No. 174 | June 1996 | Discussion Papers

Statistics Norway
Research Department

Discussion Papers

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Discussion Papers No. 174 • Statistics Norway, June 1996

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Abstract:
This paper analyses the dynamic effects of aggregate demand, supply and real oil price shocks on real output and unemployment. Oil price shocks are included explicitly in the model, to investigate their role in explaining periods of global recessions. The different structural disturbances are identified by imposing long-run and short-run restrictions on a vector autoregressive model. The analysis is applied to Germany, Norway, United Kingdom and United States. For all countries except Norway, an adverse oil price shock has had a negative effect on output in the short run, and for US, the effect is negative also in the long run. However, whereas the first oil price shock was the most important factor behind the severity of the recession in the middle 1970s, adverse demand and supply shocks were more important than the second oil price shock in explaining the recession in the early 1980s. For Norway, a small oil exporting country, an adverse oil price shock stimulates the economy, although in the long run, the effect is most likely zero.

Keywords: Oil price shocks, permanent and trasitory components, structural change, unit root, vector autoregression.

JEL classification: C22, C32, E32, O57

Akcnowledgement: The author wishes to thank Ragnar Nymoen, Danny Quah, Ådne Cappelen, Henrik Hansen and participants at seminar meetings at the London School of Economics, University of Oslo and University of Copenhagen for helpful comments and discussions. Financial support from Norges Banks fond til økonomisk forskning, Den norske Banks fond and the Research Council of Norway is acknowledged.

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1. Introduction

Several economists have argued that the two successive adverse oil price shocks in 1973/1974 and 1979/1980, could be blamed for the severe periods of inflation and recessions facing the world economy in the middle 1970s and the early 1980s, (see e.g. Hamilton 1983, Burbidge and Harrison 1984, Gisser and Goodwin 1986, and Ferderer 1996). However, in the aftermath of the second oil price shock, tight macroeconomic policies were also implemented in many industrial countries, to combat the high inflation rates experienced. These disinflationary policies may have worsened the recession that was already associated with the energy price increases, (see e.g. Rasche and Tatom 1981, Darby 1982 and Ahmed et al. 1988). Some countries like the United Kingdom, also adopted tight fiscal policies from the early 1980s, which may have reduced output growth and increased unemployment in the following years. Did the oil price shocks trigger off the international recessions in the middle 1970s and early 1980s, or were there other factors like the contractionary macroeconomic policies implemented in each country after the energy price shocks, that should be blamed for the poor economic performance?

This paper uses a structural vector autoregression (VAR) model to analyse the dynamic effects of real oil price shocks on output and unemployment. 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). In addition to oil price shocks, I assume there may be aggregate demand and aggregate supply shocks that also hit the economy. Demand and supply disturbances are defined and distinguished from each other by imposing long-run restrictions on a VAR model. Especially, I interpret shocks that have permanent effects on output as aggregate supply shocks (e.g. technology changes), and shocks that have only temporary effects on output as aggregate demand shocks (e.g. monetary changes). However, in the short and medium term, both shocks are free to influence output. The long run restriction used to identify supply and demand shocks, is similar to that employed by Blanchard and Quah (1989). I impose no restrictions on the response of output to oil price shocks.

Once identified, the VAR model also provides a method for how to decompose a nonstationary variable like output into a trend and a cyclical component. Especially, the VAR model implies that output movements will be due to three different disturbances; demand, supply and oil price shocks. As supply and oil price shocks are allowed to have permanent effects on output, these two components will be nonstationary, contributing toward the long run movements (the trend) in the output series. The demand component will be stationary, making up the short run movements (the business cycles) in output. However, as both the supply and oil price component can also affect output in the short term, essentially all three components contribute towards the business cycles.

The analysis is applied to Germany, Norway, United Kingdom and United States. Of these countries, Norway and UK have been self sufficient with oil resources during most of the period examined, whereas the remaining countries are net oil importers. For all countries except Norway, an adverse oil price shock has had a negative effect on output in the short run, and for the US, the effect is negative also in the long run (ten years). For Germany, UK and US, the oil price shock in 1973/1974 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. For Norway, (whose oil producing sector plays a large role in the economy), the effect of oil price shocks on output is positive at all horizons, although in the long run the effect is not necessarily significant.

This paper is organised as follows. In section two I present some indicators that describe the macroeconomic performance of Germany, Norway, UK and US over the whole period examined. Section three describes a model of economic fluctuations, where energy price shocks are among the disturbances hitting the economy. In section four, I present the structural VAR model. Section five reviews the effect 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. In section six, the impacts of the different shocks on output are analysed in different historical periods. Here, I specifically focus on the effects of the energy price increases in 1973/1974 and 1979/1980 on the level of output. Section seven concludes. All calculations are performed using GAUSS and RATS, unless otherwise stated.

