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Abstract

Most of the studies existing in theoretical and empirical understanding of the macroeconomic consequences of oil price shocks have been focused on US aggregate data. In contrast to these studies, this paper assesses empirically the dynamic effects of oil price shocks on the output of the main manufacturing industries in six OECD countries using an identified vector autoregression for each economy. The pattern of responses to an oil price shock by industrial output is diverse across the four European Monetary Union (EMU) countries under consideration (France, Germany, Italy, and Spain), but broadly similar in the UK and the US. Evidence on cross-industry heterogeneity of oil shock effects within the EMU countries is also reported. Moreover, our baseline results are quite robust with respect to changes in the number of lags, identification assumptions, and real oil price definition.

JEL classification: E32, Q43.

Keywords: oil price shock; identified VAR; manufacturing industries.

1 Introduction

"*Oil price shocks present policy-makers with difficult choices as they simultaneously pose upside risks to inflation and downside risks to growth. In responding to oil price shocks, it is essential to understand that policy-makers cannot offset the real effects of oil price increases. An oil price increase triggers a loss in the economy's terms-of-trade and implies a transfer of wealth from oil-importing countries to oil exporters. This change in the terms-of-trade (in relative prices) requires an adjustment of the real economy and must be absorbed by markets. The policy-makers' aim should be to facilitate this adjustment by minimising inflationary pressures and aggregate output losses.*"

Speech by Lucas Papademos, Vice-President of the European Central Bank, delivered at the Nomura Annual Euro Conference "*A challenging future for Europe*", Tokyo, 11 November 2004.

The analysis of the macroeconomic impact of oil price shocks has long been the subject of a vast and growing literature. Most of the empirical studies have relied on aggregate data,[1] concluding that an increase in oil prices has a significant negative impact on the GDP growth and contributes to higher inflationary pressures in oil-importing countries. The disaggregated effects of oil price shocks, however, have remained understudied, being Bohi (1989) and Lee and Ni (2002) the main exceptions.[2] While the latter authors focus on the effects of oil price shocks on demand and supply in several US manufacturing industries, the former also analyses the impact of oil price shocks on economies different from the US - Germany, Japan, and the UK - in the two energy price shocks of the 1970s. On the one hand, Bohi (1989) finds no correlation between the declines in industry-level outputs and the energy intensities of the industries during the two energy crises considered. Lee and Ni (2002), on the other hand, show that oil price shocks have a variety of negative effects upon US industries, with oil shocks mostly reducing the supply of oil-intensive industries and the demand of many other industries, specifically the automobile industry.

The comparison of the impact of oil price shocks across different industries provides valuable information for policy-makers on how oil shocks are propagated through industrial activity, and so it helps us to better understand the effects of such shocks on aggregate output and inflation.[3] This information may be also useful in understanding the consequences of the monetary policy reactions that may be undertaken to counteract such shocks.[4]

[1] While most of these studies have focused on the US (see Rasche and Tatom, 1981; Darby, 1982; Hamilton, 1983; Gisser and Goodwin, 1986; Mork, 1989; Hamilton, 1996; Hooker 1996; Hamilton, 2003; among others), very few studies have considered countries different from the US (see *e.g.* Burbidge and Harrison, 1984; Mork *et al.*, 1994; Jiménez-Rodríguez and Sánchez, 2005; and Kilian, 2005).

[2] Davis and Haltiwager (2001) study the effects of oil price changes and other shocks on the creation and destruction of US manufacturing jobs. They show that oil shocks account for about 20-25 percent of the variance in the US manufacturing employment growth and also generate important reallocative effects.

[3] Notice that oil price shocks may feed through the economy and generate further indirect effects in the coming months.

[4] Authors like Bohi (1989), Bernanke *et al.* (1997), and Hamilton and Herrera (2004) among others, point out that the indirect effects of oil price shocks involve monetary policy reactions.

The present paper extends the empirical work on oil price impacts by analysing the disaggregated effects of an oil price shock on industrial output of four European Monetary Union (EMU) countries (France, Germany, Italy, and Spain), the UK and the US.[5] Our aim is to shed more light on the question whether there are significant differences in the reactions of the manufacturing industries of these economies to oil price shocks. Thus, we investigate the pattern of output responses to an oil price shock in the different industries considered, analysing whether these responses provide evidence on cross-industry heterogeneity of oil shock effects, as well as evidence on cross-country heterogeneity. To do so, we consider an identified VAR model for each country considered using monthly data.

The rest of the paper is organized as follows. Section 2 describes the methodology. Section 3 presents the empirical results. Section 4 discusses the robustness of the empirical results. Section 5 concludes.

2 Econometric specification and identification

We consider a pth-order structural Vector Autoregression model that includes both macroeconomic and industry-level variables (*i.e.*, $Y_t = [Y_{1t} \quad Y_{2t}]'$). Let Y_{1t} be a $(N_1 \times 1)$ vector that contains the macroeconomic variables: the Total Industrial Production (y_t),[6] the Consumer Price Index (cpi_t), a monetary aggregate (m_t), a nominal short-term interest rate (sr_t), the Real Effective Exchange Rate (xr_t), and the real oil price (oil_t).[7] Let Y_{2t} be a $(N_2 \times 1)$ vector that contains the specific industrial variables; in this case, we only consider the specific industrial output (y_{jt}) because data availability does not allow us to include the specific industrial price. All variables except interest rates are in logs.[8] See Data Appendix for a detailed data description.

The reduced-form VAR model is the following

$$Y_t = c + R(L)Y_t + u_t, \tag{1}$$

where $R(L) = R_1 L + R_2 L^2 + ... + R_p L^p$ is a matrix polynomial in the lag operator L, and u_t is the generalisation of a white noise process with variance-covariance matrix $\Omega = \begin{bmatrix} \Omega_{11} & \Omega_{12} \\ \Omega_{21} & \Omega_{22} \end{bmatrix}$. We impose, as Lee and Ni (2002) and Davis and Haltiwanger (2001) did, that macroeconomic variables affect industrial variables,

[5] The lack of monthly data by sub-sector for all countries under study forces us to confine the analysis to the industrial level.

[6] We use Total Industrial Production as a proxy of economic activity instead of GDP, because they are highly correlated and the latter is only available at quarterly frequency.

[7] The use of non-linear transformations of oil price to analyse the impact of oil price shocks on aggregate output has been theoretically justified by the inter-sectoral adjustments to which they involve (see Jiménez-Rodríguez and Sánchez, 2005, and references therein). Thus, we do not apply such transformations in our study given that our main goal is to analyse the impact at the industrial level, and their use may give rise to biased results.

[8] In this paper we do not perform an explicit analysis of the long-run behaviour of the economy. By doing the analysis in levels we allow for implicit cointegrating relationships in the data, and still have consistent estimates of the parameters. For further discussion in this issue, see *e.g.* Sims *et al.* (1990), Hamilton (1994), and Ramaswamy and Slϕk (1998).

but the latter variables do not affect the former variables.[9] Thus, macroeconomic shocks are the same for all industries and the cross-industry comparison of responses to such shocks is meaningful. The economic interpretation behind this assumption is that changes in a specific industrial output are not individually able to affect the macroeconomy. However, this assumption is not incompatible with the fact that changes in output of several industries involve macroeconomic consequences.

$$\begin{bmatrix} Y_{1t} \\ Y_{2t} \end{bmatrix} = \begin{bmatrix} c_1 \\ c_2 \end{bmatrix} + \begin{bmatrix} R_{11}(L) & 0 \\ R_{21}(L) & R_{22}(L) \end{bmatrix} \begin{bmatrix} Y_{1t} \\ Y_{2t} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix}, \tag{2}$$

where $R_{ij}(L)$ is a matrix polynomial in the lag operator L, i.e. $R_{ij}(L) = R_{1,ij}L + R_{2,ij}L^2 + ... + R_{p,ij}L^p$ with $i, j = 1, 2$.

The structural VAR approach assumes that the disturbances u_t are related to structural macroeconomic shocks ε_t via a matrix, A_0, such that $A_0 u_t = \varepsilon_t$. To ensure that macroeconomic shocks are the same for all industries we also impose that A_0 is block recursive (i.e., the macroeconomic variables are neither contemporaneously affected by industrial variables):

$$\begin{bmatrix} A_{11}^0 & 0 \\ A_{21}^0 & A_{22}^0 \end{bmatrix} \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} = \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}. \tag{3}$$

Thus, the structural VAR is described by:

$$A_0 Y_t = A_0 c + A_0 R(L) Y_t + \varepsilon_t, \tag{4}$$

where ε_t is a white noise vector with variance-covariance matrix given by the *identity* matrix (without loss of generality). Although it would be possible to identify a structural VAR when the structural shocks are smaller than the number of variables (see Uhlig, 2005, for sign restrictions approach, and Bernanke and Boivin, 2003, for factor augmented VAR approach), we adopt, for simplicity, the standard structural VAR approach with an exact match between the number of structural shocks and the number of variables (see, for example, Kim and Roubini, 2000). Thus, we assume A_0 matrix to be square and invertible. To achieve the identification of the model one could have used as the baseline identification scheme the popular and convenient method based on the Choleski decomposition (as in Sims, 1980, among others). However, this approach implies a recursive structure which imposes restrictions (which cannot be tested) on the basis of an arbitrary ordering of the variables and their estimate results may be sensitive to the ordering imposed. As such, we identify the model by using a non-recursive structure and we only consider the recursive structure to examine the robustness of our results. The non-recursive identification used as the baseline identification imposes exclusion on the contemporaneous incidence

[9] The likelihood ratio tests (based on the so-called block-exogeneity test) indicate that the block-recursive restrictions (i.e., $R_{12}(L) = 0$) cannot be rejected for most industries and most countries, being the case of the UK the main exception. Even in the cases of rejection, the estimate of the variance-covariance matrix of the macroblock, Ω_{11}, is not significantly altered by the presence of the specific industrial output. Thus, we estimate under the restriction that macroeconomic variables are not affected by the specific industrial output.

of the structural shocks based on prior theoretical and empirical information about the economic structure.[10]

$$\begin{bmatrix} a_1 & 0 & 0 & 0 & 0 & a_2 & 0 \\ a_3 & a_4 & 0 & 0 & 0 & a_5 & 0 \\ a_6 & a_7 & a_8 & a_9 & 0 & 0 & 0 \\ 0 & 0 & a_{10} & a_{11} & a_{12} & a_{13} & 0 \\ a_{14} & a_{15} & a_{16} & a_{17} & a_{18} & a_{19} & 0 \\ 0 & 0 & 0 & 0 & 0 & a_{20} & 0 \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} & a_{26} & a_{27} \end{bmatrix} \begin{bmatrix} u_t^y \\ u_t^{cpi} \\ u_t^m \\ u_t^{sr} \\ u_t^{xr} \\ u_t^{oil} \\ u_t^{y_j} \end{bmatrix} = \begin{bmatrix} \varepsilon_t^y \\ \varepsilon_t^{cpi} \\ \varepsilon_t^m \\ \varepsilon_t^{sr} \\ \varepsilon_t^{xr} \\ \varepsilon_t^{oil} \\ \varepsilon_t^{y_j} \end{bmatrix}. \quad (5)$$

Before we explain the details of our identifying restrictions, it is worth noting that the following relations are contemporaneous restrictions on the structural parameters of A_0 without further restrictions on the lagged structural parameters. In constructing our identifying restrictions, we follow Gordon and Leeper (1994), Sims and Zha (1998), Kim and Roubini (2000), Davis and Haltiwanger (2001), and Lee and Ni (2002). We assume that aggregate output is only contemporaneous influenced by oil price shocks, and the prices only react immediately to innovations in aggregate output and oil prices. The first two equations of the system (5) support the idea that the reaction of the real sector (aggregate output and prices) to shocks in the monetary sector (money, interest rate and exchange rate) is sluggish. The third equation of the system (5) can be interpreted as a short-run money demand equation. Money demand is allowed to respond contemporaneously to innovations in output, prices and interest rate. The forth equation represents the monetary policy reaction function. The monetary authority sets the interest rate after observing the current money stock, oil prices and the exchange rate, but does not respond contemporaneously to disturbances in aggregate output and prices. The argument is that information about the latter variables is only available with a lag, since they are not observable within a month. The exchange rate, being an asset price, reacts immediately to all other macroeconomic variables. We also assume that oil prices are contemporaneously exogenous, that is, oil prices do not respond contemporaneously to disturbances in other macroeconomic variables (see Lee and Ni, 2002, for discussion). Furthermore, the specific industrial output responds contemporaneously to all macroeconomic variables.

