The Manchester School Vol 68 No. 5 September 2000
1463–6786 578–607

THE DYNAMIC EFFECTS OF AGGREGATE DEMAND, SUPPLY AND OIL PRICE SHOCKS—A COMPARATIVE STUDY*

by
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This paper analyses the dynamic effects of aggregate demand, supply and oil price shocks on GDP and unemployment in Germany, Norway, the UK and the USA, and establishes the role of the different shocks in explaining output fluctuations over time. Symmetries of economic fluctuations across countries are also examined. The different shocks are identified by imposing dynamic restrictions on a structural vector autoregression model. For all countries except Norway, oil price shocks have significant negative effects on output. However, whereas the oil price shock in 1973–74 triggered off a global recession, the recession in the early 1980s was largely caused by other disturbances.

1 Introduction

The debate as to whether the two successive adverse oil price shocks in 1973–74 and 1979–80 could be blamed for the severe periods of recession facing the world economy in the middle 1970s and early 1980s has been controversial. Early studies like those of Hamilton (1983), Burbidge and Harrison (1984) and Gisser and Goodwin (1986) have typically argued that the two oil price shocks lowered world output, through a reduction in the supply of a major input of production. On the other hand, Rasche and Tatom (1981), Darby (1982) and Ahmed *et al.* (1988) have blamed the poor economic performance in the 1970s and 1980s on other factors. In particular, the tight macroeconomic policies implemented in many industrial countries in the aftermath of the oil price shocks, to combat the high inflation rates experienced, may have worsened the recession that was already associated with the energy price increases.

The aim of this paper is to specify a model that distinguishes oil price shocks from other demand and supply shocks, and to analyse the relative contribution of these shocks in explaining economic fluctuations in a set of

* Manuscript received 17.8.98; final version received 8.2.99.
† I am grateful to R. Nymoen, D. Quah, an anonymous referee and seminar participants at the ESEM-1996 meeting in Istanbul, the London School of Economics, Statistics Norway, University of Copenhagen and University of Oslo for useful comments and discussions on previous versions of this paper. The work has been supported by the Research Council of Norway. The usual disclaimers apply.

Published by Blackwell Publishers Ltd, 108 Cowley Road, Oxford OX4 1JF, UK, and 350 Main Street, Malden, MA 02148, USA.

countries over time. A second goal of the paper is to analyse symmetries in economic fluctuations. By investigating the nature of the shocks that causes these cycles, I ask whether the different shocks are symmetric *across* countries, or whether for instance all countries have responded more to idiosyncratic (country-specific) demand and supply shocks.

The model that is used to identify the different shocks is a structural vector autoregression (VAR) model. The complexity of ways that energy shocks can influence the economy typically motivates the use of a VAR model instead of a fully specified large-scale model (that is specified through a whole set of relations restrictions). The analysis is applied to Germany, the UK, Norway and the USA, i.e. two medium-sized EC countries, a small non-EC European country and a large non-Europe OECD country respectively. Of these countries, Norway and the UK have been self-sufficient in oil resources during most of the period examined, whereas the remaining two countries are net oil importers.

Many of the previous studies analysing the effects of oil price shocks on macroeconomic performance have used VAR models identified through exclusion restrictions that follow a recursive structure, as in Sims's (1980) original work. However, this type of identification structure implies a causal ordering on how the system works in the short run and the results will be very sensitive to how identification was achieved (see for example Cooley and LeRoy, 1985). This was demonstrated by among others Ahmed *et al.* (1988), who showed how the contribution of money and energy prices in the variance decomposition of industrial production in the OECD changed substantially as a result of a variation in the ordering of these variables. In this paper, the different disturbances will instead be identified through a combination of the short-run and long-run restrictions on the VAR model that are implied by an economic model.[1]

The paper is organized as follows. In Section 2, I describe a model of economic fluctuations that incorporates energy price shocks. Section 3 discusses how one can identify a structural VAR model that is consistent with the economic model put forward in Section 2. In Section 4 I review the effects of the different shocks on average for output and unemployment, and the relative importance of the different shocks in accounting for the forecast errors in the variables is assessed. Section 5 analyses the impact of the different shocks on output in different historical periods. Symmetries of the different shocks across countries are investigated at the end. Section 6 concludes.

[1]Shapiro and Watson (1988) also analyse the effects of real oil price shocks on the US economy using a VAR model that is identified using the long-run restrictions implied by an economic model. However, in contrast to the present analysis, oil price shocks are specified as exogenous by Shapiro and Watson. Their results will be discussed further below.

2 Oil Price Shocks and Economic Fluctuations

Analysis of the linkages between energy and the aggregate economy is complicated. An oil price shock may typically have real effects, as a higher energy price may affect output via the aggregate production function by reducing the net amount of energy used in the production. In addition, aggregate demand may also change in response to energy price changes. An oil price increase will typically lead to a transfer of income from the oil importing countries to the oil exporting countries. This reduction in income will induce the rational consumers in the oil importing countries to hold back on their consumption spending, which will reduce aggregate demand and output. However, to the extent that the increase in income in the oil exporting countries will increase demand from the oil importing countries, the global effect will be minimized.[2] Finally, the level of demand may also change due to actions taken by the government in response to changes in oil prices. For instance, to offset the increase in the general price level that was observed after the second oil price shock, several countries pursued tight monetary policy, which may itself have lowered real activity.

Below I propose a simple economic model where energy price shocks may affect the economy through several channels. In addition to energy price shocks, I assume that there are other demand and supply shocks that also hit the economy. The model is a variant of a simple (Keynesian) model of output fluctuations presented in Blanchard and Quah (1989) that builds on Fischer (1977). It consists of an aggregate demand function, a production function, a price setting behaviour and a wage setting behaviour.

$$y_t = m_t - p_t + a\theta_t + bo_t \tag{1}$$

$$y_t = n_t + \theta_t + co_t \tag{2}$$

$$p_t = w_t - \theta_t + do_t \tag{3}$$

$$w_t = w|(E_{t-1}n_t = \overline{n}) \tag{4}$$

where y is the log of real output, o is the log of real oil prices, n is the log of employment, θ is the log of productivity, p is the log of the nominal price level, w is the log of the nominal wage, m is the log of nominal money supply and $\overline{n}$ implies the log of full employment. The unemployment rate is defined as $u = \overline{n} - n$. a, b, c and d are coefficients.

Equation (1) states that aggregate demand is a function of real balances, productivity and real oil prices. Real oil prices are introduced into the aggregate demand function as the level of aggregate demand may change with higher oil prices. Both productivity and real oil prices

[2]See for example Bohi (1989) and Mork (1994) for a further discussion.

are allowed to affect aggregate demand directly. If $a > 0$, a higher level of productivity may imply higher investment demand (cf. Blanchard and Quah, 1989, p. 333), whereas if $b < 0$, higher real oil prices may imply a lower level of demand by, for example, the rational consumers.[3]

The production function (2) relates output to employment, technology and real energy prices, through an increasing return Cobb–Douglas production function. Real oil prices are explicitly included as a third factor of production. As will be seen below, it is through this mechanism that oil prices will affect output in the long run. The real price of oil is used in the production function, instead of an energy quantity, as competitive producers treat the real price of oil as parametric. Hence, c reflects the inverse of the energy elasticity and one would expect $c \leq 0$ (see, for example, Rasche and Tatom, 1981, pp. 22–24; Darby, 1982, p. 739).

The price setting behaviour (3) gives nominal prices as a mark-up on real oil prices and productivity-adjusted wages. Oil prices are introduced into the price equation so that oil prices can also affect the level of aggregate demand through the price effect in (3). Wages are chosen one period in advance to achieve full employment (4). The model is closed by assuming m, θ and o evolve according to

$$m_t = m_{t-1} + \varepsilon_t^{\mathrm{AD}} \tag{5}$$

$$\theta_t = \theta_{t-1} + \varepsilon_t^{\mathrm{AS}} \tag{6}$$

$$o_t = o_{t-1} + \varepsilon_t^{\mathrm{OP}} \tag{7}$$

where $\varepsilon^{\mathrm{AD}}$, $\varepsilon^{\mathrm{AS}}$ and $\varepsilon^{\mathrm{OP}}$ are serially uncorrelated orthogonal demand, supply and real oil price shocks. Solving for Δy and u yields

$$\Delta y_t = \Delta\varepsilon_t^{\mathrm{AD}} + a\Delta\varepsilon_t^{\mathrm{AS}} + (b-d)\Delta\varepsilon_t^{\mathrm{OP}} + \varepsilon_t^{\mathrm{AS}} + c\varepsilon_{t-1}^{\mathrm{OP}} \tag{8}$$

$$u_t = -\varepsilon_t^{\mathrm{AD}} - a\varepsilon_t^{\mathrm{AS}} + (c+d-b)\varepsilon_t^{\mathrm{OP}} \tag{9}$$

From (8) we can see that only supply and oil price shocks will affect the level of output (y_t) in the long run, as y_t will be given as accumulations of these two shocks. However, in the short run, due to nominal and real rigidities, all three disturbances can influence output. Equation (9) implies that neither of the shocks will have long-run effects on unemployment. This is consistent with a view that there is a 'natural' level of unemployment, determined by social institutions such as, for example, union bargaining power. All shocks can have a temporary effect on the unemployment rate, but in the long run, wages and prices will adjust so

[3] $b > 0$ is plausible for Norway, where the oil producing sector is large compared with the rest of the economy. Higher oil prices will typically increase the level of demand from energy producers (like the government).

that the unemployment rate returns to its natural level (see for example Layard *et al.*, 1991).

