. Impact of global economic activity shock

Notes: figures are median impulse responses to a 10 percent long-run rise in oil prices, together with the 16th and 84th percentile error bands, horizon is quarterly

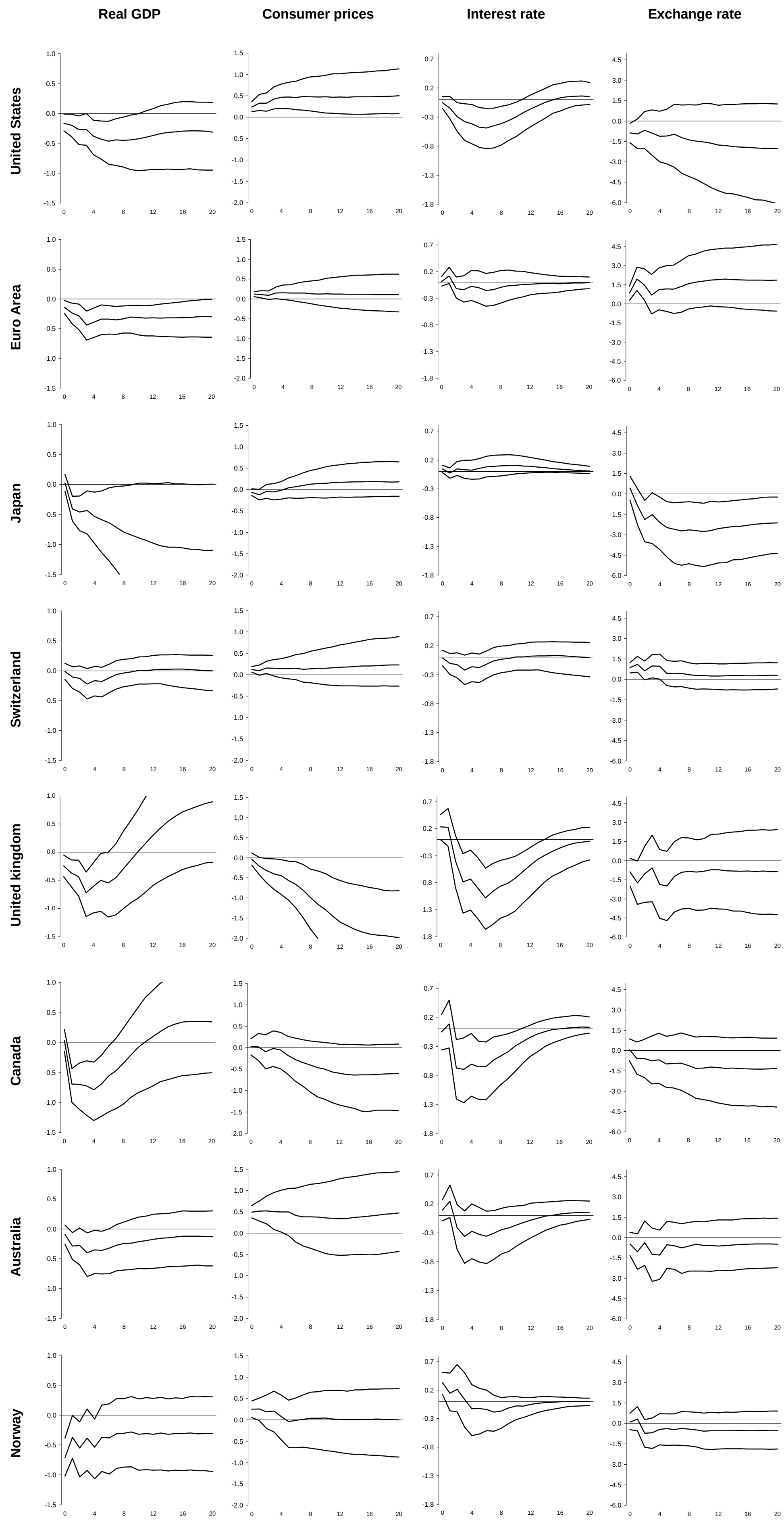


Figure 4. Impact of oil-specific demand shock

Notes: figures are median impulse responses to a 10 percent long-run rise in oil prices, together with the 16th and 84th percentile error bands, horizon is quarterly