As a result of the zero-restrictions imposed to identify our SVAR,[11] the sub-system referred to the macroeconomic variables is overidentified with one overidentifying restriction. While to impose an overidentifying restriction in the macroblock allows us to check the validity of the set of the full identifying restrictions, this checking cannot be performed when the sub-system is just-identified. Thus, we test the restricted model against the reduced-form model

[10] It is worth noting that the non-recursive structure (contrary to the recursive one) allows us here to consider the contemporaneous interactions between the interest rate and the exchange rate, and the non-reaction of the interest rate contemporaneously to changes in output and inflation (see Sims and Zha, 1998), as well as the contemporaneous interactions between the interest rate and money stock (see Kim and Roubini, 2000).

[11] Notice that A_{21} and Ω_{21} contain the same numbers of elements, and so we do not impose restrictions. The same thing happens with A_{22} and Ω_{22}.

by employing a likelihood ratio test: $LR = 2ln\ L(\hat{\Omega}_{11}) - 2ln\ L(\tilde{\Omega}_{11})$, which is $\chi^2_{(1)}$ distributed under H_0 (validity of the full set of identifying restrictions), and $ln\ L(\hat{\Omega}_{11})$ and $ln\ L(\tilde{\Omega}_{11})$ are the concentrated log-likelihood functions for the reduced and structural form, respectively (see Hamilton, 1994, and Amisano and Giannini, 1997). The set of restrictions we select gives a $\chi^2_{(1)}$ *p-value* larger than 0.05 for all countries under study. Clearly, that set of restrictions cannot be rejected for any country.

We estimate the structural VAR model by maximum likelihood, with the optimal lag length chosen on the basis of the Information Criteria. We obtain the forecast-error variance decomposition, the impulse responses to an oil price shock (a unit shock) and their corresponding confidence bands calculated through a bootstrapping procedure with 100 draws, although no significant differences exist when either 500 or 1000 repetitions are considered.

To verify the robustness of our baseline results, we first explore 3 alternative identification schemes; second, we consider the standard lag length used in most of the previous empirical studies concerning aggregate data; and finally, we re-estimate our SVAR using real oil prices country specific, since the inflation development over the period considered may differ significantly across countries (see Appendices A-C).

We apply this methodology to four EMU countries (namely, France, Germany, Italy and Spain), the UK, and the US. The industrial data refer to aggregate manufacturing industry and eight individual manufacturing industries grouped according to the two-digit International Standardized Industrial Classification (ISIC). The Data Appendix provides sources, and an explanation of the choice of the Industry database considered. The available sample runs from 1975:1 to 1998:12, for all countries but France and Spain[12] where data start in 1980:1. Despite the fact that our database ends in 1998:12 and does not allow us to analyze what has happened in the last eight years, the analysis reported in the present paper provides valuable lessons of experience. Although the past does not repeat itself exactly, given that the global and country specific macroeconomic and geopolitical conditions change over time, it may help us to gauge the vulnerability of the countries studied to the possible forthcoming oil supply shocks.[13]

3 Empirical results

The analysis is focused on the response of manufacturing industrial output to an oil price shock in the four EMU countries under consideration (namely, France, Germany, Italy and Spain), the US, and the UK - the latter being the only net

[12] The Spanish results using the sample period 1975:1-1998:12 were not easy to reconcile with the theory since they could reflect the Spanish policy implemented up to the end of 1970s by subsidizing the oil prices. Thus, the effects of oil price shocks on the Spanish industries could have been distorted by the use of 1970s' data. Therefore, we have decided to reduce the sample, starting in 1980:1, to avoid a distorted conclusion.

[13] Notice that the growing tendency of real oil prices from 2002 onwards differs from previous oil price shocks, which were mainly caused by sizeable disruptions to the supply of oil. The factors driving the oil price increases over the last years are basically caused by demand factors.

oil exporting country in our sample. A lack of data forces us to confine the analysis to differences or similarities in the output effects, overlooking possible differences or similarities in pricing behaviour. Figures 1-9 display the cumulative dynamic effects on the manufacturing industrial output for each industry and each country under consideration. In each figure, the dynamic effect of an oil price shock is reported with a standard deviation band (calculated by bootstrapping procedure) around the point estimated.

An oil price increase lowers the level of aggregate manufacturing output in all countries under study, although the pattern of response differs somewhat across countries (see Figure 1). On the one hand, a similar response of aggregate manufacturing output is observed in the Anglo-Saxon countries and two EMU countries - Germany and Italy -, becoming the negative effect permanent.[14] On the other hand, such an effect becomes positive two years after the shock in France and Spain. Furthermore, not all countries respond by the same magnitude. The magnitude of impact is larger in Anglo-Saxon countries than in the EMU countries considered, with the largest negative impact observed in the UK two years after the shock.[15] Therefore, the results indicate that the sensibility of aggregate manufacturing output to changes in oil prices differs marked across the EMU countries under study, but it is similar in the US and the UK.

On examining the output responses of the eight industry groups within manufacturing, we observe significant differential pattern of output responses to an oil price shock across countries (see Figures 2-9). Whereas the output responses of EMU manufacturing industries substantially differ from country to country, the negative pattern of responses is similar for most industries in the Anglo-Saxon countries. Among EMU countries considered, similarities are observed between German and Italian output reactions for four industries (namely, "wood and wood products", "paper and paper products", "chemical", and "non-metallic mineral products" industries), and also between French and Spanish output responses for other four industries ("wood and wood products", "paper and paper products", "non-metallic mineral products", and "metal products, machinery and equipment" industries). Moreover, the Italian and German industrial output responses are relatively similar to those found in the Anglo-Saxon countries, with all manufacturing industries negatively affected by an oil price increase. The exceptions are the “textiles, wearing apparel and leather” and “basic metals” industries in Germany, which have a positive response when oil price increases.

To analyse the extent to which the industrial effects of oil price shocks are similar across countries, we look at the standard correlation coefficient.[16] We first observe that the correlation coefficient of impulse responses in the two Anglo-Saxon countries is larger than 0.80 for all industries but "basic metals"

[14] The finding that UK manufacturing activity falls after an increase in oil price is consistent with what was reported for overall economic activity in Jiménez-Rodríguez and Sánchez (2005). These authors attribute this result to a Dutch disease-type effect.

[15] This result contrasts with the fact that the Anglo-Saxon countries seem to be less sensible to oil shocks than the EMU countries under study according to the oil vulnerability indicators (see Appendix D: Table D.1).

[16] The output responses in the "textiles, wearing apparel and leather" industry substantially differ across countries, and so we take it out for comparison purposes.

industry, where the coefficient decreases up to 0.70. Second, the correlation coefficients of output responses between the Anglo-Saxon and German industries and those between the Anglo-Saxon and Italian industries reach values larger than 0.50 for all industries. The exceptions are the correlation coefficients between the Italian/German "non-metallic mineral products" industries and their analogous UK industries, and those between the Italian/German "wood and wood products" industries and their analogous US industries. Third, the Italian-German correlation coefficient is above 0.90 for all industries but "food, beverages and tobacco", "basic metals", and "metal products, machinery and equipment" industries. Finally, a positive correlation (larger than 0.70) between the responses of four industries (namely, "wood and wood products", "paper and paper products", "non-metallic mineral products", and "metal products, machinery and equipment" industries) is found for the other two EMU countries (France and Spain). Therefore, the output responses of the manufacturing industries show cross-country heterogeneity for the four EMU countries considered and homogeneity across the Anglo-Saxon countries.

Regarding the responses of manufacturing industries within each country, whereas we find evidence on cross-industry heterogeneity of oil shock effects in France, Germany, and Spain, similar responses are observed in Italy, the UK and the US (see Figures 2-9).

The different effects may have to do with the manufacturing industrial structures and the oil consumptions, among other factors.[17] First, whereas we observe that the Anglo-Saxon countries show high similarities in their manufacturing industrial structures (see Appendix D: Table D.3), the similarities decrease in the case of the EMU countries under consideration, being the German and Italian structures the most similar ones. Second, we observe a general decrease in oil consumption for all industries (exceptions: "food, beverages and tobacco" and "chemical" industries) in all countries (see Appendix D: Figure D.1). In the Anglo-Saxon countries, despite the fact that the oil consumption in the US industries is proportionally larger than that observed in the British industries, we observe a high similarity in the last years[18] with two exceptions: "paper and paper products" and "wood and wood products" industries, where the US consumption is proportionally much larger. In the EMU countries, although there is some disparity in consumptions, three industries - "food, beverages and tobacco", "chemical", and "non-metallic mineral products" industries - maintain their most important oil consumption. Additionally, other possible explanations for our results like those related to the product and labour market rigidities have been also explored, although these alternative/complementary explanations do not actually help us to understand what is behind our results. According to the index of product market regulation in the manufacturing sector and the indicator about overall strictness of employment protection legislation (both reported by OECD) and information from the Fraser Institute, the Anglo-Saxon countries exhibit more flexible product and labour markets than those of the EMU coun-

[17] Table D.2 from Appendix D identifies the manufacturing industries among the different databases used (see Appendix D for further details).

[18] We only compare the last years since the US data from the homogeneous Energy Statistics database are only available for the first eight and the last four years of the sample period (see Appendix D: Table D.4, for data availability).

tries under study.[19] Thus, the manufacturing industries of the EMU countries considered seem to be less flexible than those of the Anglo-Saxon countries, so it would be expected that the EMU manufacturing industries are more adversely affected by the disturbance in oil prices but it is not, however, the case.

To quantify the output effects of oil price shocks across industries and countries, we construct a summary measure of impact: the maximum elasticity recorded between 12 and 36 months after an oil price increase. This maximum elasticity is the smallest output change registered between 12 and 36 months after an oil price shock. Table 1 reports this measure and the forecast-error variance decomposition of output due to oil price shocks at the point of maximum elasticity. This measure reveals that the impact of an oil price shock on industrial output is usually negative in all countries and the largest (negative) impacts tend to be in the UK. While evidence on cross-country heterogeneity of oil shock effects is observed in the EMU countries considered, a broadly similar impact is observed in the UK and the US. Furthermore, the maximum elasticity differs quantitatively across manufacturing industries within each country. The industry more linked to housing and construction (that is, "wood and wood products" industry) seems to be one of the most affected industries by an oil price shock in all EMU countries under consideration,[20] with oil price shocks explaining the output variability of this industry with a percentage of around 20% in France and Germany, 10% in Italy and 6% in Spain. In the Anglo-Saxon countries, however, the most affected industries are those linked to industrial demand (that is, the "chemical" industry in the UK and the "metal products, machinery and equipment" industry in the US) and the less affected industries are the two industries linked more closely to personal consumption (that is, "food, beverages and tobacco" and "textiles, wearing apparel and leather" industries). We observe that the share of output variability explained by oil prices in the most affected industries is around 25% in the UK and around 15% in the US, while the fraction of output's variance due to oil prices is instead rather low (around 5%) for the less affected industries.

The response heterogeneity to an oil price shock indicates that economic policy should respond cautiously to oil price shocks. Lucas Papademos pointed out in his speech (Tokyo, 11 November 2004) that "*[...] in reacting to oil price shocks, it is, therefore, important that policy-makers do not repeat the mistakes of the past [...] Monetary policy should aim to ensure that inflation expectations are not adversely affected by the unavoidable "first-round" direct and indirect effects of an oil price shock on the price level and that they remain anchored to price stability. By preventing oil price shocks from having "second-round" effects on inflation expectations and on wage and price-setting behaviour, monetary policy can contain the unfavourable consequences of these shocks on both inflation and growth [...] we at the ECB stress the need to be extremely vigilant against the materialisation of second-round effects that may result from a rise in oil prices.*" The adoption of a common monetary policy to

[19] An Appendix with all this information is available from the author upon request.