The finding that aggregate demand shocks have only short-term effects on output and unemployment is consistent with the interpretation of an upward-sloping short-run supply schedule, which is vertical in the long run. A positive demand shock (e.g. a monetary expansion) will typically increase output (and prices) along the short-run supply schedule, inducing a temporary fall in unemployment. In the long run, the economy adjusts to higher prices, and the short-run supply schedule shifts backwards to its long-run equilibrium output level, consistent with a natural rate of unemployment. However, the speed of adjustment to a demand shock is unrestricted and may be instantaneous (as in the new classical school) or slow (as in the Keynesian models with a relatively flat short-run supply schedule).

3 Identifying the Structural VAR

The VAR model specified here focuses on three variables: real GDP, real oil prices and unemployment. As suggested by equations (7)–(9), these variables are the minimum variables that are necessary to identify three structural disturbances: aggregate demand, supply and oil price shocks. First, I define z_t as a vector of stationary macroeconomic variables $z_t = (\Delta y_t, \Delta o_t, u_t)'$, where Δy_t is the first difference of the log of real GDP, Δo_t is the first difference of the log of real oil prices and u_t is the unemployment rate.[4] A reduced form of z_t can be modelled as

$$\begin{aligned} z_t &= \alpha + A_1 z_{t-1} + \ldots + A_p z_{t-p} + e_t \\ A(L) z_t &= \alpha + e_t \end{aligned} \tag{10}$$

where $A(L)$ is the matrix lag operator, $A_0 = I$ and e_t is a vector of reduced form residuals with covariance matrix Ω. To go from the reduced form to the structural model, a set of identifying restrictions must be imposed. As all the variables defined in z_t are assumed to be stationary, z_t is a covariance-stationary vector process. The implied moving-average (MA) representation of (10) can be found using the Wold representation theorem, and is written as (ignoring the constant term for now)

$$\begin{aligned} z_t &= C_0 e_t + C_1 e_{t-1} + C_2 e_{t-2} + \ldots \\ z_t &= C(L) e_t \end{aligned} \tag{11}$$

where $C(L) = A(L)^{-1}$ and C_0 is the identity matrix. I now define the orthogonal structural disturbances as ε_t, and assume that they can be

[4]The assumption of stationarity is discussed and verified empirically below in Section 4.1.

written as linear combinations of the Wold innovations, $e_t = D_0\varepsilon_t$.[5] Substituting into (11) yields

$$\begin{aligned} z_t &= D_0\varepsilon_t + D_1\varepsilon_{t-1} + D_2\varepsilon_{t-2} + \dots \\ z_t &= D(L)\varepsilon_t \end{aligned} \tag{12}$$

where $C_j D_0 = D_j$ or

$$C(L)D_0 = D(L) \tag{13}$$

The structural disturbances will be normalized for convenience, so they all have unit variance, e.g. $\text{cov}(\varepsilon_t) = I$. If D_0 is identified, I can derive the MA representation in (12) since $C(L)$ is identifiable through inversions of a finite-order $A(L)$ polynomial. Consistent estimates of $A(L)$ can be found by applying ordinary least squares to (10). However, the D_0 matrix contains nine elements, and to orthogonalize the different innovations, nine restrictions are required. First, from the normalization of $\text{var}(\varepsilon_t)$ it follows that

$$\Omega = D_0 D_0' \tag{14}$$

There are $n(n+1)/2$ distinct covariances (due to symmetry) in Ω. With a three-variable system, this imposes six restrictions on the elements in D_0. Three more restrictions are then needed to identify D_0. One will come from a restriction on the long-run multipliers of the $D(L)$ matrix, whereas the other two will come from restrictions on the contemporaneous matrix D_0 directly.

The three serially uncorrelated orthogonal structural shocks are ordered as $\varepsilon_t = (\varepsilon_t^{AD}, \varepsilon_t^{OP}, \varepsilon_t^{AS})'$, where ε_t^{AD} is an aggregate demand shock, ε_t^{OP} is a real oil price shock and ε_t^{AS} is an aggregate supply (or productivity) shock. The long-run restriction that aggregate demand shocks have no long-run effects upon the level of y_t (cf. equation (8)) is simply found by setting the infinite sum of lag coefficients, $\sum_j^{\infty} D_{11,j}$, equal to zero. This restriction is similar to that employed by Blanchard and Quah (1989), although here I allow in addition real oil price shocks to affect output in the long run. Note that no restrictions are placed on the short-run effects of oil price shocks on output (or unemployment), as this may be when producers adjust their capital stocks to a new configuration of relative prices. In terms of the notation in (13), the long-run restriction then implies

$$C_{11}(1)D_{11,0} + C_{12}(1)D_{21,0} + C_{13}(1)D_{31,0} = 0 \tag{15}$$

[5]The assumption that the structural disturbances can be written as linear combinations of the Wold innovations is essential, as without it the economic interpretations of certain VAR models may change; see, for example, Lippo and Reichlin (1993) and Blanchard and Quah (1993) for a discussion of the problem of non-fundamentalness.

where $C(1) = \sum_{j=0}^{\infty} C_j$ and $D(1) = \sum_{j=0}^{\infty} D_j$ indicate the long-run matrices of $C(L)$ and $D(L)$ respectively.

The two other restrictions are found by assuming two zero short-run restrictions on oil prices. In (7), oil prices were assumed to be exogenous, with changes in oil prices driven by exogenous oil price shocks. In a more complex model, demand and supply shocks may also affect oil prices, at least from large economies such as the USA. However, oil prices have been dominated by a few large exogenous developments (e.g. the OPEC embargo in 1973, the Iranian revolution in 1978–79, the Iran–Iraq War in 1980–81, the change in OPEC behaviour in 1986, and most recently the Persian Gulf War in 1990–91). The oil price is a financial spot price that reacts quickly to news. I therefore assume that if demand and supply shocks influence oil prices they do so with a lag. Hence the contemporaneous effects of demand and supply shocks on real oil prices are zero, and only oil price shocks will contemporaneously affect oil prices. However, after a period (one quarter), both demand and supply shocks are free to influence oil prices. The two zero restrictions on real oil prices then imply that

$$D_{21,0} = D_{23,0} = 0 \tag{16}$$

The system is now just identifiable. By using a minimum of restrictions I have been able to disentangle movements in three endogenous variables (real output, real oil prices and unemployment) into parts that are due to three structural shocks (aggregate demand, supply and oil price shocks).[6] It turns out that the system is linear in its equations and can be solved numerically. The joint use of short-run and long-run constraints used in the VAR model should also be sufficient to side-step some of the criticism of Faust and Leeper (1994), who argue that for a long-run identifying restriction to be robust it has to be tied to a restriction on finite horizon dynamics.

Despite the many advantages of using a simple structural VAR, it is also subject to some limitations. In particular, a small VAR should be viewed as an approximation to a larger structural system, since the limited number of variables and the aggregate nature of the shocks implies that one will not for instance be able to distinguish between different aggregate demand shocks (e.g. increases in money supply or fiscal policy). One way to assess whether the identification structure applied here is meaningful is to empirically examine whether the different shocks have had the effects

[6]Note that no restrictions are imposed on the long-run effect of demand shocks on real oil prices. However, one would expect demand shocks to have zero influence on the real oil price in the long term, as the domestic price level will adjust to the new situation. By examination, I find the effects of demand shocks on oil prices to be negligible in the long run.

expected on average and in the different historical periods. This will be discussed in the sections that follow.

4 Empirical Results

In the VAR model specified above, the variables were assumed to be stationary and the levels of the variables were not cointegrated. Below I perform some preliminary data analyses to verify whether I have specified the variables according to their time series properties.

4.1 Data Analysis and Model Specifications

The data used for each country are the log of real GDP (non-oil GDP for Norway), the log of real oil prices converted to each country's national currency and the total unemployment rate (see the Appendix for data descriptions and sources). The data are quarterly, and the sample varies somewhat between the different countries, reflecting data availability (USA, 1960–94; Germany, 1969–94; UK, 1966–94; Norway, 1967–94).

