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In 2004 all publications will carry a motif taken from the €100 banknote.

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CONTENTS

Abstract

This paper assesses empirically the effects of oil price shocks on the real economic activity of the main industrialised countries. Multivariate VAR analysis is carried out using both linear and non-linear models. The latter category includes three approaches employed in the literature, namely, the asymmetric, scaled and net specifications. We find evidence of a non-linear impact of oil prices on real GDP. In particular, oil price increases are found to have an impact on GDP growth of a larger magnitude than that of oil price declines, with the latter being statistically insignificant in most cases. Among oil importing countries, oil price increases are found to have a negative impact on economic activity in all cases but Japan. Moreover, the effect of oil shocks on GDP growth differs between the two oil exporting countries in our sample, with oil price increases affecting the UK negatively and Norway positively.

Keywords: Macroeconomic fluctuations; Oil price shock; Non-linear models.

JEL codes: E32, Q43.

Non-technical summary

The present paper assesses empirically the effects of oil price shocks on the real economic activity of the main industrialised OECD countries (individual G-7 countries, Norway and the euro area as a whole). The wide spectrum of countries included stands in contrast with most of the empirical literature on the subject which has focused on the US economy. While our sample of countries consists mostly of oil importing economies, we also analyse OECD's two main oil exporting countries.

In order to pursue our study, we carry out multivariate vector autoregressions. In doing so, we consider the leading approaches employed in the empirical literature, estimating both linear and non-linear models. Until the mid-1980s econometric studies on the subject used to estimate linear models linking oil prices and real activity. At that point in time such linear relationship began to lose significance. In fact, the declines in oil prices occurred over the second half of the 1980s were found to have smaller positive effects on economic activity than predicted by linear models. Thus, some authors introduced non-linear transformations of oil prices to re-establish the negative relationship between increases in oil prices and economic downturns. In this paper, we consider the three main non-linear approaches used in the literature, namely, the asymmetric, scaled and net specifications.

The main findings of this paper may be summarised as follows. As a first step, our use of Granger causality-type tests allows us to conclude that the interaction between oil prices and macroeconomic variables is found to be significant, with the direction of causality going in at least one direction in all countries, and in both directions in most countries. The effects of an increase in oil prices on real GDP growth are found to differ substantially from those of an oil price decrease, providing evidence against the linear approach that assumes that oil prices have symmetric effects on the real economy.

We investigate this comparison between different models further in the paper. The results show that there is evidence of a non-linear impact of oil prices on real GDP growth in both oil importing and exporting countries. We find that one of the non-linear models, namely the scaled specification, performs somewhat better than the other models. The scaled model has two important characteristics. First, it shares with the asymmetric model the notion that a given oil price increase may have an impact on real GDP which is different from that of an oil price fall of the same magnitude. Moreover, it involves a transformation of the oil price that standardises the estimated residuals of the autoregressive model by its time-varying (conditional) variability. This transformation seems very plausible in light of the pattern of oil price changes over time, with most changes being rather small and being punctuated by occasional sizeable shocks. The good performance of the scaled model indicates that, for the analysis of output growth, it is important to consider the environment in which oil price changes take place, highlighting in particular that a given oil price change has a larger impact in a context of previously stable prices than in one of volatile market behaviour. Moreover, as with the asymmetric model, the scaled specification allows us to compare the real impact of oil price rises and falls. We find that oil price increases have an impact on GDP growth of a larger magnitude than that of oil price declines, with the latter being statistically insignificant in most cases.

Given that the scaled specification appears to dominate competing models in terms of standard measures of goodness of fit, we focus on this approach when describing our econometric results. Moreover, we distinguish between oil importing and exporting countries as the results are expected to different depending on the type of country under consideration. We find that an increase in oil prices has a significant negative impact on the GDP growth in all oil importing countries but Japan. In the latter country, the model fails to identify any negative real effect of oil prices, possibly due to the special circumstances undergone by the Japanese economy. This unexpected result, however, is not robust to changes in the lag specification. In addition, the effects of an oil price hike on GDP growth are overall strongest for the US, although euro area countries (Germany, France and Italy) exhibit similarly strong real effects when we use non-linear modelling. In these cases, we find that a decline in oil prices affects significantly only a few countries, having a positive impact on the US and UK economies while doing harm to the Canadian economy. The latter result can be explained by the fact that large decreases in oil prices took place after the early 1980s, which is when Canada was switching from a net oil importer into a net oil exporter. With regard to the two oil exporting countries in our sample, we find that the effect of oil shocks on GDP growth differ. Oil prices are found to affect positively Norwegian GDP growth, while having a negative impact on oil exporter UK's economic activity (relating to the standard Dutch disease effect).

As far as the size of the responses is concerned, non-linear specifications tend to yield larger real impacts of oil price shocks compared with the linear model. For the sake of concreteness, let us focus on the preferred (scaled) specification. We find that in the US the output loss resulting from a 100% oil price hike increases from around 3.5% in the linear approach to 5% in the scaled case. Among the other oil importing countries, the respective increase in the output loss arising from the same shock is from around 2% to a range of 3 to 5% in the case of individual euro area countries, from less than 1% to 2% in the case of the euro area as a whole, and from very small values to around 1% in Canada. Among the oil exporters in our sample, in the UK the corresponding rise in the output loss from the same shock is from less than 2% to over 2%, while in Norway the output gain increases from 1% to more than 2%.

We also pursue variance decomposition analysis, which suggests that oil price shocks are a considerable source of volatility for many of the variables in the model. For real GDP, oil prices shocks are together with monetary shocks the largest source of variation other than the variable itself for most of the countries. Finally, we do not find evidence of instability of the oil price coefficients of the GDP equation in any model with the exception of the linear specification for the euro area.

1 Introduction

A large body of research suggests that oil price fluctuations have considerable consequences on economic activity. These consequences are expected to be different in oil importing and in oil exporting countries. Whereas an oil price increase should be considered good news in oil exporting countries and bad news in oil importing countries, the reverse should be expected when the oil price decreases.[1] The transmission mechanisms through which oil prices have an impact on real economic activity include both supply and demand channels.[2] The supply side effects are related to the fact that crude oil is a basic input to production, and consequently an increase in oil price leads to a rise in production costs that induces firms to lower output. Oil prices changes also entail demand-side effects on consumption and investment. Consumption is affected indirectly through its positive relation with disposable income. The magnitude of this effect is in turn stronger the more the shock is perceived to be long-lasting. Moreover, oil prices have an adverse impact on investment by increasing firms' costs. It is worth noting that, in addition to the previously discussed impacts of oil prices on supply and demand, oil price changes influence foreign exchange markets and inflation, giving thus rise to indirect effects on real activity.[3]

The related empirical studies started by finding a linear negative relationship between oil prices and real activity in oil importing countries.[4] By the mid-1980s, however, the estimated linear relationship between oil prices and real activity began to lose significance. In fact, the declines in oil prices occurred over the second half of the 1980s were found to have smaller positive effects on economic activity than predicted by linear models. Thus, Mork (1989),[5] Lee *et al.* (1995) and Hamilton (1996) introduced

[1] It has normally been the case that international spillovers through trade have reinforced these effects among oil importing industrial economies. This is due to the fact that these economies (which are overall negatively affected by oil price increases) trade mostly among themselves and that oil exporting countries do not use all the extra income induced by high oil prices in ways that end up increasing their own demand for foreign products.

[2] For this reason, the theoretical literature has been of a general equilibrium nature, with different authors assigning different weights to the supply and demand channels. See, for example, Rasche and Tatom (1977, 1981), Kim and Loungani (1992), and Rotemberg and Woodford (1996). One of the key common features of these models is the linearity assumed between the logarithm of real GDP and the logarithm of the price of oil. For these models, an oil price decline of a given size is as beneficial to economic activity as an oil price increase of the same size is detrimental to it.

[3] Some of these indirect effects may involve economic policy reactions. For instance, authors like Bohi (1989) and Bernanke *et al.* (1997) argue that economic downturns observed after oil price shocks are caused by a combination of direct impacts of the shocks themselves and the monetary responses to them.

[4] Those studies include Rasche and Tatom (1981), Darby (1982), Hamilton (1983), Burbidge and Harrison (1984), and Gisser and Goodwin (1986). While all these contributions consider the case of the US, Darby (1982) and Burbidge and Harrison (1984) also analysed other developed countries (Japan, Germany, the UK, Canada, France, Italy, and the Netherlands in the former case, and Japan, Germany, the UK and Canada in the latter).

[5] Mork's study found that the effects of oil price increases are different from those of decreases, and that oil price decreases are not statistically significant in the US. This implied a departure from the linear specifications, in which oil price rises and falls have symmetrically equal impacts on real activity. Mork's contribution has proved influential in that many authors

non-linear transformations of oil prices to re-establish the negative relationship between increases in oil prices and economic downturns, as well as to analyse Granger causality between both variables. More recently, Hamilton (2003) and Jiménez-Rodríguez (2004) also found evidence of a non-linear relationship between the two variables for the US economy. To be more specific about the non-linear transformations proposed in the empirical literature, Mork (1989) allowed for an asymmetric response of the US economic activity to oil price changes by specifying increases and decreases in the real price of oil as separate variables. He found that the effects of oil price increases were different from those of decreases, and that oil price decreases were not statistically significant.[6] Given that the asymmetry is a very special case of non-linear relationship between GDP and oil prices, the literature has proposed two other non-linear transformations, namely: *scaled specification* (Lee *et al.*, 1995), taking the volatility of oil prices into account;[7] and *net specification* (Hamilton, 1996), which considers the amount by which oil prices have gone up over the last year.

While the recent empirical literature has thus developed into the area of non-linear modelling, the theoretical literature is normally not explicit about asymmetries in the response of real activity to oil prices. The main exception to this is given by one economic justification for an asymmetric relationship that has been offered in the literature. For instance, Lilien (1982) has formulated the so-called *dispersion hypothesis*, which relies on the argument that a change in oil price alters the equilibrium allocation across various sectors. More concretely, this explanation relates to adjustment costs resulting from the implied sectoral reallocation of resources.[8] According to this argument, an increase (decrease) in oil prices would lead to a contraction (expansion) in sectors that make use of oil in the production process. Moreover, the increase (decrease) in oil prices would generate an expansion (contraction) of energy-efficient sectors relative to energy-intensive sectors. However, given that in the short run the cost of reallocation of resources between sectors is high, oil shocks that imply readjustment between energy-efficient and energy-intensive sectors will give rise to an overall loss in output. While this loss will aggravate the economic

have thereafter not even considered the possibility of effects derived from a decrease in oil prices.

[6] Mork *et al.* (1994) documented the asymmetry in the inverse relationship between oil price and aggregate economic activity for countries other than the US (including both oil-importing and oil-exporting countries). In particular, they found asymmetry in the cases of Norway and all G-7 countries but Italy.

[7] Ferderer (1996) also considers oil price volatility, albeit in a different way. He constructs a measure of it and plugs it into the empirical model alongside the level of oil prices. As the author recognises, this procedure is confronted with the difficulty usually found in isolating the level and volatility channels.

[8] For related approaches, see Loungani (1986), and Davis (1987), Hamilton (1988), and Davis *et al.* (1997). In addition to the theoretical reason for the asymmetric real effect given in the text, the presence of an asymmetric pattern in the changes of prices of crude and oil refining products themselves may provide a further, in this case empirical, justification. In this regard, Bacon (1991), Karrenbock (1991), and Balke *et al.* (1998) have all found evidence of asymmetric response in gasoline prices. Their common finding is that gasoline prices rise more quickly when oil prices are increasing than they fall when oil prices are decreasing.

contraction when oil prices increase, it will constrain the economic expansion when oil prices decline, thereby giving rise to the asymmetric effect.

The present paper extends the existing empirical literature in two directions. First, unlike most of the existing literature, which focuses on the oil importing US economy,[9] we analyse the effects of an oil price shock in the main industrialised countries (individual G-7 countries, Norway and the euro area as a whole). While most of these countries are oil importing, we also include in our sample two net oil exporting countries, namely the UK and Norway. Second, we assess the relation between oil prices and real activity using the linear and three leading non-linear approaches. To our knowledge, this paper is the first to assess the impact of oil price shocks on the level of real activity in the main industrialised OECD countries considering such variety of econometric specifications.

Our main findings may be summarised as follows. As a first step, Granger causality-type analysis permits us to conclude that the interaction between oil prices and macroeconomic variables is found to be significant, with the direction of causality going in at least one direction in all countries, and in both directions in most countries. The effects of an increase in oil prices on real GDP growth are found to differ substantially from those of an oil price decrease, providing evidence against the linear approach that assumes that oil prices have symmetric effects on the real economy. An increase in oil prices is found to have a significant negative impact on the GDP growth in all oil importing countries but Japan. In the latter country, the model fails to identify any negative real effect of oil prices, possibly due to the special circumstances undergone by the Japanese economy. This unexpected result, however, is not robust to changes in the lag specification. With regard to the two net oil exporting countries under consideration, oil prices are found to affect positively Norwegian GDP growth, while having a negative impact on oil exporter UK's economic activity (relating to the standard Dutch disease effect). In addition, the effects of an oil price hike on GDP growth are overall strongest for the US, although euro area countries (Germany, France and Italy) exhibit similarly strong real effects when we use non-linear modelling. Two non-linear approaches, namely the asymmetric and scaled specifications, allow us to compare the impact of oil price rises and falls. In these cases, we find that a decline in oil prices affects significantly only a few countries, having a positive impact on the US and UK economies while doing harm to the Canadian economy. The latter result can be explained by the fact that large decreases in oil prices took place after the early 1980s, which is when Canada was switching from a net oil importer into a net oil exporter. Inspection of confidence bands around impulse responses allow us to assess that non-linear models tend to yield a more precise representation of the relationship between GDP growth and oil price changes. Moreover, evidence on the relative performance of the different specifications suggests that the model that controls for the volatility of oil price shocks (i.e. the scaled specification) appears to dominate competing models

[9] Some of the few relevant exceptions are cited in footnotes 4 and 6.

in terms of standard measures of goodness of fit. We thus focus on this specification when describing our econometric results. Variance decomposition analysis suggests that oil price shocks are a considerable source of volatility for many of the variables in the model. For real GDP, oil prices shocks are together with monetary shocks the largest source of variation other than the variable itself for most of the countries. Finally, we do not find evidence of instability of the oil price coefficients of the GDP equation in any model with the exception of the linear specification for the euro area.

The paper is organised as follows. Section 2 describes the methodology. Section 3 presents the empirical results. Concluding remarks are offered in Section 4.

2 Methodology

We consider the following vector autoregression model of order p (or simply, VAR(p)):[10]

$$y_t = c + \sum_{i=1}^{p} \Phi_i y_{t-i} + \varepsilon_t, \tag{2.1}$$

where y_t is a $(n \times 1)$ vector of endogenous variables, $c = (c_1, ..., c_7)'$ is the (7×1) intercept vector of the VAR, Φ_i is the i$^{\text{th}}$ (7×7) matrix of autoregressive coefficients for $i = 1, 2, ..., p$, and $\varepsilon_t = (\varepsilon_{1t}, ..., \varepsilon_{7t})'$ is the (7×1) generalisation of a white noise process.

In this paper we use a quarterly seven-variable VAR for each country under study. The variables considered for the model are the following: real GDP, real effective exchange rate (REER),[11] real oil price, real wage, inflation, and short and long-term interest rates. Some variables (real GDP, REER, real oil price and real wage) are expressed in logs, while the remaining ones are simply defined in levels. We include real oil prices and real GDP growth since our main objective is to analyse the effects of the former variable on the latter.[12] We use only one measure of economic activity, namely, real GDP, thus doing without a separate role for unemployment. The remaining variables are included to capture some of the most important transmission channels through which oil prices may affect economic activity indirectly, in part by inducing changes in economic policies. Those channels include effects of oil prices on inflation and exchange rates, which then induce changes in real economic activity. Our VAR model also incorporates a monetary sector (by means of short- and long-term interest rates rather than money

[10] Sims (1980) was the first to represent the reduced form of a standard macroeconomic model as a multivariate dynamic system. This dynamic model was given by an "unconstrained" (i.e. restrictions only on lag length) vector autoregression.

[11] REER is defined such that an increase means a real appreciation of the currency considered. An appreciation of the real exchange rate is expected to hurt the country's external competitiveness.

[12] We follow the existing literature in measuring the value of the oil price *excluding* taxes. The reason is simply that there is no database for tax-including end-use prices of oil products for a comparably large number of countries over the sample period.

supply indicators), which can react to inflationary pressures. We also allow for a labour market channel (by using a real wages index), in light of the role it may play with regard to aggregate demand or supply.[13] As is customary in studies focusing on the impact of oil prices, we do not use import prices as a whole but only oil prices,[14] while also allowing for the exchange rate to capture part of the pass-through from import prices (in foreign currency) into domestic prices.

The choice of the oil price variable is a difficult and important one. We define oil prices in real terms, taking the ratio of the price of an internationally traded variety of crude (UK Brent) in US dollars to the US Producer Price Index. This way of measuring oil prices has three important advantages over competing definitions.[15] First, it avoids the undesirable property resulting from nominal oil price definitions (e.g. Hamilton, 1996) that, owing to positive inflation, an identical shock to the nominal price would tend to induce a decreasing effect on real variables over the sample period. Second, in the context of the methodology followed here, our definition of real oil prices represents a common shock to all countries. It is important to be aware, however, that the actual economic impact of the oil shock would be modified in countries other than the US by changes in the bilateral real exchange rate.[16] Third, by taking the real price directly affecting the US, the definition used here makes our results comparable with those found in the large majority of the literature.[17] One caveat to our definition is that the econometric models that we use cannot recover the real price of oil facing each individual economy other than the US. This has to do with the fact that we do not have in our models a bilateral real exchange against the US dollar, but a broader exchange rate variable defined in effective terms.

Before studying the effects of oil shocks on economic activity, we proceed to investigate the stochastic

[13] The effect of an increase in oil prices on the labour market itself is hard to assess. On the one hand, the increase in the price of a substitute input (particularly if capital is complementary to oil) implies a higher demand for labour and higher real wages, while, on the other hand, the overall lower level of production implies a downward pressure on both the demand for labour and real wages.

[14] We do not follow authors such as Bernanke *et al.* (1997) and Brown and Yücel (1999), who use both an oil price index and an overall commodity price index.

[15] A comparable definition has been used in a multi-country study by Darby (1982).

[16] We prefer the definition used here over that used by Mork *et al.* (1994) which converts the dollar world price of crude into each respective country's currency. By getting closer to the real oil price affecting each country, their definition brings in one more variable - the exchange rate - which would further blur the identification of a structural shock. Moreover, their definition varies from country to country, and no comparison could thus be made of the impact of a given size of the oil shock for a concrete episode.

[17] See, e.g., Mork (1989), Lee *et al.* (1995), Carruth *et al.* (1998), and Hooker (1996, 1999). We do not follow Burbidge and Harrison (1984), who deflate the price of oil using a weighted average of the consumer price indices in five advanced economies. By using this special deflator, their study becomes harder to compare with the rest of the literature.

While the literature on the American experience normally uses a different data source for the price of crude oil, i.e. a US-based nominal price of oil, this does not make a difference in light of the very high correlation among alternative crude prices that is observed at a quarterly frequency.

properties of the series considered in the model by analysing their order of integration on the basis of a series of unit root tests. Specifically, we perform the $DFGLS$ and P_T tests of Elliott *et al.* (1996), and the $DFGLSu$ and Q_T tests of Elliott (1999), as well as the Augmented Dickey-Fuller (ADF) test (See Appendix 1).[18] Results of these formal tests are summarised in Tables 1A-1C, indicating that the first differences of all seven variables are stationary. We therefore follow the related literature in defining the vector y_t in (2.1) to be given by the first log-differences of the first four aforementioned variables (real GDP, REER, real oil price, and real wage), along with the first differences of the remaining ones (inflation, and short and long-term interest rates).[19]

The VAR system can be transformed into its Moving Average representation in order to analyse the system's response to a real oil price shock, that is:

$$y_t = \mu + \sum_{i=0}^{\infty} \Psi_i \varepsilon_{t-i}, \tag{2.2}$$

where Ψ_0 is the identity matrix, and μ is the mean of the process ($\mu = (I_n - \sum_{i=1}^{p} \Phi_i)^{-1} c$). The moving average representation is used to obtain both the forecast error variance decomposition and the impulse-response functions. The variance decomposition shows the proportion of the unanticipated changes of a variable that is attributable to its own innovations and to shocks to other variables in the system.

In order to assess the impact of shocks on endogenous variables, we examine the orthogonalised impulse-response functions, using Cholesky decomposition, as well as the accumulated responses. To do so, we should choose an ordering for the variables in the system, since this method of orthogonalisation involves the assignment of contemporaneous correlation only to specific series. Thus, the first variable in the ordering is not contemporaneously affected by shocks to the remaining variables, but shocks to the first variable do affect the other variables in the system; the second variable affects contemporaneously the other variables (with the exception of the first one), but it is not contemporaneously affected by them; and so on. In our case, we have assumed the following ordering: real GDP, real oil price, inflation, short-term interest rate, long-term interest rate, real wage, and REER.[20] This ordering assumes, as in much of the related literature, that real output does not react contemporaneously on impact to the rest of the variables. The oil price variable is also ranked as a largely exogenous variable, which have an immediate impact on the rate of inflation. The latter is then allowed to feed into changes in interest rates, while two relative prices, namely the real wage rate and the exchange rate, close the system.

[18] It is worth noting that the tests proposed by Elliott *et al.* (1996) and Elliott (1999) are more powerful than the Dickey-Fuller test.

[19] An alternative valid approach would be to estimate a cointegrated VAR model, in which non-stationary variables enter the model in levels, while being allowed to interact through long-run relationships.

[20] The two standard error bands around the impulse responses are based on Lutkepohl (1990).

As a robustness check, we also report results on an alternative ordering, namely: short-term interest rate, long-term interest rate, real GDP, real wage, REER, real oil price, and inflation.[21] This alternative ordering takes into consideration some plausible aspects that are not incorporated in the baseline ordering, namely:[22]

i) given that the oil price is an asset price and thus likely to react to financial variables, making the assumption that it is contemporaneously exogenous could be found to be restrictive;

ii) given that crude oil is an important input in the production process, we still allow the price level to adjust contemporaneously to oil prices;

iii) the alternative ordering also allows for a non-zero contemporaneous impact of interest rate shocks on output.

We start by estimating a linear specification of the VAR in (2.1). Furthermore, on the basis of the previous empirical literature and economic arguments we also consider three non-linear transformations of oil prices. Such non-linear transformations are the following: 1) *asymmetric specification*, in which increases and decreases in the price of oil are considered as separate variables; 2) *scaled specification* (Lee *et al.*, 1995), which takes the volatility of oil prices into account; and 3) *net specification* (Hamilton, 1996), where the relevant oil price variable is defined to be the net amount by which these prices in quarter t exceed the maximum value reached in the previous four quarters.[23]

The *asymmetric* specification distinguishes between the positive rate of change in the oil price, o_t^+, and its negative rate of change, o_t^-, which are defined as follows:

$$o_t^+ = \begin{cases} o_t & if \ o_t > 0 \\ 0 & otherwise \end{cases}$$

$$o_t^- = \begin{cases} o_t & if \ o_t < 0 \\ 0 & otherwise \end{cases}$$

where o_t is the rate of change in the real oil price. The *asymmetric* model can be rationalised in terms of the dispersion hypothesis described in the Introduction.