[20] The most negative effects are on "wood and wood products" and "non-metallic mineral products" industries in France and Germany, being the former industry also the most affected in the Spanish case. Moreover, "wood and wood products" and "paper and paper products" industries record the largest maximum impacts in Italy.

counteract oil shocks may well create asymmetric effects as long as the effects of oil price shocks are different in the EMU industries under study. Moreover, while country specific fiscal policy might be possible to smooth final prices by adjusting energy taxes, there is a number of reasons why such a policy may be problematic (nature of the oil shock: temporary or permanent, application environment, budget constraints, among others; for further details see OECD, 2006).

To summarize, we show evidence on cross-industry heterogeneity of oil shock effects in the EMU countries, being Italy the only EMU considered in which manufacturing industries respond similarly. We also find that the output responses of all the industries considered are highly similar within the UK and the US. Furthermore, we observe heterogeneity of output response across EMU countries, but not so across Anglo-Saxon countries. These results seem to be more related to the manufacturing industrial structures than the oil consumptions.

4 Robustness of the results

The benchmark results on the dynamic effects of oil price shocks presented in the previous section rely on specific identification assumptions and the lag length chosen. For all countries under consideration the optimal lag length is substantially shorter than that used in most of the previous empirical studies using aggregate data (i.e., twelve months). As such, we repeat our analysis by considering twelve lags. Likewise, we check the sensitivity of our baseline results to three alternative identifying schemes. First, oil price shocks can be identified through a standard Choleski decomposition with the variables ordered as follows: $[oil, y, cpi, m, sr, xr, y_j]$. The Choleski decomposition implies that each variable is contemporaneously affected only by variables which are above in the ordering. Thus, this ordering presupposes that oil price variable does not contemporaneously react to the rest of the variables in the system. Aggregate output is also ranked as a largely exogenous variable, having an immediate impact on prices, money, interest rate and the effective exchange rate. Another underlying assumption is that monetary policy shocks have no contemporaneous impact on output, prices and money. A monetary policy shock does have an immediate impact on the exchange rate, but the central banks do not respond to changes in the exchange rate within the month. Specific industrial output responds contemporaneously to all macroeconomic shocks. Second, an alternative recursive ordering of the variables considered here follows Jiménez-Rodríguez and Sánchez (2005), adapting their ordering to our set of variables. We exclude long-term interest rate and real wages, but we include monetary aggregate and specific industrial output: $[y, oil, cpi, m, sr, xr, y_j]$. Finally, we adapt the recursive identification proposed by Christiano *et al.* (1999) with both the inclusion of oil price variable, exchange rate and industrial output, and the exclusion of non-borrowed reserves, total reserves and commodity price. Thus, the ordering of the variables is as follows: $[y, cpi, sr, m, xr, oil, y_j]$. In all cases, the orderings of the variables considered are implicitly assuming that A_0 is block recursive, with macroeconomic variables also not being affecting contemporaneously by specific industrial output.

The results using any of these alternative schemes are remarkably similar to our baseline results (see Appendix A). Moreover, the results obtained using 12 lags compared with our baseline results indicate quite similar responses (see Appendix B).[21]

In addition, we check to what extent our baseline results are sensitive to the real oil price definition by re-estimating our SVAR using real oil prices country specific. These results do not change considerably compared with our baseline results (see Appendix C).[22]

In sum, the output responses are quite robust with respect to changes in the number of lags, identification assumptions, and real oil price definition.

5 Conclusions

This paper studies the effects of oil price shocks on the output of the main manufacturing industries in six industrialized countries using disaggregated data at the industry level. The pattern of responses to oil price shocks by industrial output is diverse across the four EMU countries under study (France, Germany, Italy, and Spain), but highly similar in the UK and the US. Moreover, while the effects of an oil price shock seem to be unevenly distributed across the manufacturing industries in three of the four EMU countries under consideration (France, Germany, and Spain), the response homogeneity is the general norm in the remaining countries.

Therefore, response heterogeneity across EMU countries is shown, but not so across Anglo-Saxon countries. Also, evidence on cross-industry heterogeneity of oil shock effects within the EMU countries is found. These results seem to be more related to the manufacturing industrial structures than the oil consumptions. Furthermore, our baseline results are quite robust with respect to changes in the number of lags, identification assumptions, and real oil price definition.

[21] Due to space constraints, we only report the impulse-response functions of "chemical" industries as a sample. The remaining impulse responses are available from the author upon request.

[22] In Appendix C, we only report the impulse-response functions of "chemical" industries as a sample. The remaining impulse responses are available from the author upon request.

6 Data Appendix

A.1. *Macroeconomic data*

The macroeconomic data used in this study and their sources are as follows: CPI from IMF's International Financial Statistics - henceforth IFS- for all countries but Germany, where data come from Deutsche Bundesbank (henceforth DB); Total Industrial Production from IFS; short-term interest rate from IFS for all countries except France (from OECD's Main Economic Indicators, henceforth MEI); REER from MEI; and monetary aggregate from IFS for France (M3) and the US (M1), from DB for Germany (M1), from Banca d'Italia for Italy (M1), from National Government for Spain (M3) and for the UK (M0); real oil prices are computed as the UK Brent price deflated by the US PPI (both from IFS); finally, real oil prices country specific are given by the ratio of the UK Brent price converted into domestic currency (using exchange rates from IFS) and the corresponding CPI.

A.2. *Industrial data*

The choice of Industry database has not been an easy task. We arrange two Industry database: the OECD-STAN Industry database (annual data over the period 1970-2001) and the OECD database "Indicators for Industry and Services" (monthly data over the period 1990:1-2001:9), both based on the International Standard Industrial Classification (ISIC) Revision 3. The former does not allow us to well uncover our aim, since we are interested in the dynamic effects of oil price shocks at lower frequency. In turn, the latter does not include data corresponding to the important movements of oil prices occurred in the mid-70s and the 1980s. Nevertheless, the latter database is also available monthly classified according to the ISIC Revision 2 from 1975:1 to 1998:12. The two classification systems (ISIC Revision 2 and ISIC Revision 3) are not fully compatible and, thus, comparisons have to be made with caution, as we do when elaborating Table D.2 from Appendix D.

Therefore, we have chosen the OECD database "Indicators for Industry and Services" (ISIC Rev.2) because it better uncovers the periods in which oil prices have had more influence. Data are indices (seasonally adjusted) on the base 1990 = 100. The following industries for each country are included in our analysis:

- Manufacturing (3)
- Food, beverages and tobacco (31)
- Textiles, wearing apparel and leather (32)
- Wood and wood products (33)
- Paper and paper products (34)
- Chemical industries (35)
- Non-metallic mineral products (36)
- Basic metals (37)
- Metal products, machinery and equipment (38).

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Table 1.A.: *Elasticity of industrial output to an oil price shock*

Industry	France		Germany		Italy	
Manufacturing (3)	-0.0131	21%	-0.0376	5%	-0.0696	15%
Food, beverages and tobacco (31)	-0.0038	7%	-0.0460	8%	-0.0323	7%
Textiles, wearing apparel and leather (32)	-0.0209	0%	0.0185	1%	-0.0361	3%
Wood and wood products (33)	-0.0297	18%	-0.1252	19%	-0.1211	10%
Paper and paper products (34)	-0.0243	9%	-0.0258	2%	-0.1335	20%
Chemical industries (35)	-0.0055	8%	-0.0568	13%	-0.0899	23%
Non-metalic mineral products (36)	-0.0335	11%	-0.0805	8%	-0.0676	7%
Basic metals (37)	-0.0123	5%	-0.0073	5%	-0.1096	14%
Metal products, machinery and equipment (38)	-0.0286	19%	-0.0277	3%	-0.0676	6%

Note: The first column for each country presents the *maximum elasticity*, which is defined as the smallest output response recorded between 12 and 36 months after an increase in oil price. The second column shows the forecast-error variance decomposition of output due to oil price shocks at the point of maximum elasticity.

Table 1.B: *Elasticity of industrial output to an oil price shock*

Industry	Spain		UK		US	
Manufacturing (3)	-0.0344	3%	-0.1249	39%	-0.0685	16%
Food, beverages and tobacco (31)	-0.0133	3%	-0.0358	12%	-0.0094	4%
Textiles, wearing apparel and leather (32)	-0.0265	4%	-0.0707	6%	-0.0074	4%
Wood and wood products (33)	-0.0842	6%	-0.1436	31%	-0.0472	18%
Paper and paper products (34)	-0.0227	2%	-0.1430	39%	-0.0412	5%
Chemical industries (35)	-0.0186	1%	-0.1442	27%	-0.0606	22%
Non-metalic mineral products (36)	-0.0621	14%	-0.1266	22%	-0.0768	18%
Basic metals (37)	0.0064	4%	-0.1170	21%	-0.1140	13%
Metal products, machinery and equipment (38)	-0.0798	5%	-0.1384	30%	-0.1201	15%

Note: See remarks below Table 1.A.

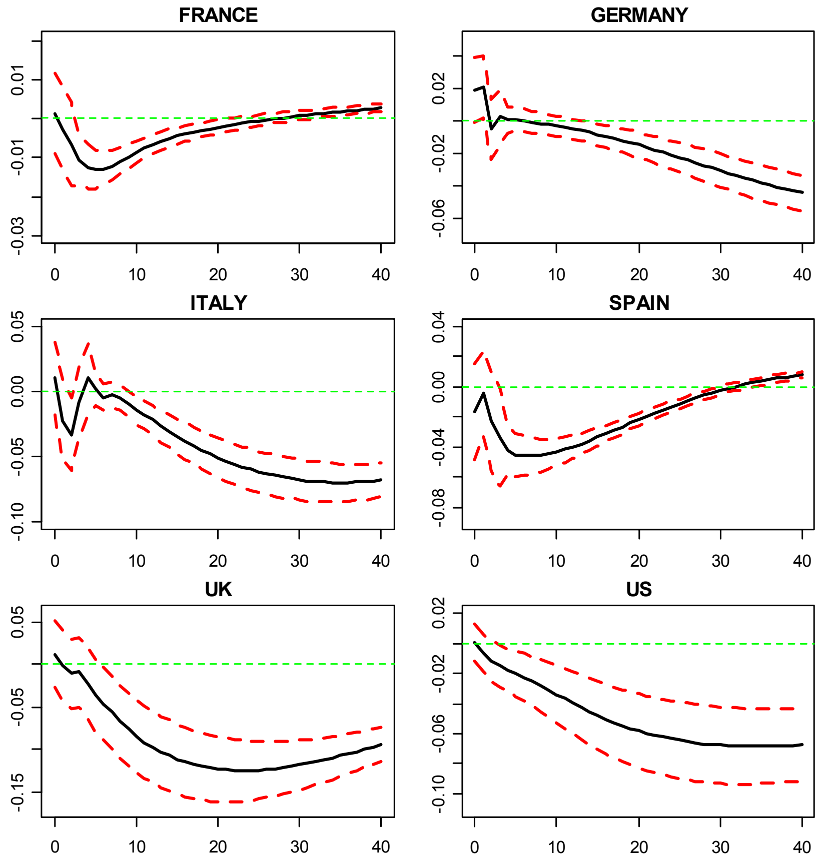


Figure 1: Impulse responses of industry 3 (manufacturing) to an oil price shock.