The lag order of the VAR models is determined using the Schwarz and Hannan–Quinn information criteria and F forms of likelihood ratio tests for model reductions. Based on the 5 per cent critical level, I decided to use three lags for the USA, five lags for Germany, and six lags for Norway and the UK. None of the models showed any evidence of serial correlation in the residuals.[7]

Above it was assumed that GDP and real oil prices were non-stationary integrated, I(1), variables, whereas unemployment was assumed to be stationary, I(0). To test whether the underlying processes contain a unit root, I use the augmented Dickey–Fuller (ADF) test of a unit root against a (trend) stationary alternative. However, a standard ADF test may fail to reject the unit root hypothesis if the true data-generating process is a stationary process around a trend with one structural break. Misspecifying a 'breaking trend' model as an integrated process would mean that one would attribute too much persistence to the innovations in the economic variables. To allow for the possibility of a structural break in the trend, I therefore also conduct the Zivot and Andrews (1992) test of a unit root against the alternative hypothesis of stationarity around a deterministic time trend with a one-time break that is unknown prior to testing (see Tables A1–A2).

In none of the countries can I reject the hypothesis that GDP and oil

[7]To investigate whether the results are sensitive to the truncation of lags, I also estimated VAR models using eight lags for all countries. The results using eight lags did not differ much from the results presented below and can be obtained from the author on request.

prices are I(1) in favour of the (trend) stationary alternative or the trend stationary with break alternative.[8] However, I can reject the hypothesis that oil prices and GDP are integrated of second order, I(2).

Based on the ADF tests, in none of the countries can I reject the hypothesis that the unemployment rate is I(1). However, using the test suggested by Zivot and Andrews (1992), I can reject the hypothesis that unemployment is I(1) in favour of the trend–break alternative at the 5 per cent level in Norway, at the 10 per cent level in the UK and Germany, but only at the 20 per cent level in the USA. The break points occurred in 1974Q3 in the USA, in 1980Q2 in the UK, in 1985Q3 in Germany and in 1988Q2 in Norway. Although a deterministic trend is included in the estimation procedure, for Norway, the UK and the USA the trend in the unemployment rate is virtually flat before and after the break (and barely significant judged by a standard *t* test). In the remaining analysis I therefore de-trend the unemployment rate using the break dates indicated above for all four countries. For the USA where the results for unemployment were more ambiguous, I also perform the analysis using a deterministic trend with no break.

The use of trend with a one-time break in the unemployment rate has some substantial economic implications. Although theoretically the unemployment rate may be a bounded variable that will return to its natural level in the long run, many countries have experienced a prolonged upward drift in unemployment rates over the last 10–15 years. This upward drift may suggest that the natural rate itself at some point has increased owing to, for instance, growing union power or the introduction of policies that have obstructed the free workings of the labour market.

To be able to capture this potential structural shift in the natural rate, the use of a deterministic trend with an endogenous break date may then be a plausible, although crude, approximation to the observed upward drift in the unemployment rate. In fact, by using a deterministic trend that is allowed to shift up (or down) once, I introduce some flexibility between the two contrasting economic views that, on the one hand, the unemployment rate is stationary, deviating only temporarily from its natural level, and, on the other hand, the unemployment rate is non-stationary, with no tendency to return to its natural rate. Proponents of the last view typically argue that there is hysteresis in the unemployment rate, so that all shocks can have a permanent effect on the unemployment rate.

All the break dates suggested above coincide with periods of important structural changes in the given countries. For instance, the

[8]Using a very similar test procedure to that of Zivot and Andrews (1992), Banerjee *et al.* (1992) do not find any evidence either against the unit root null hypothesis for real GDP in the relevant countries analysed here.

break suggested in 1974 for the USA may reflect the sharp decline in labour productivity growth at that time (see for example Sachs, 1982), although the first oil price shock may also be an important contributor. In the UK, the break in 1980 coincides with the change in policies after the Thatcher government took over the year before, which implied severe negative permanent effects on the labour market. The break in unemployment in Norway in 1988 most probably reflects the severe recession in the late 1980s, which was preceded by a financial deregulation. The break in Germany is somewhat different, as it is the slope of the trend in the unemployment rate that is changing. In fact, the trend has a positive drift until the middle 1980s, reflecting the fact that the natural rate is increasing steadily during this period. After 1985, the slope of the trend in unemployment is virtually flat. The plausibility of the estimated break dates will be discussed further in Section 5, when I focus on specific historical periods using the VAR model.

Finally, using the maximum likelihood estimation procedure advocated by Johansen (1988, 1991), I can confirm that none of the variables in the VAR models is cointegrated (see Table A3). Hence, the variables are appropriately modelled as described by the VAR model above.

4.2 Dynamic Responses to Aggregate Demand, Aggregate Supply and Oil Price Shocks

The cumulative dynamic effects (calculated from equation (12)) of demand, supply and oil price shocks on GDP are reported in Figs 1(a)–1(h), whereas the dynamic effects of the same three disturbances on unemployment are given in Figs 2(a)–2(h). In each figure, the dynamic effect of the oil price shock is reported with a standard deviation band around the point estimate.[9]

In Germany, the UK and the USA, an adverse oil price shock (that increases the real price of oil) lowers GDP for the first two to three years. The effect is largest after six quarters, where the (one standard error) oil price shock reduces GDP by 0.3–0.5 per cent. The effect thereafter essentially dies out in Germany and the UK, whereas for the USA real GDP is permanently reduced by 0.4 per cent. In Norway, the adverse oil price shock has an initial (negligible) negative effect on GDP, but the effect thereafter becomes positive, and GDP has increased by about 0.4 per cent

[9]The standard errors are calculated using Monte Carlo simulation based on normal random drawings from the distribution of the reduced form VAR. The draws are made directly from the posterior distribution of the VAR coefficients, as suggested by Doan (1992). The standard errors that correspond to the distributions in the $D(L)$ matrix are then calculated using the estimate of D_0. Impulse responses for all shocks with a standard deviation band can be obtained from the author on request.

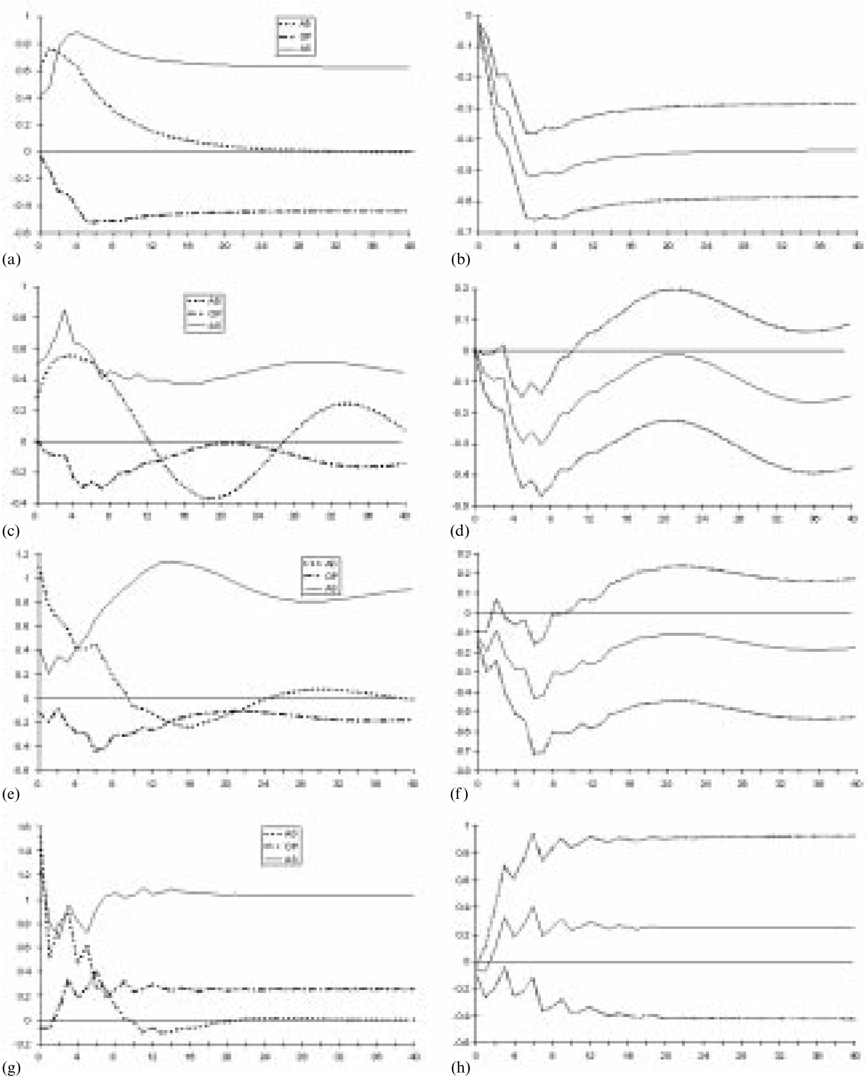


FIG. 1 GDP Impulse Responses to an Oil Price (OP) Shock, an Aggregate Demand (AD) Shock and an Aggregate Supply (AS) Shock (Percentage Change): (a), (c), (e), (g) OP, AD and AS Shocks for (a) the USA, (c) Germany, (e) the UK and (g) Norway; (b), (d), (f), (h) OP Shock, One Standard Error Band, for (b) the USA, (d) Germany, (f) the UK and (h) Norway