[21] We also considered alternative orderings, verifying that the impulse responses - which we do not report here due to space constraints - do not change considerably compared with the baseline specification. For instance, in the case of an alternative ordering that only differs from the baseline model in that we allow for the contemporaneous influence of real oil price innovation on GDP growth, the contemporaneous effect is all that changes, being zero when the oil-price variable is not placed at the top of the ordering.

[22] Another way of addressing this issue would be to identify the structural model by mean of a sign-restricted VAR as in Peersman (2003). We leave this for further research.

[23] Unlike Hamilton (1996), who uses nominal oil price, Mork (1989) and Lee *et al.* (1995) use the real price of oil. As explained before, the present paper follows the latter approach.

The *scaled* and *net* specifications were developed by Lee *et al.* (1995) and Hamilton (1996), respectively, to account for the fact that oil price increases after a long period of price stability have more dramatic macroeconomic consequences than those that are merely corrections to greater oil price decreases during the previous quarter. In order to put this idea in practice, these authors use some transformation of the oil price variable. Lee *et al.* (1995) proposed the following AR(4)-GARCH(1,1) representation of oil prices:

$$\begin{aligned}
o_t &= \alpha_0 + \alpha_1 o_{t-1} + \alpha_2 o_{t-2} + \alpha_3 o_{t-3} + \alpha_4 o_{t-4} + e_t \\
e_t | I_{t-1} &\sim N(0, h_t) \\
h_t &= \gamma_0 + \gamma_1 e_{t-1}^2 + \gamma_2 h_{t-1} \\
SOPI_t &= \max(0, \hat{e}_t / \sqrt{\hat{h}_t}) \\
SOPD_t &= \min(0, \hat{e}_t / \sqrt{\hat{h}_t})
\end{aligned}$$

where $SOPI$ stands for *scaled oil price increases*, while $SOPD$ for *scaled oil price decreases*. The *scaled* model builds on the asymmetric model, while it also employs a transformation of the oil price that standardises the estimated residuals of the autoregressive model by its time-varying (conditional) variability. This transformation seems very plausible in light of the pattern of oil price changes over time, with most changes being rather small and being punctuated by occasional sizeable shocks.

Hamilton (1996) proposed a different non-linear transformation, by using as an explanatory variable what he calls *net oil price increase* ($NOPI$). This variable is defined to be the amount by which (the log of) oil prices in quarter t, p_t, exceed the maximum value over the previous 4 quarters; and 0 otherwise. That is:

$$NOPI_t = \max\{0, p_t - \max\{p_{t-1}, p_{t-2}, p_{t-3}, p_{t-4}\}\}$$

Hamilton's definition is also asymmetric in the specific sense that it captures oil price increase-type shocks while neglecting the impact of oil price declines. This is inspired by earlier evidence that oil price decreases had played a smaller role in the US business cycle.

The sample period used is common to all countries under study, and it runs (including the lagged initial values) from 1972:III to 2001:IV, for a total of $T = 118$ available quarterly observations (See Appendix 2). To find the suitable lag length, we consider different tests, namely, the Sims' (1980) modification of the Likelihood Ratio test, as well as the Akaike, Schwarz and Hannan-Quinn Criteria. Whenever there is disagreement among the different tests, the optimal lag length is chosen using the Likelihood Ratio test.

3 Empirical results

In this section we analyse the empirical results for the linear and the three non-linear models described in the previous section. While most of these countries in our sample are net oil importing, we also include in our sample two net oil exporting European countries, namely the UK and Norway (see Figure 1).[24] In subsection 3.1 we test for the significance of the different oil price variables and carry out Granger-causality analysis in a multivariate context. We next turn in subsection 3.2 to the examination of the effects of oil price shocks on GDP growth. Before presenting formally the results, we compare the performance of the different specifications considered here in order to focus on that specification preferred for each country. We then present the results on impulse-response functions and accumulated responses, distinguishing between the cases of the net oil importing countries and the two exporting countries under study. We next discuss the results of the variance decompositions. In the cases of both impulse response and variance decomposition analysis, we examine the results for all linear and non-linear specifications, while focusing on the preferred specification for each country. In subsection 3.3 we test for the stability of the oil price coefficients of the GDP equation under the four competing models for each country.

3.1 Testing for significance and Granger-causality

Under this item we investigate the relationship between oil prices and the other variables of the model, focusing on the significance of the impact of oil prices on real activity. We carry out different tests for both linear and non-linear specifications for all countries.

First, we perform the Wald test statistic, which tests the null hypothesis that all of the oil price coefficients are jointly zero in the GDP equation of the VAR model.[25] Table 2 displays the p-values of the Wald test statistic, indicating that we accept the hypothesis that the different oil prices variables (in either linear or non-linear models) are not statistically significant at a 5% critical level in most of the countries considered.[26] This means that oil prices do not appear to have a significant *direct* impact on real activity.[27]

[24] Norway and the UK switched from a position of net oil importing to oil exporting in the 1970s. Canada also switched its position at the beginning of the 1980s (See Figure 1), making it hard to interpret the results for Canada. Since our sample starts in 1972:III, Canada has been a net oil importer during three of the four oil crises considered. As such, we thereafter consider Canada tentatively as a net oil importing country.

[25] Some authors, like for instance Hooker (1999) in the related literature, call this test a multivariate Granger causality test. We reserve this name for some block exogeneity-type tests reported below.

[26] The main exception is the euro area as a whole, in which case all of the non-linear oil price variables are statistically significant at a 5% critical level.

[27] We have also considered the bivariate Granger-causality test, whose null hypothesis is that the oil price variable under consideration does not Granger-cause real GDP growth. The results indicate that the null hypothesis can be rejected in three cases (US, the euro area, and Italy) under the linear model and the oil price increase variables of the non-linear

Second, we test for the significance of oil price variable under consideration for the VAR system as a whole, being the null hypothesis that all of the oil price coefficients are jointly zero in all equations of the system but its own equation (See Table 3). This Likelihood Ratio (LR) test is thus informative in that it could well be that oil prices do not affect GDP directly (as assessed by the Wald test), but through third variables in the system. We find that the oil price variable in the linear model, the positive changes in the asymmetric model, the SOPI, and the NOPI are significant for the system in all of the countries, with the only exception of the US in the linear model. The latter result is consistent with the concerns expressed in the literature about the poor performance of US linear models since the mid-1980s.[28] Moreover, the negative changes in the asymmetric and scaled models are not significant in most countries. These negative changes are only significant in Canada and the UK for both models, and in the US for the former model.[29] The price decrease variable is subsequently eliminated from those asymmetric and scaled specifications in which it is not significant.[30]

Finally, we perform some so-called tests of block exogeneity, including two multivariate Granger-causality tests. We first test the null hypothesis that the oil price variable under consideration is Granger-caused by the remaining variables of the system (See Table 4, line 1 for each country). We generally reject the null hypothesis.[31] Second, we test for whether a given oil price variable Granger-causes the remaining variables of the system (See Table 4, line 2 for each country), obtaining that oil price variables generally Granger-cause the remaining variables of the system at the 5% significance level. The exceptions to this are the linear models of the US and the euro area, as well as the scaled and net specifications for the US. Third, we perform the test for the lack of any relationship between oil prices and the rest of the

approaches. Instead, we cannot reject the null in the cases of Germany, Japan, Canada and Norway. In the cases of France and the UK the results depend on the model considered. More specifically, in France we do not reject the null at the 5% significance level (but we reject it at the 10% level) in the case of the linear model, while we reject it for all oil price increase variables. In the UK we accept the null at the 5% level in all cases but the net specification (although we reject the null at the 10% level also for the latter specification). Furthermore, we accept in all models the null hypothesis that oil price decrease variables do not Granger-cause real GDP growth. (These results are available from the author upon request).

[28] This result for the US is consistent with the concerns expressed in the literature about the poor performance of linear models since the mid-1980s. Already in the late 1980s, Mork (1989) - who also employed a multivariate framework - found that the oil price coefficients were not significant at the 5% critical level in his US GNP equation, showing only borderline significance at the 10% level.

[29] Similar results for Canada and the US are found by Mork *et al.* (1994) using a somewhat different version of the asymmetric specification. The finding that oil price decreases are found to be significant for the US economy, with the implication that we shall thus explicitly consider the impact of the negative oil price variable, contrasts with the approach of most of the studies in the literature who simply omit consideration of oil price decreases in their models.

[30] We have also tested for the null hypothesis that positive and negative coefficients are equal in the VAR framework, obtaining the rejection of null hypothesis in all cases. For this reason, in the cases where the negative movements are significant we consider positive and negative oil prices as separate variables.

[31] The exceptions to this are given by the linear models of the US and Canada (where we can reject the null at the 10% level), as well as the linear model of Italy, the net model of Canada and all models of Norway.

system, which is reported in the third lines for each country in Table 4. This test permits us to reject the hypothesis that there is no relationship between oil prices and the rest of the system in all countries but Norway - results which are robust across model specifications.[32]

In sum, the results show that the interaction between oil prices and macroeconomic variables is generally significant, with the direction of causality going in at least one direction in all countries and in both directions in most countries.

3.2 Macroeconomic impacts of oil price shocks: Linear and non-linear specifications

In this subsection, we assess empirically the effects of oil price shocks on economic activity. In order to simplify the presentation of the results, we distinguish between linear and non-linear models, focusing on the preferred model specification for each country. We first present, under item 3.2.1, the results derived both from the examination of the impulse-response functions and from their corresponding accumulated responses. This analysis is preceded by an assessment of the relative performance of different linear and non-linear specifications, which allows us to focus on the preferred model for each country. In item 3.2.2, we study the sources of variation of each variable of the VARs by means of variance decomposition. Under final item 3.2.3 we present the stability analysis of the GDP equations of the VAR system.

3.2.1 Impulse response functions and accumulated responses

Under this item we examine the effects of oil prices on GDP growth in terms of both orthogonalised impulse-response functions and accumulated responses for the linear and the non-linear specifications of the model. Figure 2 represents the orthogonalised impulse response functions of GDP growth to one standard deviation oil price shock with their corresponding two standard error bands in the linear case, while Figures 3.1 through 5 represent those for non-linear specifications of the model.[33] In turn, the first five lines of Table 5 for each country reports the accumulated responses of GDP growth to an oil price shock normalised to correspond to a 1% increase in the linear model, while the last fifteen lines for each country reports those obtained in the non-linear models under study. In order to better understand the mechanisms behind the impulse and accumulated responses of GDP growth, we have analysed impulse

[32] Consideration of all tests reported in Table 4 suggest that the result for Norway is driven by the already mentioned lack of response of oil prices to the remaining variables of the system.

[33] In the linear model, the optimal lag length was found to be four for all countries but France, Italy and Norway, where the appropriate lag length is three. In the case of the non-linear models, the optimal lag lengths remain the same as in the linear specification for all countries in which the oil price measures are statistically significant. The only exception to the latter statement was Canada in the case of the net specification, where the optimal lag is no longer four but three.

and accumulated responses of other variables.[34] We find that one of the key channels playing a role in the effect of oil prices on real activity is related to the real effective exchange rate. Table 6 reports accumulated responses of REER to an oil price shock normalised to correspond to a 1% increase in the corresponding current oil price measure under study, the Table's first five lines referring to the case of the linear model and the last fifteen lines referring to the corresponding non-linear specification of the model under consideration.[35]

We describe the results for the three non-linear specifications, namely the asymmetric, scaled and net approaches at the same time, stressing the results obtained for the preferred model. We choose to do this because the results tend to be qualitatively similar across non-linear models. When discussing the results, we distinguish between the results for net oil importing as opposed to those for the two exporting countries here considered. While the linear model supposes that the effects of an oil price increase and those of a decline are totally symmetric, non-linear specifications allow for differential impacts of oil shocks of the same magnitude and opposite sign. [36] We have reported in subsection 3.1 that the negative movements of oil prices in non-linear specifications are not statistically significant in most of the countries under study. We describe here the effects of positive oil shocks for all specifications in all countries (as captured by Figures 2, 3.1, 4.1, and 5), then turning to the impacts of negative oil shocks for the asymmetric and scaled specifications in the few countries in which oil price decrease variables are significant (see Figures 3.2 and 4.2).[37] As far as the accumulated responses are concerned, the relevant lines in Tables 5 and 6 contain empty cells in the case of those countries for which the negative oil price measure was previously found not to be significant.

As mentioned before, let us start the analysis of results by evaluating the relative performance of the different linear and non-linear specifications for the whole VAR system of equations. This can be done in two different ways. First, the precision of the estimation of the impulse responses can be gauged by looking at the confidence bands as shown in Figures 2, and 3.1 through 5. We find that the non-linear

[34] We only report figures referred to the accumulated impacts of oil shocks on other variables for the preferred specification (See Figure 6). We do not report any other figures or tables concerning the oil shock effects on other variables, but summarily highlight the main conclusions. (These results are available from the author upon request).

[35] We also present in the Figures of the Annex the impulse response functions for an alternative ordering, including the comparison with the baseline ordering. We report the results for scaled specification only. The results for all other specifications are available from the authors upon request.

[36] In what follows, we refer to positive oil shock as one where the price of crude oil increases. Such measure is given by the standard oil price changes in the linear model, and by variables o^+, $SOPI$, and $NOPI$ in the non-linear specifications. Conversely, we refer to negative oil shock as one where the price decreases.

[37] We do not describe the results of the negative oil shocks in the linear model, since they are of the same magnitude than those of the positive oil shocks but with opposite sign.

models yield impulse responses that are comparably precise. In four cases (the US, Canada, the euro area and Germany) a non-linear specification yields a more accurate representation than the linear model, while the linear model seems to dominate only in the case of the UK's impulse responses. In the remaining cases - namely France, Italy and Norway -, the linear model and at least one non-linear approach produce similarly precise results. Second, we assess the goodness of fit of the four different model specifications for each country. Given that these models are non-nested, we look at selection criteria such as the Akaike Information Criterion (AIC) and Schwarz Bayesian Information Criterion (BIC). Table 7 reports the AIC and BIC for all countries obtained from each econometric specification. On the basis of these two criteria, we conclude that the scaled specification performs in all countries somewhat better than the other approaches used in the present study.[38] This result indicates that it is important to consider not just whether oil prices increase or decline (and by how much), but also the environment in which the movements take place. An oil shock in a stabile price environment is likely to have larger economic consequences than one in a volatile price environment. In this regard, the scaled model more specifically highlights the importance of controlling for the time-varying conditional variability of oil price shocks.

3.2.1.1 Results for net oil importing countries

In the case of positive movements in oil prices, we observe that despite the fact that each of the countries responds somewhat differently to an oil price shock, there is a similar pattern of impulse response functions. In fact, we observe that the real impact of oil prices is negative in the short-term with the only exception of Japan where it is positive. The largest negative short-run influence takes place within the year of the shock, being reached in either the third or the fourth quarter after the shock depending on the country and on the specification under consideration.[39] The impact of the shock becomes very small after the first year, dying out almost completely after three years.

Table 5 indicates that the accumulated responses of GDP growth to a positive oil price shock in the linear and non-linear models are qualitatively similar. An oil price shock has a negative accumulated effect on GDP growth in all oil importing countries but Japan.[40] With regard to the magnitude of the

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[38] Hamilton (2003) also favours the scaled specification in his study of the US economy. Jiménez-Rodríguez (2002) finds that a kernel semiparametric specification could improve even upon the scaled specification in the case of the US. Given that the estimation of a kernel model requires a longer sample that the one available for most of the countries represented here, this methodology was not considered in the present paper.

[39] The only exception to this is the asymmetric case in the US, where the maximum negative effect occurs during the fifth quarter after the shock.

[40] As with the impulse responses, the accumulated result is not robust to changes in the order of the VAR. The second-order VAR yields a negative accumulated impact of oil shocks in Japanese GDP growth, even though the loss of growth is in this case relatively small (slightly less than 0.002% after 12 periods in the linear case). A negative real impact of oil prices for Japan was also found by Lee *et al.* (2001) for a similar lag range (5 to 7 months in their case).

accumulated response, the largest negative accumulated effect of an oil price shock is on the US economy.[41] Considering the linear model, we see that the accumulated loss of GDP growth after a 100% oil price shock in the US is 3.2%, which is at least double the size of that observed in most of the other net oil importing countries. One important mechanism that helps explain the larger negative effects of an oil price hike on US GDP growth is that the US is the only oil importing country for which the linear model yields a real exchange rate appreciation after such shock (see the first five lines in Table 6).[42] Euro area countries Germany, France and Italy also exhibit relatively large accumulated real impacts of a positive oil price shock, which is consistent with a considerable oil dependency. The real effective exchange depreciation induced by the shock offsets only in part the negative impact on output growth predominant in these countries.[43] Regarding non-linear specifications, we observe that Canada is the only country other than the US for which an oil price hike is found in a robust fashion to induce an exchange rate appreciation in effective terms.[44] Moreover, the non-linear specifications yield larger negative accumulated impacts on GDP growth than in the linear case, with the $SOPI$ variant showing a larger impact than the $NOPI$ approach and the latter in turn producing larger effects than in the o^+ case. For instance, the output loss of a 100% shock to oil prices increases from around 3.5% to a range of 4 to 6% in the US, from values below 2% to levels ranging from 2 to 6% in the case of individual euro area countries, and from values below 1% to levels ranging from 1 to 4% in the case of the euro area as a whole. The only exception to the statement that non-linear models yield larger real impacts of oil shocks than the linear model is the net specification for Canada, where the losses of GDP growth rate during the first year and a half after the shock are smaller than in the linear case. Except for this case, in Canada the accumulated output loss from a 100% oil shock increases from very small values to around 1%.

The unexpected result of a positive reaction of Japanese GDP growth to an oil price increase is common to linear and non-linear models. This result can be rationalised in terms of the peculiar circumstances undergone by the Japanese economy during the period under study. Indeed, this economy proved rather resilient to the oil shocks of the 1970s and early 1980s despite its large dependence on oil,[45] while it

[41] Burbidge and Harrison (1984), Mork *et al.* (1994), and Bjϕrnland (2000) also find a similar result.

[42] Amano and van Norden (1998) also find that an oil price hike in the US is accompanied by an appreciation of its real effective exchange rate. Also broadly in line with our results, Maeso-Fernandez *et al.* (2002) report that in the euro area oil price increases induce a REER depreciation.

[43] The accumulated impulse response for the euro area as a whole shows a much smaller negative real impact of the oil shock. This may be partly attributed to econometric problems relating to the aggregation of the transmission mechanisms of the different individual countries which formed the euro area only at the end of our sample.

[44] See Table 6. The fact that the Canadian dollar exhibits a real effective appreciation represents a difference with respect to the linear approach. Among European net oil importers, the euro area as a whole and France exhibit a real effective exchange rate depreciation which is robust across non-linear specifications (and also observed in the linear model). In Italy and Germany, the sign of the accumulated impact on REER depends on the non-linear specification in question.

[45] Mork (1994) also reports that, among the industrialised countries, the Japanese economy was the least hurt by higher

failed to benefit from the declines of oil prices observed since the mid-1980s as the country started exhibiting a negative economic performance traced to structural factors. Finally, it is worth noting that the exceptional results for Japanese output growth after an oil shock are not robust to changes in the order of the VAR.[46]

In the case of decreases in oil prices, we find evidence of a jointly significant negative impact on US real GDP growth according to the asymmetric specification - a result that contrasts with the earlier literature which found no evidence of any significant effect. The positive impulse responses for GDP growth start after the first year, contributing to turn positive the medium-term accumulated effects. However, the significance of this effect vanishes when we look at the results obtained using the scaled model - a somewhat better specification in terms of the analysis done at the beginning of this subsection. In Canada, the asymmetric and scaled approaches both yield the surprising result that a lower oil price induces a fall in GDP growth and a real effective exchange-rate appreciation. One possible interpretation of this unexpected result is that the largest oil price decreases occurred after the early 1980s, that is, after the country switched from net oil importer into net oil exporter.

In sum, we find that the output growth of all countries but Japan responds negatively to an increase in oil prices. Focusing on the preferred (scaled) specification, we obtain the following results. The largest negative impact on GDP occurs in the fourth quarter after the shock in all countries but France and Italy, where it takes place in the third quarter after the shock. The effects of the shock die out almost completely after three years in all countries. An increase of a 100% yields a negative accumulated effect on GDP growth of around 5% in the US[47] and Germany, 4% in Italy, 3% in France, 2% in the euro area, and 1% in Canada. The appreciation of the real exchange rate in the US and Germany contributes to explain why the larger negative impacts on economic activity are found in these two countries.[48] France, Italy and the euro area as a whole also exhibit considerable negative impacts on their real GDP despite the fact that the depreciation of their real effective exchange rates plays a partly offsetting role. Turning to variables other than GDP and REER, the results indicate that an oil price shock increases inflation and long-term interest rates in all countries but Germany, as well as the short-term interest rates in all countries with the exception of the US, Germany and the euro area.[49] Regarding the impact of oil shock

oil prices following the Yom Kippur War started in 1973.

[46] For instance, when we use a VAR with two lags, the largest short-run response of GDP growth to oil shock is negative and takes place during either the third (linear and scaled specifications) or the fourth (asymmetric and net specifications) quarter after the shock (see Figure 7).

[47] This result for the US is broadly in line with the elasticity estimated in the related literature. See, for example, Mory (1993), and Mork *et al.* (1994).

[48] In the German case, the REER appreciation does not take place in the net specification. Instead, the REER depreciates slightly, contributing to reduce the decline in GDP to some 4%.

[49] In these three cases both interest rates actually fall after one year.

on real wage, we observe a decline in all countries with the exception of Canada and Japan.[50] These results are plausible and provide evidence of transmission mechanisms - other than the exchange rate channel - playing the expected roles in most countries. Furthermore, oil price increases generally have an impact on GDP growth of a larger magnitude than that of oil price declines, with the latter being statistically insignificant in all countries with the exception of Canada. In particular, Canada responds negatively to a decline in the oil price variable, being the largest negative impact in the third quarter after the shock and with an accumulated output loss after a 100% decline in oil prices of around 2.5%. These losses may be related to the fact that there is a larger real exchange rate appreciation after such shock. Moreover, despite the fact that an oil price decline reduces inflation and, consequently, increases real wages, the short- and long-term interest rates rises.

3.2.1.2 Results for net oil exporting countries

Regarding positive movements in oil prices, we observe that there is a similar general pattern in the reaction of British and Norwegian real GDP growth to oil prices within the first year, with a positive response during the first two quarters followed by a negative response during the next two quarters. After the first year, the impulse responses differ somewhat in the two countries, which leads to the difference in Table 5 in terms of the accumulated impact beyond the short term, with overall a positive real impact in Norway and negative real impact in the UK. This means that the UK exhibits a surprising behaviour: while it is expected that an oil price shock has positive effects on the GDP growth for a net oil exporting country, an oil price increase of 100% actually leads to a loss of British GDP growth rate of more than 1% after the first year in all specifications. An extensive literature has highlighted that this unexpected result has to do with the fact that oil price hikes led to a large real exchange rate appreciation of the pound (Dutch disease), a fact that is captured in the results presented in Table 6. In connection with this, Table 6 also shows that the Norway's real exchange rate appreciation after the first year is much weaker than in the British case, thereby lessening the positive impact of oil shock on Norwegian GDP growth by a considerably smaller amount.[51] With respect to the magnitude of the accumulated response,

[50] This is also the case in the euro area between the third and the seventh quarters after the shock.