2. Macroeconomic performance

A comparison of some OECD countries, shows that real GDP grew at a much faster rate in Norway than in the other OECD countries in the aftermath of the oil price shock in 1973/1974 and 1979/1980. While Germany, United Kingdom and United States saw their prosperous growth rates from the 1960s fall back during the international recession in the 1970s and early 1980s, Norway managed to maintain growth rates at the 1960s OECD levels (cf. table 1).

The favourable economic performance in Norway until the late 1980s, has been attributed to the discovery and use of oil resources in Norway from 1970 onwards, which stimulated the economy so it grew at a higher rate than otherwise would have been possible. Especially, the government followed a highly expansionary fiscal policy in the 1970s. Despite the fact that the United Kingdom was self sufficient of oil resources by the time the second oil price shock occurred in 1979, UK has experienced a much deeper and longer recession than most other oil importing countries from the middle 1970s.

Table 1. Macroeconomic indicators.
Pct. change from previous year (average), unless otherwise stated

	United States	Germany[a]	United Kingdom	Norway
Real GDP				
1968-1973	3.2	4.9	3.4	4.1
1974-1979	2.6	2.4	1.5	4.9
1980-1985	2.1	1.1	1.3	3.5
1986-1991	2.2	3.6	2.5	1.6
1992-1994	3.2	1.3	1.8	3.6
CPI				
1968-1973	5.0	4.6	7.5	6.9
1974-1979	8.6	4.7	15.7	8.7
1980-1985	6.8	4.2	9.0	9.4
1986-1991	4.0	1.7	5.9	5.8
1992-1994	2.9	3.7	2.6	2.0
Unemployment, level[b]				
1968-1973	4.6	1.0	3.3	1.7
1974-1979	6.7	3.2	5.0	1.8
1980-1985	8.0	5.8	10.5	2.6
1986-1991	5.9	5.6	8.8	3.8
1992-1994	6.7	5.9	10.1	5.8

Sources: OECD Historical statistics 1960-1989, OECD Economic Outlook, various issues.
a) Data for CPI and Unemployment refer to Western Germany
b) Standardised unemployment rates, (average)

With low growth rates in most industrial countries, unemployment rates started to increase in the 1970s. Especially, unemployment rates rose drastically from the middle of the 1970s in US and Germany and from the early 1980s in UK. In Norway on the other hand, unemployment rates have remained low until the late 1980s (cf. table 1). For all countries except Germany, the high oil prices in the 1970s were also followed by increasing inflation rates. During this period, several countries also adopted tight monetary policy and in some cases tight fiscal policy (e.g. in UK from the early 1980s), to combat the high inflation rates experienced.

Based on the information in table 1, one can argue that both the first and the second energy price shocks preceded periods of low growth rates and increasing unemployment rates in all countries but Norway, and high inflation rates in all countries except Germany. However, whether the oil price shocks actually caused the recessions experienced in these countries, or whether for instance the macroeconomic policies implemented in each country after each energy price shock are to be blamed for the poor economic performances, can not be answered by examining table 1. The remaining of this paper sets out to analyse the effects of real oil price shocks on output and unemployment in each country using instead a structural VAR model. The interpretation of the structural shocks in the VAR model will be motivated by a simple economic model of output fluctuations as described below.

3. Oil price shocks and economic fluctuations

Analysis of the linkages between energy and the aggregate economy is complicated, as it is difficult to capture all the channels of influence without a fully specified model. Energy shocks may typically have both demand and supply effects on the real activity. The supply effect of a higher real energy price, may affect output via the aggregate production function by reducing the net amount of energy used in the production. The effects on the other resources used in the production will depend on whether we substitute more or less of the other resources. The employed resources may further be indirectly affected, if wage rigidities prevent markets from clearing.

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 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, this effect will be minimised. Finally, the level of demand may also change due to actions taken by the government in response to changes in oil prices. For instance, several countries pursued countercyclically monetary policy following the second oil price shock to offset the increase in the general price level, which lowered real activity[1].

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 like Fischer (1977), adopted from Blanchard and Quah (1989) (BQ hereafter), and consists of an aggregate demand function, a production function, a price setting behaviour and a wage setting behaviour. The model is modified by including real oil prices into the system:

(1) $$y_t = m_t - p_t + a\theta_t + bo_t$$

(2) $$y_t = n_t + \theta_t + co_t$$

(3) $$p_t = w_t - \theta_t + do_t$$

(4) $$w_t = w \big| \left[E_{t-1} n_t = \bar{n} \right]$$

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, and m is the log

[1] See e.g. Bohi (1989) and Mork (1994) for a further theoretical discussion.

of nominal money supply. $\bar{n}$ implies the log of full employment. The unemployment rate is defined as $u = \bar{n} - n$.

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 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 e.g. the rational consumers[2].