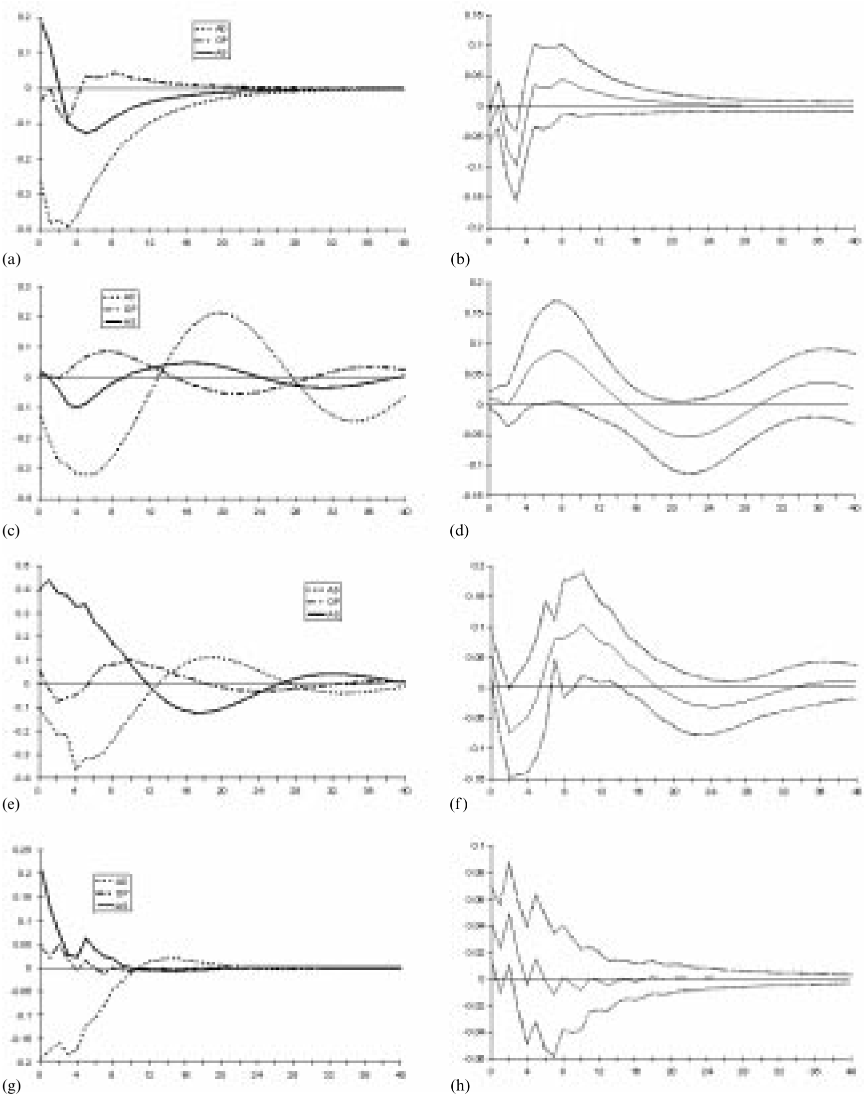


FIG. 2 Unemployment Responses to an Oil Price (OP) Shock, an Aggregate Demand (AD) Shock and an Aggregate Supply (AS) Shock (Percentage Point Change): (a), (c), (e), (g) OP, AD and AS Shocks for (a) the USA, (c) Germany, (e) the UK and (g) Norway; (b), (d), (f), (h) OP Shock, One Standard Error Band, for (b) the USA, (d) Germany, (f) the UK and (h) Norway

after two years.[10] However, as the one standard error band includes zero and becomes wider as the horizon increases, the effect may not be significant in the long run.

A demand shock has a positive impact on the level of GDP in all countries and the response is highest in the smallest country, Norway. The response of GDP in all countries thereafter declines gradually as the long-run restriction bites. A supply disturbance has a permanent positive effect on the level of GDP in all countries, increasing GDP by 0.5–1 per cent after ten years. However, the immediate impact of a unit supply shock varies between the different countries, with again the highest response in the smallest country, Norway.

It is interesting to compare the results for the USA with the findings in Blanchard and Quah (1989). Whereas Blanchard and Quah found the initial output response in the USA after a supply shock to be small and approaching zero in the first two quarters, I find the output response in the USA to be much higher initially. On the other hand, I find real oil price shocks to have negative effects on output at all horizons. Hence, the initial negative response in output to supply shocks reported in Blanchard and Quah (1989) may be due to the fact that they have not separated the effects of oil price shocks from the effects of other supply (productivity) shocks.

A real oil price shock has small effects on the unemployment rate for all countries, increasing by less than 0.1 percentage point after two years. The wide standard deviation bands also indicate that the effect of the oil price shocks on unemployment is only really significant for a few quarters.

The response of the unemployment rate to an aggregate demand shock mirrors the response of output to the same disturbance. Following a positive demand shock the unemployment rate falls immediately in all countries, but the effect is no longer significantly different from zero after four years. A positive supply disturbance, on the other hand, works to increase the unemployment rate in all countries initially (although the effect is negligible in Germany), but after two to three years the effect has died out.

Tables 1–4 present the forecast-error variance decompositions (the relative contribution of the different shocks) for GDP and unemployment in the USA, Germany, the UK and Norway respectively. A real oil price shock has only a small effect on output initially. However, after two years, oil price shocks explain 15 per cent of the output fluctuations in the USA (increasing to 20 per cent after three years), 10 per cent of the output fluctuations in the UK, 7–8 per cent of the output movements in Germany and less than 5 per cent of output movements in Norway. The oil price

[10]Similar results are also found when the effects of an oil price shock on manufacturing production are examined (see Bjørnland, 1998).

TABLE 1
VARIANCE DECOMPOSITION OF GDP AND UNEMPLOYMENT IN THE USA

	GDP			*Unemployment*		
Quarters	*AD shock*	*OP shock*	*AS shock*	*AD shock*	*OP shock*	*AS shock*
1	69.2	0.2	30.6	64.9	1.1	34.0
4	50.7	5.0	44.2	87.0	2.7	10.3
8	32.1	14.6	53.2	86.3	2.1	11.6
12	25.7	18.4	55.9	86.0	2.2	11.8
16	21.5	20.6	57.8	85.9	2.3	11.8
40	11.3	26.3	62.4	85.9	2.3	11.8

TABLE 2
VARIANCE DECOMPOSITION OF GDP AND UNEMPLOYMENT IN GERMANY

	GDP			*Unemployment*		
Quarters	*AD shock*	*OP shock*	*AS shock*	*AD shock*	*OP shock*	*AS shock*
1	24.8	0.0	75.2	96.3	0.4	3.3
4	33.1	0.8	66.1	95.5	0.2	4.3
8	36.7	6.9	56.4	91.6	4.0	4.3
12	33.6	7.8	58.6	90.7	5.3	4.0
16	32.2	7.5	60.3	90.2	5.1	4.7
40	25.6	5.9	68.4	90.4	5.4	4.2

TABLE 3
VARIANCE DECOMPOSITION OF GDP AND UNEMPLOYMENT IN THE UK

	GDP			*Unemployment*		
Quarters	*AD shock*	*OP shock*	*AS shock*	*AD shock*	*OP shock*	*AS shock*
1	86.6	1.0	12.4	6.2	1.8	92.1
4	82.9	3.3	13.8	16.3	1.6	82.1
8	49.8	10.9	39.2	36.6	1.8	61.6
12	30.2	9.4	60.4	37.6	3.5	58.9
16	21.3	7.1	71.6	37.2	4.0	58.8
40	10.1	4.7	85.1	38.2	4.0	57.8

TABLE 4
VARIANCE DECOMPOSITION OF GDP AND UNEMPLOYMENT IN NORWAY

	GDP			*Unemployment*		
Quarters	*AD shock*	*OP shock*	*AS shock*	*AD shock*	*OP shock*	*AS shock*
1	59.8	0.1	40.1	44.2	2.2	53.7
4	52.0	1.6	46.3	63.6	2.5	33.8
8	36.6	3.8	59.7	70.6	2.0	27.4
12	27.0	4.5	68.5	70.6	2.0	27.3
16	21.3	4.7	74.0	70.7	2.0	27.2
40	9.7	5.1	85.2	70.8	2.0	27.2

shocks have little importance in explaining unemployment fluctuations in any of the countries.