[51] In addition to the exchange rate responses, adjustments in real wages and interest rates provide additional insights as to why the oil shock improves Norway's output performance while harming the British economy. Indeed, an oil price increase leads to a stronger positive adjustment in interest rates in the UK, together with a different behaviour of real wages - which decrease in the UK but rise in Norway. Real wage developments are in line with a stronger inflationary impact of oil prices in the British case.

In her study of the manufacturing production of the UK and Norway, Bjϕrnland (1998) finds that an oil shock has a positive real impact in the case of Norway and an adverse real effect in the British case. This study also highlights the role of the labour market, while tracing some of the differential behaviour of the two economies to the response of unemployment (rather than real wages). Bjϕrnland also mentions that, in the case of Norway and unlike the British case, deliberate the net and scaled specifications (in both the British and Norwegian cases) yield accumulated impacts on GDP growth after three years of similar magnitude, which is for both models somewhat larger than the overall effect captured by the asymmetric and linear approaches. Indeed, in the UK the output loss of a 100% shock to oil prices increases from less than 2% in the asymmetric and linear approaches to above 2% in the net and scaled models, while in Norway the output gain rises from values of around 1% in the former specifications to levels above 2% in the latter.

Oil price decrease variables are only significant in the case of the UK. Figures 3.2 and 4.2 show that the shapes of the impulse-response functions of British GDP growth to changes in the o^- and $SOPD$ variables are largely similar. In accumulated terms, Table 5 reports that both the asymmetric and scaled models exhibit a positive accumulated effect,[52] which is somewhat larger in the latter case.

In sum, we observe, focusing on the preferred (scaled) specification, that whereas the Norwegian output growth responds positively to an increase in the oil price variable with an accumulated gain around 2.5% after an increase of a 100%, the British output growth is "unexpectedly" negatively affected with an accumulated loss of around 2%. The difference in the responses between the two countries can be explained in part by the fact that there is a larger exchange rate appreciation in the UK, and in part by the different adjustments in inflation, interest rates and real wages. In particular, the British inflation and interest rates suffer from stronger positive adjustment than those of Norway, and whereas the Norwegian real wage increases that of the UK decreases. Furthermore, declines in the oil price variable are only significant in the UK, with this country behaving as one would expect from an oil importing country, i.e., showing an accumulated output gain of around 6% following a 100% decline in oil prices. When comparing the impact on British GDP growth of oil price increases with that of oil price decreases, we see that the latter have a much larger effect (about three times as large). Moreover, we observe that an oil price decline leads to a large real exchange rate depreciation, increases real wages, and reduces the short- and long-term interest rates, as well as inflation in the first year.

3.2.2 Variance decomposition analysis

Tables 8.A through 8.D present the results of the forecast error variance decomposition, which shows how much of the unanticipated changes of the variables are explained by different shocks.[53] The variance

subsidies were implemented to maintain manufacturing output in periods of high oil prices.

[52] Again, in light of the real effective depreciation documented in Table 6, the impact of a fall in oil prices on real GDP growth can be interpreted as a Dutch disease effect operating in reverse direction.

[53] We report, but do not analyse the variance decompositions for Japan. The reason is that the basic models for this country are not well behaved. Under item 3.2.1 we have explored the reasons for this and provided better results for an alternative lag specification.

decompositions suggest that oil price shocks are a considerable source of volatility for many of the variables in the model. For real GDP, oil prices are together with short-term interest rates the largest sources of shock other than the variable itself for most of the countries. Innovations in short-term interest rates represent monetary shocks in our model. The contribution of oil prices and short-term interest rates to GDP variability ranges in most of the cases between 4% and 10%. The only two (partial) exceptions to the leading role of these two variables are given by oil prices in Canada and short-term interest rates in Italy, for which countries other variables - inflation and real wages, respectively - play a more important role. In the case of Norway, shocks to real wages and REER exhibit a contribution to output volatility which is comparable to that of oil prices and short-term interest rates.

We now turn to a comparison of the role of oil prices and short-term interest rates regarding GDP variability between linear and non-linear models, focusing on the preferred (scaled) specification. We find that shocks to oil price variables tend to explain more of output volatility in non-linear than in linear specifications. In contrast, monetary shocks contribute to output volatility in similar percentage in both linear and non-linear models. In consequence, the number of countries for which oil price shocks contribute to GDP volatility more than monetary shocks is higher in non-linear models than in the linear specification. Indeed, while this is the case in only two countries for the linear model, it applies to at least five countries (including the euro area region) when we use a non-linear approach - and exactly five in the case of the scaled model. For the latter model, there are four countries (US, France, Italy and the UK) and a region (the euro area) for which oil price shocks explain between 8% and 12% of output variability.

Furthermore, we find that part of the movements in the short-term interest rate arise from changes in oil prices. For the scaled model, the oil price variable contributes somewhat in the range of 5% to 15% of the volatility in the short-term interest rate, depending on the country. This result can in part be interpreted as a reaction of monetary policy to oil price shocks.

In order to compare our results with those obtain in the related literature, we focus on the US case while also referring to Bjϕrnland (2000) who looks at variance decompositions for countries other than the US (namely, Germany, the UK, and Norway). Dotsey and Reid (1992) found that oil prices explain between 5% and 6% of the variation in GNP, whereas shocks to the federal funds rate explain about 5% and 8% of the variation in GNP in their preferred specification. In the case of both variables, these estimates are somewhat below the contributions reported in the present paper, while still being roughly in line with them. Our finding on the contribution of oil shocks to output variability seems to lie within the range of estimates computed in more recent studies. On the low side of this range, Brown and Yücel (1999) show evidence that oil price shocks explain little of the variation in output, compared with the much larger role played by monetary shocks. On the high side of the range, Bjϕrnland (2000) finds that oil price shocks explain 18% of the GDP variance in the US. This author also studied the contribution of oil shocks to GDP variability for some European countries, estimating it at 8% in Germany, 9% in the UK, and 5% in Norway. These figures are roughly in line with the ones computed here. Overall, our results are thus roughly consistent with the findings reported in the literature.

3.2.3 Stability test

In this subsection we investigate the stability of the oil price coefficients in the GDP equation of the VAR model. We do this for each country, considering in turn each of the four specifications used in the paper. The tests we compute are the Andrews's (1993) and Andrews and Ploberger's (1994) tests. The results are reported in Table 9.

The basic idea behind these stability tests is to compare the econometric results for the GDP equations in the first part of the sample with those obtained in the last part of the sample. More technically, we define the first part of the sample to be $T_1 = [\pi T]$ and the last part of the sample to be $T_2 = [(1-\pi)T]$, where π is some arbitrary fraction that we set equal to 30%, which determines that the period between T_1 and T_2 lies between 1981:III and 1993:II. We then look for a possible breakdate t_1 between T_1 and T_2. Let the GDP equation of the VAR be written in the following way:

$$y_t = a_0 + \alpha' x_{0t} + \beta_1' x_{1t} + \beta_2' x_{1t}\delta_{[t>t_1]} + \gamma' x_{2t} + \varepsilon_t \tag{3.1}$$

where y_t is the real GDP growth; x_{0t} and x_{1t} are p-dimensional vectors which contain lags in y_t and in oil price growth, respectively; x_{2t} is a $((n-2)\times p)\times 1$ vector which contains lags in all of the other variables of the VAR model.[54]

Let $F(t_1)$ be the Wald test of equality of the coefficients β_1 and β_2 under the null hypothesis that there is not a structural break, that is,

$$F(t_1) = \frac{(T-k)(RSS_0 - RSS_1)}{RSS_1} \sim^a \chi^2_p$$

where RSS_0 is the residual sum of squares from OLS estimation of (3.1) under the null hypothesis of no structural break, and RSS_1 is the corresponding to unconstrained OLS estimation of (3.1).

Andrews (1993) proposes to test for the presence of a break point by the following test statistic:

$$\sup F = \sup_{T_1 \le t_1 \le T_2} F(t_1)$$

If the observed statistic passes the critical value, then the date t_1 that satisfies $\sup_{T_1 \le t_1 \le T_2} F(t_1)$ will be the estimated breakdate. Likewise, Andrews and Ploberger (1994) suggest two alternatives test statistics to

[54] Notice that t_1 is a nuisance parameter that appears under the alternative hypothesis, but not under the null hypothesis.

verify the existence of a break point:

$$Avg\ F = (T_2 - T_1 + 1)^{-1} \sum_{t_1=T_1}^{T_2} F(t_1)$$

$$Exp\ F = \ln \left[(T_2 - T_1 + 1)^{-1} \sum_{t_1=T_1}^{T_2} \exp(F(t_1)/2) \right]$$

The results in Table 9 suggest that, in general, there is no evidence of instability of oil price coefficients at a 5% significance level for any specification and for all countries. The only exception is the linear specification for the euro area, where we find evidence of instability in 1981:IV.

4 Concluding remarks

This paper studies the effects of oil price shocks on the real economic activity of the main industrialised OECD countries, distinguishing between net oil importing and exporting countries. We focus on the relationship between oil prices and GDP growth, which is analysed in terms of vector autoregressions by using four specifications, namely a linear model and three leading non-linear specifications proposed in the literature. We find evidence of non-linear effects of oil price on real economic activity, with oil prices (or a transformation thereof) having different impacts on real output when they increase than when they fall. This contrasts with the linear approach in which oil prices are assumed to have symmetrical impacts on real activity.

As a first step, Granger causality-type analysis permits us to conclude that the interaction between oil variables and macroeconomic variables is found to be significant, with the direction of causality going in at least one direction in all countries and in both directions in most countries. The results we obtain from vector autoregressions are broadly consistent with the expectation that the real GDP growth of oil importing economies suffers from increases in oil prices in both linear and non-linear models. With regard to the two net oil exporters in our sample, Norway benefits from oil price hikes while in the UK a rise in oil prices is found to have a significant negative impact on GDP growth. These contrasting results for oil exporting countries can be traced to a sharper real exchange-rate appreciation in the case of the UK. In the case of net oil importer Japan, the results obtained using the optimal order of the model (i.e. four lags) indicate a positive association between oil prices and real performance. This unexpected result can be rationalised in terms of the peculiar circumstances undergone by the Japanese economy during the period under study. Furthermore, the unexpected result is not robust, being reversed in the case of a second-order vector autoregression.

A distinction between the effects of oil price increases and decreases is possible in the case of two types of non-linear models, namely the asymmetric and scaled specifications. By using these approaches, we find that a decline in oil prices affects significantly only a few countries. For instance, we observe that a fall in oil prices have a positive impact on the US economy (after the first year following the oil shock) and on the British economy, while it has a negative effect in Canada. The latter result can be explained by the fact that large decreases in oil prices took place after the early 1980s, which is when the Canadian economy was switching from a net oil importer into a net oil exporter.

Inspection of the confidence bands around impulse responses allows us to conclude that the non-linear models yield results that are comparably accurate. Moreover, the accuracy of impulse responses in the non-linear specifications tends to be higher than in the case of the linear model, the latter only appearing to dominate in the case of the UK. Additionally, information criteria indicate that the scaled specification performs somewhat better than the other models. This indicates that, for the analysis of output growth, it is important to consider the environment in which oil price changes take place. In particular, the scaled model, by controlling for the conditional variability of oil shocks, highlights that a given oil price change has a larger impact in a context of previously stable prices than in one of volatile market behaviour.

With regard to the size of the responses, non-linear specifications tend to yield larger real impacts of oil price shocks compared with the linear model. For the sake of concreteness, let us focus on the preferred (scaled) specification. We find that in the US the output loss resulting from a 100% oil price hike increases from around 3.5% in the linear approach to 5% in the scaled case. Among the other oil importing countries, the respective increase in the output loss arising from the same shock is from around 2% to a range of 3 to 5% in the case of individual euro area countries, from less than 1% to 2% in the case of the euro area as a whole, and from very small values to around 1% in Canada. Among the oil exporters in our sample, in the UK the corresponding rise in the output loss from the same shock is from less than 2% to over 2%, while in Norway the output gain increases from 1% to more than 2%.

Our variance decomposition analysis indicates that oil price shocks are a considerable source of volatility for many of the variables in the model. For real GDP, oil prices shocks are, together with monetary shocks, the largest source of variation other than the variable itself for most of the countries. Finally, we find no evidence of instability of the oil price coefficients in the GDP equations for any specification but the linear model of the euro area.

Appendix 1: Unit root tests

Section 2 analyses the order of integration of the different series used in the paper on the basis of four different unit root tests in addition to the standard Augmented Dickey-Fuller (ADF) test. These tests are the DFGLS and P_T tests of Elliott *et al.* (1996), and the DFGLSu and Q_T tests of Elliott (1999), both of which potentially yield much larger power than the standard ADF test.

Consider the data generating process of the form:

$$\begin{aligned} y_t &= z_t + u_t \\ u_t &= \vartheta u_{t-1} + v_t \end{aligned}$$

where $\{z_t\}$ is the deterministic component, $z_t = (1, t)'$, and $\{v_t\}$ is an unobserved stationary zero-mean-error process whose spectral density function is positive at zero frequency. It is our aim to find methods for testing whether y_t can be considered to be integrated of order zero, or simply $I(0)$. To do so, we test whether $\vartheta = 1$ (i.e. y_t is integrated of order one, or simply $I(1)$) against the $|\vartheta| < 1$ (i.e. y_t is $I(0)$).

The DFGLS assesses whether $\rho = 0$ (i.e. y_t is $I(1)$) against the one-sided alternative that $\rho < 0$ (i.e. y_t is $I(0)$) in the following regression:

$$\Delta y_t^{\bar{\rho}} = \rho y_{t-1}^{\bar{\rho}} + \sum_{i=1}^{k} \rho_i \Delta y_{t-i}^{\bar{\rho}} + \varepsilon_t \tag{A.1}$$

where $y_t^{\bar{\rho}}$, the locally demeaned and detrended process under the local alternative of $\bar{\rho} = 1 + \bar{c}/T$ with $\bar{c} < 0$, is given by:

$$y_t^{\bar{\rho}} = y_t - \hat{\beta} z_t$$

being $\hat{\beta}$ the least-square regression coefficient of y^l on z^l (denoting by L the lag operator):

$$\begin{aligned} y^l &= [y_{1,}(1 - \bar{\rho}L)y_2, ..., (1 - \bar{\rho}L)y_T] \\ z^l &= [z_{1,}(1 - \bar{\rho}L)z_2, ..., (1 - \bar{\rho}L)z_T] \end{aligned}$$

The P_T test is defined as follows:

$$P_T = [S(\bar{\rho}) - \bar{\rho}S(1)]/\hat{\varpi}^2$$

where $S(\bar{\rho})$ and $S(1)$ are the sums of squared error from a GLS regression with $\rho = \bar{\rho}$ and $\rho = 1$, respectively. Let $\hat{\varpi}^2$ the autoregressive estimate of the spectral density at frequency zero of v_t, defined as:

$$\hat{\varpi}^2 = \hat{\varpi}_{ek}^2/(1 - \hat{\rho}(1))^2$$

with $\hat{\varpi}^2_{ek} = (T-k)^{-1}\sum_{t=k+1}^{T}\hat{e}^2_t$, $\hat{\rho}(1) = \sum_{i=1}^{k}\hat{\rho}_i$, and $\hat{\rho}_i$, $\{\hat{e}^2_t\}$ obtained from the regression $(A.1)$.

The DFGLSu and the Q_T are defined similarly to the DFGLSu and the P_T, respectively, with the difference that the initial observation of the locally detrended process is now drawn from the unconditional distribution (i.e. $y^l = [(1-\bar{\rho})^{1/2}y_{1,}(1-\bar{\rho}L)y_2, ..., (1-\bar{\rho}L)y_T]$ and $z^l = [(1-\bar{\rho})^{1/2}z_{1,}(1-\bar{\rho}L)z_2, ..., (1-\bar{\rho}L)z_T]$) (See Elliott, 1999).

Elliott *et al.* (1996) and Elliott (1999) report the asymptotic critical values for both the model with a constant and the model with a constant and a deterministic trend.[55] In addition, we use, in the no deterministic parameters case for the DFGLS test, the standard Dickey-Fuller critical values.

[55] When the DFGLS and the P_T tests are used, the authors suggest setting $\bar{c} = -7$ for the model with a constant, and $\bar{c} = -13.5$ for the model with a constant and a deterministic trend. Likewise, when the DFGLSu and Q_T tests are considered, Elliott (1999) recommends setting $\bar{c} = -10$ in both the model with a constant and the one with a constant and a deterministic trend.

Appendix 2: Data sources

The data used in this paper are from 1972:III to 2001:IV. The corresponding sources are as follows:

Real GDP: IFS, line 99bvr except in the following cases: for Japan, OECD data (line NAGVVO01); for Norway, OECD data (line 582027KSA) up to 1978:I, and from that date on (line NAGVTT01.NCALSA); and for the euro area the data come from Fagan *et al.* (2001) up to 2000:IV and from then on the OECD data (line EUVNBQRSA 1995.S1).

Nominal Oil Price: IFS, UK Brent price (line 11276AAZZF).

US Producer Price Index: IFS, line 63.

Real Oil Price: Nominal Oil Price deflated by the US Producer Price Index.

Real Effective Exchange Rate: OECD data from Main Economic Indicators, which is based on consumer price indices, line CCRETT01.IXOB, except for the euro area. For the euro area, the data come from Fagan et al. (2001) up to 1998:IV and from then on the data come from ECB's DESIS database (line EFFCPI.IND). This series is instead based on GDP deflator indices.

Short-term Interest Rate: IFS, line 60c (Treasury Bill Rate) except in the following cases: for Germany, Italy, Japan, and Norway, line 60b (Money Market Rate); and for the euro area, the data come from Fagan *et al.* (2001) up to 2000:IV, and from then on the monthly data come from ECB's DESIS database (line IR_EURIBOR_3M.AV.REUTERS). The latter series was aggregated from monthly into quarterly data by taking averages.

Long-term Interest Rate: IFS, line 61 (Government Bond Yield) except in the following cases: for Japan, from 2001:I onwards, OECD data (line IRLTGV02.ST); and for the euro area, the data come from Fagan *et al.* (2001) up to 2000:IV, and from then on the monthly data come from ECB's DESIS database (line IR_L.AV.REUTERS). The latter series was aggregated from monthly into quarterly data by taking averages.

Wage: OECD data, line LCEAMN01 except in the following cases: for Japan, OECD data (LCEAMN03) (these data are adjusted for seasonality by means of X11 Multiplicative Adjustment Method); for US and Canada, IFS data (line 65EY); and for the euro area, the data come from Fagan *et al.* (2001) up to 1994:IV, and from then on the data come from Eurostat-ESA database, line UNLACO.0000.TTTT.D.U.I (Unit Labour Cost).

Consumer Price Index: OECD data, line CPALTT01 except in the following cases: for Japan, line CPALCY01 (these data are adjusted for seasonality by means of X11 Multiplicative Adjustment Method); and for the euro area, the data come from Fagan *et al.* (2001) up to 2000:IV, and from then on the data from IFS database (line 64h).

Real Wage: Nominal Wage deflated by the corresponding CPI.

References

[1] Amano, R., and van Norden, S. (1998), "Oil Prices and the Rise and Fall of the US Real Exchange Rate", *Journal of International Money and Finance* 17: 299-316.

[2] Andrews, D. (1993), "Tests for Parameter Instability and Structural Change with Unknown Change Point", *Econometrica* 61: 821-856.

[3] — and Ploeberger, W. (1994), "Optimal Tests When a Nuisance parameter is Present Only Under the Alternative", *Econometrica* 62: 1383-1414.

[4] Bacon, R. W. (1991), "Rockets and Feathers: The Asymmetric Speed of Adjustment of U.K. Retail Gasoline Prices to Cost Changes", *Energy Economics* 13: 211-18.

[5] Balke, N., Brown, S. and Yücel, M. (1998), "Crude Oil and Gasoline Prices: An Asymmetric Relationship?", *Federal Reserve Bank of Dallas Economic Review*, First Quarter: 2-11.

[6] Bernanke, B., Gertler, M. and Watson, M. (1997), "Systematic Monetary Policy and the Effect of Oil Price Shocks", *Brookings Papers on Economic Activity* 1: 91-142.

[7] Bjϕrnland, H. (1998), "The Economic Effects of North Sea Oil on the Manufacturing Sector", *Scottish Journal of Political Economy*, 45(5): 553-585.

[8] — (2000), "The Dynamic Effects of Aggregate Demand, Supply and Oil Price Shocks - A Comparative Study", *The Manchester School* 68(5): 578-607.

[9] Bohi, D. (1989), "Energy Price Shocks and Macroeconomic Performance", Washington DC: Resources for the Future.

[10] Brown, S. and Yücel, M. (1999), "Oil Prices and U.S. Aggregate Economic Activity", *Federal Reserve Bank of Dallas Economic Review*, Second Quarter: 16-23.

[11] Burbidge, J. and Harrison, A. (1984), "Testing for the Effects of Oil-Price Rises Using Vector Autoregressions", *International Economic Review* 25(2): 459-484.

[12] Carruth, A., Hooker, M., and Oswald, A. (1998), "Unemployment Equilibria and Input Prices: Theory and Evidence from the United States", *Review of Economic Studies* 10: 271-287.

[13] Darby, M. (1982), "The Price of Oil and World Inflation and Recession", *American Economic Review* 72: 738-751.

[14] Davis, S. (1987), "Allocative Disturbances and Specific Capital in Real Business Cycle Theories", *American Economic Review*, Papers and Proceedings 77: 326-332.

[15] —, Loungani, P. and Mahidhara, R. (1997), "Regional Labor Fluctuations: Oil Shocks, Military Spending, and Other Driving Forces", *International Finance Discussion Paper* No. 578, Board of Governors of the Federal Reserve System.

[16] Dotsey, M. and Reid, M. (1992), "Oil Shocks, Monetary Policy, and Economic Activity", *Federal Reserve Bank of Richmond Economic Review*, July: 14-27.

[17] Elliott, G., Rothenberg, T. and Stock, J.H. (1996), "Efficient Tests for an Autoregressive Unit Root", *Econometrica* 64: 813-836.

[18] Elliott, G. (1999), "Efficient Tests for a Unit Root when the Initial Observation is Drawn from its Unconditional Distribution", *International Economic Review* 40(3): 767-783.

[19] Fagan, G., Henry, J. and Mestre, R. (2001), "An Area-Wide Model (AWM) for the Euro Area", *ECB Working Paper* No. 42.

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

[21] Gisser, M. and Goodwin, T. (1986), "Crude Oil and the Macroeconomy: Tests of Some Popular Notions", *Journal of Money, Credit and Banking* 18: 95-103.