The production function (2) relates output to employment, technology and real energy prices, through an increasing return Cobb-Douglas production function ($c\geq 0$). 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 production function is a variant of Rasche and Tatom (1981), which relates output to labour input, capital input, the real price of oil and a time trend through a constant return to scale technology. 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, see e.g. Rasche and Tatom (1981, pp. 22-24) and Darby (1982, p. 739).

The price setting behaviour (3) gives nominal prices as a mark up on real oil prices and wages adjusted for productivity. Real oil prices are introduced into the price setting equation, to allow prices to be a mark up on oil prices, 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:

(5) $$m_t = m_{t-1} + \varepsilon_t^{AD}$$

(6) $$\theta_t = \theta_{t-1} + \varepsilon_t^{AS}$$

(7) $$o_t = o_{t-1} + \varepsilon_t^{OP}$$

where, ε^{AD}, ε^{AS} and ε^{OP} are serially uncorrelated, orthogonal demand, supply and real oil price shocks. Solving for Δy and u yield:

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

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

Solving for the level of output, y_t, one can see that only supply and oil price shocks will affect the level of output in the long run (through the production function), as y_t will be given as accumulations of these two shocks. The size of c will determine the magnitude of the long run effect of the oil price shock on output. However, in the short run, due to nominal and real rigidities, all three disturbances can influence output. From (9) one can see that neither of the shocks will have long run effects on unemployment. In BQ, only aggregate supply shocks were found to have long run effects on output. By including oil prices into the system, I have disentangled the effects of oil price shocks from productivity (aggregate supply) shocks, and shown that they can have different (short and) long run effects on output.

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

The finding that aggregate demand shocks have only short term effects on output, is also consistent with the interpretation of an upward sloping short run supply schedule, but a vertical long run supply schedule. 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].

4. Structural VARs and integrated data

Sims (1980) first proposed to use VARs as an alternative to the traditional structural models. Sims' main dissatisfaction with large scale econometric models was that too many parameters were identified in these models by excluding variables, most often lagged endogenous variables, without proper theoretical justifications. The results from simulations on a fully specified large scale model, would typically be a product of the structure of the model. In Sims' original work, the system was identified recursively. Empirical studies analysing the effects of oil price shocks like Burbidge and Harrison (1984) and Ahmed et al. (1988), typically adopted this identification structure. This implies a causal ordering on how the system works. Subsequently, Sims (1986), Bernanke (1986), Blanchard and Watson (1986) and Blanchard (1989) have suggested that one might choose a more 'structural' system of the VAR, by choosing restrictions (typically short run restrictions), which are based on economic or statistical reasoning. Other researchers have exploited other type of restrictions, and Blanchard and Quah (1989) and Shapiro and Watson (1988) used long run restrictions to identify the system. Especially, BQ imposed long run restrictions on a bivariate VAR model of the first differences of output and the (detrended) unemployment rate, to distinguish between disturbances that have only transitory effects on the level of output (e.g. aggregate demand shocks), and disturbances that have permanent effects on the level of output (e.g. aggregate supply shocks).

Here I will show how I instead can use a *combination* of short run and long run restrictions on a VAR model, to identify different types of structural shocks. The VAR model specified here, focuses on three variables; Real output, real oil prices and unemployment. As suggested by equations (7)-(9), these variables are a minimum of variables that are necessary to identify three structural disturbances; aggregate demand, supply and oil price shocks. The long run restriction applied here is motivated by the findings in (8), namely that aggregate demand shocks have no long run effects on output. This restriction is similar to that applied in BQ, although there the economy is subject to only one type of shock with long run effect, namely aggregate supply shock. If for instance there are many supply disturbances that each affects the dynamic interaction between output and unemployment differently, their interpretations may be meaningless (Blanchard and Quah 1989, p. 659). As demonstrated in (8), both productivity shocks and real oil price shocks may have long run effects on output, and should therefore be examined separately. Finally, real oil price shocks will be identified by imposing contemporaneous restrictions on the equation for oil prices.

In this analysis, both GDP and real oil prices will be taken to be nonstationary integrated, I(1), variables, where stationarity is obtained by taking first differences[4]. Unemployment is assumed to be a stationary, I(0), variable. 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 differences 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[5].

[3] For a textbook discussion, see e.g. Dornbusch and Fischer (1994).

[4] The whole exercise would be meaningless if real GDP did not contain a unit root, as one of the aims of this analysis is to calculate permanent and transitory components in GDP. If GDP instead had been (trend)-stationary, no shocks like e.g. technology changes would have long run impacts on GDP.

[5] The assumptions of stationarity are discussed and verified empirically below in section five.