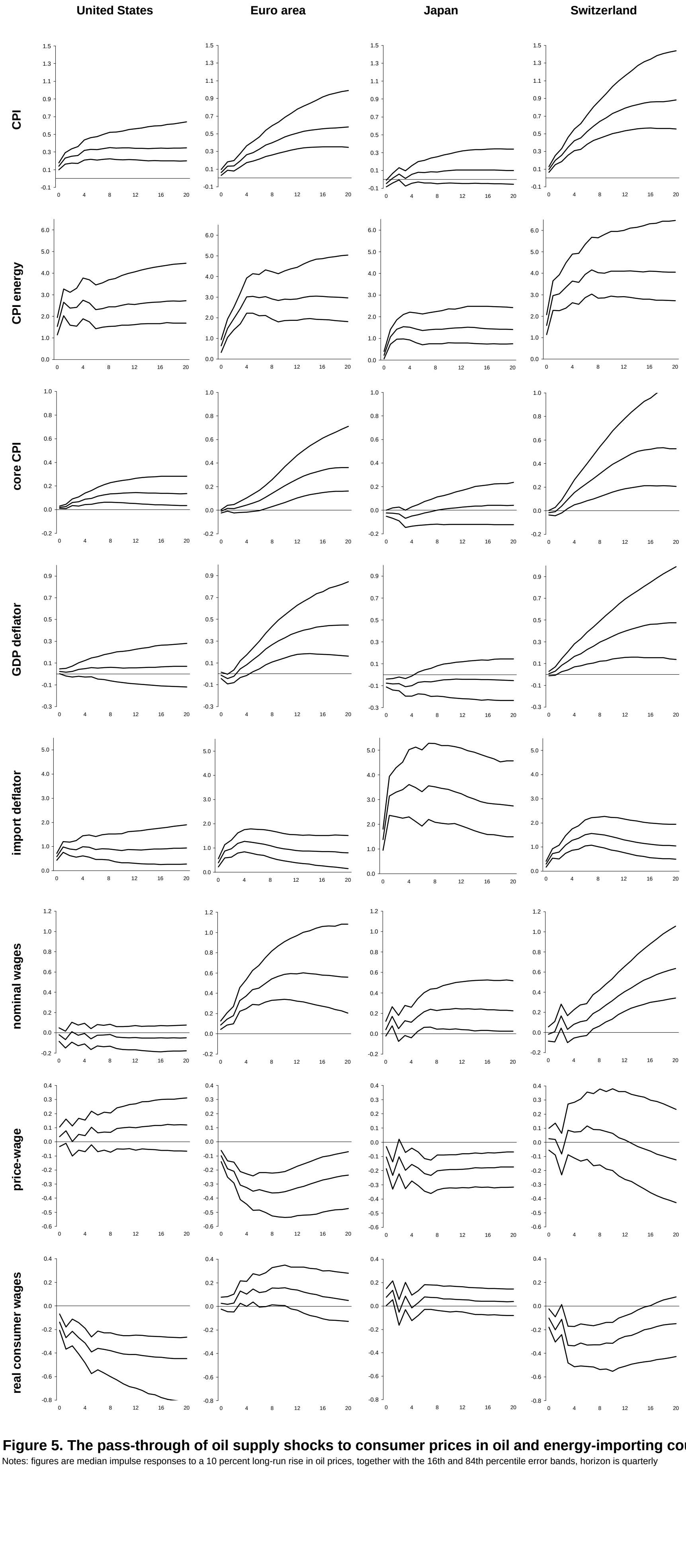


Figure 5. The pass-through of oil supply shocks to consumer prices in oil and energy-importing countries

Notes: figures are median impulse responses to a 10 percent long-run rise in oil prices, together with the 16th and 84th percentile error bands, horizon is quarterly