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

[23] — (1988), "A Neoclassical Model of Unemployment and the Business Cycle", *Journal of Political Economy* 96: 593-617.

[24] — (1994), Time Series Analysis, Princeton University Press.

[25] — (1996), "This is What Happened to the Oil Price-Macroeconomy Relationship", *Journal of Monetary Economics* 38: 215-220.

[26] — (2003), "What is an Oil Shock?", *Journal of Econometrics* 113: 363-398.

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

[28] Hooker, M. (1999), "Oil and the Macroeconomy Revisited", *Finance and Economics Discussion Series* No. 43, Board of Governors of the Federal Reserve System.

[29] Jiménez-Rodríguez, R. (2002), “The Macroeconomy and Oil Price Shocks: A Non-linear Approach”, mimeo, University of Alicante.

[30] — (2004), “Oil Price Shocks: Testing for Non-linearity”, *Center for Studies in Economics and Finance Working Paper* No. 115.

[31] Kim, I. and Loungani, P. (1992), “The Role of Energy in Real Business Cycle Models,” *Journal of Monetary Economics* 29: 173-89.

[32] Karrenbock, J. (1991), “The Behavior of Retail Gasoline Prices: Symmetric or Not?” *Federal Reserve Bank of St. Louis Review*, July/August: 19-29.

[33] Lee, K., Ni, S. and Ratti, R. (1995), ”Oil Shocks and the Macroeconomy: the Role of Price Variability”, *Energy Journal* 16: 39-56.

[34] —, Lee, B. and Ratti, R. (2001), “Monetary Policy, Oil Price Shocks, and the Japanese Economy”, *Japan and the World Economy* 13: 321-349.

[35] Lilien, D. (1982), “Sectoral Shifts and Cyclical Unemployment”, *Journal of Political Economy* 90: 777-793.

[36] Loungani, P. (1986), “Oil Price Shocks and the Dispersion Hypothesis”, *Review of Economics and Statistics* 58: 536-539.

[37] Lutkepolh, H. (1990), “Asymptotic Distributions of Impulse Responses, Step Responses, and Variance Decompositions of Estimated Linear Dynamic Models”, *Review of Economics and Statistics* 72: 53-78.

[38] Maeso-Fernández, F., Osbat, C. and Schnatz, B. (2002): "Determinants of the Euro Real Effective Exchange Rate: A BEER/PEER Approach", *Australian Economic Papers* 41(4): 437-461.

[39] Mork, K. (1989), “Oil Shocks and the Macroeconomy when Prices Go Up and Down: An Extension of Hamilton’s Results”, *Journal of Political Economy* 97: 740-744.

[40] — (1994), “Business Cycles and the Oil Market”, *Energy Journal* 15(special issue): 15-38.

[41] —, Olsen, O. and Mysen, H. (1994), “Macroeconomic Responses to Oil Price Increases and Decreases in Seven OECD Countries”, *Energy Journal* 15: 19-35.

[42] Mory, J. (1993), “Oil Prices and Economic Activity: Is the Relationship Symmetric?”, *Energy Journal* 14: 151–161.

[43] Peersman, G. (2003), “What Caused the Early Millennium Slowdown? Evidence Based on Vector Autoregression”, *Journal of Applied Econometrics*, forthcoming.

[44] Rasche, R. and Tatom, J. (1977), “The Effects of the New Energy Regime on Economic Capacity, Production and Prices”, *Federal Reserve Bank of St. Louis Review*, May: 2-12.

[45] — — (1981), “Energy Price Shocks, Aggregate Supply and Monetary Policy: The Theory and the International Evidence”, in K. Brunner and A. H. Meltzer, eds., *Supply Shocks, Incentives and National Wealth*, Carnegie-Rochester Conference Series on Public Policy 14: 9-93.

[46] Rotemberg, J. and Woodford, M. (1996), “Imperfect Competition and the Effects of Energy Price Increases”, *Journal of Money, Credit, and Banking*, 28: 549-577.

[47] Sims, C. (1980), "Macroeconomics and Reality", *Econometrica* 48: 1-48.

Table 1.A
Results of unit-root tests. Output and Exchange Rate variables

	Model with constant and trend					Model with constant					Model without constant	
	ADF	DFGLS	PT	DFGLSU	QT	ADF	DFGLS	PT	DFGLSU	QT	ADF	DFGLS
GDP in Levels												
CAN	-2.67	-1.35	25.88	-2.07	8.98	-1.34	2.44	336.17	-0.57	132.42	4.41	4.41
FRA	-3.20*	-1.79	13.72	-2.45	4.44	-0.71	2.13	315.46	-0.21	87.03	4.01	4.01
GER	-2.95	-3.04**	3.50***	-2.98*	1.93***	-0.27	1.39	161.78	-0.20	68.25	2.59	2.59
ITA	-1.87	-0.76	39.40	-1.38	14.68	-2.10	2.03	322.98	-0.57	115.63	4.33	4.33
JAP	0.94	-0.09	29.13	-0.28	15.48	-1.74	0.84	170.74	-0.63	83.48	2.20	2.20
NOR	-3.18*	-1.12	20.83	-1.97	5.81	-2.22	0.91	107.90	-0.75	33.37	2.35	2.35
UK	-2.42	-2.42	4.58**	-2.43	2.53**	-0.17	1.28	142.99	-0.87	28.66	3.20	3.20
US	-3.37*	-3.41**	3.13*	-3.41**	1.62***	0.18	1.60	233.82	-0.53	42.98	4.24	4.24
EA	-3.49**	-2.48	6.53	-3.19*	2.36**	-0.53	1.96	301.0	-0.16	78.18	4.19	4.19
GDP in First Log-differences												
CAN	-7.09***	-5.41***	2.73***	-6.69***	1.25***	-7.03***	-3.31***	1.93***	-6.91***	1.50***	-1.75*	-1.75*
FRA	-5.41***	-4.96***	1.40***	-4.95***	0.80***	-5.42***	-4.44***	0.77***	-546***	0.69***	-2.67***	-2.67***
GER	-4.02**	-3.72***	6.53*	-3.80***	3.50	-4.24***	-3.48***	1.47***	-4.27***	1.57***	-3.05***	-3.05***
ITA	-6.45***	-4.88***	1.04***	-6.20***	0.00***	-3.71***	-1.86*	9.48	-3.59***	1.22***	-1.99**	-1.99**
JAP	-4.31***	-3.46**	4.68**	-3.63**	2.39**	-3.67***	-1.77*	6..12	-3.75***	4.83*	-2.84***	-2.84***
NOR	-3.48**	-1.68	107.49	-2.08	28.51	-3.17**	-0.14	122.21	-2.24	26.23	-1.88*	1.88*
UK	-3.69**	-2.84*	22.65	-3.38**	5.07	-3.82***	-1.41	23.03	-3.74***	2.64***	-2.00**	-2.00**
US	-3.47**	-2.25	13.57	-2.92	2.23**	-3.48**	-1.10	13.49	-3.36***	0.52***	-1.51	-1.51
EA	-5.21***	-5.14***	0.54***	-4.97***	0.35***	-5.22***	-5.25***	0.14***	-5.23***	0.28***	-1.66*	-1.66*
REER in Levels												
CAN	-2.28	-2.34	6.00*	-2.36	3.32*	-0.46	0.56	29.52	-0.62	23.53	-1.53	-1.53
FRA	-3.85**	-3.66***	2.28***	-3.83***	1.12***	-1.82	-1.63*	3.54*	-1.94	5.14*	-0.91	-0.91
GER	-3.00	-2.96**	3.70***	-3.03*	1.99***	-2.48	-2.40**	1.77***	-2.52*	2.95***	-1.44	-1.44
ITA	-2.53	-2.00	10.61	-2.29	4.93	-2.51	-1.48	5.60	-2.48*	5.00*	-0.58	-0.58
JAP	-2.81	-2.57	2.17***	-2.81	0.84***	-1.52	-0.15	32.69	-1.39	20.34	0.84	0.84
NOR	-2.80	-1.84	11.81	-2.38	3.78	-2.10	-1.57	4.84	-2.09	4.37**	0.14	0.14
UK	-2.62	-2.60*	4.88**	-2.67	2.18**	-2.33	-2.45**	1.69***	-2.43	3.20	0.21	0.21
US	-2.17	-2.11	6.53*	-2.25	3.34*	-2.26	-1.66*	4.25*	-2.25	3.84**	0.13	0.13
EA	-2.00	-1.42	17.35	-2.04	7.79	-2.30	0.05	66.86	-1.99	41.22	1.38	1.38
REER in First Log-differences												
CAN	-4.81***	-4.42***	2.05***	-4.57***	1.01***	-4.79***	-3.52***	1.43***	-4.81***	0.93***	-4.52***	-4.52***
FRA	-5.59***	-4.79***	0.15***	-5.45***	0.04***	-5.58***	-3.23***	1.06***	-5.46***	0.04***	-5.51***	-5.51***
GER	-4.87***	-4.91***	4.08**	-4.87***	2.13**	-4.90***	-4.89***	1.01***	-4.92***	2.33**	-4.78***	-4.78***
ITA	-5.29***	-5.19***	0.56***	-5.30***	1.09***	-5.29***	-5.26***	2.03**	-5.32***	1.09***	-5.28***	-5.28***
JAP	-5.25***	-5.28***	0.28***	-5.25***	0.16***	-5.24***	-5.25***	0.08***	-5.27***	0.16***	-5.17***	-5.17***
NOR	-9.43***	-9.33***	1.60***	-9.45***	0.87***	-9.44***	-8.46***	0.45***	-9.41***	0.87***	-9.47***	-9.47***
UK	-3.64**	-3.67***	0.16***	-3.66**	0.10***	-3.66***	-3.65***	0.06***	-3.66***	0.11***	-3.63***	-3.63***
US	-3.61**	-3.59***	5.50**	-3.63**	2.97**	-3.57***	-3.10***	2.02**	-3.58***	3.17**	-3.60***	-3.60***
EA	-5.37***	-5.38***	0.18***	-5.37***	0.10***	-7.74***	-7.68***	0.45***	-7.77***	0.92***	-7.55***	-7.55***

Notes: Sample is 1972:II-2001:IV for the variables in levels, and starts one quarter later for the variables in first differences. We use data-driven lag selection procedures for the Augmented Dickey-Fuller tests, taking 1.645 as the critical value used for significance of lagged terms and 8 as the maximum number of lags allowed in these procedures into account. The same number of lags is used in the other tests considered. We denote with one/two/three asterisks the rejection of the null hypothesis at a 10%/5%/1% critical levels.

Critical levels used for ADF test are the following:
- In the model with constant and trend: -4.05 (1%), -3.45 (5%) and -3.15 (10%).
- In the model with constant: -3.50 (1%), -2.89 (5%) and –2.58 (10%).
- In the model without constant: -2.59 (1%), -1.94 (5%) and –1.62 (10%).

Critical levels used for DFGLS test are the following:
- In the model with constant and trend: -3.48 (1%), -2.89 (5%) and –2.57 (10%).
- In the model with constant: -2.58 (1%), -1.95 (5%) and –1.62 (10%).
- In the model without constant: -2.58 (1%), -1.95 (5%) and –1.62 (10%).

Critical levels used for PT test are the following:
- In the model with constant and trend: 3.96 (1%), 5.62 (5%) and 6.89 (10%).
- In the model with constant: 1.99 (1%), 3.26 (5%) and 4.48 (10%).

Critical levels used for DFGLSu test are the following:
- In the model with constant and trend: -3.71 (1%), -3.17 (5%) and –2.91 (10%).
- In the model with constant: -3.28 (1%), -2.73 (5%) and –2.46 (10%).

Critical levels used for QT test are the following:
- In the model with constant and trend: 2.05 (1%), 2.85 (5%) and 3.44 (10%).
- In the model with constant: 3.06 (1%), 4.65 (5%) and 5.94 (10%).

Table 1.B
Results of unit-root tests. Price variables

	Model with constant and trend					Model with constant					Model without constant	
	ADF	DFGLS	PT	DFGLSU	QT	ADF	DFGLS	PT	DFGLSU	QT	ADF	DFGLS
Real Oil Price in Level												
All	-2.99	-1.80	17.40	-2.55	6.78	-2.58	-1.41	8.06	-2.49	6.71	-0.06	-0.06
Real Oil Price in First Log-differences												
All	-8.47***	-8.31***	1.23***	-8.17***	0.70***	9.99***	-10.0***	0.52***	-9.92***	0.97***	-10.0***	-10.0***
CPI in Levels												
CAN	-1.64	-0.94	4.74**	-1.44	3.51	-3.65***	-0.59	11.19	-1.59	27.69	0.35	0.35
FRA	-1.66	-1.18	5.44**	-1.60	4.39	-3.34**	-0.46	15.70	-1.49	30.06	0.39	0.39
GER	-1.76	-1.29	13.61	-1.59	6.22	-1.85	0.75	106.64	-0.22	40.41	1.50	1.50
ITA	-2.24	-1.79	0.08***	-2.08	0.37***	-3.39**	-0.80	11.57	-1.47	30.51	-0.32	-0.32
JAP	-5.25***	-0.75	22.41	-1.30	10.50	-5.49***	-0.10	67.12	-1.30	50.16	0.41	0.41
NOR	-0.76	-0.79	9.40	-1.15	5.76	-3.00**	-0.19	22.42	-1.07	25.48	0.52	0.52
UK	-2.69	-0.69	19.28	-1.37	9.24	-4.40***	0.01	37.23	-1.36	35.74	0.96	0.96
US	-1.36	-0.55	17.95	-0.98	8.92	-3.11**	0.11	44.89	-0.93	32.90	0.84	0.84
EA	-1.89	-1.76	1.00	-1.84	2.77	-2.35	-0.20	49.63	-0.69	41.63	0.23	0.23
CPI in First Log-differences												
CAN	-3.19*	-2.15	18.04	-2.79	2.63**	-1.21	-1.35	8.51	-1.33	14.88	-1.16	-1.16
FRA	-3.81**	-2.49	9.00	-3.33**	3.34*	-1.30	-1.34	6.51	-1.36	12.57	-1.22	-1.22
GER	-2.89	-2.91*	4.15**	-2.75	2.24**	-2.38	-1.91*	8.10	-2.49*	11.42	-1.95**	-1.95**
ITA	-2.43	-1.54	41.47	-1.85	11.29	-0.74	-1.15	16.86	-0.93	30.17	-1.30	-1.30
JAP	-3.56**	-3.09**	6.26*	-3.46**	2.84**	-3.97***	-3.00***	13.50	-3.79***	25.69	-4.54***	-4.54***
NOR	-3.34*	-2.58*	8.34	-3.07*	3.29*	-1.35	-1.27	7.35	-1.40	13.23	-1.38	-1.38
UK	-3.37*	-2.65*	6.00*	-3.16*	1.03***	-1.88	-1.91*	4.15*	1.99	7.88	-1.57	-1.57
US	-3.54**	-2.49	7.12	-3.24**	1.73***	-1.64	-1.56	5.62	-1.66	9.77	-1.05	-1.05
EA	-1.90	-1.74	26.39	-.91	8.67	-1.27	-1.25	14.47	-1.39	27.26	-1.79*	-1.79*
CPI in Second Differences												
CAN	-9.62***	-3.39**	7.55	-5.22***	1.98***	-9.62***	-1.51	8.07	-9.48***	0.05***	-9.64***	-9.64***
FRA	-6.23***	-3.24**	11.07	-5.09***	0.74***	-6.25***	-1.60	8.77	-5.78***	0.05***	-6.23***	-6.23***
GER	-5.31***	-2.65*	48.55	-2.84	21.44	-5.29***	-1.79*	25.49	-5.10***	3.39**	-5.23***	-5.23***
ITA	-7.41***	-4.42***	0.15***	-6.25***	7.23	-7.46***	-2.47**	4.59	-6.97**	14.51	-7.38***	-7.38***
JAP	-6.74***	-1.28	94.63	-2.18	25.54	-6.37***	-0.37	65.97	-3.98***	1.73***	-5.91***	-5.91***
NOR	-13.1***	-9.28***	0.14***	-9.44***	0.04***	-13.1***	-6.34***	0.55***	-10.5***	0.03***	-13.1***	-13.1***
UK	-6.11***	-5.62***	0.94***	-6.10***	2.91*	-6.12***	-4.61***	0.56***	-6.10***	2.94***	-6.13***	-6.13***
US	-13.7***	-11.9***	0.71***	-12.6***	0.36***	-13.7***	-9.43***	0.39***	-13.7***	0.33***	-13.7***	-13.7***
EA	-6.31***	-2.99**	14.05	-4.79***	0.06***	-6.33***	-1.47	11.68	-4.87***	0.13***	-6.19***	-6.19***
Real Wages in Levels												
CAN	-3.32*	-1.41	5.48**	-1.91	3.95	-3.81***	-0.11	23.19	-1.00	22.79	0.59	0.59
FRA	-3.28*	-1.78	2.80***	-2.21	3.90	-3.57	-0.41	17.90	-1.23	27.70	0.16	0.16
GER	-2.00	-1.03	6.78*	-1.36	3.96	-2.00	0.19	71.11	-0.34	38.23	0.85	0.85
ITA	-2.55	-1.86	9E-4***	-1.94	1.44***	-3.25**	-0.75	35.78	-1.30	50.94	-0.47	-0.47
JAP	-4.33***	-0.76	30.30	-0.95	13.97	-3.61***	0.34	123.5	-0.73	60.48	0.69	0.69
NOR	-2.72	-1.12	10.23	-1.76	4.52	-3.15**	0.17	30.36	-0.78	18.85	0.97	0.97
UK	-2.82	-0.60	18.20	-1.18	8.63	-5.27***	0.09	33.50	-0.88	24.40	0.31	0.31
US	-4.19***	-2.16	0.77***	-2.81*	1.31***	-3.03**	-0.28	9.25	-0.98	13.33	0.45	0.45
EA	-2.99	-1.03	14.76	-1.43	8.61	-4.44***	0.24	45.69	-0.74	30.81	0.71	0.71
Real Wages in First Log-differences												
CAN	-2.77	-2.36	8.84	-2.54	3.51	-1.42	-1.16	9.47	-1.43	16.07	-1.25	-1.25
FRA	-2.12	-2.15	11.53	-2.15	6.38	-1.12	-0.33	29.05	-1.11	26.57	-1.27	-1.27
GER	-2.38	-1.91	60.09	-2.14	28.49	-1.68	0.11	58.45	-1.62	50.87	-1.75*	-1.75*
ITA	-2.15	-1.51	74.97	-1.72	23.27	-0.92	-1.38	26.07	-1.14	49.92	-1.83*	-1.83*
JAP	-3.21*	-3.37**	15.27	-3.32**	6.39	-2.52	-2.15**	11.67	-2.60*	20.96	-2.64***	-2.64***
NOR	-3.05	-2.83*	13.88	-3.03*	4.93	-1.86	-0.63	24.67	-1.78	17.66	-1.20	-1.20
UK	-4.78***	-4.55***	1.76***	-4.38***	0.68***	-1.31	-0.50	21.61	-1.27	18.42	-0.93	-0.93
US	-1.73	-1.46	24.42	-1.59	12.32	-1.04	-0.81	13.59	-1.02	25.51	-0.93	-0.93
EA	-3.69***	-2.58*	6.65*	-3.08*	2.08**	-1.58	-1.55	5.42	-1.60	10.83	-1.31	-1.31

Note: See remarks below Table 1.A.

Table 1.C
Results of unit-root tests. Monetary variables

	Model with constant and trend					Model with constant					Model without constant	
	ADF	DFGLS	PT	DFGLSU	QT	ADF	DFGLS	PT	DFGLSU	QT	ADF	DFGLS
Short-term Interest Rate in Levels												
CAN	-2.34	-1.15	22.80	-1.79	7.72	-1.33	-1.07	8.88	-1.36	9.22	-0.72	-0.72
FRA	-2.64	-1.30	22.52	-2.00	7.52	-1.20	-1.16	7.68	-1.26	10.80	-0.74	0.74
GER	-2.94	-3.13**	7.92	-3.09*	3.44	-2.98**	-3.02***	2.71**	-3.10**	3.78**	-1.79*	-1.79*
ITA	-2.82	-1.13	29.28	-2.04	10.31	-1.29	-1.02	10.64	-1.30	12.59	-0.61	-0.61
JAP	-3.58**	-2.83*	6.76*	-3.42**	1.01***	-2.01	-2.02**	2.91***	-2.04	5.43*	-1.28	-1.28
NOR	-1.74	-0.89	46.48	-1.25	16.70	-1.34	-0.71	25.43	-1.29	16.44	-0.39	-0.39
UK	-3.55**	-.93	13.66	-2.99*	4.91	-2.43	-1.62*	5.26	-2.36	5.47*	-0.80	-0.80
US	-2.17	-1.34	17.02	-1.87	5.54	-1.34	-1.27	6.41	-1.43	7.26	-0.88	-0.88
EA	-2.06	-1.12	27.20	-1.63	9.65	-0.97	-1.09	9.66	-1.10	12.15	-0.83	-0.83
Short-term Interest Rate in First Differences												
CAN	-4.92***	-4.79***	0.08***	-4.66***	0.01***	-4.72***	-4.67***	0.02***	-4.69***	0.01***	-4.74***	-4.74***
FRA	-6.02***	-5.94***	0.01***	-6.00***	0.00***	-5.91***	-5.85***	0.01***	-5.90***	0.01***	-5.92***	-5.92***
GER	-5.79***	-5.35***	1.85***	-5.81***	0.17***	-5.82***	-3.65***	1.97***	-5.82***	0.17***	-5.80***	-5.80***
ITA	-4.85***	-4.44***	0.12***	-4.94***	1.35***	-6.50***	-5.62***	0.18***	-6.46***	0.10***	-6.52***	-6.52***
JAP	-4.60***	-4.66***	0.36***	-4.68***	0.38***	-4.67***	-4.35***	0.00***	-4.68***	0.36***	-4.51***	-4.51***
NOR	-5.99***	-2.32	18.82	-4.07***	0.53***	-5.90***	-1.00	17.64	-5.01***	0.42***	-5.93***	-5.93***
UK	-4.52***	-4.41***	1.35***	-4.32***	0.55***	-4.46***	-4.03***	0.04***	-4.49***	0.70***	-4.45***	-4.45***
US	-4.60***	-4.33***	0.06***	-4.18***	0.12***	-4.51***	-3.89***	0.08***	-4.51***	0.00***	-4.52***	-4.52***
EA	-5.69***	-5.53***	0.27***	-5.68***	0.07***	-5.58***	-5.26***	0.14***	-5.60***	0.12***	-5.59***	-5.59***
Long-term Interest Rate in Levels												
CAN	-2.10	-1.10	27.42	-1.67	10.69	-1.07	-1.01	9.23	-1.11	13.02	-0.53	-0.53
FRA	-2.28	-1.33	21.98	-1.86	8.84	-1.00	-1.08	7.21	-1.07	12.99	-0.68	-0.68
GER	-3.23*	-2.91**	4.22**	-3.19**	1.87***	-2.15	-2.14**	2.33**	-2.22	4.16**	-0.93	-0.93
ITA	-2.38	-1.43	22.28	-2.07	9.46	-1.41	-1.26	7.22	-1.42	11.01	-0.63	-0.63
JAP	-4.09***	-2.79*	5.27**	-3.61**	1.96***	-1.09	-0.86	7.96	-1.16	11.33	-1.00	-1.00
NOR	-1.79	-1.10	24.24	-1.47	11.08	-1.27	-1.06	8.26	-1.26	11.47	-0.41	-0.41
UK	-4.04**	-1.44	24.20	-2.81	7.57	-0.90	-1.03	8.64	-1.00	14.63	-0.72	-0.72
US	-2.08	-1.21	24.22	-1.72	9.57	-1.20	-1.11	8.11	-1.23	11.56	-0.55	-0.55
EA	-2.42	-1.54	10.67	-2.07	3.92	-1.46	-1.39	3.85*	-1.52	4.98*	-0.75	-0.75
Long-term Interest Rate in First Differences												
CAN	-5.48***	-5.27***	0.31***	-5.47***	0.09***	-5.24***	-3.79***	0.84***	-5.25***	0.19***	-5.25***	-5.25***
FRA	-5.38***	-4.75***	1.34***	-5.31***	0.42***	-5.24***	-4.08***	0.62***	-5.22***	0.46***	-5.25***	-5.25***
GER	-3.36*	-2.39	8.32	-2.83	2.53**	-3.39**	-1.60	6.76	-3.35**	1.24***	-3.28***	-3.28***
ITA	-6.75***	-6.29***	2.10***	-6.70***	1.09***	-6.55***	-5.91***	061***	-6.55***	1.09***	-6.58***	-6.58***
JAP	-4.54***	-4.13***	3.89***	-4.44***	1.89***	-4.48***	-3.71***	1.35***	-4.49***	1.86***	-4.46***	-4.46***
NOR	-3.52**	-3.19**	4.93**	-3.41**	1.96***	-3.16**	-3.01***	1.76***	-3.10**	3.11**	-3.17***	-3.17***
UK	-9.19***	-8.57***	1.66***	-9.12***	0.89***	-9.06***	-6.44***	0.69***	-9.05***	0.96***	-9.07***	-9.07***
US	-5.16***	-5.20***	0.61***	-5.21***	0.33***	-5.35***	-5.18***	0.08***	-5.37***	0.10***	-5.36***	-5.36***
EA	-3.07	-3.06**	4.65***	-3.09*	2.40*	-2.88*	-2.87***	1.62***	-2.90**	3.22**	-2.87***	-2.87***

Note: See remarks below Table 1.A.