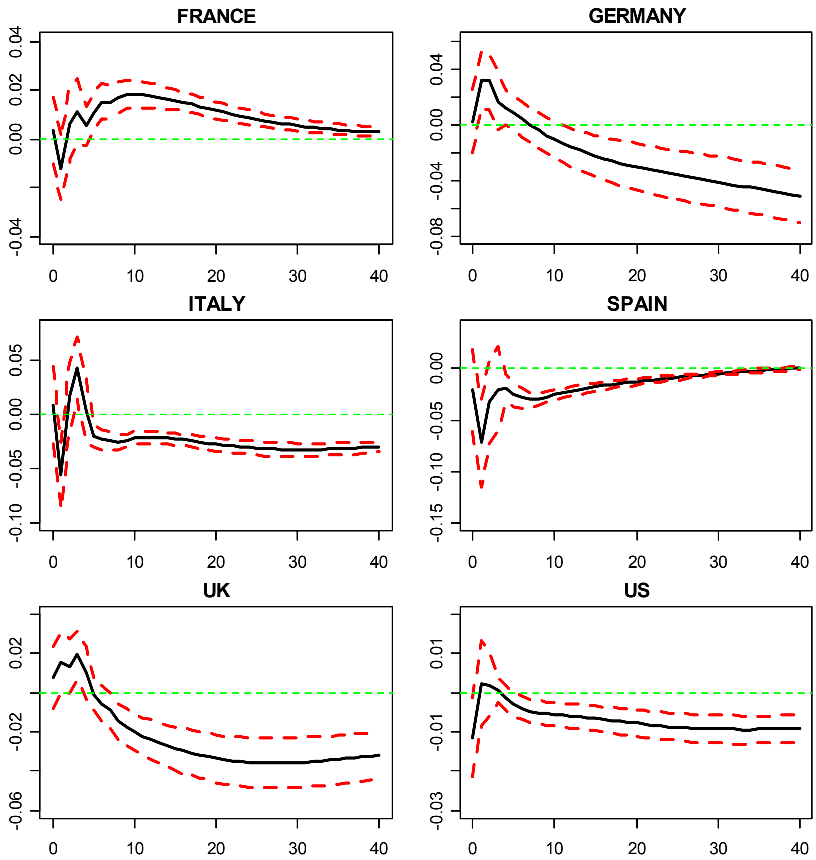


Figure 2: Impulse responses of industry 31 (food, beverages and tobacco) to an oil price shock.

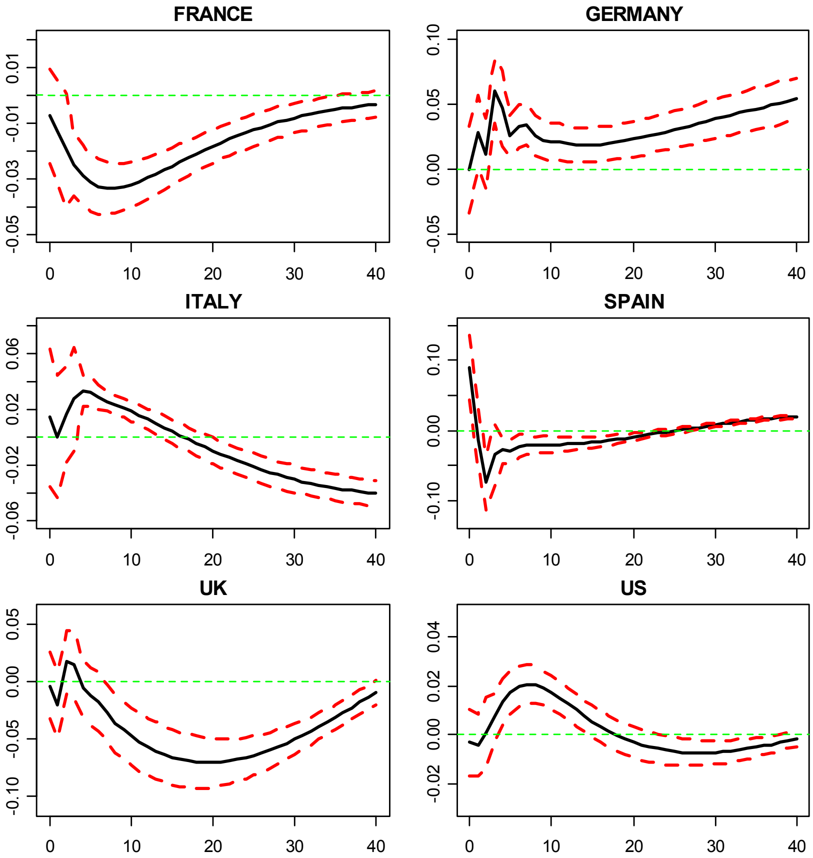


Figure 3: Impulse responses of industry 32 (textiles, wearing apparel and leather) to an oil price shock.

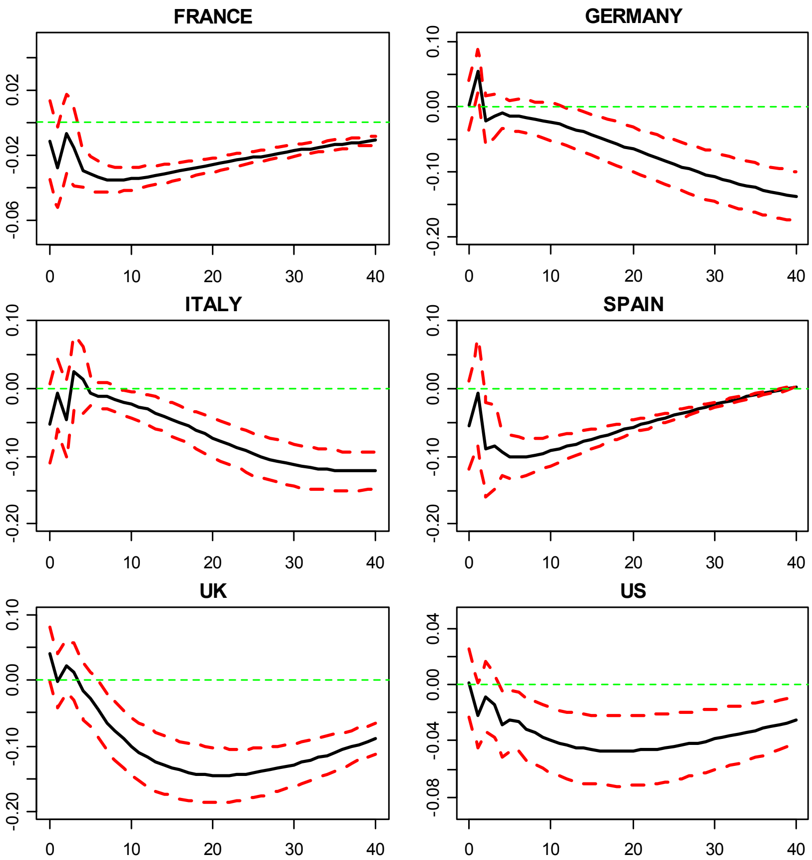


Figure 4: Impulse responses of industry 33 (wood and wood products) to an oil price shock.

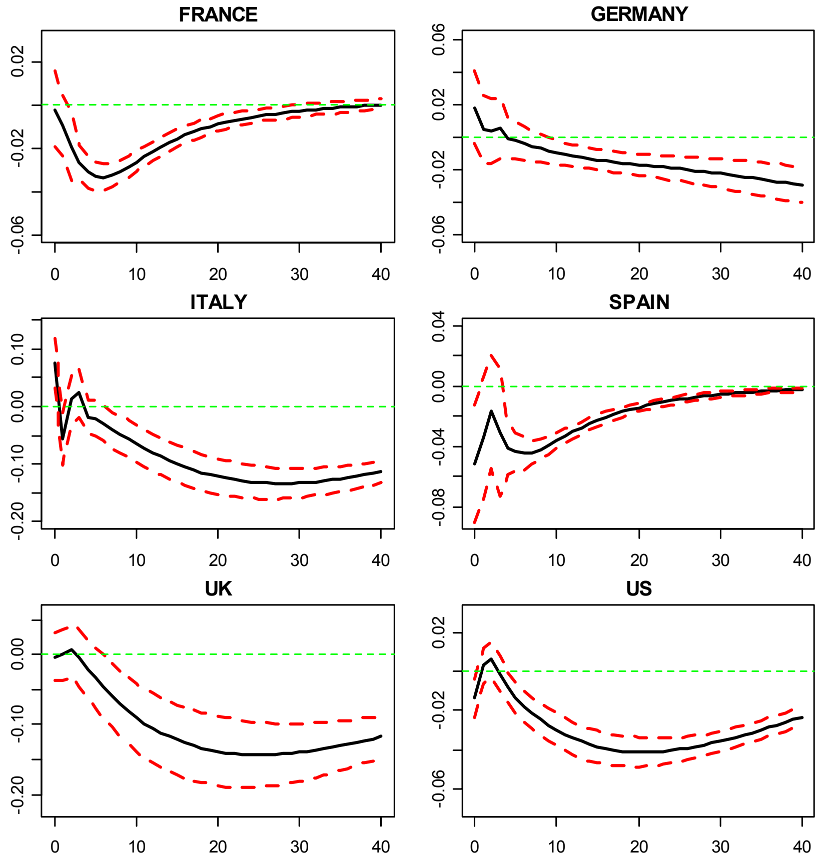


Figure 5: Impulse responses of industry 34 (paper and paper products) to an oil price shock.

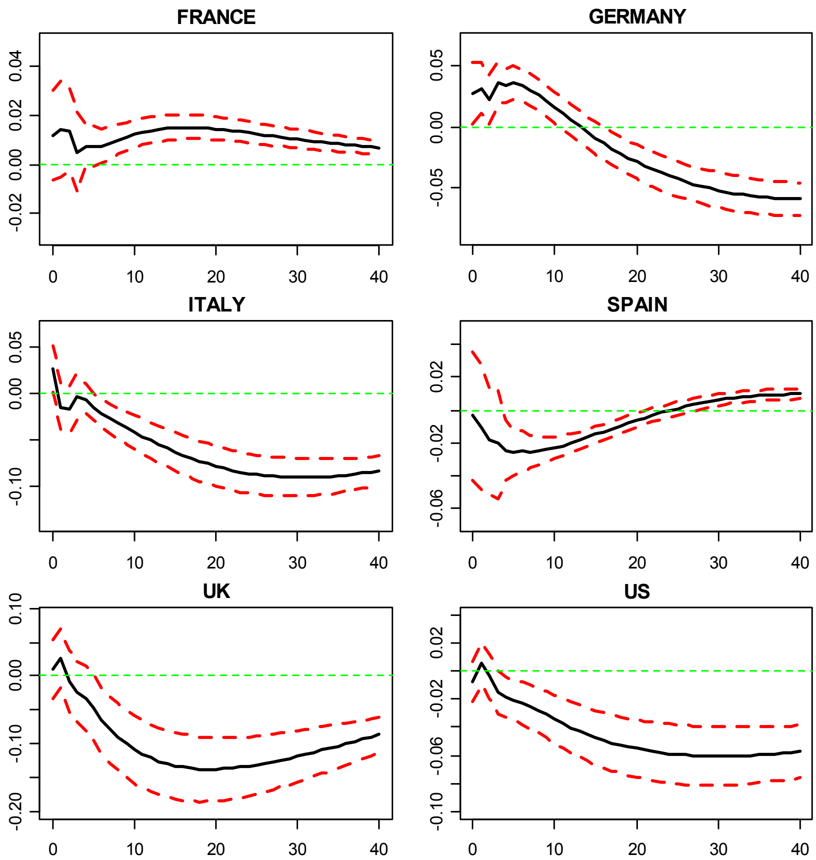


Figure 6: Impulse responses of industry 35 (chemical industries) to an oil price shock.

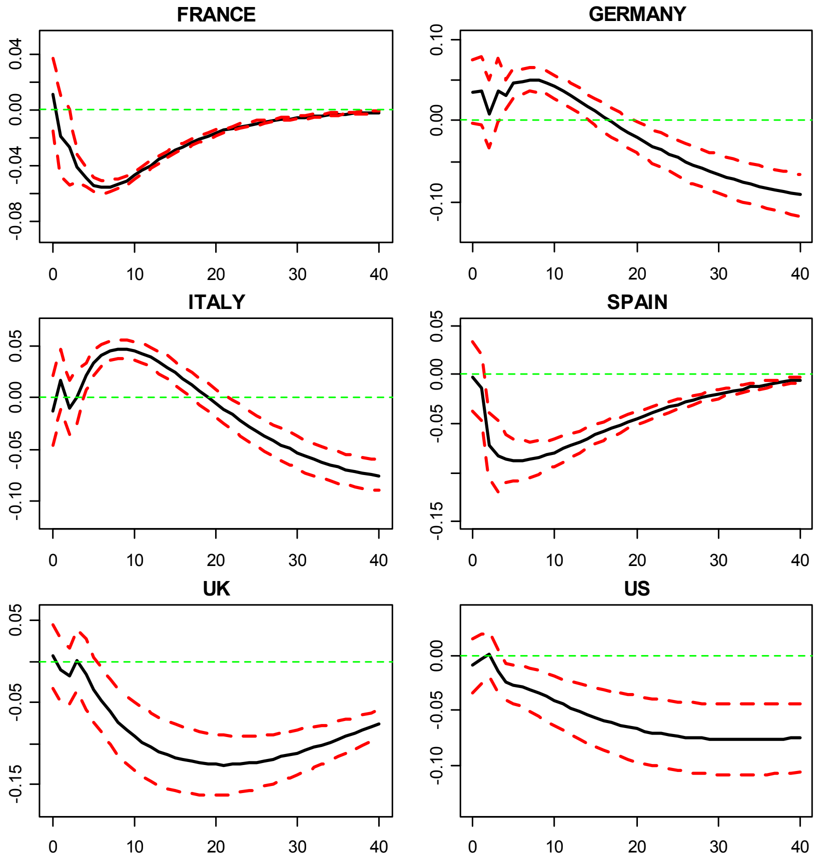


Figure 7: Impulse responses of industry 36 (non-metallic mineral product) to an oil price shock.