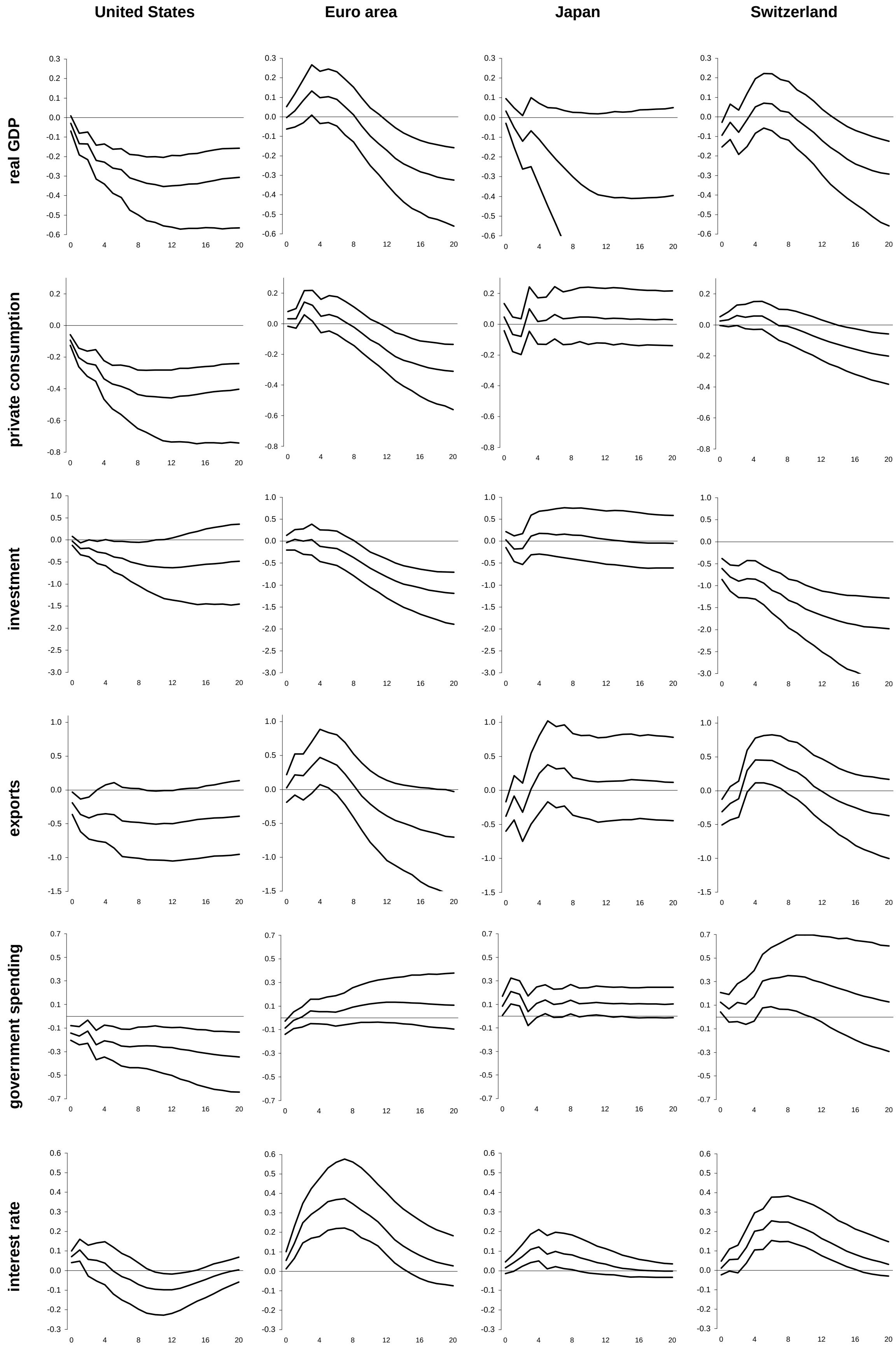
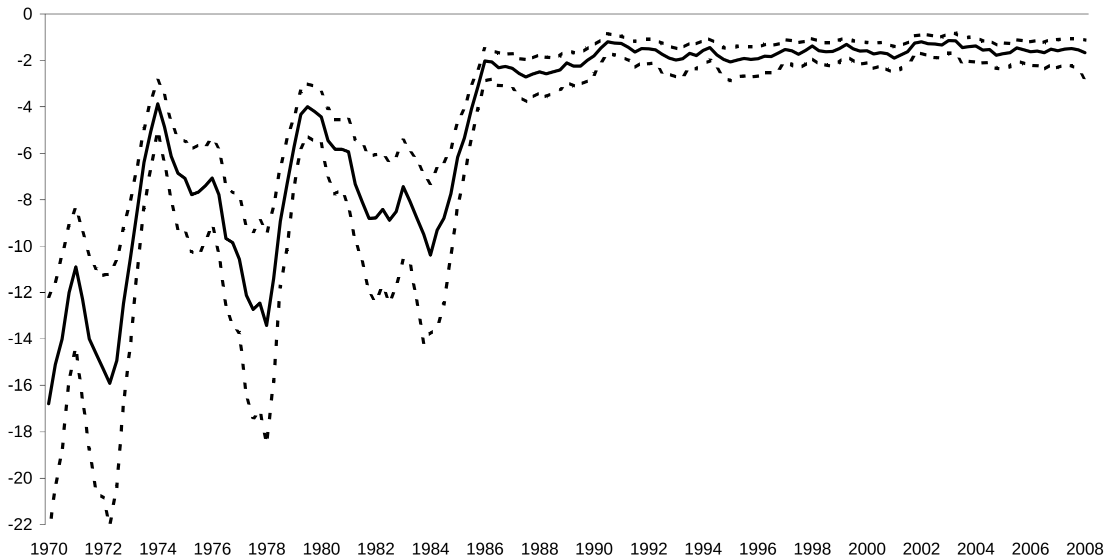