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 stationary, z_t is a covariance stationary vector process. The Wold Representation Theorem implies that under weak regularity conditions, a stationary process can be represented as an invertible distributed lag of serially uncorrelated disturbances. The implied moving average representation from (10) can be found and 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. The C_j matrix refers to the moving average coefficient at lag j. As the elements in e_t are contemporaneously correlated, they can not be interpreted as structural shocks. The elements in e_t are orthogonalized by imposing restrictions. A (restricted) form of the moving average containing the vector of original disturbances as linear combinations of the Wold innovations can be found as:

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

where ε_t are orthogonal structural disturbances which for convenience I normalise so they all have unit variance, e.g. $cov(\varepsilon_t)=I$. The assumption that the underlying structural disturbances are linear combinations of the Wold innovations (e_t) is essential, as without it the economic interpretations of certain VAR models may change, see e.g. Lippo and Reichlin (1993) and Blanchard and Quah (1993) for a discussion of the problem of nonfundamentalness. With C_0 as the identity matrix, (11) and (12) imply that $e_t=D_0\varepsilon_t$, and $C_jD_0=D_j$ so:

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

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 OLS to (10). However, the D_0 matrix contains nine elements, and to orthogonalise the different innovations we need nine restrictions. First, from the normalisation of $var(\varepsilon_t)$ 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. I first order the three serially uncorrelated orthogonal structural shocks 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.

As z_t is defined as a vector of stationary variables, none of the three structural shocks will have long run effects on the rate of change in output, Δy_t, the rate of change in real oil prices, Δo_t, or unemployment, u_t. However, both output and real oil prices are integrated variables, so all shocks can have long run effects on the level of these variables. From (12) the effect of a demand shock on the rate of change in output, Δy_t, after j periods is given as $D_{11,j}$, whereas the effect of a demand shock on the level of output, y_t, after k periods is $\sum_{j=0}^{k} D_{11,j}$. The restriction that aggregate demand shocks have no long run effects upon the level of y_t, is then simply found by setting the infinite number of lag coefficients, $\sum_{j=0}^{\infty} D_{11,j}$, equal to zero. From (13), the long run expression, $\sum_{j=0}^{\infty} C_j D_0 = \sum_{j=0}^{\infty} D_j$, can be written out in its full matrix format as:

$$\begin{bmatrix} C_{11}(1) C_{12}(1) C_{13}(1) \\ C_{21}(1) C_{22}(1) C_{23}(1) \\ C_{31}(1) C_{32}(1) C_{33}(1) \end{bmatrix} \begin{bmatrix} D_{11,0} D_{12,0} D_{13,0} \\ D_{21,0} D_{22,0} D_{23,0} \\ D_{31,0} D_{32,0} D_{33,0} \end{bmatrix} = \begin{bmatrix} D_{11}(1) D_{12}(1) D_{13}(1) \\ D_{21}(1) D_{22}(1) D_{23}(1) \\ D_{31}(1) D_{32}(1) D_{33}(1) \end{bmatrix}$$

where $C(1) = \sum_{j=0}^{\infty} C_j$ and $D(1) = \sum_{j=0}^{\infty} D_j$ indicate the long run matrixes of C(L) and D(L) respectively. C(1) is observable, found by inversion of A(1). The long run identification then implies that $D_{11}(1) = 0$. Hence:

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

In our trivariate system, two further restrictions are required to identify the system. These are found by assuming two 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 as the US. However, oil prices have been dominated by a few large exogenous developments, (e.g. the OPEC embargo in 1973, the Iranian revolution in 1978/1979, the Iran-Iraq War in 1980/1981, the change in OPEC behaviour in 1986, and most recently, the Persian Gulf War in 1990/1991). 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 in each country on real oil prices are zero, and only exogenous 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 short term restrictions on real oil prices then imply that:

(16) $D_{21,0} = D_{23,0} = 0$

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). It turns out that the system is linear in its equations, and can be solved numerically[6].

[6] Note that no restrictions are imposed on the long run effects 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.

Despite the many advantages of using a simple structural VARs, it is also subject to some limitations. Especially, 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 we will for instance not be able to distinguish between different aggregate demand shocks (like e.g. increases in money supply or fiscal policy)[7]. One way to assess whether the identification structure applied here is meaningful, is to empirically examine whether the different shocks have had the effects as expected in the different periods examined. This will be discussed in the sections that follows.

5. Empirical results

In the VAR model specified above, the variables were assumed to be stationary and the level of the variables were not cointegrating. Below I perform some preliminary data analyses, to verify whether I have specified the variables according to their time series properties. The dynamic effects of the different shocks on the variables are thereafter estimated.

5.1. Data analysis and model specifications

The data used for each country is the log of real GDP, the log of real oil prices converted to each country's national currency and the total unemployment rate (see appendix A for data descriptions and sources)[8]. The lag order of the VAR-models are determined using the Schwarz (SC) and Hannan-Quinn (HQ) information criteria and the F-forms of likelihood ratio tests for model reductions as suggested by Doornik and Hendry (1994). Lag lengths between one and eight orders are considered. I report two different types of F-tests, one where I reduce the order of the VAR model sequentially and one where the order of the VAR is reduced directly. The test statistics are given in table B.1-B.4 in appendix B for US, Germany, UK and Norway respectively. Both the SC and HQ information criteria are minimised using two lags in US, two (SC) or three (HQ) lags in Germany, and one lag in both UK and Norway. However, based on the 5 pct. critical levels, the F-tests suggest that we keep three lags in US, five lags in Germany, four lags in UK, and two lags in Norway.