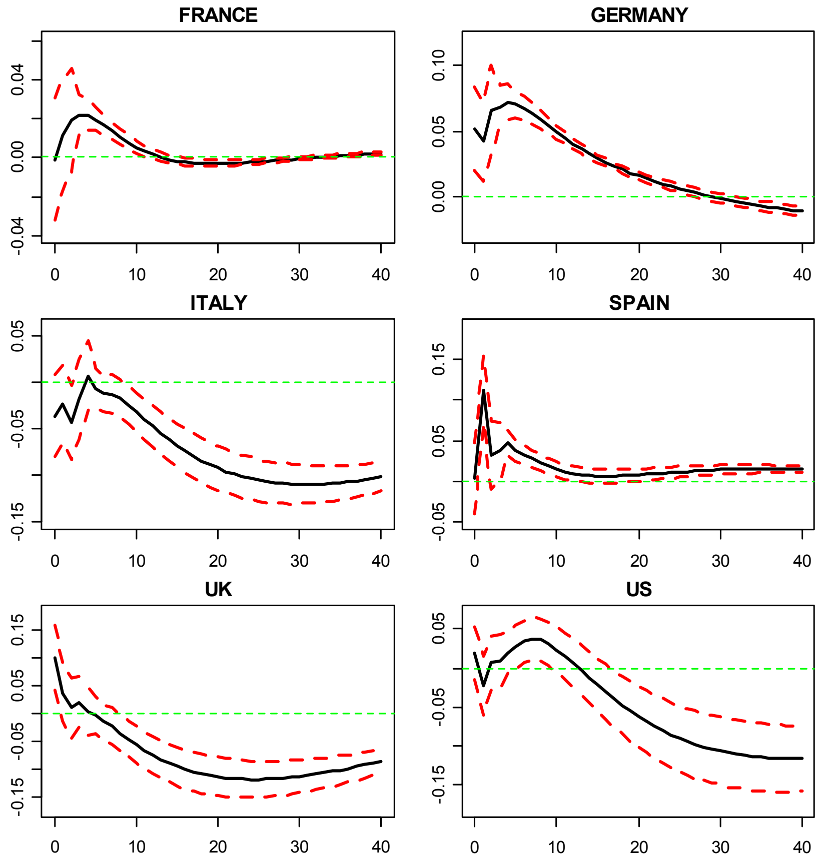


Figure 8: Impulse responses of industry 37 (basic metals) to an oil price shock.

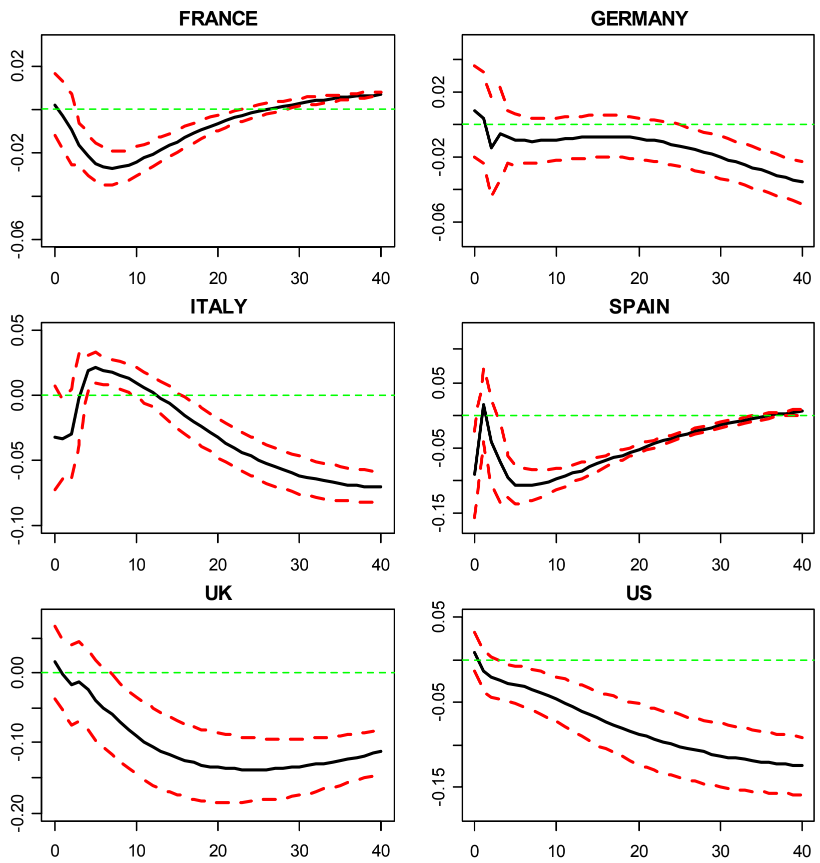


Figure 9: Impulse responses of industry 38 (metal products, machinery and equipment) to an oil price shock.

Appendix A

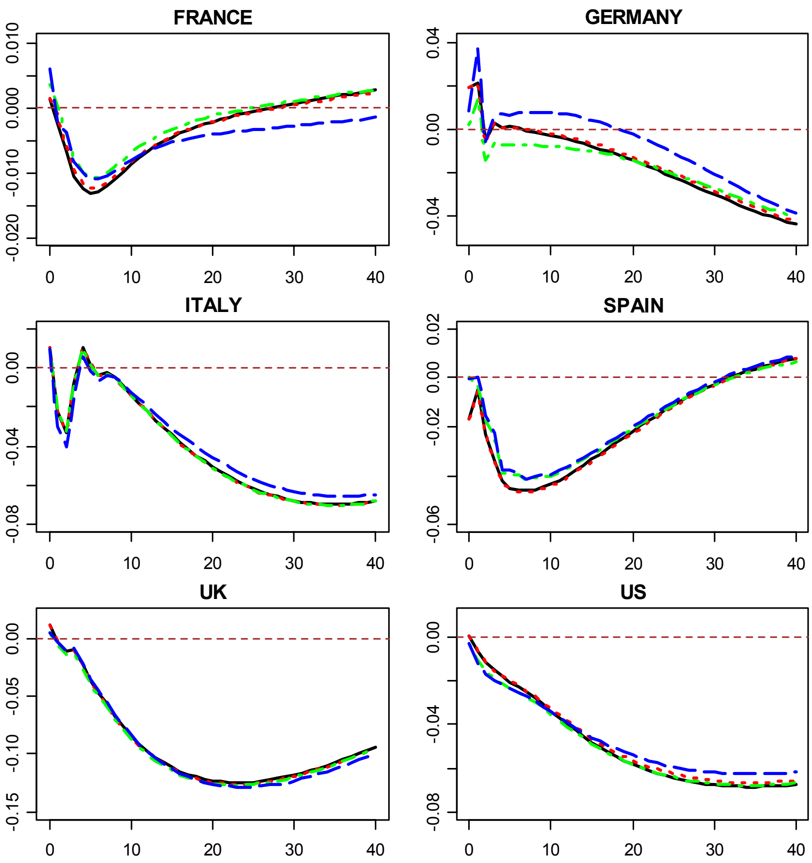


Figure 1: Impulse responses of industry 3 (manufacturing) to an oil price shock under different identification schemes: baseline identification (solid lines), first alternative identification (dashed lines), second alternative identification (dotted and dashed lines), and third alternative identification (dotted lines).

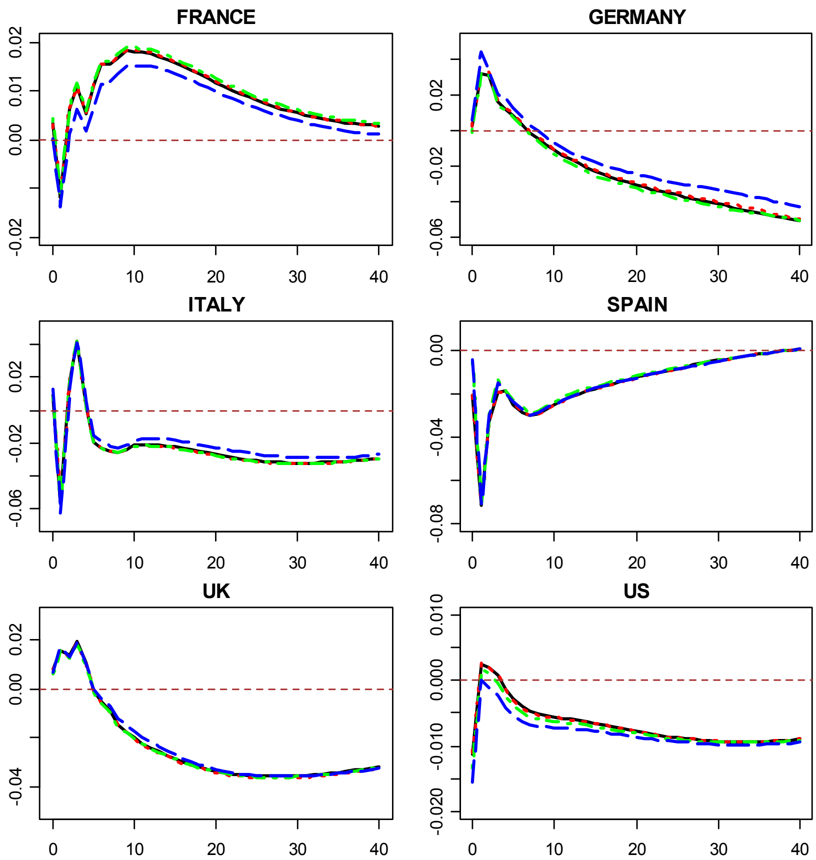


Figure 2: Impulse responses of industry 31 (food, beverages and tobacco) to an oil price shock under different identification schemes: baseline identification (solid lines), first alternative identification (dashed lines), second alternative identification (dotted and dashed lines), and third alternative identification (dotted lines).

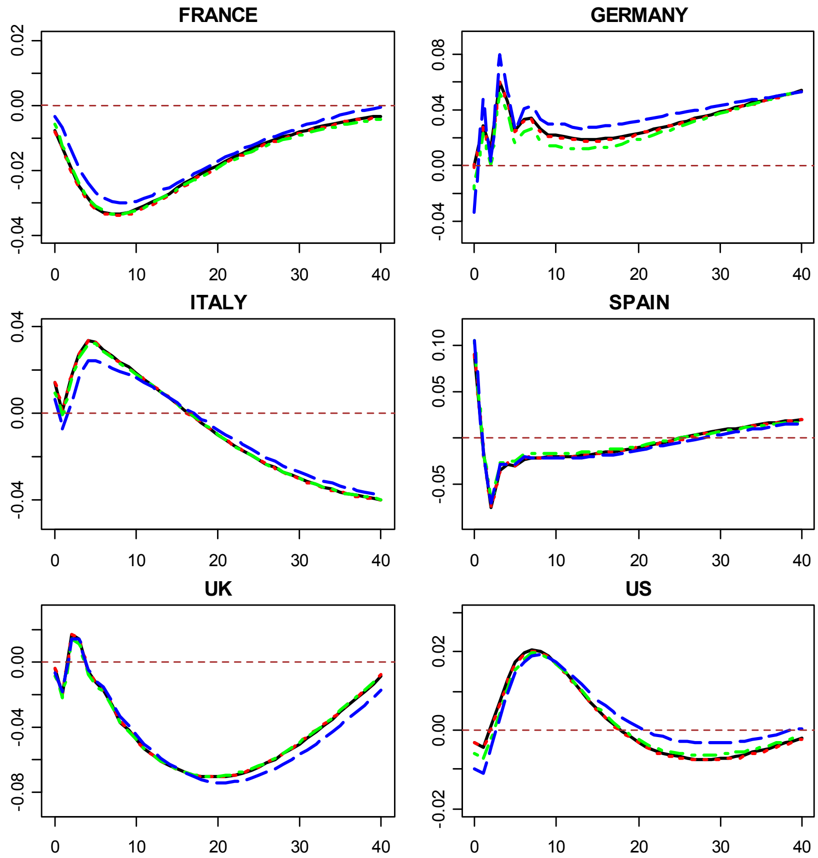


Figure 3: Impulse responses of industry 32 (textiles, wearing apparel and leather) to an oil price shock under different identification schemes: baseline identification (solid lines), first alternative identification (dashed lines), second alternative identification (dotted and dashed lines), and third alternative identification (dotted lines).