Table 2
Wald Test

p-values of the asymptotic distribution Chi-Squared are reported for the different models considered.

H_0: The oil price coefficients are jointly equal to zero in the GDP equation of the VAR model.

	LINEAR	ASYMMETRIC		SCALED OIL PRICE		NET OIL PRICE
	o_t	o_t^+	o_t^-	$SOPI_t$	$SOPD_t$	$NOPI_t$
Country/ Region						
US	0.79505	0.81229	0.37737	0.47193	0.62892	0.33489
Euro area	0.33712	0.01127**	0.02595**	0.00088***	0.01765**	0.00048***
Japan	0.27980	0.46182	0.22198	0.33901	0.32490	0.32291
Canada	0.16691	0.82090	0.15353	0.72218	0.03244**	0.96115
France	0.18320	0.07699*	0.57619	0.05946*	0.53181	0.07422*
Italy	0.19089	0.12767	0.62054	0.11419	0.69565	0.08848*
Germany	0.32321	0.05971*	0.41479	0.03122**	0.51590	0.00951***
UK	0.94260	0.49526	0.24439	0.28650	0.74116	0.20778
Norway	0.53323	0.63854	0.06257*	0.67749	0.86550	0.84935

Note: One/two/three asterisks mean a p-value less than 10%/5%/1%.

Table 3
Likelihood Ratio Test

Let the p-th order VAR model be rewritten as follows:

$y_{1t} = k_1 + D_1' x_{1t} + D_2' x_{2t} + \varepsilon_{1t}$

$o_t = k_2 + C_1' x_{1t} + C_2' x_{2t} + \varepsilon_{2t}$

where y_{1t} is the vector of variables other than o_t, x_{1t} contains lags of y_{1t}, o_t represents the real oil price change, and x_{2t} contains lags of o_t.

H_0: All oil price coefficients are jointly zero in all equations of the system but its own equation, i.e. $D_2 = 0$.

The statistic is as follows:

$2 \times [\mathcal{L}(\theta_1) - \mathcal{L}(\theta_2)] \sim^{a} \chi^2(rows(y_{1t}) \times p)$

where $\mathcal{L}(\theta_1)$ and $\mathcal{L}(\theta_2)$ denote the value of the log likelihood function of the unrestricted and restricted models, respectively.

p-values of the asymptotic distribution are reported for the different specifications considered.

	LINEAR	*ASYMMETRIC*		*SCALED OIL PRICE*		*NET OIL PRICE*
	o_t	o_t^+	o_t^-	$SOPI_t$	$SOPD_t$	$NOPI_t$
Country/ Region						
US	0.18515	0.00078***	0.01285**	0.00402***	0.31146	0.00284***
Euro area	6.6E-005***	2.5E-007***	0.17735	9.8E-008***	0.13732	1.9E-006***
Japan	0.00561***	0.00069***	0.61894	6.9E-006***	0.10267	4.6E-006***
Canada	5.4E-005***	5.9E-005***	0.01947**	2.2E-005***	0.00504***	0.04724**
France	0.02715**	5.6E-008***	0.31297	1.3E-006***	0.80259	6.4E-006***
Italy	9.0E-005***	4.0E-007***	0.35895	9.6E-007***	0.38396	1.8E-006***
Germany	1.8E-006***	7.3E-008***	0.28881	9.4E-007***	0.13869	1.7E-008***
UK	0.00352***	6.9E-010***	0.03516**	8.0E-011***	0.02535**	1.0E-010***
Norway	0.02189**	0.00146***	0.26545	1.2E-007***	0.05412*	0.00971***

Note: One/two/three asterisks mean a p-value less than 10%/5%/1%.

Table 4
Granger Causality in a Multivariate Context
(Block-Exogeneity Test)

We consider two groups of variables in the VAR, as represented by the $(n_1 \times 1)$ vector y_{1t} and the $(n_2 \times 1)$ vector y_{2t}. We rewrite the pth-order VAR as follows:

$$y_{1t} = c_1 + A_1' x_{1t} + A_2' x_{2t} + \varepsilon_{1t} \qquad (1)$$

$$y_{2t} = c_2 + B_1' x_{1t} + B_2' x_{2t} + \varepsilon_{2t} \qquad (2)$$

where x_{1t} is an $(n_1 p \times 1)$ vector containing lags of y_{1t}, and x_{2t} is an $(n_2 p \times 1)$ vector containing lags of y_{2t}.

y_1 (y_2) is *block-exogenous in the time series sense* with respect to y_2 (y_1) when $A_2 = 0$ ($B_1 = 0$).

The statistic for testing the null hypothesis $A_2 = 0$ is the following:

$$T \times \{\log |\Omega^*_{11}(0)| - \log |\Omega^*_{11}|\} \sim^a \chi^2(n_1 n_2 p)$$

where Ω^*_{11} is the variance-covariance matrix of the residuals from OLS estimation of *(1)* and $\Omega^*_{11}(0)$ that of the residuals from OLS estimation of *(1)* when $A_2 = 0$.

The test statistic for H_0: $B_1 = 0$ can be constructed analogously.

There is no relation at all between y_1 and y_2 when $A_2 = 0$, $B_1 = 0$, and $\Omega_{21} = 0$.

p-values of these three tests are reported.

		Linear	Asymmetric	Scaled	Net
	y_{1t}	o_t	o_t^+ ♣	$SOPI_t$♦	$NOPI_t$
	Null Hypotheses				
US	$A_2 = 0$	0.07235*	*0.00077****	0.01374**	0.00538***
	$B_1=0$	0.28218	*0.02295***	0.27797	0.11449
	$A_2=0, B_1=0, \Omega_{21}=0$	0.00060***	*3.4E-008****	0.00062***	4.6E-005***
EA	$A_2=0$	0.04546**	0.03223**	0.03268**	0.05025*
	$B_1=0$	0.08950*	1.9E-005***	3.3E-006***	3.0E-006***
	$A_2=0, B_1=0, \Omega_{21}=0$	0.00097***	1.5E-007***	7.8E-008***	1.8E-007***
JAP	$A_2=0$	0.00099***	4.3E-005***	0.00010***	6.0E-006***
	$B_1=0$	0.00696***	0.00099***	6.9E-005***	1.8E-005***
	$A_2=0, B_1=0, \Omega_{21}=0$	3.2E-007***	9.3E-011***	5.6E-011***	1.2E-015***
CAN	$A_2=0$	0.09702*	*0.01380***	*0.00823****	0.33964
	$B_1=0$	5.7E-05***	*3.3E-005****	*1.6E-005****	0.04858**
	$A_2=0, B_1=0, \Omega_{21}=0$	0.00025***	*4.3E-006****	*3.3E-006****	0.06119*
FRA	$A_2=0$	0.04153**	0.01059**	0.00369***	0.00220***
	$B_1=0$	0.03311**	0.00015***	6.6E-005***	1.9E-005***
	$A_2=0, B_1=0, \Omega_{21}=0$	1.5E-005***	2.2E-008***	6.9E-009***	7.3E-009***
ITA	$A_2=0$	0.16937	0.03025**	0.02091**	0.01252**
	$B_1=0$	0.00012***	1.1E-006***	2.5E-007***	4.4E-006***
	$A_2=0, B_1=0, \Omega_{21}=0$	0.00010***	1.8E-007***	4.5E-008***	2.0E-007***
GER	$A_2=0$	2.4E-005***	1.4E-009***	6.0E-010***	3.3E-010***
	$B_1=0$	4.8E-006***	1.1E-008***	5.8E-008***	3.7E-008***
	$A_2=0, B_1=0, \Omega_{21}=0$	7.2E-011***	1.2E-017***	6.0E-017***	3.8E-017***
UK	$A_2=0$	0.02953**	*2.3E-005****	*2.1E-005****	0.00127***
	$B_1=0$	0.00440***	*2.7E-005****	*8.1E-008****	1.6E-010***
	$A_2=0, B_1=0, \Omega_{21}=0$	5.3E-005***	*1.6E-011****	*2.7E-012****	1.1E-012***
NOR	$A_2=0$	0.98041	0.94354	0.95500	0.90139
	$B_1=0$	0.02193**	0.00862***	0.00271***	0.01035**
	$A_2=0, B_1=0, \Omega_{21}=0$	0.39732	0.20278	0.12006	0.18429

Notes: One/two/three asterisks mean a p-value less than 10%/5%/1%.

♣ We use both positive and negative oil price changes (that is, o^+ and o^-) in the US, the UK and Canada.

♦ We use both positive and negative scaled oil prices (that is, both SOPI and SOPD) in the UK and Canada, because both of them are statistically significant.

Table 5
Accumulated Response of GDP growth to a 1% oil price shock

Accumulated Response of GDP growth to a 1% oil price shock: LINEAR CASE

	US	Euro area	Japan	Canada	France	Italy	Germany	UK	Norway
4 quarters	-0.02747	-0.00991	+0.00936	-0.00507	-0.00988	-0.01457	-0.00911	-0.00227	+0.00150
6	-0.03809	-0.01310	+0.01206	-0.00849	-0.01455	-0.02208	-0.01803	-0.01710	+0.01804
8	-0.03872	-0.01136	+0.01674	-0.00801	-0.01466	-0.02072	-0.01825	-0.01744	+0.00898
10	-0.03515	-0.00721	+0.01544	-0.00298	-0.01434	-0.01723	-0.01745	-0.01880	+0.01215
12	-0.03269	-0.00634	+0.01603	-0.00302	-0.01393	-0.01596	-0.01695	-0.01769	+0.01197

Accumulated Response of GDP growth to a 1% oil price shock: *ASYMMETRIC* ***CASE***

	US		Euro area		Japan		Canada		France		Italy		Germany		UK		Norway	
	o_t^+	o_t^-	o_t^+	o_t^-	o_t^+	o_t^-	o_t^+	o_t^-	o_t^+	o_t^-	o_t^+	o_t^-	o_t^+	o_t^-	o_t^+	o_t^-	o_t^+	o_t^-
4 quarters	-0.0477	*-0.0144*	-0.0217	-	+0.0164	-	-0.0128	*-0.0177*	-0.0167	-	-0.0285	-	-0.0264	-	+0.0013	*+0.0244*	-0.0010	-
6	-0.0510	*+0.0022*	-0.0263	-	+0.0252	-	-0.0157	*-0.0137*	-0.0235	-	-0.0385	-	-0.0406	-	-0.0182	*+0.0308*	+0.0232	-
8	-0.0465	*+0.0111*	-0.0216	-	+0.0358	-	-0.0144	*-0.0119*	-0.0226	-	-0.0333	-	-0.0385	-	-0.0131	*+0.0406*	+0.0106	-
10	-0.0437	*+0.0101*	-0.0141	-	+0.0352	-	-0.0096	*-0.0248*	-0.0215	-	-0.0277	-	-0.0364	-	-0.0152	*+0.0433*	+0.0143	-
12	-0.0420	*+0.0100*	-0.0129	-	+0.0373	-	-0.0106	*-0.0282*	-0.0206	-	-0.0269	-	-0.0320	-	-0.0138	*+0.0376*	+0.0146	-

Accumulated Response of GDP growth to a 1% oil price shock: *SCALED* ***CASE***

	US		Euro area		Japan		Canada		France		Italy		Germany		UK		Norway	
	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$
4 quarters	-0.0573	-	-0.0337	-	+0.0246	-	*-0.0160*	*-0.0216*	-0.0258	-	-0.0466	-	-0.0435	-	*-0.0007*	*+0.0320*	+0.0049	-
6	-0.0662	-	-0.0380	-	+0.0383	-	*-0.0192*	*-0.0110*	-0.0340	-	-0.0567	-	-0.0605	-	*-0.0247*	*+0.0470*	+0.0372	-
8	-0.0607	-	-0.0304	-	+0.0516	-	*-0.0162*	*-0.0868*	-0.0326	-	-0.0481	-	-0.0599	-	*-0.0178*	*+0.0655*	+0.0192	-
10	-0.0554	-	-0.0207	-	+0.0517	-	*-0.0115*	*-0.0232*	-0.0312	-	-0.0412	-	-0.0569	-	*-0.0228*	*+0.0691*	+0.0258	-
12	-0.0511	-	-0.0194	-	+0.0551	-	*-0.0117*	*-0.0262*	-0.0300	-	-0.0414	-	-0.0505	-	*-0.0218*	*+0.0613*	+0.0253	-

Accumulated Response of GDP growth to a 1% oil price shock: NET CASE

	US	Euro area	Japan	Canada	France	Italy	Germany	UK	Norway
4 quarters	-0.04648	-0.02638	+0.01405	-0.00357	-0.02004	-0.03204	-0.02835	-0.00495	+0.00547
6	-0.05845	-0.02632	+0.02465	-0.00830	-0.02747	-0.04350	-0.04441	-0.02557	+0.03391
8	-0.05415	-0.02556	+0.03771	-0.00808	-0.02649	-0.03739	-0.04618	-0.02313	+0.02179
10	-0.04851	-0.01700	+0.03787	-0.00800	-0.02531	-0.03118	-0.04437	-0.02581	+0.02386
12	-0.04324	-0.01295	+0.04075	-0.00798	-0.02432	-0.03067	-0.04000	-0.02288	+0.02550

Note: In the asymmetric case, negative oil prices are only statistically significant in the US, the UK and Canada. In the scaled case, negative movements are only statistically significant in the UK and Canada.

Table 6
Accumulated Response of the rate of change in REER to a 1% oil price shock

Accumulated Response of the rate of change in REER to a 1% oil price shock: LINEAR CASE

	US	Euro area	Japan	Canada	France	Italy	Germany	UK	Norway
4 quarters	+0.03814	-0.03885	-0.05364	-0.00654	-0.01784	-0.02378	-0.00919	+0.10651	+0.00981
6	+0.04880	-0.04264	-0.03727	-0.02305	-0.01015	-0.01995	-0.01571	+0.12627	+0.01684
8	+0.05424	-0.05397	-0.03977	-0.02359	-0.01139	-0.02844	-0.01512	+0.12513	+0.01611
10	+0.06656	-0.05031	-0.05589	-0.02360	-0.01411	-0.03020	-0.01385	+0.10597	+0.01648
12	+0.07125	-0.03999	-0.05678	-0.02630	-0.01392	-0.02921	-0.01033	+0.10134	+0.01702

Accumulated Response of the rate of change in REER to a 1% oil price shock: *ASYMMETRIC* ***CASE***

	US		Euro area		Japan		Canada		France		Italy		Germany		UK		Norway	
	o_t^+	o_t^-	o_t^+	o_t^-	o_t^+	o_t^-	o_t^+	o_t^-	o_t^+	o_t^-	o_t^+	o_t^-	o_t^+	o_t^-	o_t^+	o_t^-	o_t^+	o_t^-
4 quarters	+0.0245	*-0.0746*	-0.0353	-	-0.0582	-	+0.0185	*+0.0679*	-0.0259	-	+0.0006	-	+0.0012	-	+0.0821	*-0.1558*	-0.0015	-
6	+0.0382	*-0.0664*	-0.0555	-	-0.0170	-	+0.0015	*+0.0994*	-0.0223	-	+0.0039	-	+0.0029	-	+0.1238	*-0.1643*	+0.0076	-
8	+0.0467	*-0.7800*	-0.0716	-	-0.0273	-	+0.0048	*+0.1155*	-0.0231	-	-0.0130	-	+0.0043	-	+0.1268	*-0.1068*	+0.0067	-
10	+0.0645	*-0.0742*	-0.0640	-	-0.0424	-	+0.0055	*+0.1162*	-0.0264	-	-0.0144	-	+0.0081	-	+0.0100	*-0.0911*	+0.0066	-
12	+0.0609	*-0.0816*	-0.0463	-	-0.0424	-	+0.0038	*+0.1198*	-0.0278	-	-0.0108	-	+0.0202	-	+0.1027	-0.0860	+0.0075	-

Accumulated Response of the rate of change in REER to a 1% oil price shock: *SCALED* ***CASE***

	US		Euro area		Japan		Canada		France		Italy		Germany		UK		Norway	
	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$	$SOPI_t$	$SOPD_t$
4 quarters	+0.0583	-	-0.0373	-	-0.0840	-	*+0.0281*	*+0.0917*	-0.0235	-	-0.0039	-	+0.0210	-	*+0.0958*	*-0.2639*	+0.0104	-
6	+0.0763	-	-0.0751	-	-0.0399	-	*+0.0104*	*+0.1426*	-0.0210	-	+0.0009	-	+0.0206	-	*+0.1544*	*-0.2736*	+0.0211	-
8	+0.0950	-	-0.0915	-	-0.0605	-	*+0.0113*	*+0.1523*	-0.0224	-	-0.0256	-	+0.0028	-	*+0.1691*	*-0.2077*	+0.0190	-
10	+0.1132	-	-0.0782	-	-0.0759	-	*+0.0111*	*+0.1532*	-0.0270	-	-0.0246	-	+0.0105	-	*+0.1355*	*-0.1755*	+0.0197	-
12	+0.1087	-	-0.0542	-	-0.0750	-	*+0.0084*	*+0.1573*	-0.0290	-	-0.0187	-	+0.0285	-	*+0.1390*	*-0.1625*	+0.0202	-

Accumulated Response of the rate of change in REER to a 1% oil price shock: NET CASE

	US	Euro area	Japan	Canada	France	Italy	Germany	UK	Norway
4 quarters	+0.04587	-0.04407	-0.02825	+0.03599	-0.01986	+0.02157	-0.01148	+0.12229	-0.01459
6	+0.05861	-0.07036	+0.02623	+0.02749	-0.01656	+0.02660	-0.02278	+0.16783	-0.00557
8	+0.06930	-0.08587	+0.02398	+0.02878	-0.01563	+0.00778	-0.02638	+0.16078	-0.00537
10	+0.08562	-0.07570	+0.01465	+0.02952	-0.01792	+0.00624	-0.01916	+0.13835	-0.00695
12	+0.08450	-0.05663	+0.01306	+0.02929	-0.01949	+0.00985	-0.00694	+0.13256	-0.00562

Note: In the asymmetric case, negative oil prices are only statistically significant in the US, the UK and Canada. In the scaled case, negative movements are only statistically significant in the UK and Canada.

Table 7
Relative Performance of the Models

		LINEAR	*ASYMMETRIC*	*SCALED*	*NET*
Country/ Region					
US	*AIC*	19.746	26.122	14.051	19.057
	BIC	24.618	32.459	18.924	23.929
Euro area	*AIC*	18.273	17.854	12.627	17.751
	BIC	21.949	22.726	17.500	22.623
Japan	*AIC*	25.688	24.970	19.749	24.574
	BIC	30.560	29.842	24.621	29.446
Canada	*AIC*	21.648	28.236	17.798	21.060
	BIC	26.520	34.572	24.135	24.736
France	*AIC*	19.313	18.640	13.398	18.499
	BIC	22.989	22.316	17.074	22.175
Italy	*AIC*	24.028	23.354	18.104	23.244
	BIC	27.704	27.030	21.780	26.919
Germany	*AIC*	19.858	18.977	13.809	18.897
	BIC	24.730	23.850	18.682	23.769
UK	*AIC*	25.626	31.834	21.352	24.521
	BIC	30.499	38.171	27.689	29.394
Norway	*AIC*	26.758	26.220	21.106	26.101
	BIC	30.434	29.896	25.978	29.777

Note: In the asymmetric specification for the US, the UK, and Canada, and in the scaled specification for the UK and Canada, we use an eight-variable system which includes both oil price increase and decrease measures.