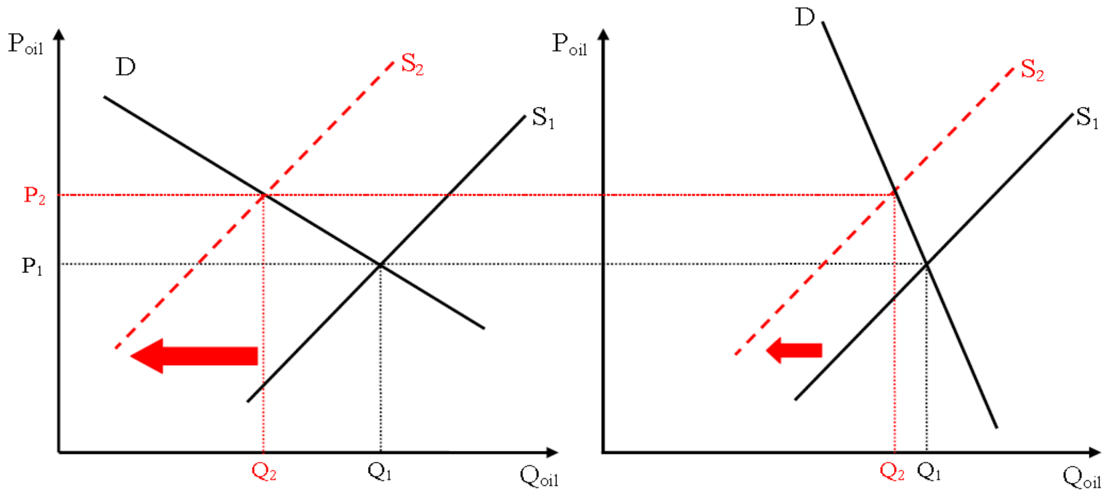