If the models selected are correctly specified, then the residual autocorrelations will be uncorrelated. To test for serial correlation in the residuals, I use the Ljung-Box Q-statistic. Using the VAR model with three lags in US and five lags in Germany, the Ljung-Box Q-statistic showed no evidence of serial correlations in the residuals. However, using two lags for Norway, I could not accept the hypothesis that the residuals were white noise. By increasing the lag length, the white noise properties improve significantly, and at six lags I do not have to accept the hypothesis that the residuals are non-white. For UK, the white noise properties also improve considerably increasing the lags in the VAR model from four to six lags. Eventually I then estimate VAR models with three lags in US, five lags in Germany, and six lags in Norway and UK[9]. These results are reported in table B.5 in appendix B.

GDP and oil prices are taken to be I(1) in the analysis. To test whether the underlying process of GDP and oil prices contain a unit root, I use the augmented Dickey Fuller (ADF) regression. The test results and details on the estimation procedure are seen in appendix C. In none of the countries can I reject the hypothesis that GDP and oil prices are I(1) in favour of the trend stationary alternative. Further, in all countries, I can reject the hypothesis that oil prices and GDP are integrated of second order I(2).

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[7] Blanchard and Quah (1989) discuss whether it is plausible to assume only one source of aggregate demand disturbance. However, they show that in the situation where the economy is subject to many demand disturbances that each have different dynamic effects on output but leave the relation between output and unemployment unaffected, their aggregation proposition is still valid (Blanchard and Quah 1989, p. 669-672). Gali (1992), uses the same identification structure as in BQ, but distinguishes between transitory IS (fiscal policy) and money supply shocks. Essentially he finds output to respond very similar to these two temporary shocks, although IS shocks dies out more quickly than money supply shocks.

[8] Note that for Norway, mainland GDP is used instead of total GDP, as 15-20 pct. of total GDP is generated in the oil sector.

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

Unemployment is taken to be I(0) in the analysis[10]. Based on data available on unemployment for most of this century, there is little to suggest that there has been a time trend in the development of the unemployment rate in most countries. However, when investigated from the 1960s and onwards, unemployment seems to behave in a nonstationary way in many countries. Especially, unemployment seems to have increased drastically from the middle 1970s in US and Germany, from the early 1980s in UK and from the late 1980s in Norway (cf. table 1).

Based on the ADF tests, in none of the countries could I reject the hypothesis that unemployment is I(1). However, the ADF tests 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. This structural change may be due to an episode like the global oil price shock in 1973 that had an adverse permanent effect on many economic series (see e.g. Perron 1989). Below I follow Zivot and Andrews (1992), and test the null hypothesis of a unit root against the alternative hypothesis that unemployment is stationary around a deterministic time trend with a one time break that is unknown prior to testing. The break in the trend is either modelled as a single change in the level of the trend, as a single change in the growth rate of the trend, or as both a change in the level and the growth rate of the trend at the same time. A description of the tests and the estimation results are presented in appendix C.

Based on Zivot and Andrews'(1992) critical values, I can reject the hypothesis that unemployment is I(1) in Norway at the 5 pct. level, in favour of a change in the level of the trend when the break point was estimated to 1988Q2. For UK, I can reject the hypothesis that unemployment is I(1) at the 10 pct. level, in favour of a change in both the level and the growth rate in the trend in 1980Q2. For Germany, the hypothesis of a unit root is rejected at the 10 pct. level in favour of a change in the growth rate in the trend in 1985Q3. For US, I can reject the hypothesis of a unit root in favour of the deterministic trend with a break in 1974Q3, but only at the 20 pct. level. Although a deterministic trend is included in the estimation procedure, for Norway, UK and US, the trend in unemployment is virtually flat before and after the break and may not even be significant.

Can one conclude anything based on the timing of these break dates? For US, the break occurred at the time of the first oil price shock (1974), whereas in UK, the break in the trend in unemployment occurred at the time of the second oil price shock (1980). However, the time of the break in UK also corresponds to a period of tight monetary and fiscal policy during the first years of the Thatcher government. Especially, the adoption of targets for the public sector borrowing requirements (see e.g. Buiter and Miller 1983), may have had long lasting negative effects on the economy. For Germany, the break point came in 1985. Unemployment had increased steadily from 1973, but after 1985, unemployment has remained relatively stable. This (favourable) change in unemployment in 1985, corresponds approximately to the start of the oil price collapse in the middle 1980s. The break point for unemployment in Norway coincides with what was found in Bjørnland (1995), in which the timing of the break occurred in a period of financial crisis and recession in the late 1980s. The preceding years had been characterised by a huge consumption and investment boom, that was primarily set off by the financial deregulation in the middle 1980s.