Table 8.A
Estimated Variance Decomposition at the 12-period horizon: Linear Case

	Innovation in	GDP	o	Infl	SR	LR	RW	REER
VAR (GDP)	US	64,34	10,91	5,75	11,28	2,28	1,94	3,50
	Euro area	69,08	7,51	3,39	9,60	1,94	4,03	4,45
	Japan	75,58	1,59	4,20	3,13	3,05	5,75	6,69
	Canada	59,33	4,91	8,78	17,72	3,98	1,53	3,74
	France	78,71	5,29	2,39	7,39	0,57	1,46	4,19
	Italy	66,45	6,75	1,01	4,50	0,30	16,87	4,13
	Germany	80,21	3,72	3,36	4,19	3,91	3,63	0,98
	Norway	78,33	4,03	1,01	5,37	1,31	5,93	4,02
	UK	74,21	5,94	4,11	3,96	4,61	3,10	4,07
	Innovation in	GDP	o	Infl	SR	LR	RW	REER
VAR (o)	US	3,83	74,57	2,24	4,79	4,16	1,41	9,00
	Euro area	3,12	76,46	5,33	4,41	0,95	4,17	5,56
	Japan	3,61	67,21	4,56	3,30	7,66	6,27	7,39
	Canada	6,88	77,64	4,71	2,48	1,36	0,40	6,52
	France	5,96	75,59	11,79	2,08	0,20	3,71	0,66
	Italy	3,03	81,64	3,40	1,84	2,91	5,62	1,57
	Germany	4,22	64,66	2,31	11,15	3,53	2,45	11,68
	Norway	0,78	93,90	0,82	0,42	0,63	1,99	1,44
	UK	11,99	69,79	2,07	5,51	1,50	4,26	4,88
	Innovation in	GDP	o	Infl	SR	LR	RW	REER
VAR (Infl)	US	6,09	10,75	54,22	8,83	10,69	5,64	3,78
	Euro area	4,81	17,20	56,66	9,42	3,75	3,35	4,82
	Japan	22,40	6,35	44,12	2,25	4,80	14,69	5,39
	Canada	7,19	5,29	71,21	4,94	3,58	4,10	3,69
	France	2,38	8,94	77,64	4,62	0,72	4,69	1,02
	Italy	4,21	5,96	75,48	5,88	2,91	3,93	1,62
	Germany	11,56	7,80	59,98	5,21	1,90	7,49	6,07
	Norway	0,56	1,10	87,91	2,96	1,84	1,65	3,96
	UK	11,56	8,03	58,61	7,66	1,90	9,89	2,36
	Innovation in	GDP	o	Infl	SR	LR	RW	REER
VAR (SR)	US	16,42	6,95	4,57	60,54	4,87	1,07	5,58
	Euro area	19,84	6,77	8,27	54,97	0,89	1,98	7,29
	Japan	13,42	7,66	8,84	40,42	9,12	11,21	9,32
	Canada	18,74	4,42	5,15	60,81	7,59	0,94	2,35
	France	8,79	7,48	10,64	68,09	0,95	0,85	3,20
	Italy	15,99	11,42	21,34	42,89	1,94	4,74	1,68
	Germany	17,82	5,73	7,62	48,79	3,69	3,16	13,19
	Norway	1,05	7,96	7,64	68,33	13,39	1,23	0,39
	UK	5,68	6,98	2,59	75,44	1,95	2,74	4,62
	Innovation in	GDP	o	Infl	SR	LR	RW	REER
VAR (LR)	US	11,35	5,30	2,71	29,99	41,66	4,15	4,83
	Euro area	9,79	11,43	5,97	12,83	50,33	2,12	7,53
	Japan	6,81	12,49	1,56	9,18	63,17	3,54	3,27
	Canada	6,48	4,54	6,17	27,76	50,01	1,56	3,49
	France	6,44	11,33	12,51	17,89	47,06	2,71	2,06
	Italy	5,74	11,11	2,53	14,51	57,06	6,86	2,19
	Germany	10,63	10,85	2,45	14,91	55,88	2,59	2,70
	Norway	4,53	7,84	4,75	2,76	76,19	2,26	1,67
	UK	2,09	13,89	4,34	28,16	44,88	3,29	3,36
	Innovation in	GDP	o	Infl	SR	LR	RW	REER
VAR (RW)	US	5,65	9,65	26,45	9,20	8,68	34,90	5,48
	Euro area	14,86	6,28	17,81	5,65	5,56	36,44	13,39
	Japan	11,70	10,60	19,84	1,18	1,14	53,78	1,76
	Canada	3,50	3,11	30,68	1,03	7,00	49,46	5,22
	France	9,93	10,29	18,15	3,68	1,98	53,03	2,93
	Italy	9,34	5,32	28,77	4,30	1,57	45,84	4,87
	Germany	6,76	3,26	21,68	8,52	4,36	48,37	7,04
	Norway	0,48	0,99	13,86	5,23	2,11	76,76	0,57
	UK	18,65	7,36	17,90	8,93	3,12	41,50	2,55
	Innovation in	GDP	o	Infl	SR	LR	RW	REER
VAR (REER)	US	2,22	4,65	4,68	8,86	19,75	2,86	56,98
	Euro area	3,34	6,42	8,83	3,09	4,06	3,20	71,06
	Japan	6,31	1,03	2,85	6,60	5,69	7,11	70,41
	Canada	4,97	4,01	14,79	17,06	2,16	0,70	56,30
	France	1,36	3,06	4,81	4,57	7,48	1,82	76,91
	Italy	2,53	2,04	6,52	3,80	5,82	1,00	78,29
	Germany	3,77	6,85	4,61	9,60	4,77	3,87	66,52
	Norway	3,15	4,70	9,85	2,34	7,84	3,81	68,31
	UK	5,34	5,49	5,82	12,68	12,75	1,91	56,02

Note: This Table presents the results of the estimated variance decomposition at the 12-period horizon.

Table 8.B
Estimated Variance Decomposition at the 12-period horizon: Asymmetric Case

	Innovation in	GDP	o^+	o^-	Infl	SR	LR	RW	REER
VAR (GDP)	US	59,85	11,07	2,27	7,06	11,24	2,50	1,80	4,20
	Euro area	64,86	11,36	-	4,10	9,14	1,44	5,35	3,75
	Japan	74,89	2,50	-	3,53	2,96	2,99	5,63	7,49
	Canada	56,35	4,05	2,62	8,92	18,20	4,68	1,23	3,96
	France	77,17	7,96	-	2,65	7,26	0,36	1,15	3,45
	Italy	64,82	9,09	-	1,33	3,95	0,44	17,41	2,97
	Germany	77,87	4,88	-	3,63	4,08	4,10	4,45	1,00
	Norway	78,54	3,74	-	0,97	5,13	1,18	6,21	4,23
	UK	70,78	8,83	1,39	4,22	4,95	2,92	3,18	3,72
	Innovation in	GDP	o^+	o^-	Infl	SR	LR	RW	REER
VAR (o^+)	US	7,40	66,82	1,27	3,35	4,79	4,05	2,40	9,92
	Euro area	3,21	76,54	-	4,03	5,40	0,63	4,22	5,97
	Japan	6,20	61,06	-	6,05	5,19	9,29	6,65	5,55
	Canada	7,11	72,85	1,45	8,22	3,80	0,93	0,41	5,22
	France	5,75	73,29	-	13,00	1,43	0,40	4,04	2,09
	Italy	4,19	77,75	-	3,74	2,86	1,95	6,58	2,93
	Germany	7,21	54,68	-	1,05	12,72	5,51	4,37	14,47
	Norway	1,69	92,31	-	0,90	1,42	0,60	2,36	0,73
	UK	16,52	64,52	0,55	1,07	6,28	2,58	4,90	3,58
	Innovation in	GDP	o^+	o^-	Infl	SR	LR	RW	REER
VAR (o^-)	US	4,25	15,62	60,77	7,33	2,51	3,97	3,21	2,34
	Canada	4,01	13,71	65,09	3,56	1,15	3,84	2,52	6,12
	UK	5,99	14,14	62,14	6,15	1,94	1,95	2,23	5,45
	Innovation in	GDP	o^+	o^-	Infl	SR	LR	RW	REER
VAR (Infl)	US	6,02	7,12	6,03	51,55	9,55	10,18	5,22	4,33
	Euro area	3,47	16,62	-	58,61	9,94	3,96	3,68	3,72
	Japan	22,25	9,01	-	44,40	1,98	4,60	11,84	5,93
	Canada	6,18	5,56	1,35	69,01	4,62	3,88	4,90	4,50
	France	2,32	9,27	-	77,32	4,53	0,78	4,41	1,37
	Italy	4,24	9,29	-	71,33	5,77	2,48	4,69	2,21
	Germany	12,84	6,44	-	59,32	5,27	2,67	7,18	6,28
	Norway	0,56	2,03	-	87,26	2,92	1,82	1,61	3,80
	UK	11,96	9,12	1,63	56,98	7,65	1,31	8,23	3,12
	Innovation in	GDP	o^+	o^-	Infl	SR	LR	RW	REER
VAR (SR)	US	14,99	5,87	3,23	5,32	59,11	3,90	1,11	6,47
	Euro area	15,22	9,79	-	9,20	55,20	1,76	2,58	6,24
	Japan	13,76	6,74	-	8,31	42,08	10,43	9,84	8,85
	Canada	18,76	4,64	1,09	4,63	59,91	7,34	0,72	2,91
	France	8,41	6,44	-	11,64	68,85	1,10	0,68	2,86
	Italy	15,35	10,45	-	21,34	43,20	2,17	5,23	2,26
	Germany	13,95	12,83	-	7,66	43,19	4,35	3,17	14,86
	Norway	1,02	9,30	-	7,12	66,53	14,17	1,56	0,29
	UK	5,23	5,16	8,96	3,74	65,76	2,04	3,20	5,92
	Innovation in	GDP	o^+	o^-	Infl	SR	LR	RW	REER
VAR (LR)	US	11,12	3,20	4,93	2,34	30,57	37,66	4,54	5,64
	Euro area	8,31	12,79	-	5,30	13,02	51,27	2,41	6,90
	Japan	7,15	9,00	-	1,30	11,56	64,32	3,23	3,43
	Canada	6,31	4,00	3,24	5,19	28,34	46,16	1,29	5,47
	France	6,77	8,02	-	12,91	18,08	49,69	2,70	1,84
	Italy	5,90	11,55	-	2,23	12,89	57,00	8,57	1,86
	Germany	7,49	11,45	-	3,33	13,99	56,42	3,71	3,60
	Norway	4,50	7,94	-	4,22	2,81	77,15	1,95	1,42
	UK	5,94	15,04	5,35	5,42	20,79	40,07	3,16	4,22
	Innovation in	GDP	o^+	o^-	Infl	SR	LR	RW	REER
VAR (RW)	US	5,77	9,69	6,67	24,49	9,00	9,82	28,27	6,28
	Euro area	13,33	8,02	-	17,86	5,54	4,60	36,69	13,98
	Japan	11,23	15,50	-	19,92	1,14	1,25	49,10	1,86
	Canada	3,70	3,02	6,35	31,26	1,20	6,05	42,83	5,60
	France	9,79	9,55	-	18,68	3,96	2,64	51,04	4,34
	Italy	8,49	7,76	-	27,83	4,09	1,58	46,88	3,37
	Germany	7,87	3,79	-	17,98	10,00	4,35	48,14	7,87
	Norway	0,41	3,29	-	13,10	4,24	2,85	75,54	0,57
	UK	17,83	11,68	2,49	18,64	9,93	2,68	34,53	2,22
	Innovation in	GDP	o^+	o^-	Infl	SR	LR	RW	REER
VAR (REER)	US	3,10	6,01	3,99	3,33	8,10	16,70	3,16	55,59
	Euro area	3,81	5,30	-	8,84	3,09	3,77	2,97	72,21
	Japan	6,39	1,87	-	2,97	6,24	5,61	6,00	70,93
	Canada	4,91	4,57	2,13	12,84	16,83	2,62	0,70	55,39
	France	1,45	7,43	-	6,88	4,96	8,60	2,27	68,41
	Italy	2,99	2,41	-	9,28	3,52	7,00	0,83	73,97
	Germany	3,89	6,97	-	4,60	8,82	4,16	3,16	68,40
	Norway	3,26	3,02	-	10,04	2,62	8,56	4,87	67,63
	UK	7,42	5,88	3,29	6,38	9,28	10,62	2,49	54,65

Note: See remark below Table 8.A.

Table 8.C
Estimated Variance Decomposition at the 12-period horizon: Scaled Case

	Innovation in	GDP	SOPI	SOPD	Infl	SR	LR	RW	REER
VAR (GDP)	US	63,91	9,66	-	7,44	11,35	2,26	1,55	3,83
	Euro area	63,07	11,49	-	4,81	9,55	1,63	5,77	3,67
	Japan	74,13	2,90	-	3,29	3,07	3,29	5,87	7,45
	Canada	54,56	2,95	3,41	9,47	18,30	5,50	1,30	4,51
	France	76,50	8,03	-	3,09	7,09	0,45	1,16	3,67
	Italy	63,60	9,86	-	1,27	3,41	0,36	18,32	3,17
	Germany	77,10	4,85	-	3,55	4,54	4,39	4,63	0,95
	Norway	78,36	4,11	-	0,88	5,08	1,16	6,17	4,22
	UK	71,03	8,82	1,80	4,10	4,34	3,03	3,42	3,46
	Innovation in	GDP	SOPI	SOPD	Infl	SR	LR	RW	REER
VAR (SOPI)	US	6,35	69,73	-	3,92	3,71	3,25	3,37	9,67
	Euro area	2,80	76,34	-	4,45	5,59	0,84	4,19	5,79
	Japan	5,88	63,99	-	5,83	4,95	8,10	7,05	4,18
	Canada	7,11	72,35	2,46	9,61	3,11	0,67	0,34	4,35
	France	5,36	72,05	-	13,82	1,12	0,57	5,59	1,50
	Italy	4,55	77,52	-	3,67	2,26	1,68	7,11	3,21
	Germany	5,94	56,45	-	1,11	14,10	4,03	4,20	14,17
	Norway	1,46	92,24	-	0,67	1,36	0,53	2,76	0,98
	UK	16,57	63,64	2,35	1,34	5,32	2,63	5,06	3,08
	Innovation in	GDP	SOPI	SOPD	Infl	SR	LR	RW	REER
VAR (SOPD)	Canada	3,73	6,55	69,92	2,78	1,61	5,34	3,25	6,83
	UK	3,20	9,46	68,84	7,76	2,47	1,27	1,78	5,23
	Innovation in	GDP	SOPI	SOPD	Infl	SR	LR	RW	REER
VAR (Infl)	US	7,05	5,22	-	57,31	9,53	10,84	6,08	3,97
	Euro area	3,54	15,32	-	59,83	9,64	4,58	3,44	3,65
	Japan	21,10	9,71	-	44,11	2,09	5,26	11,83	5,91
	Canada	5,93	5,55	3,38	67,12	4,11	3,81	6,31	3,79
	France	2,31	9,17		77,46	4,56	0,74	4,47	1,29
	Italy	4,74	8,77	-	71,12	5,80	2,51	4,76	2,29
	Germany	12,97	5,14	-	60,46	4,28	2,80	7,74	6,62
	Norway	0,55	2,05	-	86,80	3,05	2,06	1,68	3,80
	UK	12,64	8,72	1,36	57,03	7,25	1,61	8,54	2,85
	Innovation in	GDP	SOPI	SOPD	Infl	SR	LR	RW	REER
VAR (SR)	US	16,10	5,58	-	5,63	61,67	4,51	1,06	5,45
	Euro area	13,79	10,28	-	9,67	55,07	2,40	2,87	5,92
	Japan	13,68	5,31	-	8,53	42,83	10,71	10,20	8,74
	Canada	19,31	4,42	1,08	4,52	59,86	7,25	0,89	2,67
	France	8,01	5,48	-	12,37	69,00	1,32	0,65	3,15
	Italy	16,03	11,72	-	19,15	42,47	2,11	5,91	2,61
	Germany	12,68	13,63	-	6,54	44,85	4,50	3,42	14,38
	Norway	1,06	10,05	-	7,12	65,38	14,51	1,60	0,28
	UK	5,48	5,41	9,24	3,96	64,96	2,44	3,09	5,42
	Innovation in	GDP	SOPI	SOPD	Infl	SR	LR	RW	REER
VAR (LR)	US	12,94	2,99	-	3,41	30,89	40,84	4,57	4,36
	Euro area	8,37	12,86	-	5,07	13,66	51,09	2,41	6,53
	Japan	7,16	8,76	-	1,10	12,21	64,17	3,27	3,33
	Canada	6,68	4,00	2,08	4,86	29,00	47,54	1,43	4,40
	France	6,28	6,68	-	13,82	18,29	50,32	2,70	1,90
	Italy	6,62	11,47	-	2,09	11,90	56,82	9,14	1,97
	Germany	7,17	11,25	-	3,44	14,17	56,13	4,25	3,60
	Norway	4,24	8,39	-	4,31	2,62	76,97	1,96	1,52
	UK	5,10	17,26	4,73	5,54	20,34	40,17	2,96	3,91
	Innovation in	GDP	SOPI	SOPD	Infl	SR	LR	RW	REER
VAR (RW)	US	6,02	7,53	-	29,91	10,21	8,44	33,32	4,56
	Euro area	12,89	8,28	-	19,19	5,38	4,55	35,61	14,10
	Japan	10,26	14,63	-	21,42	1,06	1,32	49,48	1,83
	Canada	2,97	3,65	3,87	32,28	0,97	7,12	44,17	4,96
	France	10,49	8,78	-	19,05	3,96	2,77	50,31	4,64
	Italy	8,76	7,10	-	27,90	3,88	1,51	47,25	3,60
	Germany	7,70	3,30	-	18,39	8,86	4,33	49,52	7,91
	Norway	0,36	4,04	-	12,83	4,30	3,18	74,71	0,58
	UK	18,16	11,22	2,38	19,14	8,98	2,69	35,48	1,94
	Innovation in	GDP	SOPI	SOPD	Infl	SR	LR	RW	REER
VAR (REER)	US	2,57	4,97	-	4,29	8,97	19,32	3,09	56,79
	Euro area	3,88	5,07	-	9,50	3,02	3,55	2,87	72,11
	Japan	6,31	1,86	-	3,26	6,77	5,69	6,01	70,10
	Canada	5,42	4,61	2,16	12,26	16,28	2,42	0,79	56,07
	France	1,46	7,45	-	7,52	4,75	8,25	2,54	68,01
	Italy	2,90	2,54	-	9,42	3,35	6,85	0,85	74,09
	Germany	3,75	7,22	-	4,44	9,07	4,73	3,09	67,72
	Norway	3,25	3,08	-	9,28	2,66	8,19	5,04	68,51
	UK	7,04	5,23	4,96	7,22	9,35	11,65	2,79	51,77

Note: See remark below Table 8.A.

Table 9
Test for stability on oil prices coefficients
(GDP equation of VAR Model)

LINEAR CASE

	US	Euro-Area	Japan	Canada	France	Italy	Germany	UK	Norway
Sup F	6,658	28,407***	8,715	4,584	9,083	5,464	14,161*	3,052	3,950
(date)	(1985:IV)	(1981:IV)	(1991:II)	(1981:IV)	(1982:II)	(1990:II)	(1981:IV)	(1983:IV)	(1989:I)
Avg F	4,699	11,951***	5,155	2,269	6,089*	3,085	7,107*	1,360	2,661
Exp F	1,129	5,513**	1,299	0,532	1,540	0,713	2,478	0,362	0,599

ASYMMETRIC CASE

	US		Euro-Area		Japan		Canada		France		Italy		Germany		UK		Norway	
	o^+	o^-	o^+	o^-	o^+	o^-	o^+	o^-	o^+	o^-	o^+	o^-	o^+	o^-	o^+	o^-	o^+	o^-
Sup F	*3,604*	*5,223*	13,21*	-	14,64*	-	*3,612*	*5,894*	3,470	-	4,134	-	7,521	-	*2,084*	*5,285*	8,764	-
(date)	*1991:III*	*1982:IV*	1982:I		1989:IV		*1989:I*	*1986:I*	1983:III		1981:III		1981:III		*1992:II*	*1982:III*	1981:II	
Avg F	*2,163*	*3,670*	7,30*	-	8,34**	-	*2,069*	*3,162*	2,491	-	2,885	-	4,638	-	*1,547*	*3,329*	6,005*	-
Exp F	*0,501*	*0,837*	2,374	-	2,482	-	*0,487*	*0,746*	0,579	-	0,696	-	1,255	-	*0,343*	*0,810*	1,499	-

SCALED CASE

	US		Euro-Area		Japan		Canada		France		Italy		Germany		UK		Norway	
	SOPI	SOPD	SOPI	SOPD	SOPI	SOPD	SOPI	SOPD	SOPI	SOPD	SOPI	SOPD	SOPI	SOPD	SOPI	SOPD	SOPI	SOPD
Sup F	4,793	-	12,589	-	13,63*	-	*4,565*	*7,782*	3,586	-	3,528	-	6,569	-	*2,612*	*5,772*	8,571	-
(date)	1990:III		1981:IV		1990:IV		*1989:I*	*1981:III*	1982:IV		1982:IV		1981:IV		*1981:III*	*1982:III*	1981:III	
Avg F	2,669	-	6,720	-	7,89*	-	*2,689*	*2,782*	2,707	-	2,624	-	3,888	-	*1,282*	*2,937*	5,87*	-
Exp F	0,637	-	2,131	-	2,263	-	*0,643*	*0,787*	0,605	-	0,595	-	1,006	-	*0,287*	*0,716*	1,497	-

NET CASE

	US	Euro-Area	Japan	Canada	France	Italy	Germany	UK	Norway
Sup F	4,793	6,708	8,707	3,397	3,172	8,053	6,388	2,659	6,371
(date)	(1990:III)	(1980:III)	(1989:IV)	(1990:III)	(1985:IV)	(1989:IV)	(1989:I)	(1992:II)	(1985:IV)
Avg F	2,617	5,300	5,704	1,577	2,501	5,594*	4,594	1,334	4,811
Exp F	0,637	1,270	1,313	0,356	0,580	1,391	1,194	0,319	1,217

Note: In the asymmetric case, negative oil price changes are only statistically significant in the US, the UK and Canada. In the scaled case, negative oil price changes are only statistically significant in the UK and Canada. We have performed these tests using $\pi = 0.30$ and four or three restrictions depending on the optimal lag length used. Critical values (reported below) were taken from Andrews (1993) and Andrews and Ploberger (1994). One/two/three asterisks mean a p-value less than 10%/5%/1%.