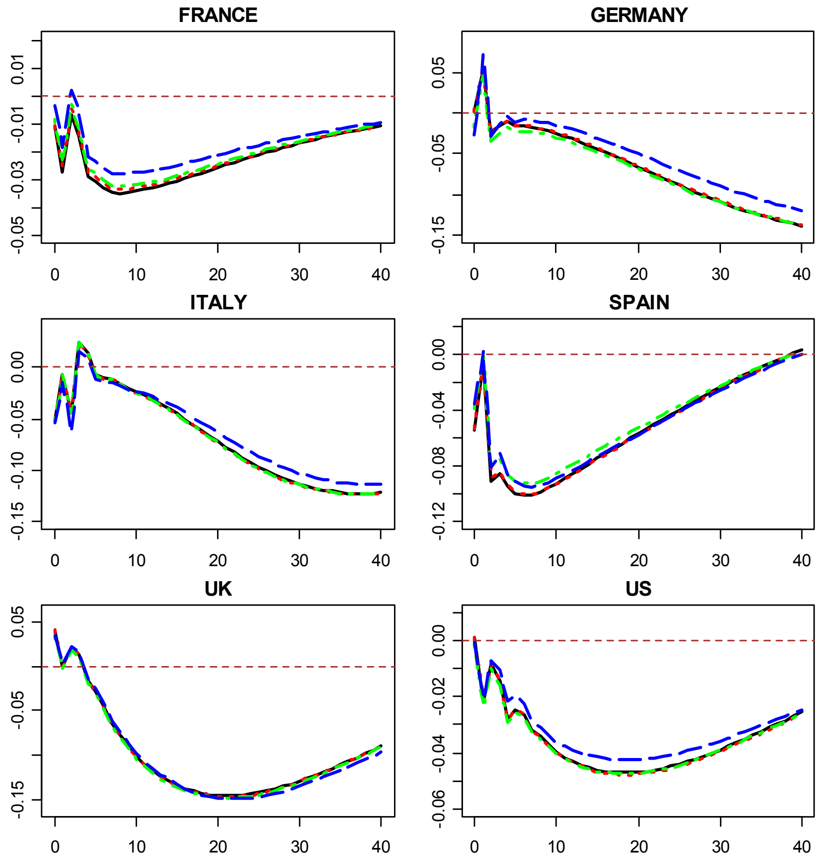


Figure 4: Impulse responses of industry 33 (wood and wood products) to an oil price shock under different identification schemes: baseline identification (solid lines), first alternative identification (dashed lines), second alternative identification (dotted and dashed lines), and third alternative identification (dotted lines).

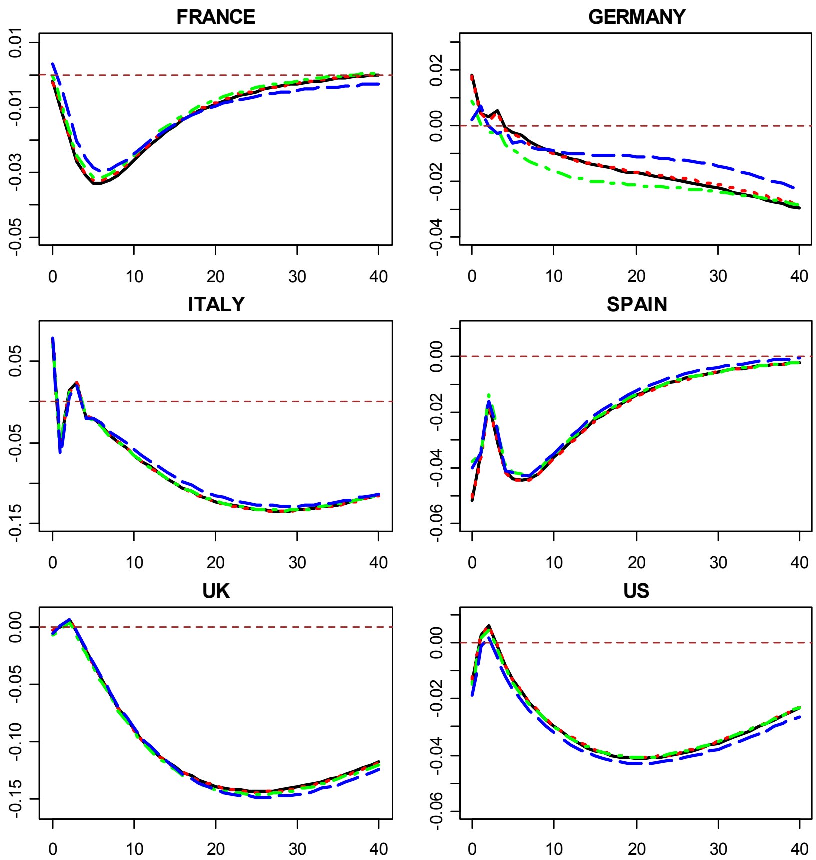


Figure 5: Impulse responses of industry 34 (paper and paper products) to an oil price shock under different identification schemes: baseline identification (solid lines), first alternative identification (dashed lines), second alternative identification (dotted and dashed lines), and third alternative identification (dotted lines).

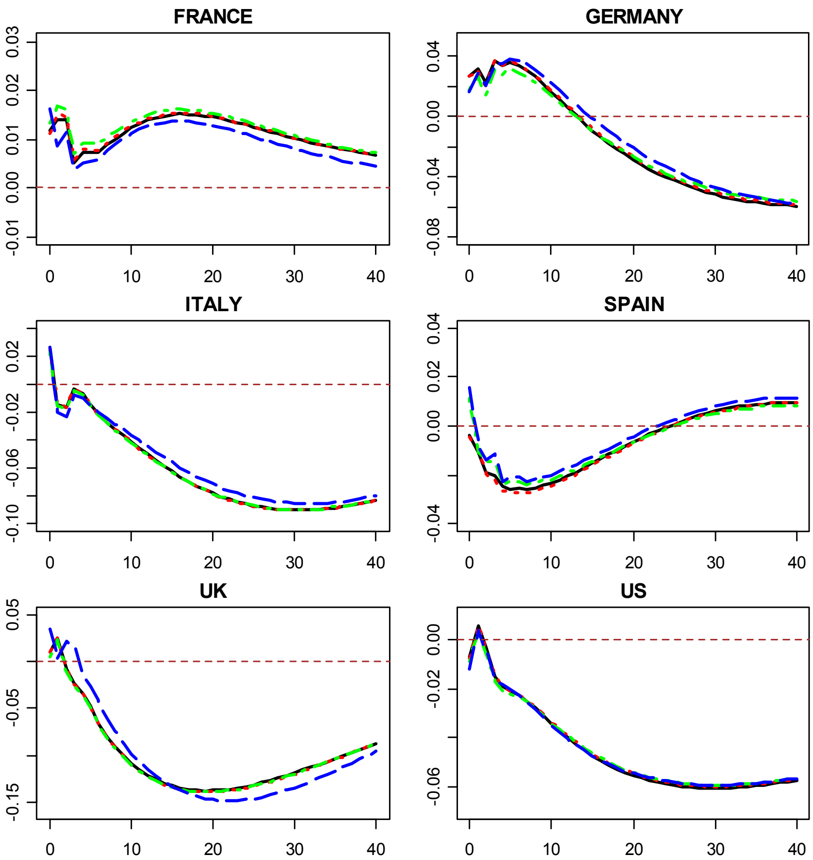


Figure 6: Impulse responses of industry 35 (chemical industries) to an oil price shock under different identification schemes: baseline identification (solid lines), first alternative identification (dashed lines), second alternative identification (dotted and dashed lines), and third alternative identification (dotted lines).

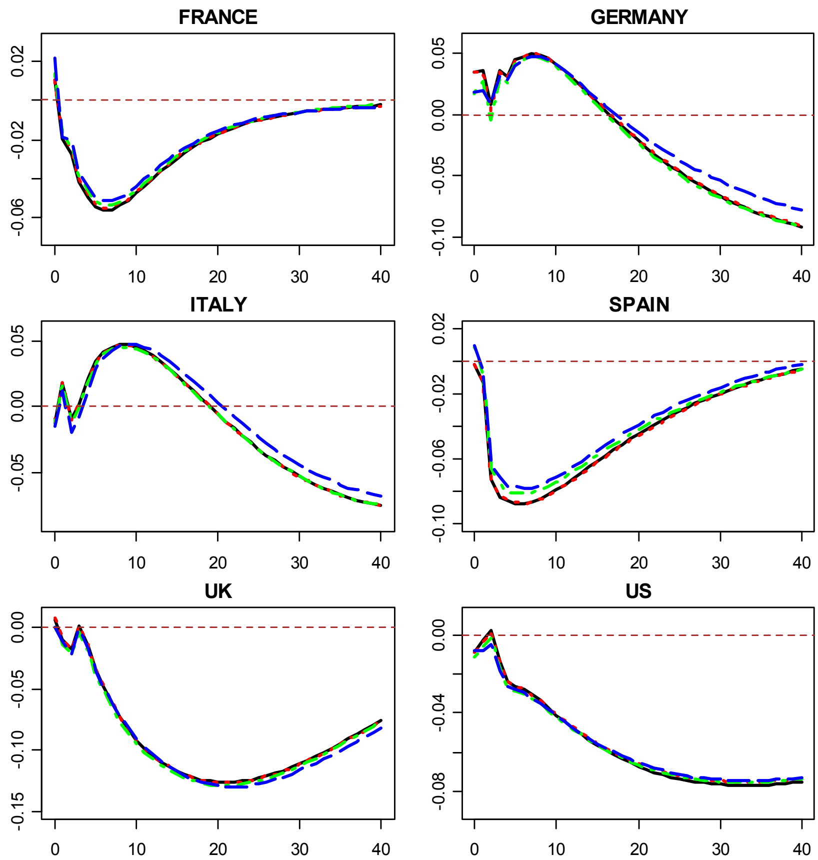


Figure 7: Impulse responses of industry 36 (non-metallic mineral product) to an oil price shock under different identification schemes: baseline identification (solid lines), first alternative identification (dashed lines), second alternative identification (dotted and dashed lines), and third alternative identification (dotted lines).