In the short term, aggregate demand disturbances are the most important source of output fluctuations in the USA, the UK and Norway, with 50–80 per cent of the variance in GDP explained by aggregate demand shocks in the first year. The relative contribution of aggregate demand disturbances thereafter declines towards zero, as supply disturbances become more important. Aggregate demand shocks explain 70–90 per cent of the variation in unemployment in Norway, the USA and Germany in the first two years, whereas in the UK less than 40 per cent of the variation in unemployment is explained by demand shocks.

Note that although an oil price shock has a larger effect on output in the USA than in Germany and the UK, the effect on unemployment from an oil price shock in the USA is relatively small. However, recall that for the USA I have allowed for an increase in the unemployment rate by shifting the trend upwards in 1974 (cf. Section 4.1), which coincides with the time of the first severe oil price shock. The effect on unemployment from an oil price shock may as a consequence have been underestimated. As I have only weak evidence that the unemployment rate experienced a structural break in 1974, I also tried to re-estimate the model using a linear trend with no break in the unemployment rate in the USA, but allowing instead for eight lags in the VAR model. The results are virtually unchanged, except that the negative effect of an oil price shock on output is somewhat smaller in the long run, explaining 13 per cent of the output variation after three years. The effect on the unemployment rate from an oil price shock is unchanged in the first year, but after two years more than 10 per cent of the variation in unemployment is explained by oil price shocks.

Hence, of the countries analysed here, the negative effects of an oil price shock on output are clearly largest in the USA, with the magnitude of the effects being somewhat dependent on the way the possible structural break in unemployment is taken into account. This large contribution of oil price shocks to the US economy stands in contrast to the results reported by Shapiro and Watson (1988), who also estimate the effects of oil price shocks on the US economy through a VAR model. Shapiro and Watson find that oil price shocks play virtually no role in explaining the GDP movements in the first year, but from two years onwards they explain approximately 8–10 per cent of the GDP variation. However, in contrast to the present analysis, oil price changes are exogenous in Shapiro and Watson (1988). In particular, no shocks other than the oil price shocks can affect the real oil price at any horizon. This identifying restriction may in fact imply that Shapiro and Watson have underestimated the effects of oil price shocks, and emphasized instead other supply shocks which may have similar effects on the variables in the model (see also the comments made by Quah, 1988).

To conclude then, why should output in the USA respond more negatively to an oil price shock than output in Germany (and the UK), and why do Norway and the UK (both being oil exporting countries) respond so differently?

The structure of the economy will probably play an important role for the macroeconomic adjustments to oil price shocks. Countries with a low production dependence on oil, a low share of oil in the consumption bundle and relatively low labour intensities in production will suffer less from oil price shocks. Germany has typically had a relatively small value of labour intensity in the traded goods sector and a low share of oil in consumption, and may therefore have been less severely affected by the oil price increases (see for example Lehment, 1982; Fieleke, 1990; Nandakumar, 1988). Rasche and Tatom (1981) suggest that, as Germany has traditionally had higher duty on oil prices than the USA, it may have replaced oil as an energy source in some of the industry by nuclear power or coal. In particular, between 1973 and 1979, consumption of crude petroleum per capita declined slightly in Germany, whereas in the USA it increased. Total import of crude petroleum also declined slightly between 1973 and 1979 in Germany, but increased in the USA (cf. *UN Yearbook of World Energy Statistics*).

The fact that in the UK output decreased whereas in Norway output actually increased in response to an oil price shock emphasizes how two countries that are self-sufficient in oil resources can react very differently to oil price shocks. Although the oil sector plays a much larger role in Norway than in the UK, macroeconomic policy has also been conducted very differently in the light of the two major oil price shocks in Norway and the UK. In Norway, the oil price increases raised the net national wealth, allowing the government to follow an expansionary fiscal policy for several periods. The UK was self-sufficient in oil resources when the second oil price shock occurred, but fiscal and monetary policies remained relatively tight during the 1980s, aimed primarily at combating the high inflation rates in that period. With factory closures and rapidly increasing unemployment rates from the late 1970s in the UK, much of the revenue from the increased oil prices went instead into social security in addition to payment of existing external debts.

Finally, the behaviour of output and unemployment in the USA, the UK and Norway seems consistent with what a Keynesian approach to business cycles would have predicted. Demand disturbances are the most important factor behind output fluctuations in the short run, but eventually prices and wages adjust to restore equilibrium. In Germany, supply disturbances are more important than demand disturbances in explaining output fluctuations in the short term, suggesting that a real business cycle view may be applicable (the results for Germany are also consistent with those of Sterne and Bayoumi (1995)).

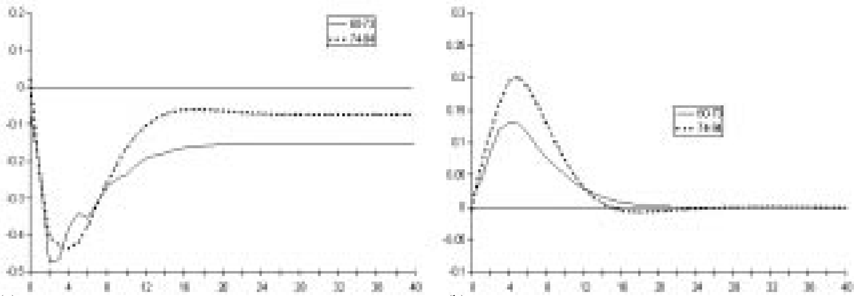
4.3 Stability of the Oil–Macroeconomic Relationship

The model specified above implies that output and unemployment will respond symmetrically to oil price increases and decreases. However, Mork *et al.* (1994) have shown that there are important asymmetries between the effects of oil price increases and decreases on the US economy. More recently, Hooker (1996) has argued that the relationship between oil and the macroeconomy has decreased dramatically in the USA since 1973. However, contrary to the results obtained by Mork *et al.* (1994), Hooker finds that re-specifying the VAR according to asymmetry theories does not restore the oil–macroeconomic relationship.

Obviously, the price of oil has behaved very differently since the middle 1980s, with huge decreases and much more short-term volatility than in the 1970s. In response to Hooker (1996), Hamilton (1996) argues that as most of the increases in the price of oil since 1986 have followed immediately after even larger decreases, they are corrections to the previous decline rather than increases from a stable environment. If one wants a measure of how unsettling an increase in the price of oil is likely to be for the spending decisions of consumers and firms, Hamilton suggests that one should compare the price of oil with where it has been over the previous year, rather than with where it was the previous quarter alone. By constructing what he refers to as the net oil price (the maximum value of the oil price observed during the preceding four quarters), Hamilton (1996) shows that the historical correlation between oil price shocks and recessions remains.

Splitting the data set into two samples, 1960Q1–1973Q3 and 1974Q1–1994Q4, and re-estimating the VAR model using the original data for the USA (but the level of the unemployment rate in each period), I find that the negative relationship between oil price shocks and real GDP has indeed declined, although it is still clearly negative.[11] However, as emphasized by Hamilton (1996), the second sample is dominated by large declines and short-term volatility and is therefore difficult to analyse separately. I therefore also estimate the VAR model using the *net* real price of oil as defined by Hamilton (1996). That is, when the value of the price of oil in the current quarter exceeds the previous year's maximum, the percentage change over the previous year is plotted. When the price of oil in the current quarter is lower than it has been during the previous year, the value is set equal to zero for that quarter (see the Appendix).

[11]The first sample ends in 1973Q3, as 1973Q4 represents an extreme outlier, making it problematic to end the sample there.



(a) (b)

FIG. 3 Impulse Responses to a Net Oil Price Shock in the USA, 1960–73 and 1974–94: (a) GDP (Percentage Change); (b) Unemployment (Percentage Point Change)

Note: The net oil price is the maximum value of the oil price observed during the preceding four quarters.

Figure 3(a) shows the responses of GDP to a *net* real oil price shock, using the pre- and post-1973 samples. The plots look very similar using the different samples, and the negative relationship between oil price increases and real GDP is clearly found for all years, although it is marginally smaller in the second sample. Figure 3(b) verifies that the unemployment rate also increases in response to an oil price shock in both sample periods.

Hence, I conclude that the negative correlation found above between oil price increases and the macroeconomy has not really declined since 1973, especially not when I focus on oil price increases from a stable environment rather than on quarterly changes. However, in the remaining analyses we are interested in the effects of both oil price increases and decreases on real output, and as the net real oil price is somewhat *ad hoc* in the sense that it rules out any effects of oil price decreases, I continue the remaining analysis using the original real price of oil.