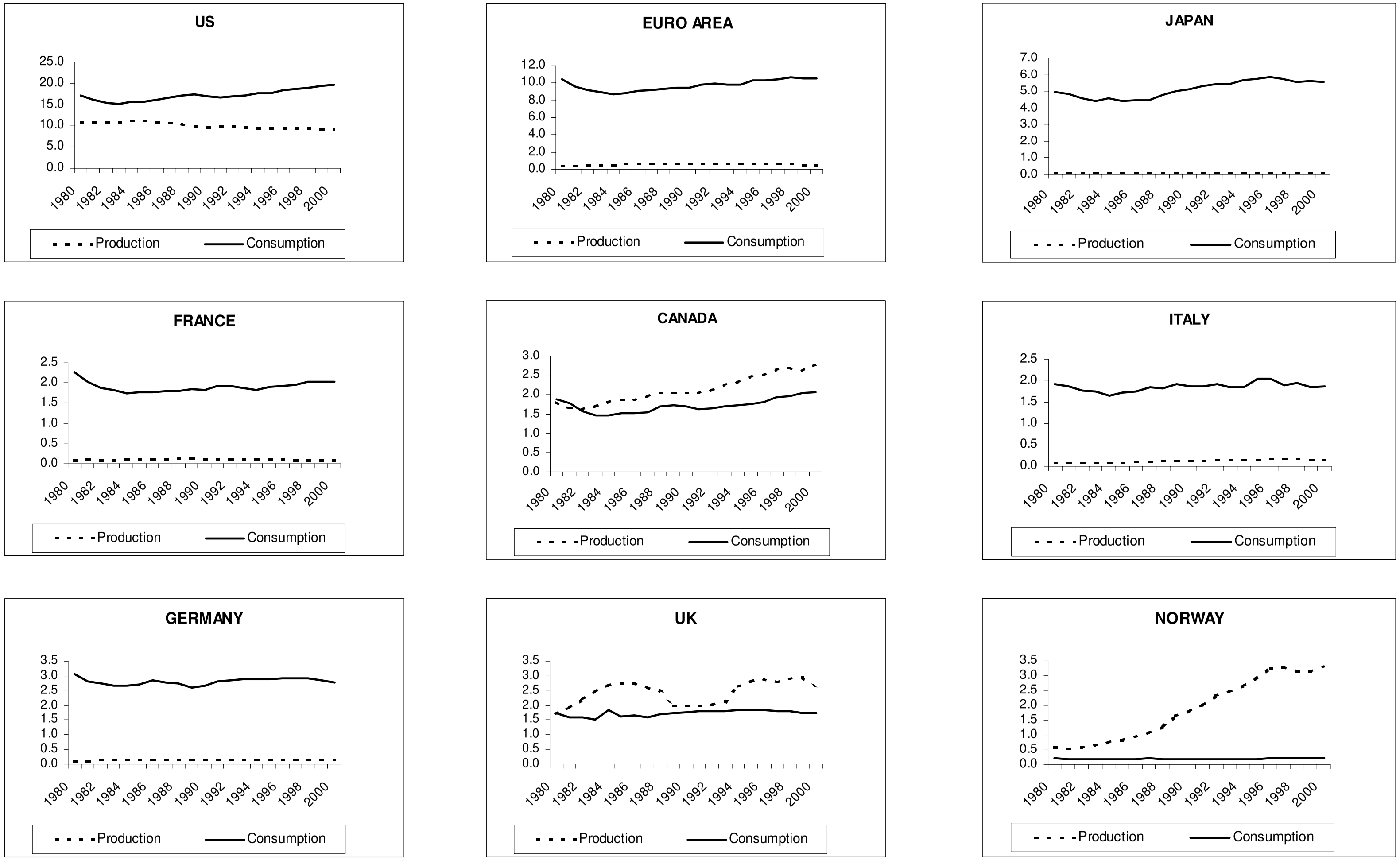
Critical levels used when p = 3 are the following:
- Sup F: 10.76 (1%), 12.58 (5%) and 16.24 (10%).
- Avg F: 5.50 (1%), 6.66 (5%) and 9.18 (10%).
- Exp F: 3.34 (1%), 4.09 (5%) and 5.63 (10%).

Critical levels used when p = 4 are the following:
- Sup F: 12.80 (1%), 14.79 (5%) and 19.10 (10%).
- Avg F: 7.02 (1%), 8.27 (5%) and 11.35 (10%).
- Exp F: 4.24 (1%), 5.06 (5%) and 6.95 (10%).

Figure 1

Oil production and consumption since 1980

(Million barrels per day)



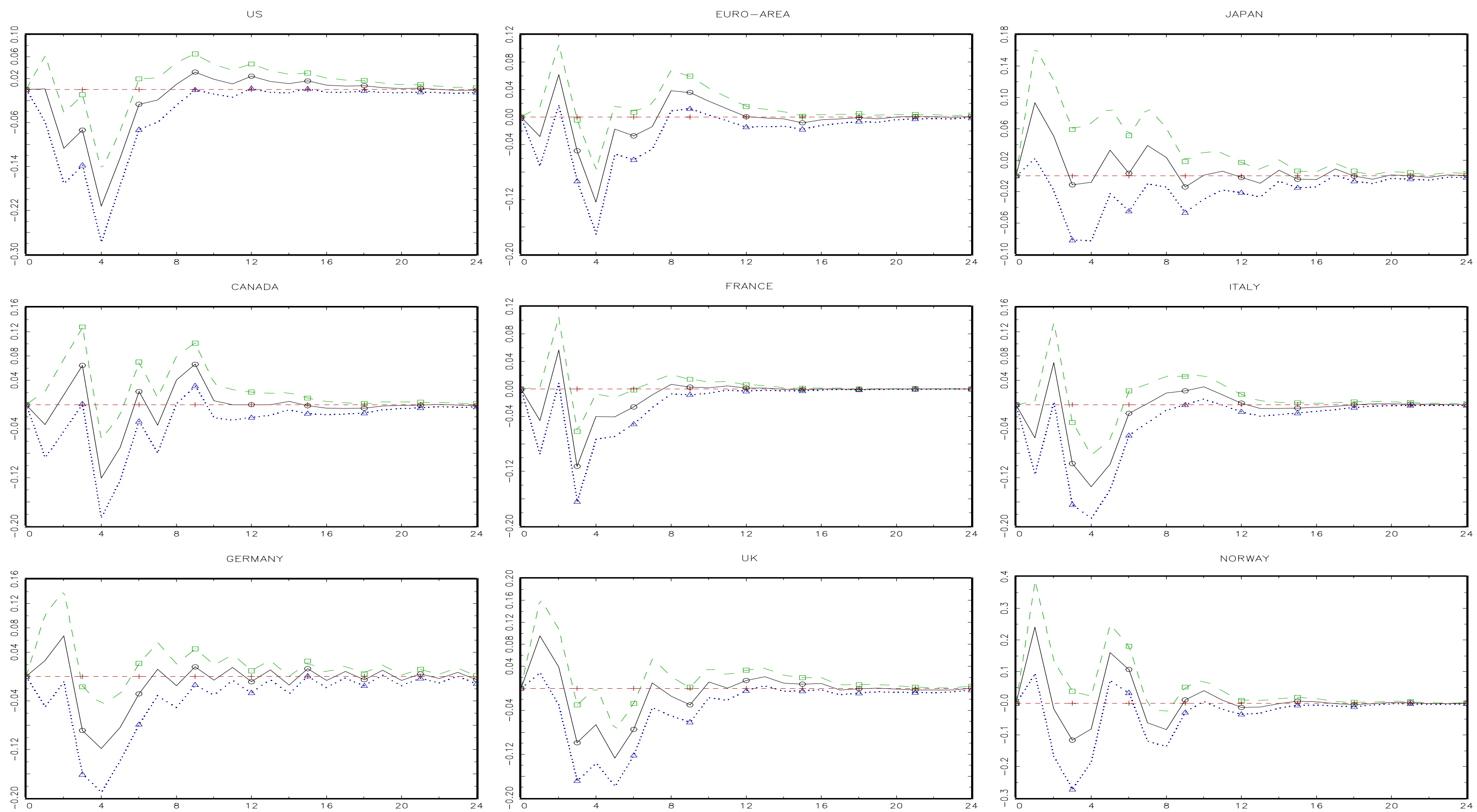
Note: This Figure presents the production and consumption of oil for each country under study since 1980.
Source: Energy Information Administration, US Dept. of Energy (web page: http://www.eia.doe.gov/pub/international/iealf/).

Figure 2

Orthogonalised impulse-response function of GDP growth

to a one-standard-deviation oil price innovation

Linear specification

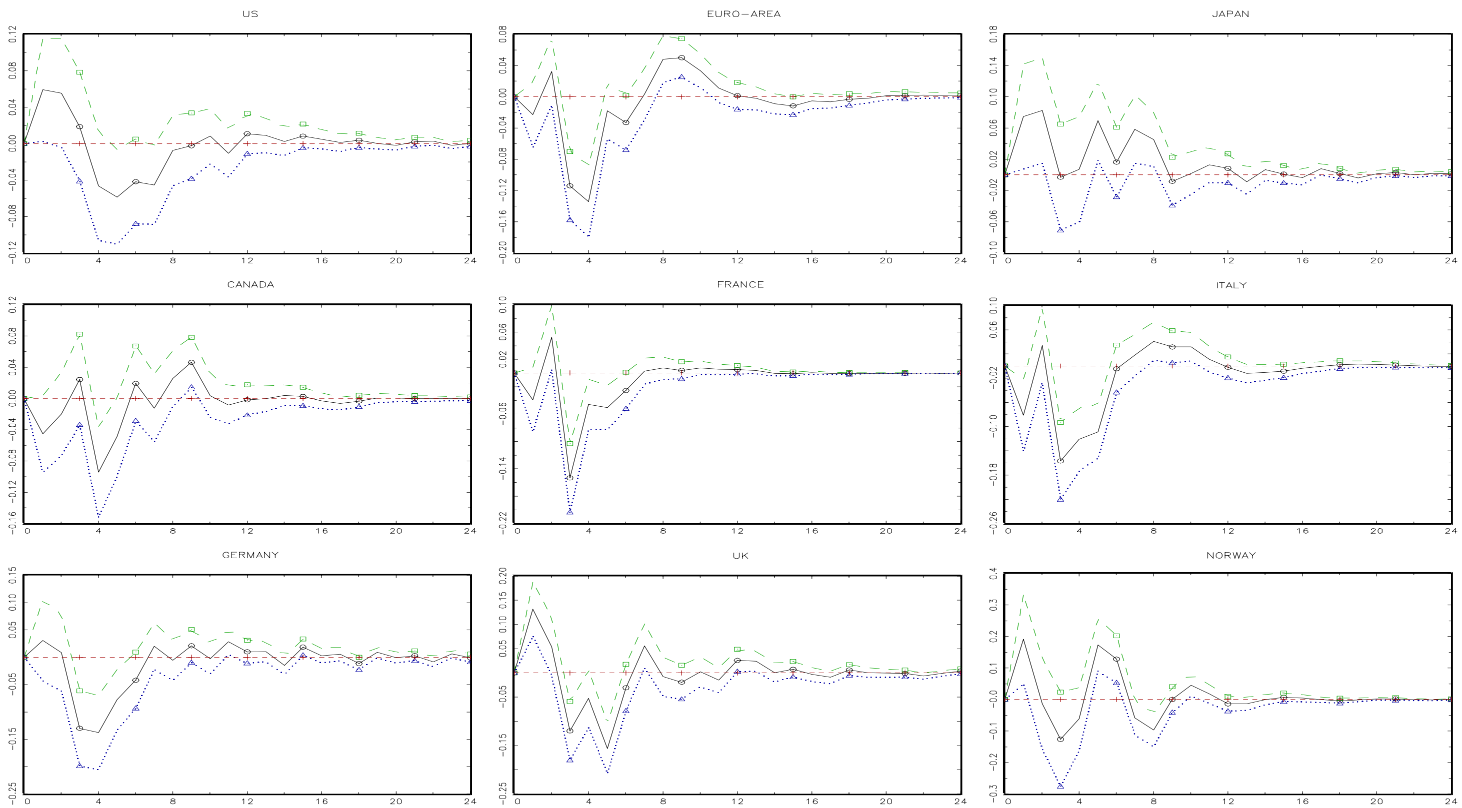


Note: This Figure presents the orthogonalised impulse-response function of GDP growth to a one-standard-deviation oil price innovation in the linear specification.

Figure 3.1

Orthogonalised impulse-response function of GDP growth to a positive one-standard-deviation oil price innovation

Asymmetric specification



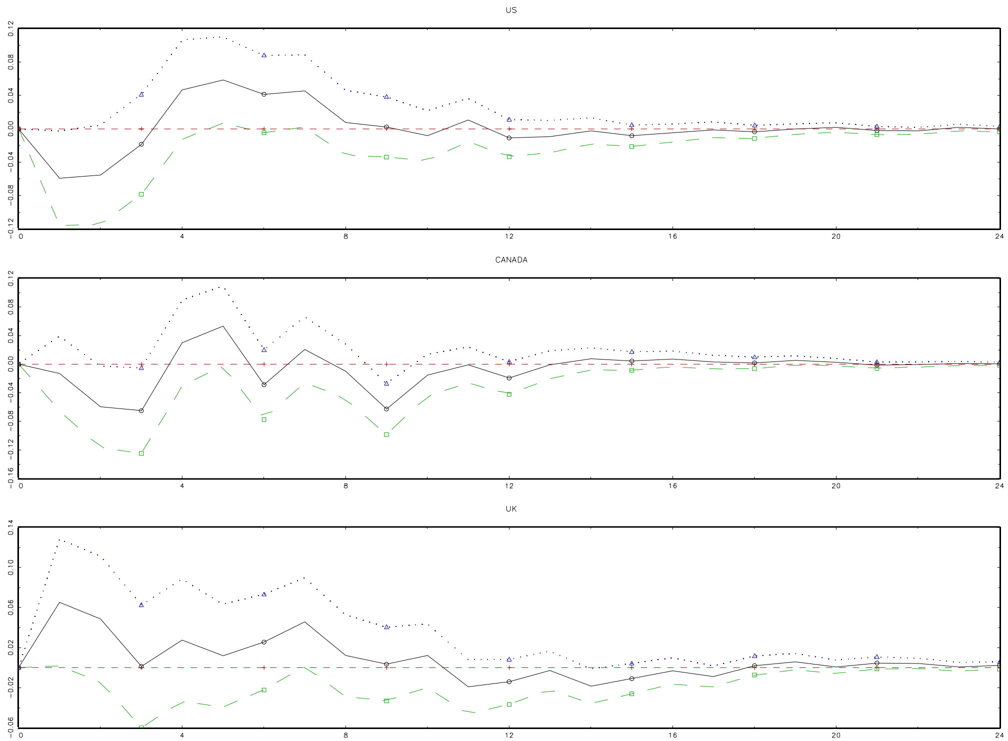
Note: This Figure presents the orthogonalised impulse-response function of GDP growth to a positive one-standard-deviation oil price innovation in the asymmetric specification. In the US, the UK and Canada the orthogonalised impulse-response function is referred to an eight-variable system which includes both positive and negative oil price measures.

Figure 3.2

Orthogonalised impulse-response function of GDP growth to a negative one-standard-deviation oil price innovation

Asymmetric Specification

US, Canada and the UK

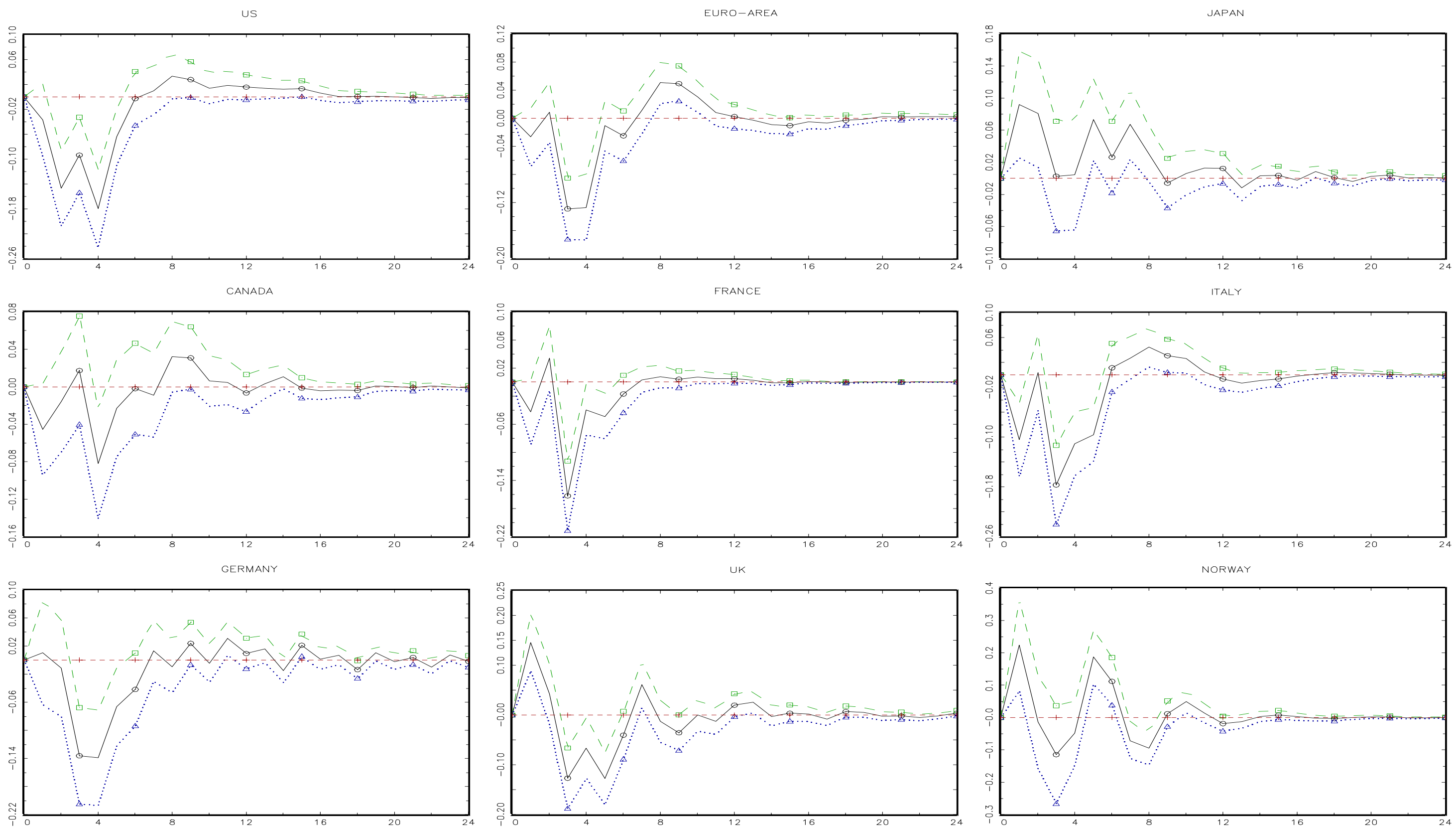


Note: This Figure presents the orthogonalised impulse-response function of the US, Canadian, and British GDP growth to a negative one-standard-deviation oil price innovation in the asymmetric specification.

Figure 4.1

Orthogonalised impulse-response function of GDP growth to a positive one-standard-deviation oil price innovation

Scaled specification



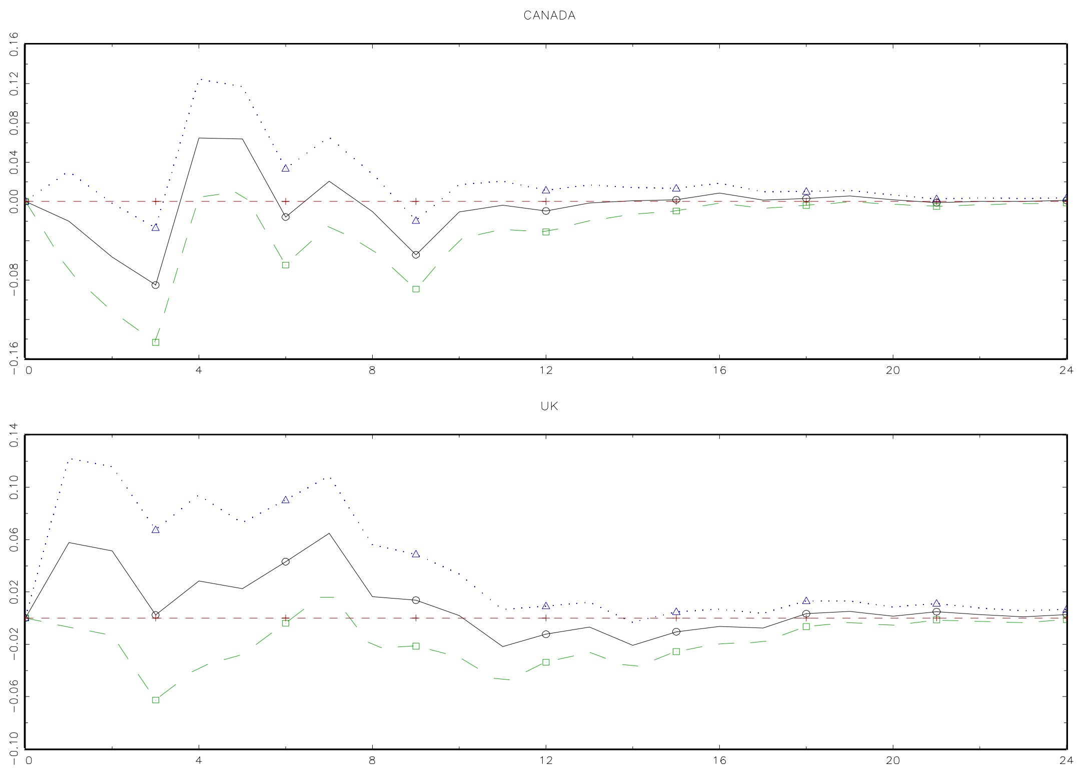
Note: This Figure presents the orthogonalised impulse-response function of GDP growth to a positive one-standard-deviation oil price innovation in the scaled specification. In the UK and Canada the orthogonalised impulse-response function is referred to an eight-variable system which includes both positive and negative oil price measures.

Figure 4.2

Orthogonalised impulse-response function of GDP growth to a negative one-standard-deviation oil price innovation

Scaled specification

Canada and the UK

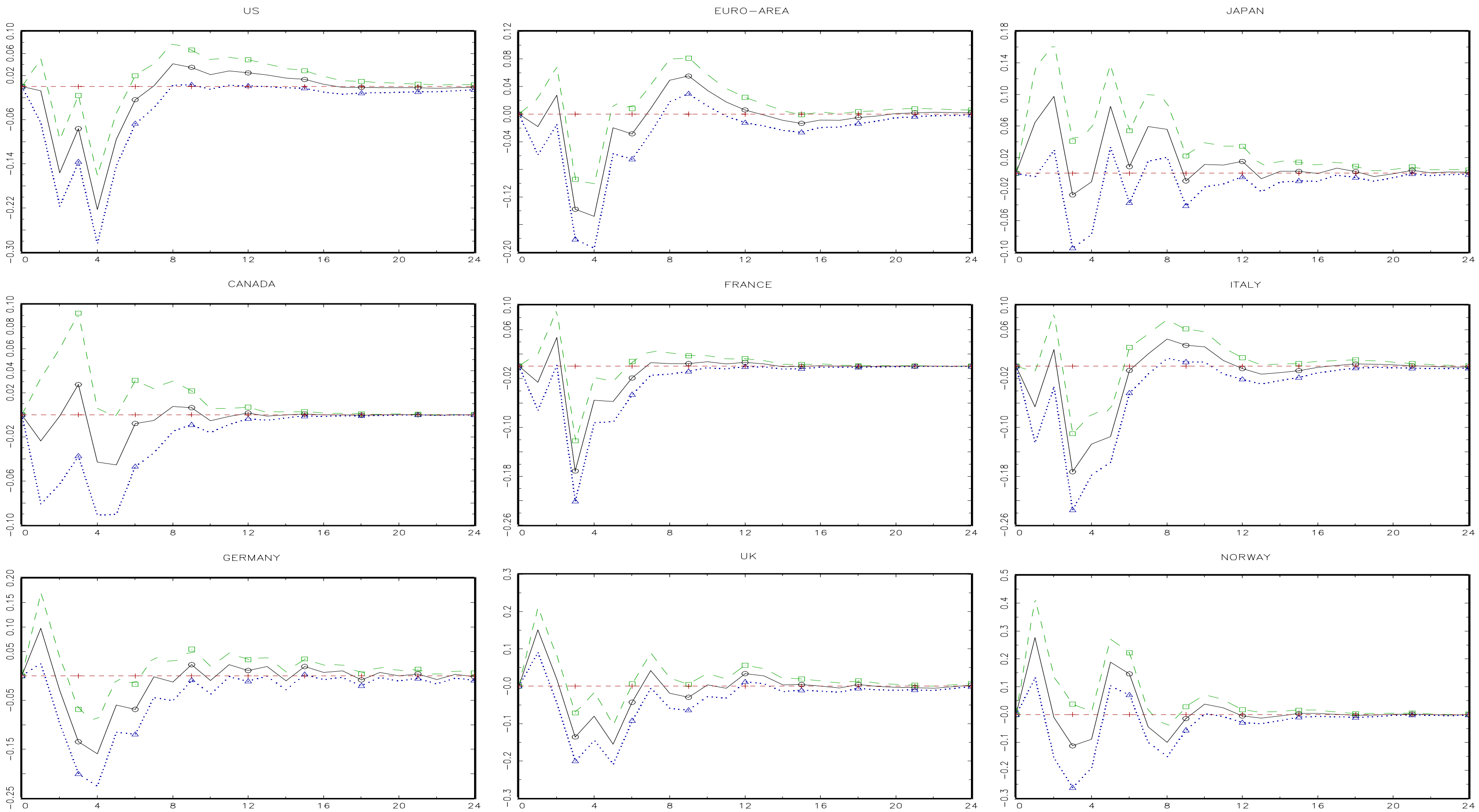


Note: This Figure presents the orthogonalised impulse-response function of British and Canadian GDP growth to a negative one-standard-deviation oil price innovation in the scaled specification.