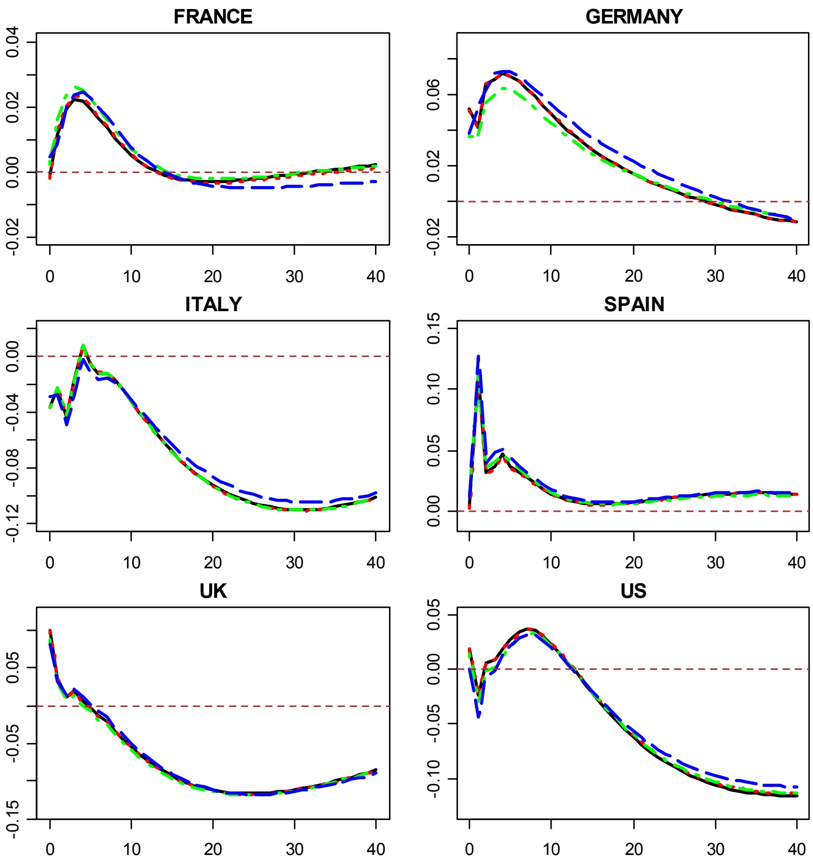


Figure 8: Impulse responses of industry 37 (basic metals) to an oil price shock under different identification schemes: baseline identification (solid lines), first alternative identification (dashed lines), second alternative identification (dotted and dashed lines), and third alternative identification (dotted lines).

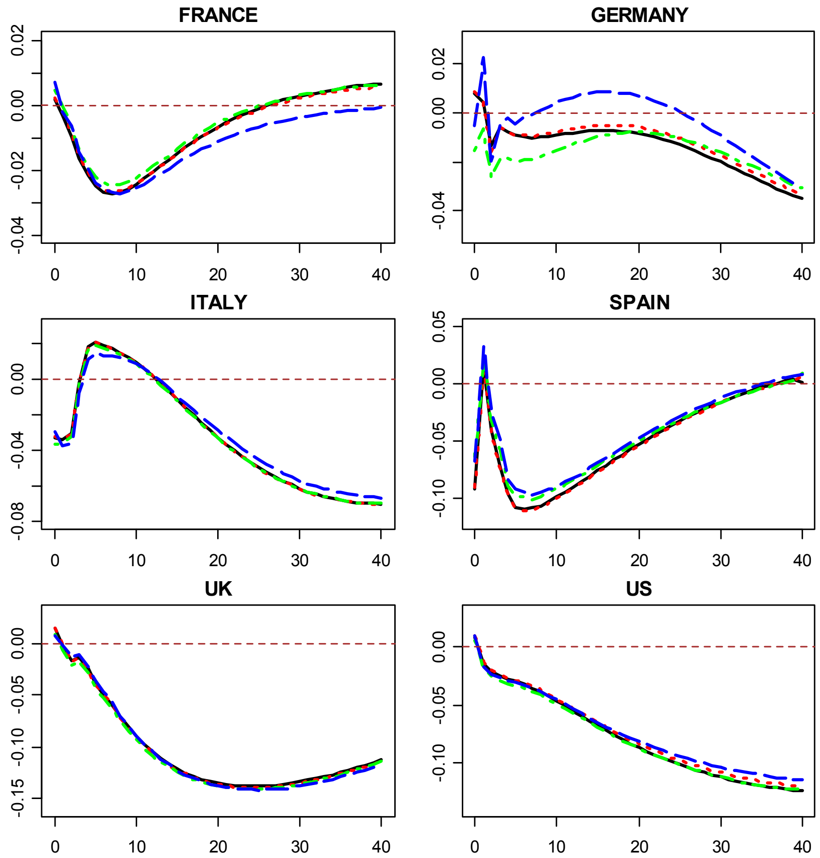


Figure 9: Impulse responses of industry 38 (metal products, machinery and equipment) to an oil price shock under different identification schemes:baseline identification (solid lines), first alternative identification (dashed lines), second alternative identification (dotted and dashed lines), and third alternative identification (dotted lines).

Appendix B

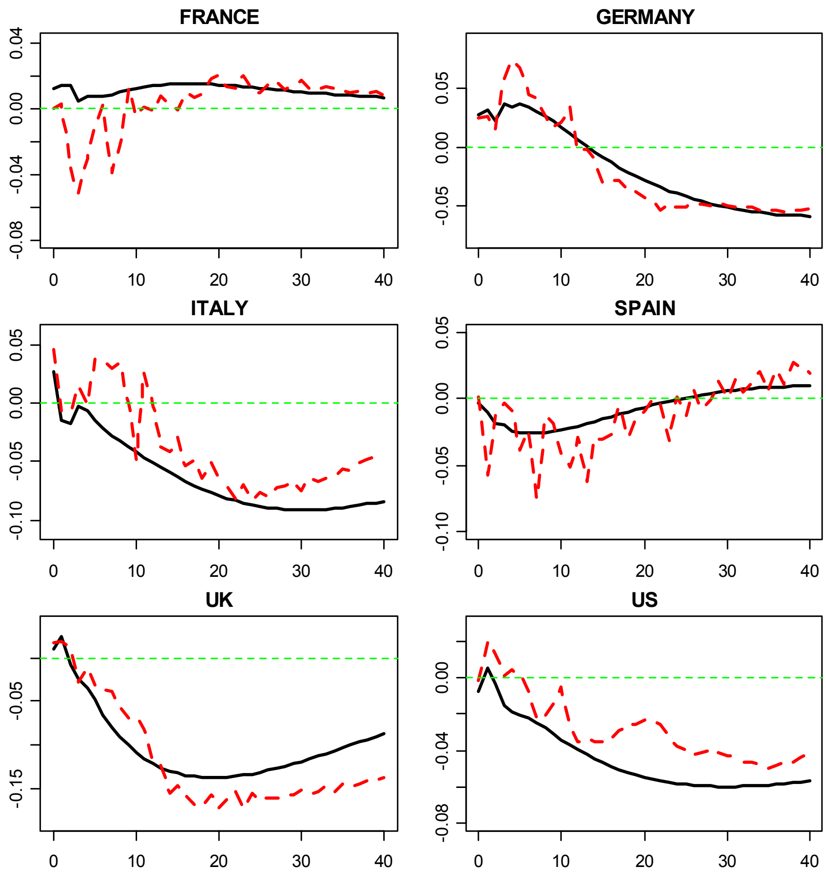


Figure 10: Impulse responses of industry 35 (chemical industries) to an oil price shock using the optimal lag (solid line) and twelve lags (dashed line).

Appendix C

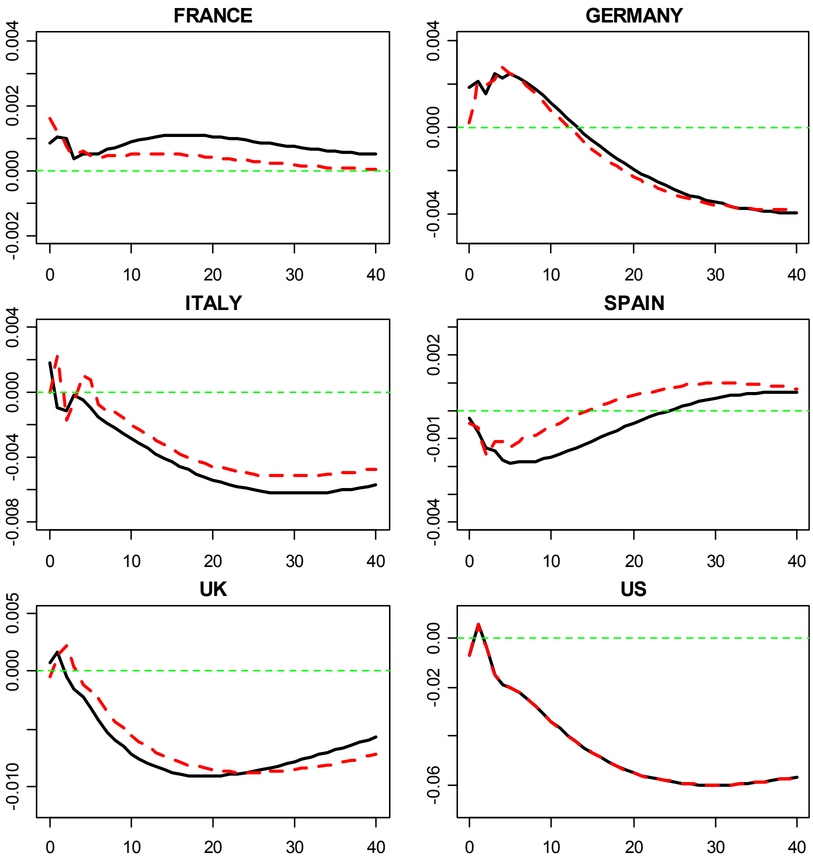


Figure 11: Impulse responses of industry 35 (chemical industries) to one s.d. oil price shock under different oil price definition: real oil prices (solid lines) and real oil prices country specific (dashed lines).

Appendix D

Amárach Consulting develops an oil vulnerability index (based on World Bank figures), which illustrates the sensitivity of an economy to developments in the global oil industry. This vulnerability is based on three measures: first, the sensitivity of the economy to a rise in oil prices (first column, Table D.1); second, the dependence of the economy on imported oil rather than indigenously produced oil (second column, Table D.1); and, finally, the share of oil in the total energy consumed by the economy (third column, Table D.1). These three measures combine to create the oil vulnerability index displayed in the forth column of Table D.1, with a higher index equating to greater vulnerability.

The OECD database "Indicators for Industry and Services" (ISIC Rev.2) only reports indices (seasonally adjusted) on the base 1990 = 100. This data presentation does not allow to establish the exact share of total manufacturing production for each industry under consideration. Thus, we decide to use the OECD-STAN Industry database (annual data over the period 1975-1998) to report the manufacturing structure for each country. To do so, we take into account the fact that the OECD-STAN database is based on the ISIC Revision 3 classification and we carefully make an equivalence among the industries of both classifications (first and second columns, Table D.2). Table D.3 reports the manufacturing industrial structure of each country under consideration. Furthermore, the data of "oil consumption by industry" do not exactly correspond with any ISIC classification, and so we also perform another equivalence between the industries reported by the Energy Statistics of OECD Countries and the ISIC Revision 2 classification (first and third columns, Table D.2). It is worth noting that oil consumption data are not always available, and although more complete data may be available for the US from other databases, we have decided to use an homogenous database. Thus, Table D.4 reports the availability of such data by year, by country and by industry and Figure D.1 displays the oil consumption of each country considered by industry and by year.

Table D.1: *Oil Indicators*

	OPS (1)	OID (2)	OED (3)	OVI (4)
France	-0.40	0.96	0.37	1.73
Germany	-0.60	0.95	0.40	1.95
Italy	-0.50	0.94	0.50	1.94
Spain	-0.60	0.98	0.54	2.12
UK	0.20	-0.51	0.36	1.07
US	-0.40	0.54	0.39	1.33

Note: (1) Oil Price Sensitivity (OPS): the percentage change of GDP on 1999-2001 base as a result of a $10/bbl oil price rise (data from World Bank calculations). (2) Oil Import Dependence (OID): (Oil consumption - Indigenous oil production)/Oil consumption (data from Energy International Agency, EIA). (3) Oil Energy Dependence (OED): ratio of petroleum consumption to total primary energy consumption (data from EIA). (4) Oil Vulnerability Index (OVI): sum of (1)-(3) (using absolute value of price elasticity). Sources: Indicators (1), (2) and (3) from Bacon (2005); Indicator (4) from Amárach Consulting estimates.