5 SOURCES OF BUSINESS CYCLES

Below I focus on specific historical periods by computing the forecast errors in output. The results are presented in Figs 4–7 for the USA, Germany, the UK and Norway respectively. In parts (a) and (b) in each figure, I plot the total forecast error in output together with the forecast error that is due to oil price shocks and demand shocks respectively. In part (c), log GDP is graphed together with the forecast error in output that is associated with the supply shock when the drift term in the model is added (I will refer to this as the supply potential). The figures allow me to examine whether the shocks identified can be well interpreted and assessed in terms of actual episodes that occurred in the periods examined.

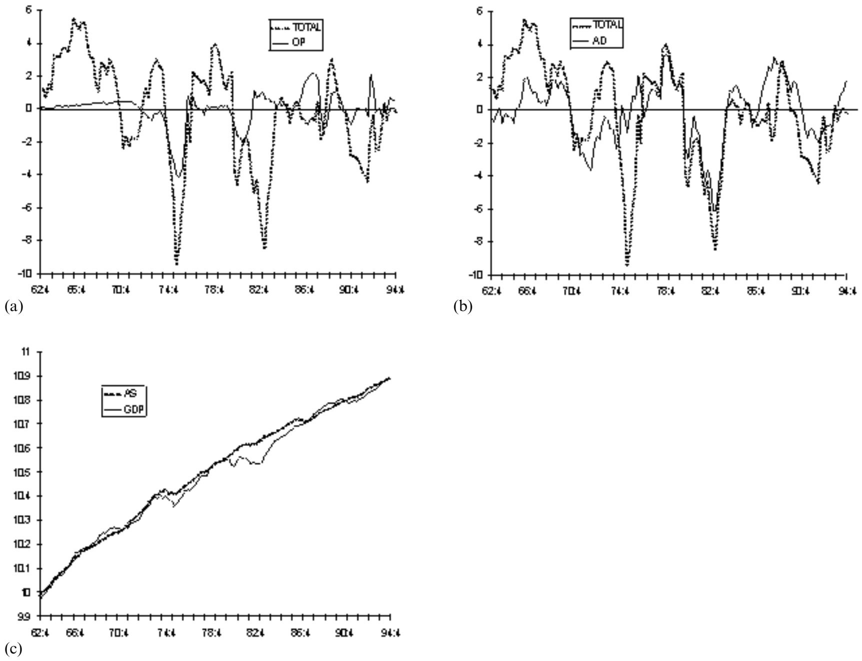


FIG. 4 Forecast-error Decompositions for GDP in the USA: (a) Oil Price (Percentage Change); (b) Aggregate Demand (Percentage Change); (c) Aggregate Supply (Drift Term Added)

Figure 4 suggests that the recession in the USA from 1974 to 1976 was at first dominated by negative oil price shocks, but from the end of 1975 adverse supply (productivity) shocks also contributed to prolonging the recession (as suggested by Sachs, 1982). From 1980, oil price shocks triggered off a new recession, but the recession was short and lasted initially only for a year. During this period, the government followed tight monetary policies (although expansionary fiscal policies), and Fig. 4(b) shows that from 1981 negative demand shocks pushed the economy into a prolonged recession that lasted almost until 1984. In contrast to the previous oil-induced recession, aggregate supply shocks played almost no role in the 1980–84 recession. The dating of these cycles corresponds well with the National Bureau of Economic Research chronology, in which the economy was at the bottom of a cycle (trough) in July 1980. The economy thereafter recovers and reaches a cyclical peak in July 1981, before it contracts until the next trough in December 1982.

Blanchard and Quah (1989) argued that the two recessions of 1974–75 and 1979–80 were attributed to equal proportions of adverse supply and adverse demand shocks. By including oil price shocks directly

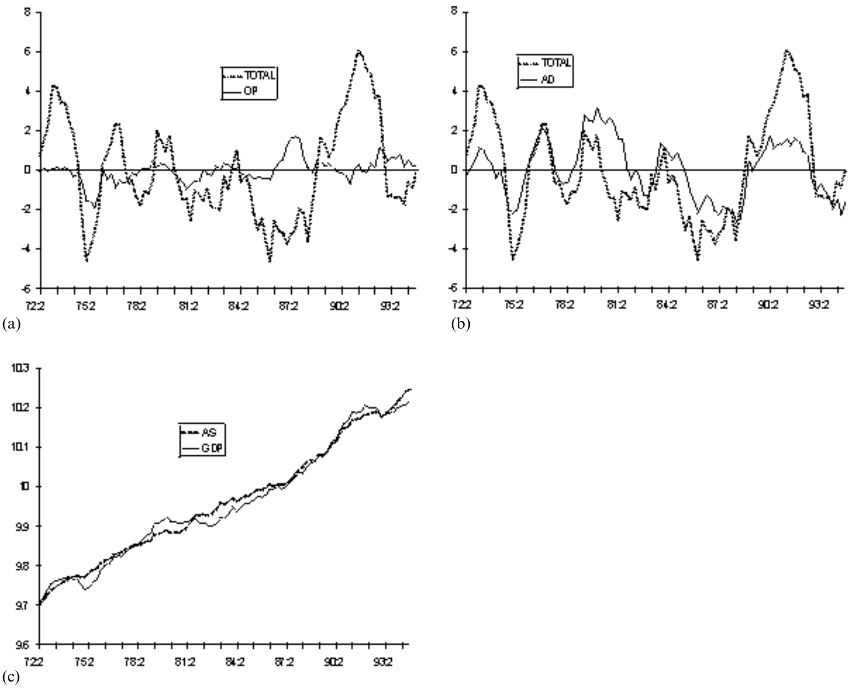


FIG. 5 Forecast-error Decompositions for GDP in Germany: (a) Oil Price (Percentage Change); (b) Aggregate Demand (Percentage Change); (c) Aggregate Supply (Drift Term Added)

in the VAR, I have found that, whereas supply disturbances have had an important role in explaining the latter part of the 1973–75 recession, supply shocks play virtually no role in the 1979–80 recession.

In 1986, the fall in oil prices had a positive stimulus on output growth, but the overall performance of the economy remained negative for two more years, as both demand and supply disturbances contributed negatively to output fluctuations. From 1990, the economy experienced another recession, this time primarily set off by the increase in oil prices during the Gulf War and negative supply shocks. Blanchard (1993) also found the recession in 1990–91 to be mainly driven by shocks with permanent effects, and argues that this is why the recovery that has followed has been so sluggish.

After the collapse of the Bretton Woods system in 1973, Germany switched to a very restrictive monetary policy to keep inflation rates down. The first oil price shock thus hit the economy after some periods of monetary restrictions (i.e. negative demand shocks in Fig. 5(b)). Negative oil price shocks eventually dominated, and prolonged the recession until 1976.

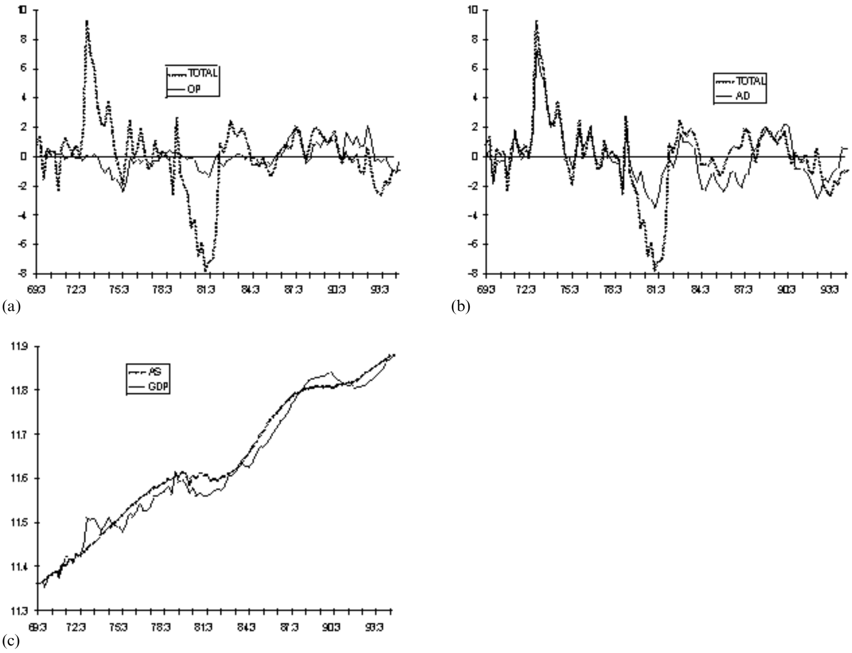


FIG. 6 Forecast-error Decompositions for GDP in the UK: (a) Oil Price (Percentage Change); (b) Aggregate Demand (Percentage Change); (c) Aggregate Supply (Drift Term Added)

The adverse oil price shock in 1979–80 had very little effect on the economic performance in the early 1980s, but a series of negative supply shocks eventually turned the economy into a recession. In contrast to the USA, negative demand shocks had very small effects on output in Germany in the early 1980s, although monetary policies were quickly tightened from 1979 onwards to avoid high inflation rates. These results are consistent with Rasche and Tatom (1981), who suggest that the policy responses in Germany that avoided high inflation rates also minimized the real effects of energy shocks, through the appreciation of the deutschmark relative to the pricing currency in the world energy market.