Figure 6. Demand effects and the pass-through to economic activity in oil and energy-importing countrie

Notes: figures are median impulse responses to a 10 percent long-run rise in oil prices, together with the 16th and 84th percentile error bands, horizon is quarterly



Panel A - Estimated elasticity of oil demand over time (Baumeister and Peersman 2008)
Notes: median effect four quarters after the shock with 16th and 84th percentiles confidence bands



Panel B - Oil supply shock with same oil price increase and flat versus steep slope of oil demand curve

Figure 7. Steepening of the oil demand curve over time

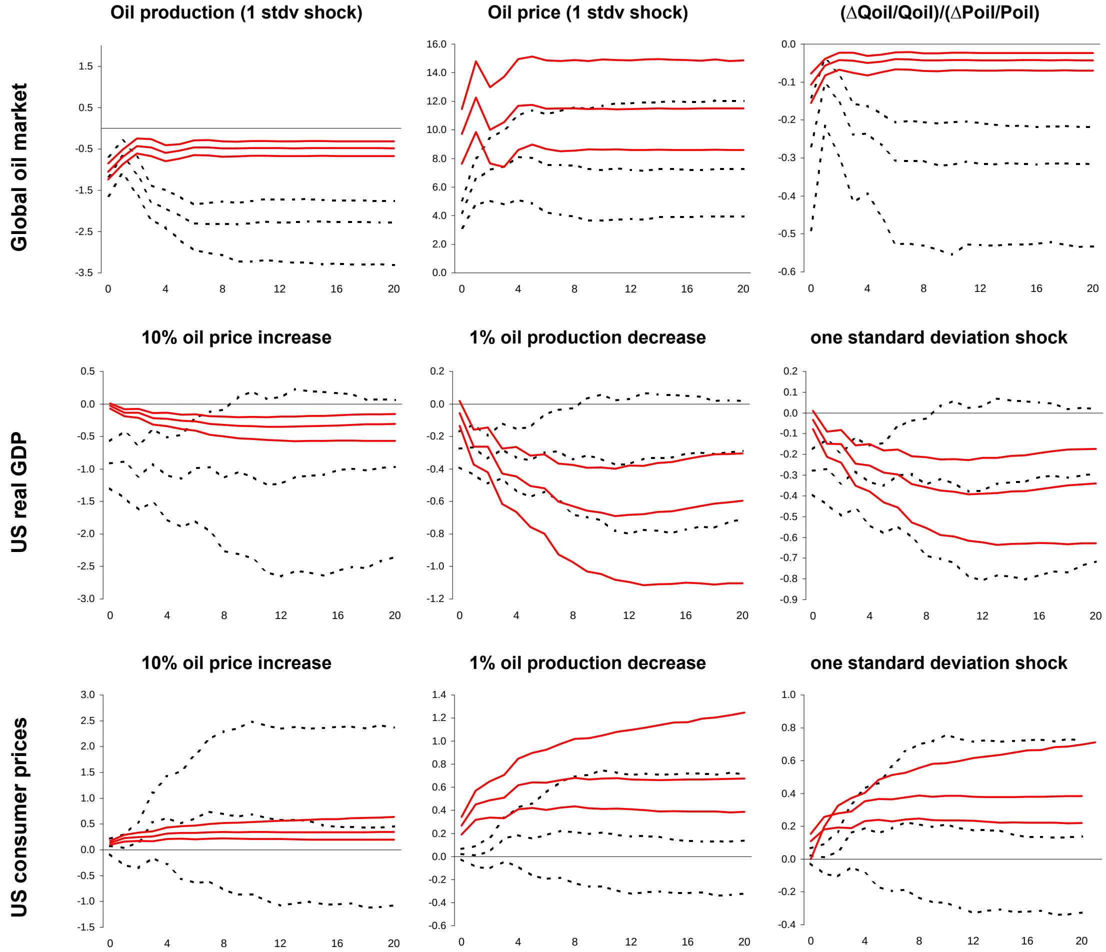
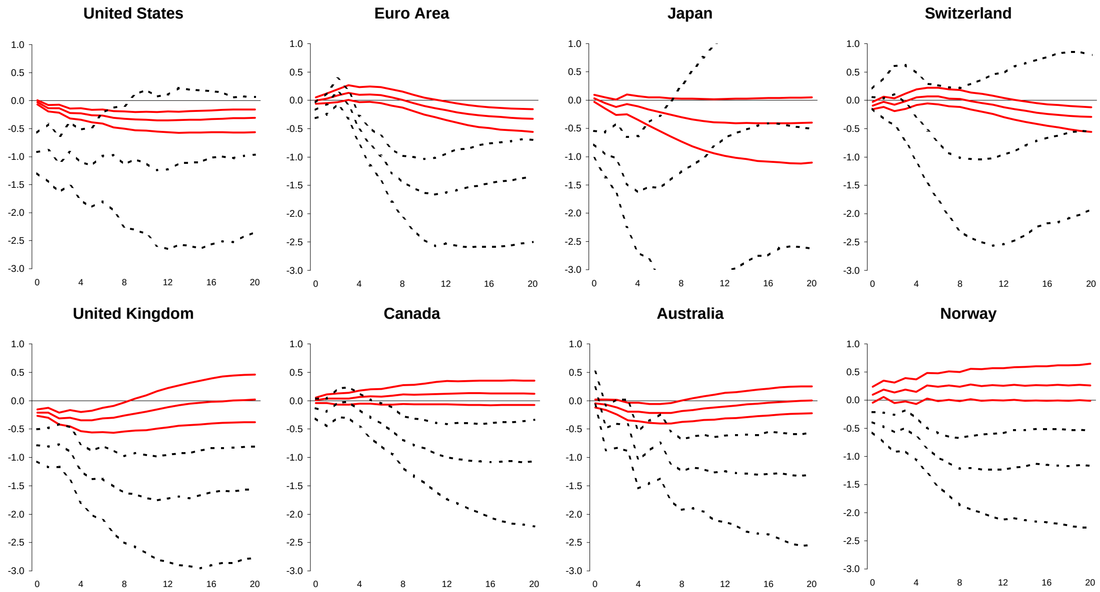