Table D.2: *Identification of manufacturing industries among the different databases*

	ISIC Rev.2	*STAN*	*Energy Statistics*
Industry 31	Food, beverages and tobacco	Food, beverages and tobacco	Food and tobacco
Industry 32	Textiles, wearing apparel and leather	Textiles, wearing apparel, leather and footwear	Textile and leather
Industry 33	Wood and wood products	Wood and products of wood and cork	Wood and wood products
Industry 34	Paper and paper products	Pulp, paper, paper products, printing and publishing	Paper, pulp and print
Industry 35	Chemical industries	Chemical, rubber, plastics and fuel products	Chemical and petrochemical
Industry 36	Non-metallic mineral products	Other non-metallic mineral products	Non-metallic minerals
Industry 37	Basic metals	Basic metals and fabricated metal products	Iron and steel
Industry 38	Metal products, machinery and equipment	Machinery and equipment	Machinery

Table D.3: *Manufacturing industries*
(share of total manufacturing production)

	France	Germany	Italy	Spain	UK	US
Industry 31	14.53	15.61	16.60	25.76	19.71	17.86
Industry 32	6.24	5.94	15.61	11.50	8.07	6.94
Industry 33	1.27	2.18	2.29	2.52	2.05	2.47
Industry 34	5.60	7.55	5.35	7.07	10.06	11.32
Industry 35	17.83	20.02	20.40	19.21	20.08	22.73
Industry 36	3.33	4.33	5.20	6.74	3.31	2.91
Industry 37	36.26	15.96	15.39	14.86	15.62	14.40
Industry 38	14.98	28.42	19.15	12.33	21.09	21.36

Note: Average of annual data for the 1975-1998 period.

Table D.4: *Availability of oil consumption (thousand tonnes) by year and by industry*

		1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
France	Industry 31	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 32	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 33	V	V	V	V	..	..	..	V	V	V	V	V	V	V	V	..	..	..	..	..	..	..	..	..
	Industry 34	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 35	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 36	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 37	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 38	..	..	..	..	..	..	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
Germany	Industry 31	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 32	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 33	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 34	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 35	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 36	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 37	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 38	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
Italy	Industry 31	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 32	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 33	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Industry 34	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 35	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 36	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 37	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
	Industry 38	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V

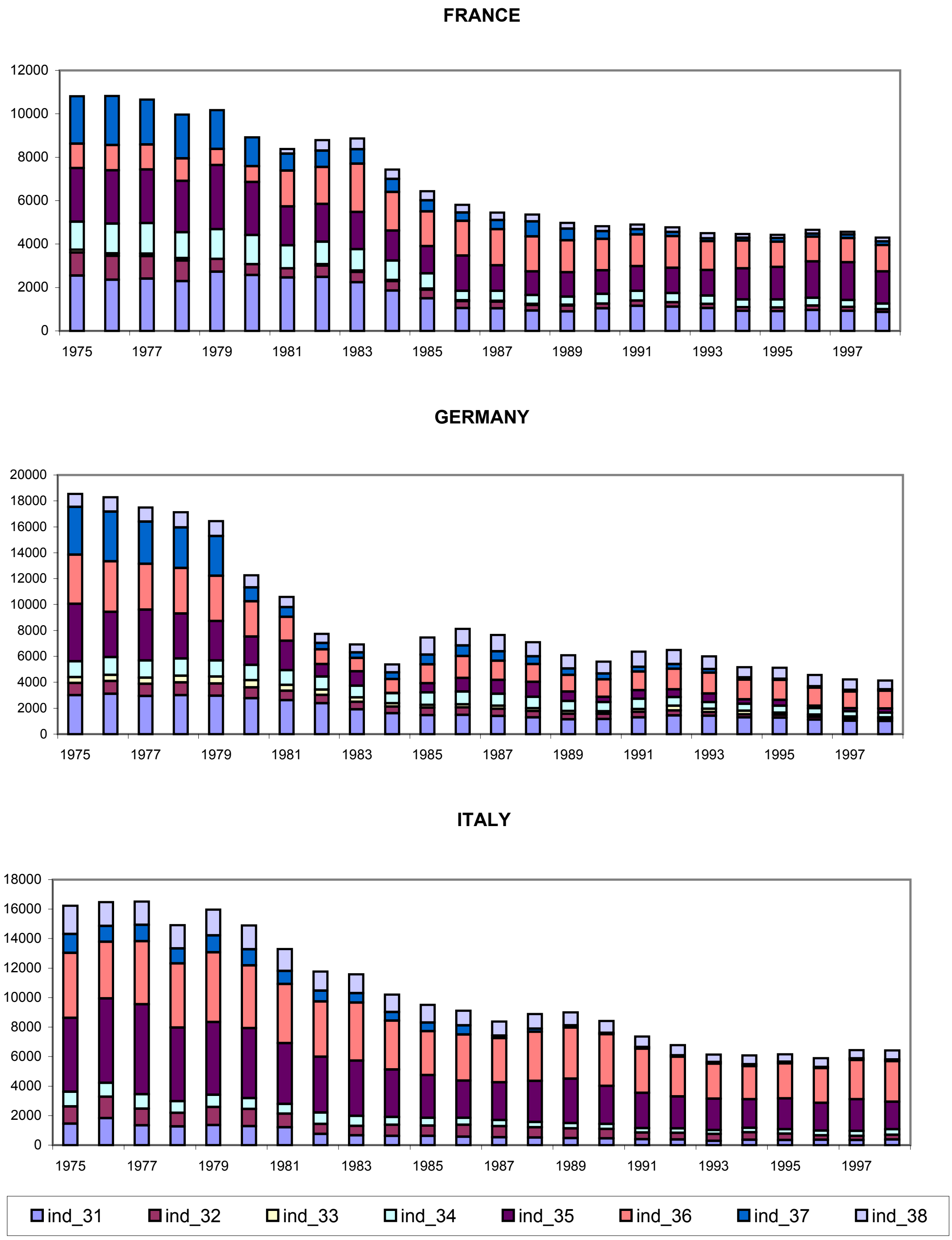
Source: Energy Statististics of OECD countries

Table D.4: *Availability of oil consumption (thousand tonnes) by year and by industry (cont.)*

		1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Spain	Industry 31	..	..	..	..	..	..	..	..	..	..	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Industry 32	..	..	..	..	..	..	..	..	..	..	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Industry 33	..	..	..	..	..	..	..	..	..	..	..	..	..	√	√	√	√	√	√	√	√	√	√	√
	Industry 34	..	..	..	..	..	..	..	..	..	..	..	√	√	√	√	√	√	√	√	√	√	√	√	√
	Industry 35	..	..	..	..	..	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Industry 36	..	..	..	..	..	..	..	..	..	..	..	√	√	√	√	√	√	√	√	√	√	√	√	√
	Industry 37	..	..	..	..	..	..	..	..	..	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Industry 38	..	..	..	..	..	..	..	..	..	..	..	..	..	√	√	√	√	√	√	√	√	√	√	√
UK	Industry 31	..	..	..	..	..	..	..	..	..	..	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Industry 32	..	..	..	..	..	..	..	..	..	..	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Industry 33	..	..	..	..	..	..	..	..	..	..	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Industry 34	..	..	..	..	..	..	..	..	..	..	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Industry 35	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Industry 36	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Industry 37	..	..	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Industry 38	..	..	..	..	..	..	..	..	..	..	√	√	√	√	√	√	√	√	√	√	√	√	√	√
US	Industry 31	√	√	√	√	√	√	√	√	..	..	..	..	..	..	..	..	..	..	..	..	√	√	√	√
	Industry 32	..	..	..	..	..	..	√	√	..	..	..	..	..	..	..	..	..	..	..	..	√	√	√	√
	Industry 33	√	√	√	√	√	√	√	√	..	..	..	..	..	..	..	..	..	..	..	..	√	√	√	√
	Industry 34	√	√	√	√	√	√	√	√	..	..	..	..	..	..	..	..	..	..	..	..	√	√	√	√
	Industry 35	..	√	√	√	√	√	√	√	..	..	..	..	..	..	..	..	..	..	..	..	√	√	√	√
	Industry 36	..	..	..	..	..	..	√	√	..	..	..	..	..	..	..	..	..	..	..	..	√	√	√	√
	Industry 37	√	√	√	√	√	√	√	√	..	..	..	..	..	..	..	..	..	..	..	..	√	√	√	√
	Industry 38	..	√	√	√	√	√	√	√	..	..	..	..	..	..	..	..	..	..	..	..	√	√	√	√

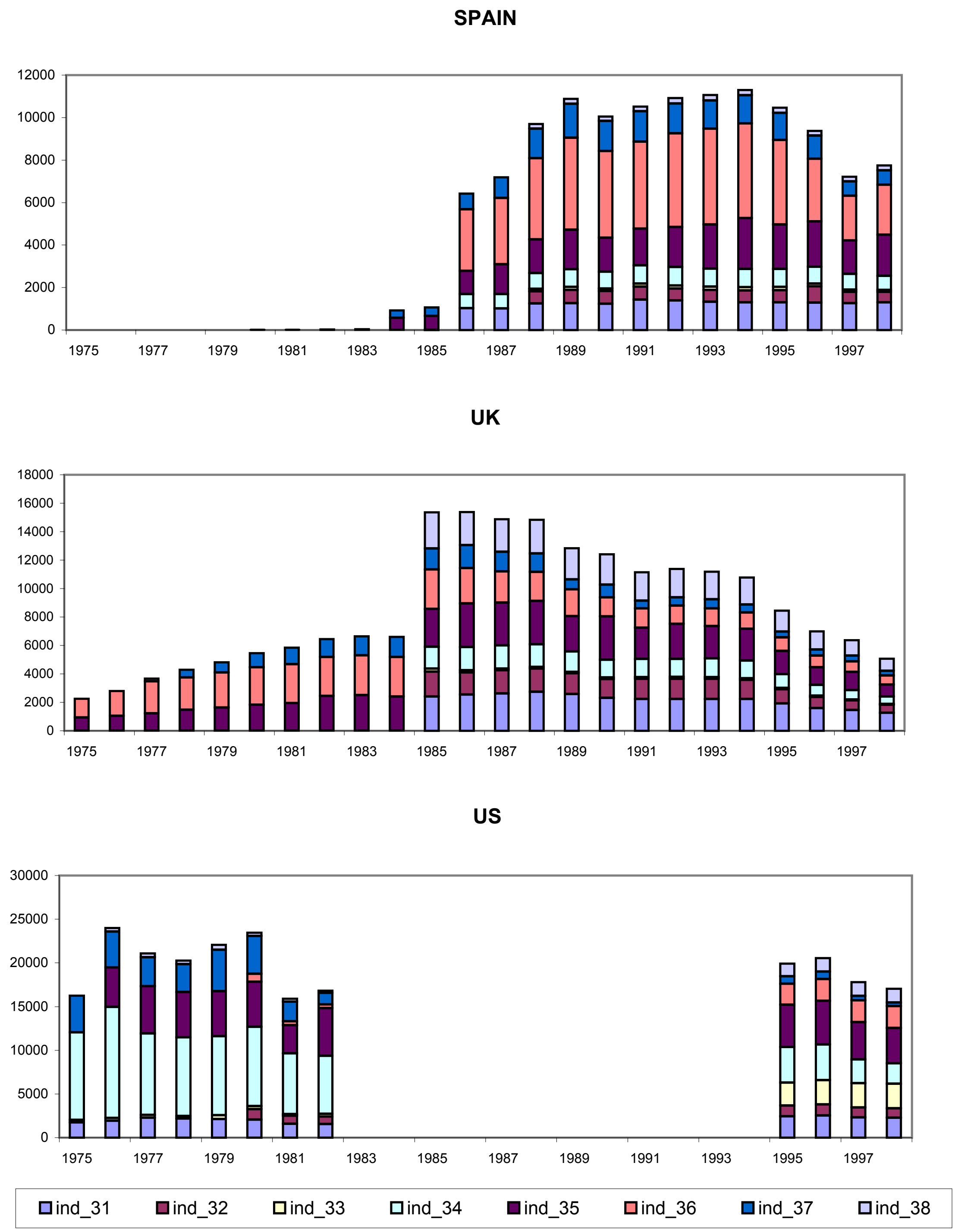
Source: Energy Statististics of OECD countries

Figure D.1: *Oil consumption (thousand tonnes) by year and by industry*



Note: These data come from the Energy Statistics of OECD Countries. See Table D.4 for data availability.

Figure D.1: *Oil consumption (thousand tonnes) by year and by industry (cont.)*



Note: These data come from the Energy Statistics of OECD Countries. See Table D.4 for data availability.

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