The huge boom in Germany from 1989 to 1993 was both demand and supply driven. The boom can be attributed to the German unification in 1989, which brought with it large (real) supply effects but also important demand effects during the following three years. However, from 1992 negative demand disturbances again plunged the economy into a (small) recession.

In the UK, the 1970s were characterized by a series of positive demand shocks, especially in 1972–73 when the broad money stock exploded by over 50 per cent (the Barber Boom, named after the

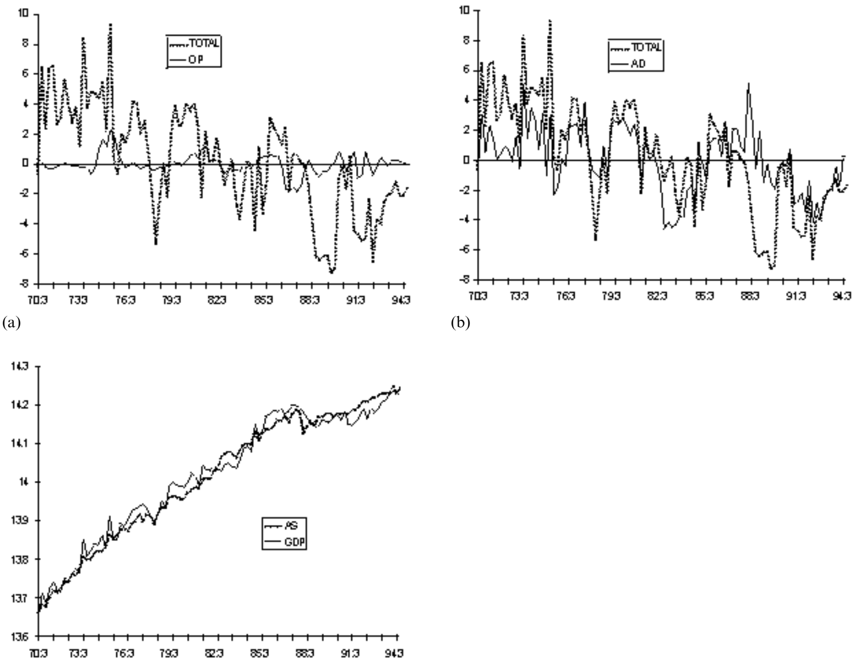


FIG. 7 Forecast-error Decompositions for GDP in Norway: (a) Oil Price (Percentage Change); (b) Aggregate Demand (Percentage Change); (c) Aggregate Supply (Drift Term Added)

Chancellor at the time). The economy continued to grow from stimulative demand policies (the so-called mini budgets) under the Wilson labour government from 1974, and the adverse oil price shocks in 1973–74 led to only a temporary decline in output (see Figs 6(a) and 6(b)).

However, inflation was rapidly increasing in this period, and when the Thatcher government took over in 1979 one of its primary aims was to reduce inflation through tight monetary control and subsequently public expenditure cuts. The impact on the economy from these policies was grave, as can be seen in Fig. 6. From 1979, negative demand shocks pushed the economy into a severe decline, but from 1981 negative supply shocks were mostly to blame for the severity of the recession. These permanent 'supply shocks' had long lasting negative effects on the economy, as the supply potential shifted down drastically (cf. Fig. 6(c)) and the unemployment rate shifted up permanently (see Section 4.1). The oil price shocks played only a small role in the recession in the UK in the early 1980s. The economy eventually recovered, mainly due to positive supply shocks (from productivity growth for example). From 1987 to 1991, the UK experienced a demand-led boom.

In Section 4, adverse oil price shocks were found to have positive effects on output in Norway. This is understood more clearly by examining Fig. 7(a). The first oil price shock in 1973–74 occurred at a time when the Norwegian economy had just discovered huge oil resources in the North Sea. However, the prospect of increased oil revenues brought about by higher oil prices created the potential for profitable output. By the end of the 1970s, Norway was a net exporter of oil, so when the second oil price rise occurred in 1979–80 overall national wealth and demand increased further. Demand shocks were also important contributors behind the good economic performance in the middle 1970s, as the government followed expansionary fiscal policies from 1974 to 1977 (see Fig. 7(b)).

During the 1980s, Norway experienced two severe recessions. The first, from 1982 to 1985, was primarily demand driven. The economy thereafter experienced a demand-driven boom, set off primarily by a financial deregulation. The high growth rates were dampened somewhat by the collapse of oil prices in 1986, which eroded the government of potential future income streams. From 1988, negative supply shocks pushed the economy into another recession, and now both the supply potential and the unemployment rate changed permanently (cf. Fig. 7(c) and Section 4.1). The economy recovered somewhat by 1990, but then the international economy was slowing down and demand shocks contributed negatively to output growth.

5.1 Synchronization of Underlying Shocks

The analysis above has suggested that, whereas the global recession in the middle 1970s was mainly due to the oil price shocks, the worldwide recession in the early 1980s was mainly due to other demand and supply shocks. However, Figs 4–7 illustrate that the business cycles due to these demand and supply shocks do not really seem to be very synchronized in any of the four countries, with the possible exception of the UK and the USA in the 1980s and Norway and Germany until the middle 1980s.

Symmetries in economic fluctuations across countries are particularly important when these countries are to coordinate their economic policies. The fact that the cycles in Germany and the UK are not synchronized, whereas the cycles in the UK and the USA seem to be more in phase, may therefore have implications for economic policy in the European Union. However, to analyse the prospects of synchronization, one needs to investigate more thoroughly the nature of the shocks that causes the cycles to relate or diverge. Table 5 presents the maximum correlation coefficient between the serially uncorrelated orthogonal demand and supply shocks identified from equation (12) (ε_t^{AD} and ε_t^{AS}), in each pair of countries over the whole period, and in the subperiods 1971–79 and 1989–94. The

TABLE 5
CORRELATION COEFFICIENT OF SUPPLY AND DEMAND SHOCKS ACROSS COUNTRIES

	Aggregate supply			*Aggregate demand*		
	1971–94	*1971–79*	*1989–94*	*1971–94*	*1971–79*	*1989–94*
Correlation coefficient with the USA						
USA	1.00	1.00	1.00	1.00	1.00	1.00
Germany	0.14 (−2)	0.43 (−1)	0.21 (+2)	0.15	0.17 (−2)	0.21 (−2)
UK	0.05 (−1)	0.31 (−1)	0.25 (−2)	0.11 (−2)	0.14 (−2)	0.42
Norway	0.11 (−1)	0.26 (−1)	0.23 (+2)	0.12 (−1)	0.10 (−1)	0.54 (−1)
Correlation coefficient with Germany						
Germany	1.00	1.00	1.00	1.00	1.00	1.00
UK	0.22	0.39	0.20	0.15 (−1)	0.32 (−1)	0.32 (+2)
Norway	0.26	0.38	0.05	0.00	0.13 (−2)	0.21 (−1)
Correlation coefficient with the UK						
UK	1.00	1.00	1.00	1.00	1.00	1.00
Norway	0.12	0.26 (−2)	0.00	0.16 (−1)	0.24	0.63 (−2)

Note: Each cell contains the maximum correlation between GDP(t) in the country reported in the column to the left, and $GDP(t-k)$, $(k = -2, -1, 0, 1, 2)$ in the anchor country reported above. The number in parentheses refers to the chosen number of leads (−)/lags (+) when different from zero. For instance, the value of 0.14 (−2) between Germany and the USA indicates that the maximum correlation between supply shocks in Germany and the USA is 0.14 when Germany leads the USA by two quarters.

numbers in parentheses refer to the chosen number of leads or lags when the maximum correlation differs from the contemporaneous correlation. The maximum correlation is allowed to occur with a time lag (or lead) of two quarters, as a shock may not occur in the same quarter in each country. In particular, there may be a time lag between the occurrences of for instance a demand shock in the USA and Europe.

The correlation coefficients are generally low and insignificant over the whole sample, suggesting that the different countries have responded more to idiosyncratic (country-specific) shocks. The supply shocks are clearly more highly synchronized in the 1970s, and the correlation coefficient between each pair of countries is highest when Germany is in the pair. Demand shocks seem to be more correlated throughout the sample, in particular in the UK and the USA from the late 1980s. The demand shocks in Norway are in phase with the demand shocks in the Anglo-Saxon countries in this period, whereas demand shocks in Germany behave more idiosyncratically, especially from the period of the German unification. Note that the demand and supply shocks in the USA mostly lag the European shocks.