Figure 8. Impulse response functions after oil supply shock over time

Notes: figures are median impulse responses, together with the 16th and 84th percentile error bands, horizon is quarterly, 1971-1985: dotted lines, 1986-2008: full lines

PANEL A: Effects on real GDP



PANEL B: Effects on consumer prices

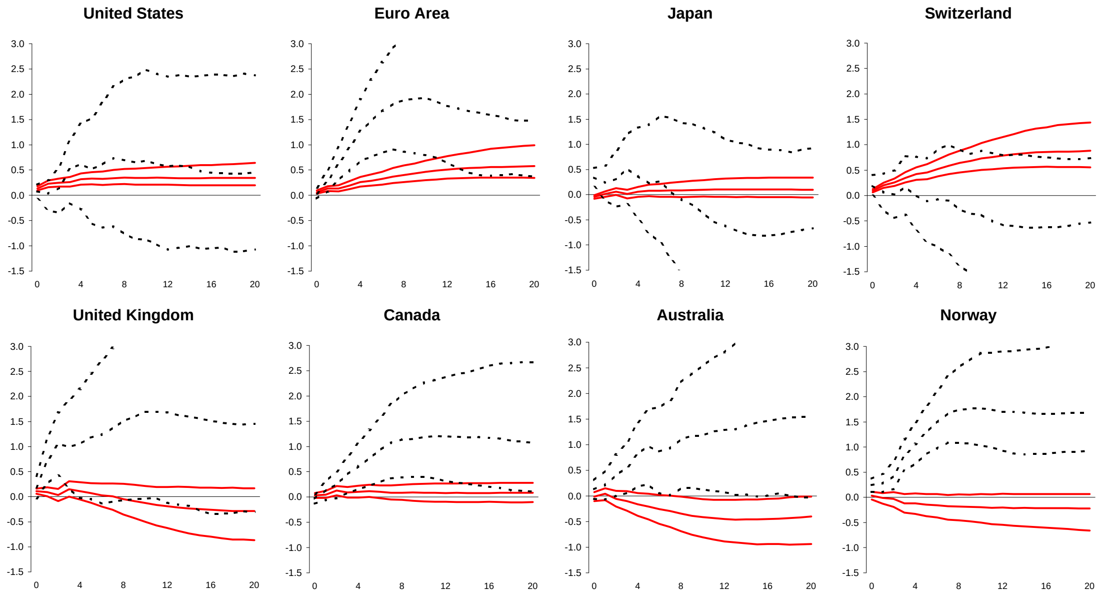


Figure 9. The effects of oil supply shocks over time

Notes: the figures are median impulse response function to a 10 percent long-run increase in oil prices, horizon is in quarters, 1971-1985: dotted lines, 1986-2008: full lines