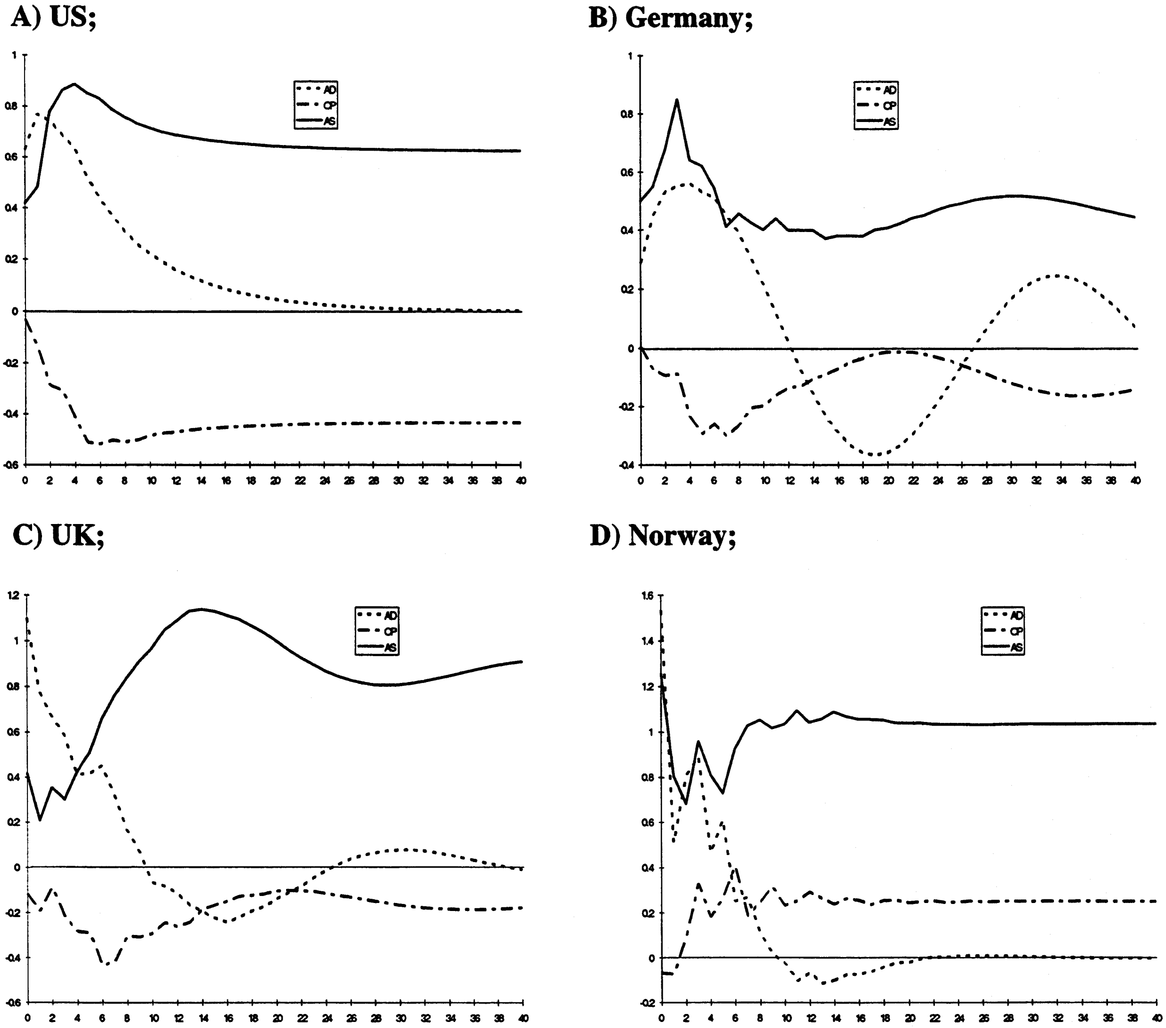
Further, in the VAR model specified above, there are no cointegration relations. Rewriting z_t as a cointegrated formula, $w_t = (y_t, o_t, u_t)'$, where u_t is the unemployment rate adjusted for the structural break, and using the maximum likelihood estimation procedure advocated by Johansen (1988, 1991), I can confirm that none of the variables in the VAR models are cointegrated (again, see appendix C for a description of the estimation procedure and the results). Hence, the variables are appropriately modelled as described by the VAR model above.

[10] Models that find unemployment to be stationary, argue that there is a 'natural' level of unemployment, determined by social institutions like e.g. union bargain power. Supply and demand shocks have only temporary effects on unemployment, and in the long run, wages and prices will adjust so unemployment returns to its natural level, see e.g. Layard, Nickell and Jackman (1991). In models that find unemployment to be nonstationary, technology changes may have long run impact on unemployment, see e.g. Blanchard and Summers (1986) model of 'hysteresis'.