Using a similar method to that used here, but distinguishing only between demand (nominal) and supply (real) shocks in the VAR model, Funke (1997) and Robertson and Wickens (1997) have computed correlation matrices between demand and supply shocks over the same sample in a set of European countries and between the USA and the UK respectively.[12] The results are very similar to those reported here except that the correlation coefficients between the supply shocks are somewhat larger than I found (0.45 between the UK and Germany and 0.24 between the UK and the USA). However, Robertson and Wickens show that, once they exclude the periods corresponding to the two severe oil price shocks in the 1970s, the correlation coefficient between the supply shocks in the UK and the USA falls considerably (0.04).

6 Conclusion

By using a minimum of restrictions on a VAR model, I have been able to interpret economic fluctuations in Germany, Norway, the UK and the USA in terms of three different shocks that have hit the economy: aggregate demand, aggregate supply and oil price shocks. In all countries, the dynamic adjustments of the variables are consistent with the economic model predictions and the shocks fit well with the actual events that have occurred in the different historical periods.

For all countries except Norway, an adverse oil price shock has had a negative effect on output in the short run, and for the USA the effect is negative also in the long run (ten years). For Germany, the UK and the USA, the oil price shock in 1973–74 played an important role in explaining the recession in the middle 1970s, whereas the recession experienced in the early 1980s was largely caused by other demand and supply disturbances.

In Norway, the effect of oil price shocks on output is positive at all horizons, although in the long run the effect is not necessarily significant. The different responses in the UK and Norway to an energy price shock emphasize how two countries that are self-sufficient in oil resources can react very differently to oil price shocks, especially if the governments have different priorities when deciding on macroeconomic policies.

Demand disturbances (temporary shocks) are the most important factors driving output in the short run in the USA, the UK and Norway, although already after two to three years supply shocks (permanent shocks) dominate. In Germany, supply shocks play the most important role for output movements at all horizons. Comparing the underlying shocks across countries, I find the supply shocks to be the most synchronized shocks across all countries in the 1970s, whereas from the middle 1980s demand shocks have been in phase in the UK, the USA and Norway.

[12]The sample used in Funke (1997) is from 1964 to 1993, whereas the sample referred to in Robertson and Wickens (1997) is from 1973 to 1991.

Appendix A: Data Sources and Model Specifications

All series are seasonally adjusted quarterly data, unless otherwise stated. The series are seasonally adjusted by their respective sources. The periodicity varies and is given for each country. All variables are measured in natural logarithms except for the unemployment rate which is measured in levels. For each country I use total GDP or GNP, except for Norway, where I use non-oil GDP which accounts for approximately 80 per cent of total GDP.

USA: 1960Q1–1994Q4

Gross domestic product, constant 1991 prices. *Source:* OECD
Unemployment, civil labour force. *Source:* OECD
Implicit GDP deflator. *Source:* OECD

Germany: 1969Q1–1994Q4

Gross domestic product, constant 1991 prices. *Source:* OECD
Unemployment (West Germany). *Source:* OECD
Implicit GDP deflator. *Source:* OECD
Exchange rate, monthly average DM:US$ (n.s.a.). *Source:* OECD

UK; 1966Q1–1994Q4

Gross domestic product, constant 1991 prices. *Source:* Datastream
Unemployment rate, total labour force. *Source:* OECD
Implicit GDP deflator. *Source:* OECD
Exchange rate, monthly average £:US$ (n.s.a.). *Source:* OECD

Norway: 1967Q1–1994Q4

Gross domestic product, mainland Norway (GDP less petroleum activities and ocean transport), constant 1991 prices. *Source:* Statistics Norway
Unemployment rate. *Source:* Statistics Norway
Consumer price index. *Source:* Statistics Norway
Exchange rate, monthly average NKr:US$ (n.s.a.). *Source:* OECD

All countries

Nominal oil price: Saudi Arabian Light-34, US$ per barrel, fob (n.s.a.). Prior to 1980, posted prices; thereafter spot prices. *Source: OPEC Bulletin* and Statistics Norway

Real oil price: Nominal oil price converted to each country's national currency and deflated by each country's implicit GDP deflator, except for Norway which uses the consumer price index (as oil prices may be included in the GDP deflator, with approximately 20 per cent of GDP in Norway generated in the oil sector)

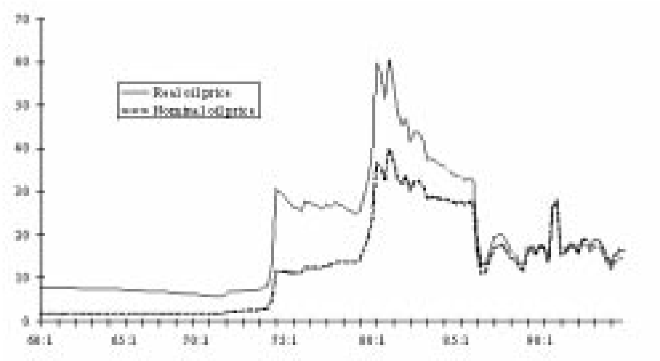


FIG. A1 Nominal and Real Oil Price, US$

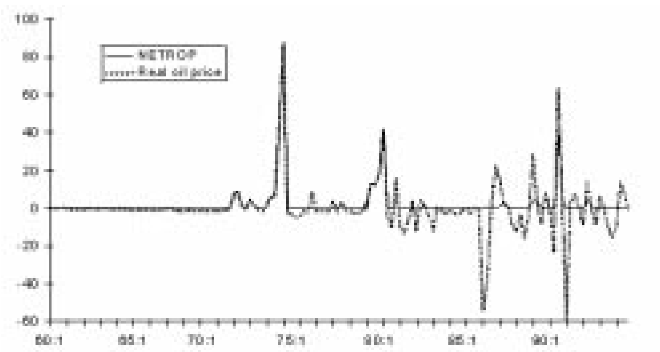


FIG. A2 Net Oil Price (NETROP) and Real Oil Price, Percentage Change

TABLE A1
AUGMENTED DICKEY–FULLER UNIT ROOT TESTS

	Constant and time trend in the regression			*Constant in the regression*			*Constant in the regression*		
	y	o	u	y	o	u	Δy	Δo	Δu
USA	−2.68	−1.07	−1.94	−1.59	−1.36	−1.88	−3.82[c]	−3.51[c]	−3.73[c]
Germany	−2.25	−1.41	−2.35	−0.57	−1.75	−1.60	−3.08[b]	−2.87[a]	−2.57
UK	−3.14	−1.13	−1.71	−0.42	−1.54	−1.45	−3.19[c]	−3.17[c]	−3.50[c]
Norway	−1.98	−1.26	−2.29	−1.75	−1.61	−0.57	−3.03[b]	−3.17[c]	−3.05[b]

Notes: The critical values were taken from Fuller (1976, Table 8.5.2, p. 373).
[a] Rejection of the unit root hypothesis at the 10 per cent level.
[b] Rejection of the unit root hypothesis at the 5 per cent level.
[c] Rejection of the unit root hypothesis at the 2.5 per cent level.

TABLE A2
SEQUENTIAL UNIT ROOT TEST FOR UNEMPLOYMENT

Series	*Model*	*Period*	*Minimum t statistics*
USA	A,C	1974Q3	−4.36
Germany	B	1985Q3	−4.36[a]
UK	C	1980Q2	−4.92[a]
Norway	A	1988Q2	−4.92[b]

Notes: The critical values were taken from Zivot and Andrews (1992, pp. 256–257). The 10 per cent (5 per cent) critical value for model A (change in the level) is −4.58 (−4.80), for model B (change in the growth rate) is −4.11 (−4.42) and for model C (both a change in the level and a change in the growth rate) is −4.82 (−5.08).
[a,b] See Table A1.

TABLE A3
JOHANSEN MAXIMUM LIKELIHOOD PROCEDURE, TRACE TESTS

H_0	H_1	*Critical values* 95%	99 %	*USA*	DF-adj.	*Germany*	DF-adj.	*UK*	DF-adj.	*Norway*	DF-adj.
$r = 0$	$r \geq 1$	29.68	35.65	22.35	20.88	32.63	27.68	32.22	26.94	21.67	17.99
$r \leq 1$	$r \geq 2$	15.41	20.04	10.23	9.56	11.74	9.96	6.79	5.68	8.20	6.81
$r \leq 2$	$r \geq 3$	3.76	6.65	1.91	1.79	2.21	1.88	1.08	0.90	2.41	2.00

Notes: Cointegration vector $(y_t, o_t, u_t)'$, where u_t is the unemployment rate adjusted for the structural break.
DF-adj. refers to the eigenvalue adjusted for degrees of freedom (see Reimers, 1992). All test statistics are calculated using PcFiml 8.0 (see Doornik and Hendry, 1994). Critical values are taken from Table 1 in Osterwald-Lenum (1992).

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