Table 1 - Structural differences across countries and the impact of oil shocks: 1986-2008

	Oil[1]			Non-oil energy[1]			Total energy[1]			oil supply[2]		global activity[2]		oil-specific dem[2]	
	net import	production	total	net import	production	total	net import	production	total	GDP	CPI	GDP	CPI	GDP	CPI
United States	55	41	96	2	156	158	57	197	254	-0.31	0.35	0.33	0.61	-0.46	0.50
Euro Area	71	2	73	30	65	95	101	67	168	-0.32	0.58	0.33	0.65	-0.44	0.11
Japan	67	0	67	62	29	91	129	29	158	-0.40	0.10	0.19	0.53	-1.10	0.18
Switzerland	22	0	22	47	50	97	69	50	119	-0.29	0.88	0.23	0.51	-0.22	0.23
United Kingdom	-21	79	58	11	95	106	-10	174	164	0.02	-0.29	0.12	0.60	-0.72	-1.99
Canada	-16	109	93	-116	329	213	-132	438	306	0.12	0.08	0.25	0.47	-0.79	-0.60
Australia	7	53	60	-220	375	155	-213	428	215	0.00	-0.40	0.21	0.85	-0.40	0.48
Norway	-704	815	111	-331	398	67	-1035	1213	178	0.26	-0.22	0.38	1.58	-0.71	0.00

Notes: [1]: Averages for 1986-2008 based on International Energy Agency (IEA) data measured as (tonnes of oil equivalent) / GDP (million USD, PPP weighted) of respectively crude oil, total energy excluding crude oil and total energy

[2]: Estimated median impulse responses of GDP in the long-run (20 quarters) to a 10% oil price rise for an oil supply shock, maximum impact for oil demand shock driven by global economic activity and maximum impact for an oil-specific demand shock; long-run (20 quarters) effect on CPI for all three shocks

Table 2 - The role of oil and energy and the impact of oil supply shocks over time

	Net import of oil[1]			Net import of energy[1]			Energy intensity[1]			Impact on GDP[2]			Impact on CPI[2]		
	1970-1985	**1986-2008**	**change**	**1970-1985**	**1986-2008**	**change**	**1970-1985**	**1986-2008**	**change**	**1970-1985**	**1986-2008**	**change**	**1970-1985**	**1986-2008**	**change**
United States	63	55	*-8*	59	57	*-2*	374	254	*-120*	-0.96	-0.31	*0.65*	0.45	0.35	*-0.10*
Euro Area	112	71	*-41*	127	101	*-26*	210	168	*-42*	-1.35	-0.32	*1.03*	1.48	0.58	*-0.90*
Japan	122	67	*-55*	174	129	*-45*	197	158	*-39*	-0.50	-0.40	*0.10*	-0.66	0.10	*0.76*
Switzerland	28	22	*-6*	86	69	*-17*	122	119	*-3*	-0.55	-0.29	*0.26*	-0.53	0.88	*1.41*
United Kingdom	44	-21	*-65*	59	-10	*-69*	239	164	*-75*	-1.57	0.02	*1.59*	1.46	-0.29	*-1.75*
Canada	12	-16	*-28*	-45	-132	*-87*	389	306	*-83*	-1.07	0.12	*1.19*	1.07	0.08	*-0.99*
Australia	31	7	*-24*	-56	-213	*-157*	260	215	*-45*	-1.30	0.00	*1.30*	1.54	-0.40	*-1.94*
Norway	-96	-704	*-608*	-178	-1035	*-857*	219	178	*-41*	-1.16	0.26	*1.42*	1.70	-0.22	*-1.92*

Notes: [1]: Averages for period based on International Energy Agency (IEA) data measured as (tonnes of oil equivalent) / GDP (million USD, PPP weighted) of respectively net import of crude oil, net import of total energy and total domestic energy consumption

[2]: Estimated long-run (20 quarters) median impulse responses to an oil supply shock thant raises oil prices by 10%