5.2. 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 figures 1A-D, whereas the dynamic effects of the same three disturbances on unemployment are seen in figures 2A-D. In figures D.1-D.3 in appendix D, the dynamic effects of demand, supply and oil price shocks on GDP and unemployment in US are again reported, but now with one standard deviation band around the point estimates. Figures D.4-D.6 also report the effects of oil price shocks on GDP and unemployment with one standard deviation bands for Germany, UK and Norway respectively[11 12].

Figure 1. GDP responses[1]



1) AD = Aggregate Demand shock, OP = Oil Price shock, AS = Aggregate Supply shock.

In all countries except Norway, an (one standard error) adverse oil price shock lowers real GDP the first two to three years. The effect is largest after six quarters, where a one unit (adverse) oil price shock lowers GDP by 0.3-0.5 pct. in Germany, UK and US. The effect thereafter nearly dies out in

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[11] The standard errors reported in appendix D 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 in the RATS manual. The standard errors that correspond to the distributions in the D(L) matrix are then calculated using the estimate of D_0.

[12] The one standard deviation bands of the effects of demand and supply disturbances for Germany, UK and Norway, can be obtained from the author on request.

Germany and UK, whereas for US, real GDP is reduced with a total of 0.4 pct. after ten years. Appendix D confirms that in the long run (ten years), only US shows a significant negative effect of oil price shocks on GDP, whereas in UK and Germany, the effects of oil price shocks on GDP are not significantly different from zero after two years, as the one standard deviation bands around the point estimate include zero. In Norway, the adverse oil price shock has an initial (negligible) negative effect on GDP, but the effect thereafter becomes positive, until GDP has increased by about 0.2-0.3 pct. after ten years. Based on figure D.6A in appendix D, I can nevertheless not conclude that the effect of oil price shocks on GDP is significantly positive in the long run, as the one standard error band includes zero and becomes wider as the horizon increases.

A demand shock has a positive impact effect on the level of GDP in all countries. The response is highest in the smallest country, Norway (cf. figure 1D), where a unit shock has about 1.5 pct. effect on GDP. The response of GDP in all countries thereafter declines gradually as the long run restriction bites. The standard error bands also confirm that demand shocks die out over time, and for e.g. US, the effect of a demand shock on GDP is not significantly different from zero after four years (cf. figure D.2A).

Supply disturbances have a permanent effect on the level of GDP in all countries. The impact effect of a one unit supply shock is positive, varying from 0.2 to 1.1 pct., with again the highest response in the smallest country, Norway. After ten years, the effect of a unit shock has stabilised, increasing GDP with 0.4-0.6 pct. in Germany and US, and with 0.8-1.0 pct. in UK and Norway. However, the point estimate is not precisely estimated, and for e.g. US, the one standard deviation band includes values between 0.4 and 0.8 after ten years, (cf. figure D.3A)[13].

It is interesting to compare the results for US, with the findings in Blanchard and Quah (1989). Whereas BQ found the initial output response in US after a supply shocks to be small and approaching zero the first two quarters, I find the output response in US 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 BQ, may therefore be due to the fact that they have not separated the effects of oil price shocks from the other supply (productivity) shocks.

Real oil price shocks have little effect on unemployment rates in all countries. In US, UK and Germany, an oil price disturbance has increased the unemployment rate by less than 0.1 pct. points after two years, but thereafter the effect dies out. In Norway, the effect is negligible, increasing unemployment rates initially with less than 0.05 pct. points. The standard deviation bands reported in appendix D, also indicate that the effects of oil price shocks on unemployment are not really significantly different from zero for more than a few quarters.