Figure 5

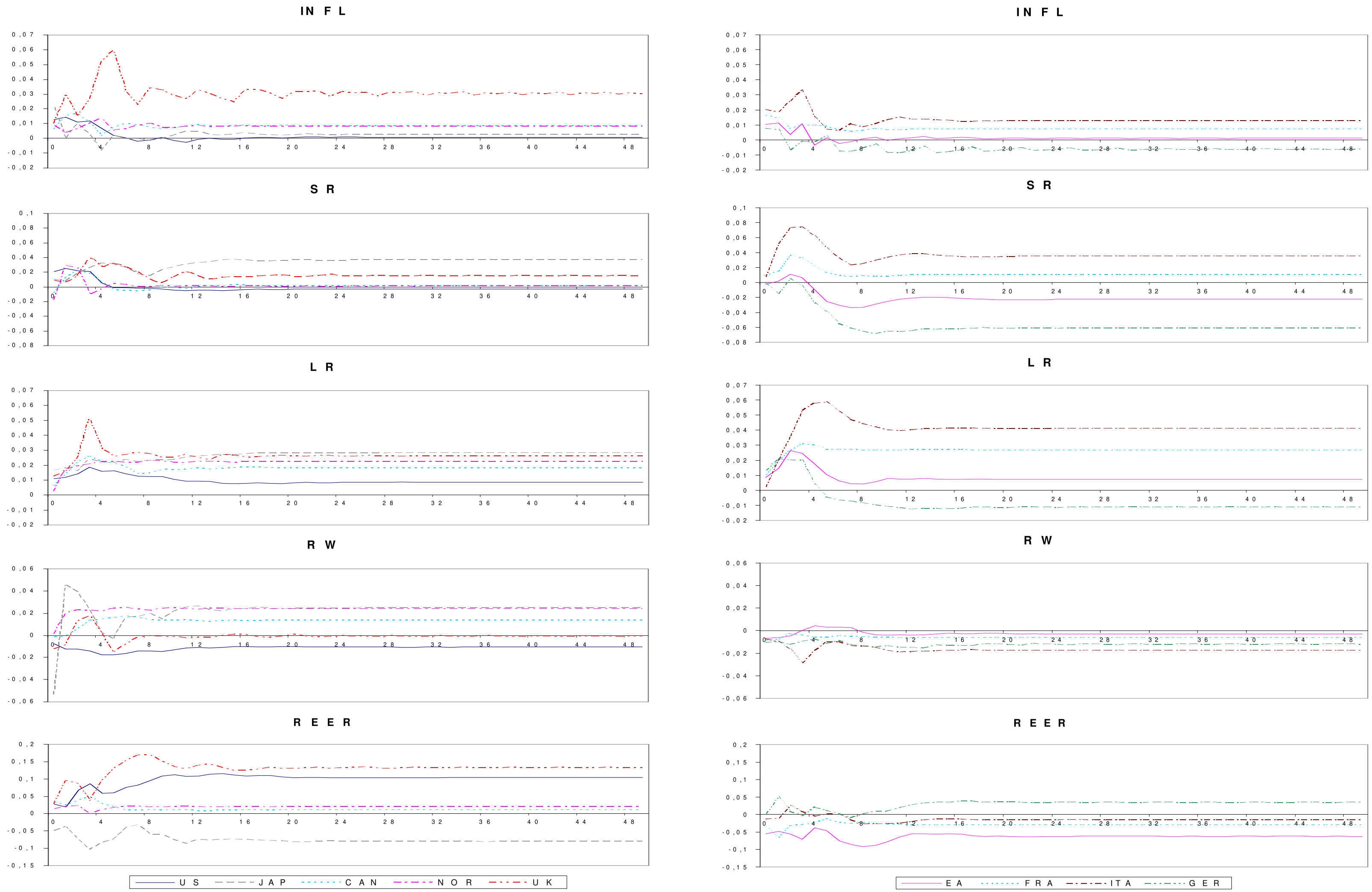
Orthogonalised impulse-response function of GDP growth to a one-standard-deviation oil price increase innovation

Net specification



Note: This Figure presents the orthogonalised impulse-response function of GDP growth to a one-standard-deviation oil price innovation in the net specification.

Figure 6
Accumulated Responses to a 1% oil price shock (selected variables): Scaled specification



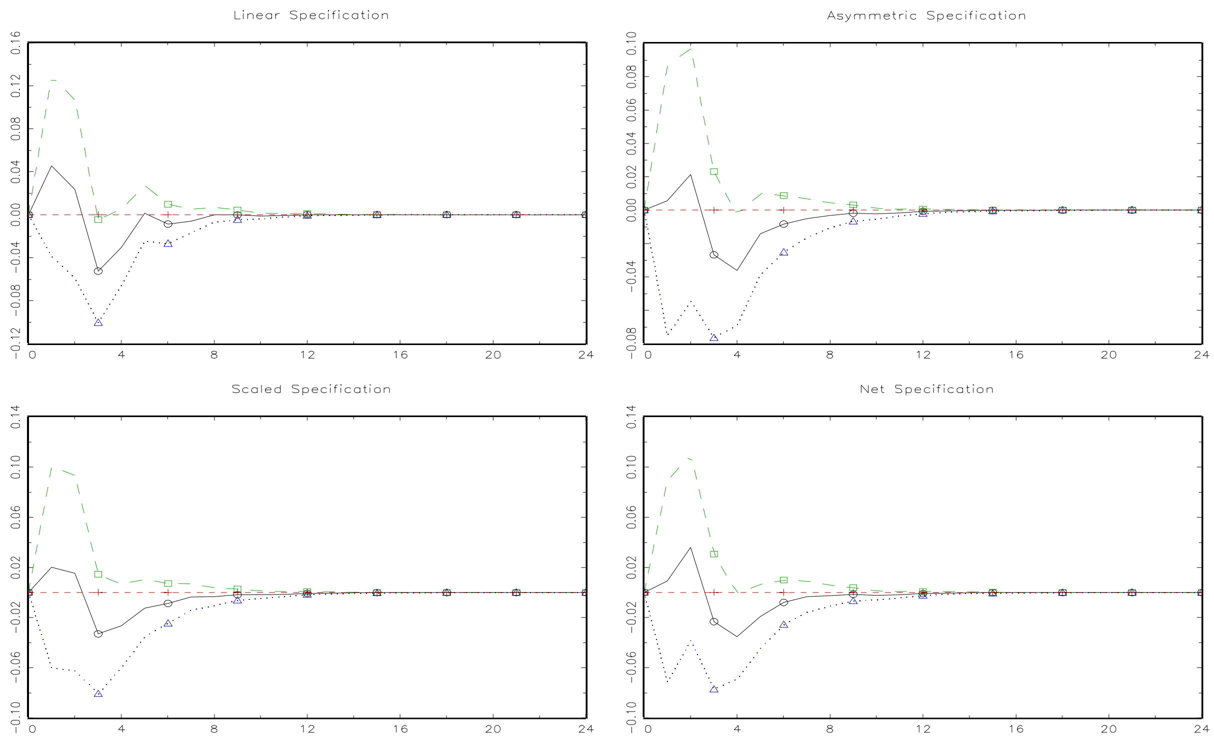
Note: This Figure presents the accumulated responses of inflation, short- and long-term interest rate, real wage, and REER for the US, Japan, Canada, Norway, and the UK (charts on the left-hand side), and for the euro area, France, Italy, and Germany (charts on the right-hand side).

Figure 7

Orthogonalised impulse-response function of GDP growth to a positive one-standard-deviation oil price innovation

All specifications (p=2)

Japan



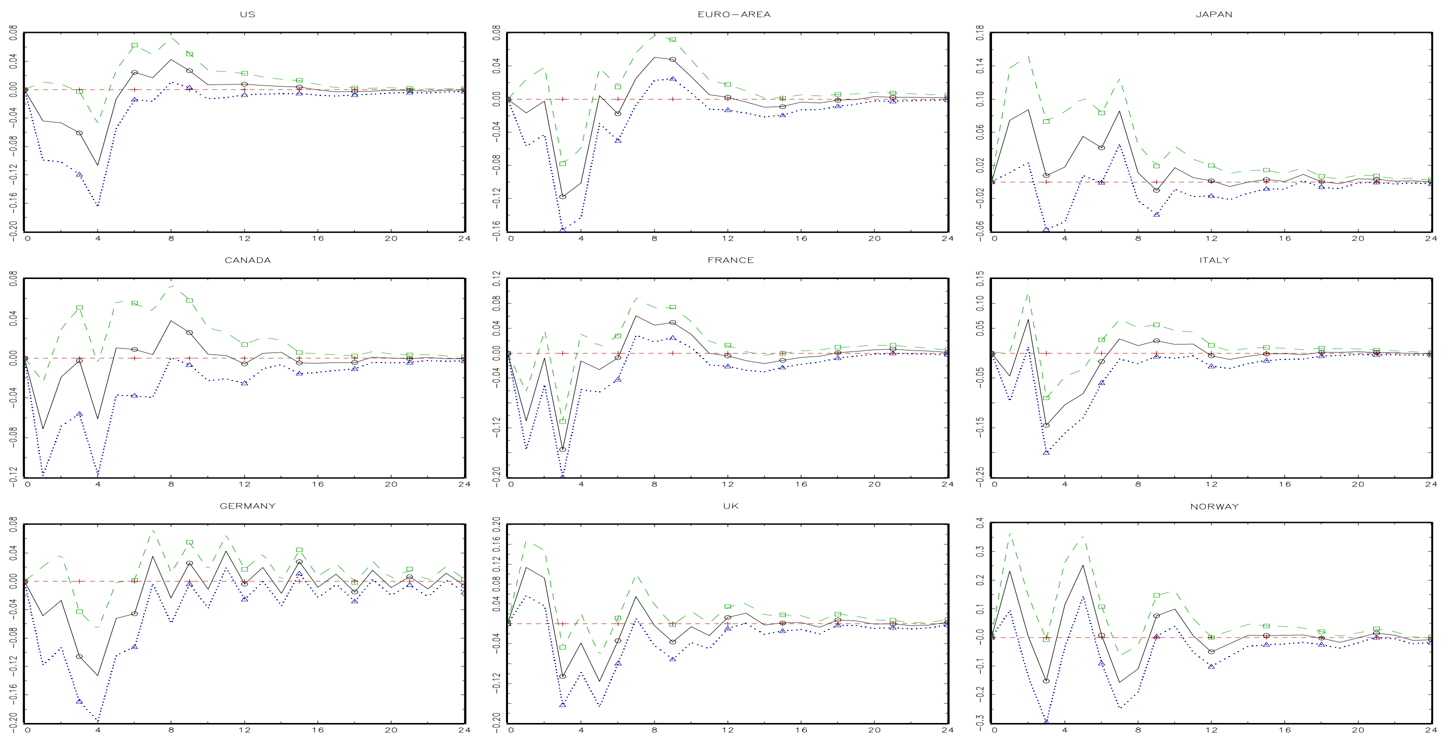
Note: This Figure presents the orthogonalised impulse-response function of Japanese GDP growth to a positive one-standard-deviation oil price innovation in the four specifications under study, when the number of lag included in the VAR is two.

Annex

Figure A.1 (a)

Orthogonalised impulse-response function of GDP growth to a positive one-standard-deviation oil price innovation

Alternative ordering, scaled specification

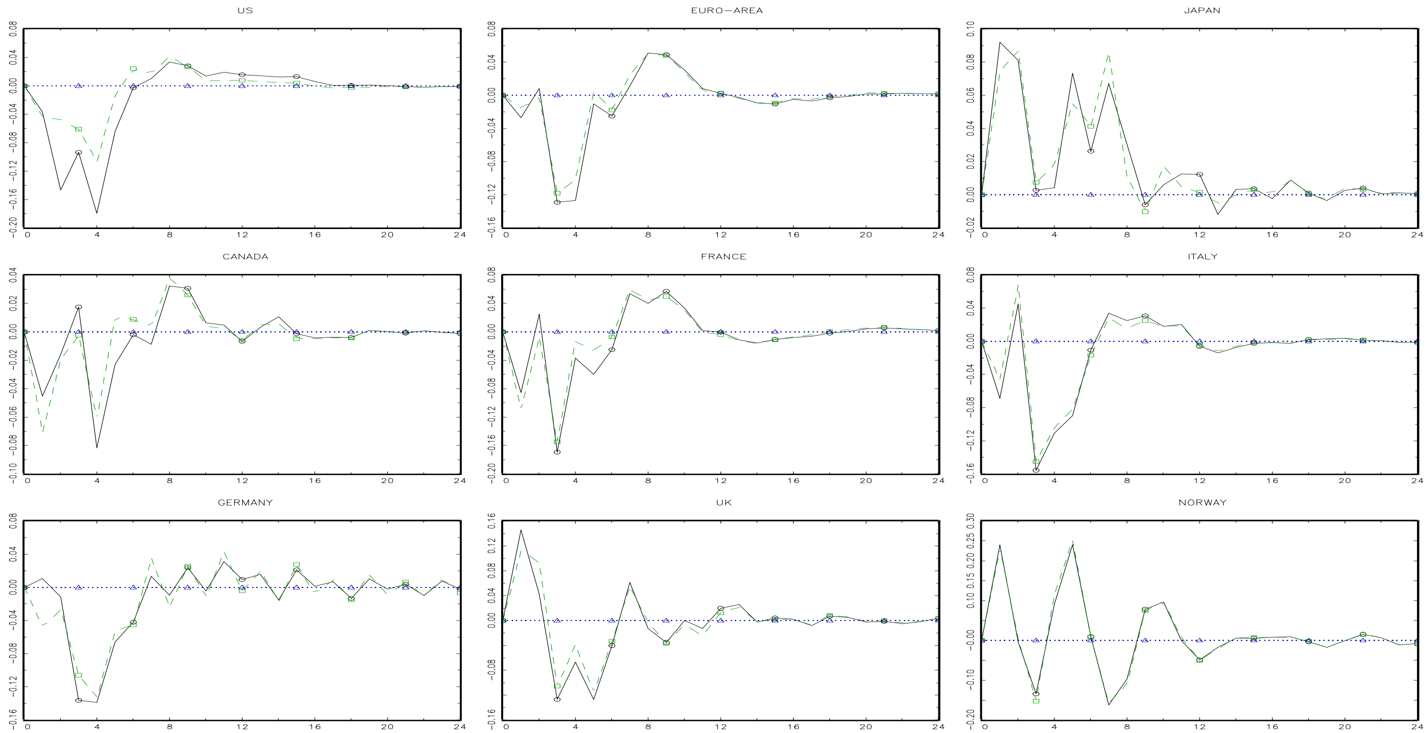


Note: This Figure presents the orthogonalised impulse-response function of GDP growth to a one-standard-deviation innovation in the positive oil price measure. The model used is the scaled specification. In the UK and Canada the orthogonalised impulse-response function is referred to an eight-variable system which includes both positive and negative oil price measures, that is, SOPI and SOPD, respectively. The ordering of the variables is the following: short-term interest rate, long-term interest rate, real GDP, real wage, REER, (SOPD), SOPI, and inflation.

Figure A.1 (b)

Orthogonalised impulse-response function of GDP growth to a positive one-standard-deviation oil price innovation

Baseline and alternative orderings, scaled specification



Note: This Figure presents the orthogonalised impulse-response function of GDP growth to a one-standard-deviation innovation in the positive oil price measure. The model used is the scaled specification. In the UK and Canada the orthogonalised impulse-response function is referred to an eight-variable system which includes both positive and negative oil price measures, that is, SOPI and SOPD, respectively. The orderings of the variables considered are the following:

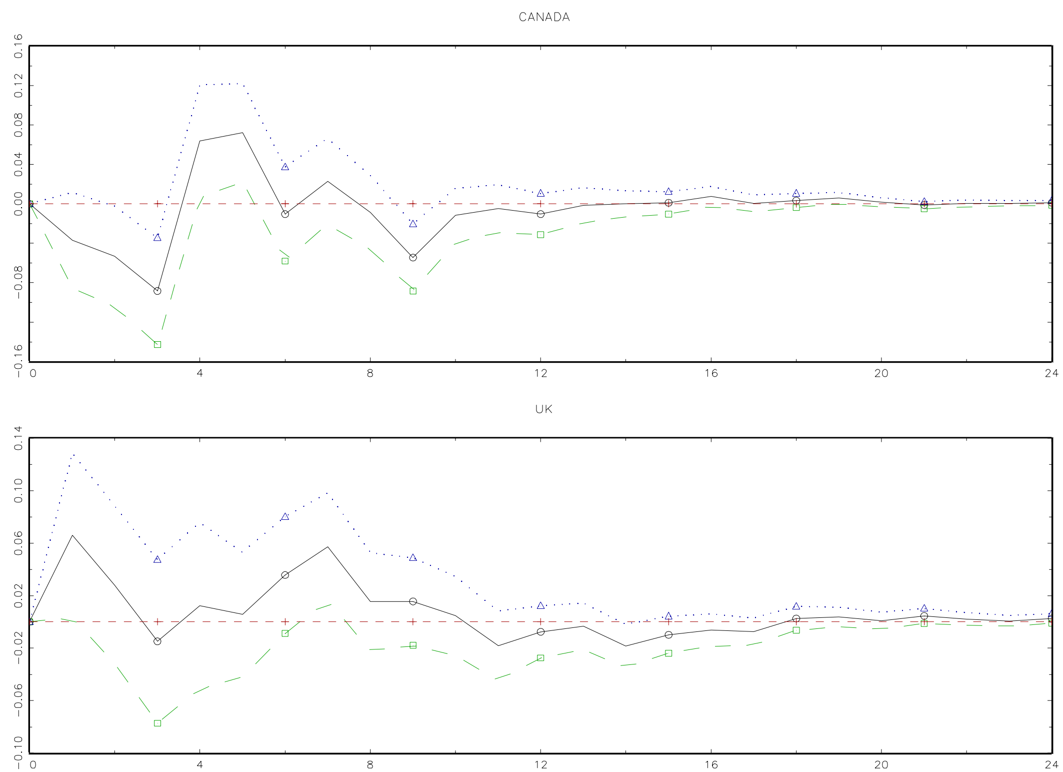
- GDP, oil price, inflation, short-term interest rate, long-term interest rate, real wage, and REER (solid line)
- short-term interest rate, long-term interest rate, GDP, real wage, REER, oil price, and inflation (dashed line)

Figure A.2 (a)

Orthogonalised impulse-response function of GDP growth to a negative one-standard-deviation oil price innovation

Alternative ordering, scaled specification

Canada and the UK



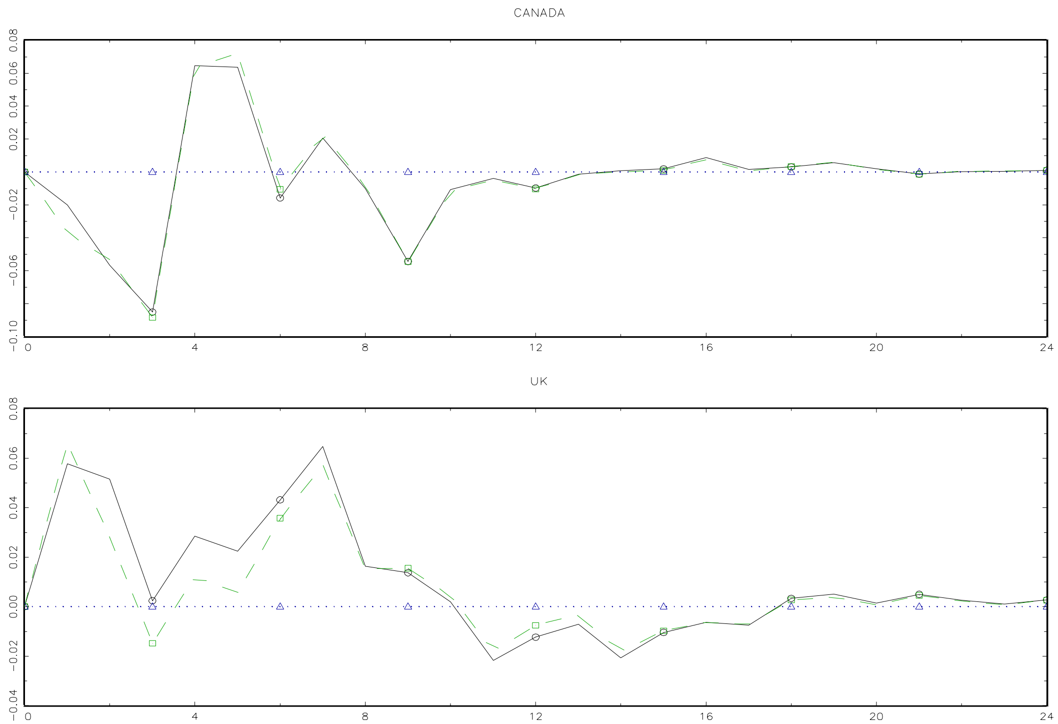
Note: This Figure presents the orthogonalised impulse-response function of British and Canadian GDP growth to a one-standard-deviation innovation in the negative oil price measure. The model used is the scaled specification. The ordering of the variables is the following: short-term interest rate, long-term interest rate, real GDP, real wage, REER, SOPI, SOPD, and inflation.

Figure A.2 (b)

Orthogonalised impulse-response function of GDP growth to a negative one-standard-deviation oil price innovation

Baseline and alternative orderings, scaled specification

Canada and the UK



Note: This Figure presents the orthogonalised impulse-response function of British and Canadian GDP growth to a one-standard-deviation innovation in the negative oil price measure. The model used is the scaled specification. The ordering of the variables is the following: short-term interest rate, long-term interest rate, real GDP, real wage, REER, SOPI, SOPD, and inflation.

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