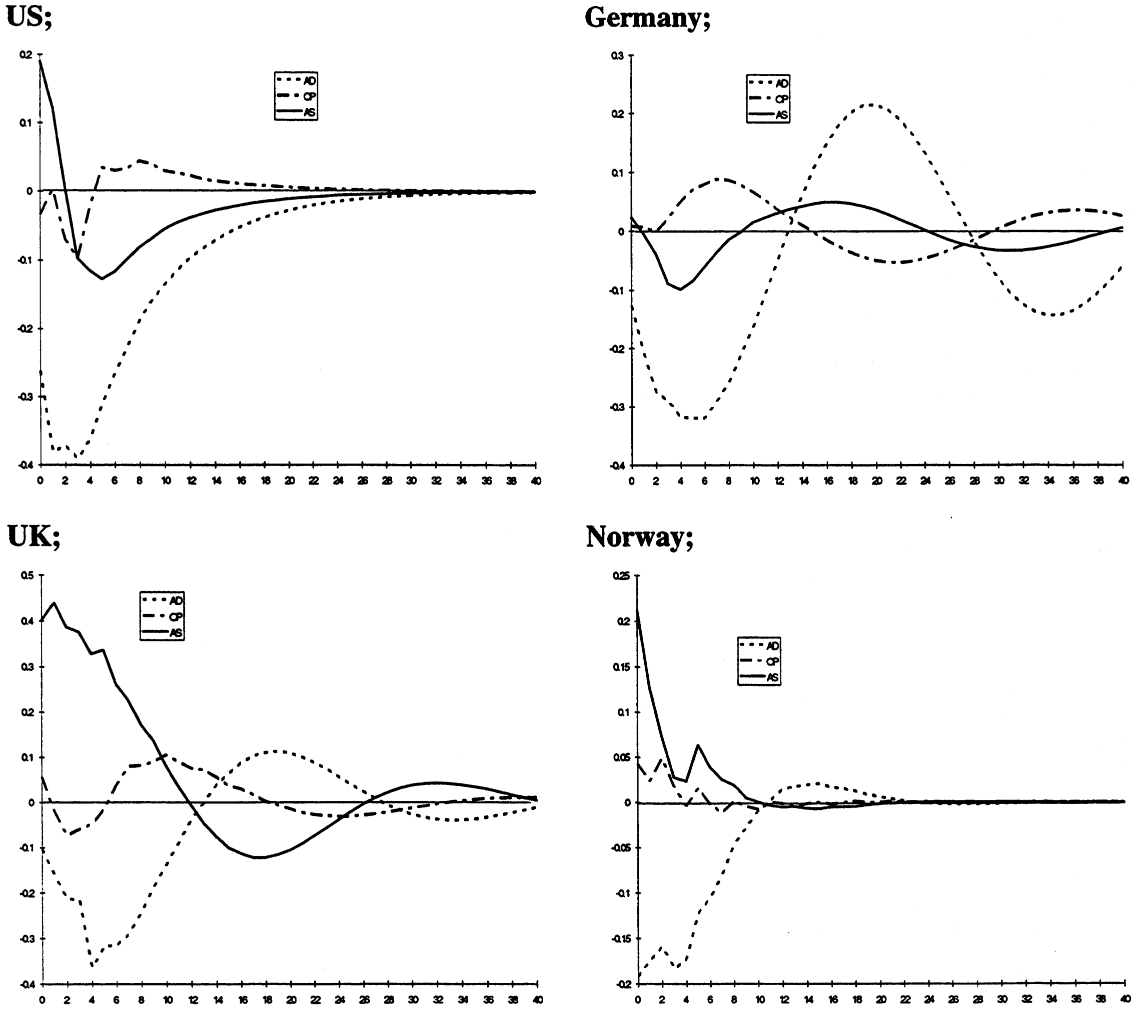
Note that although the oil price shocks have larger effects on output in US than in Germany, the adverse effects on unemployment from oil price shocks are larger in Germany than in US. However, for US I have allowed for an increase in the unemployment rate by shifting the trend upwards in 1974 (cf. section 5.1), which corresponds to the timing of the first oil price shock. This implies that the oil price shock in 1973/1974 may have had a permanent adverse effect on unemployment in US, in addition to the effects I have reported above.

The response of unemployment to aggregate demand shocks mirrors the response of output to the same disturbances. The effect of a positive demand shock reduces the unemployment rate immediately in all countries. The effect is largest after about a year. The effect is smallest in Norway, where unemployment is reduced with less than 0.2 pct. point, and largest in UK and US, where

[13] Standard deviation bands around the impulse responses functions using standard VARs will typically be wide, see e.g. Runkle (1987) and the comments in the same journal.

unemployment is reduced with approximately 0.3-0.4 pct. points. The effect thereafter declines, until after three to four years, the effect on unemployment is not significantly different from zero.

Figure 2. Unemployment responses[1]



1) AD = Aggregate Demand shock, OP = Oil Price shock, AS = Aggregate Supply shock.

A positive supply disturbance on the other hand, work to increase the unemployment rate in all countries initially, (although the effect is negligible in Germany). The effect is largest in UK, where unemployment increases with about 0.4 pct. points initially. After two quarters, the unemployment rate decreases and becomes negative in US and Germany, whereas in UK and Norway, the effect remains positive for about three years, until it eventually dies out.

Finally, note that whereas both demand and supply shocks have hit real output much harder in Norway than in the other three countries, the effects on unemployment from the same shocks are much smaller in Norway than in the other countries. As Norway is a small open economy, one would typically expect there to be large effects from the different shocks on the real economy. The fact that unemployment seems to be less affected than GDP in Norway than in the other countries, implies that the labour market may have been sheltered from these shocks, (by e.g. accommodating policies implemented by the government).

Next, I set out to calculate the relative contribution of the different shocks to output and unemployment variations.This is measured as the fraction of the variance of the forecast errors that is attributed to each of the shocks (cf. Lütkepohl 1993, ch. 2.3.3). Tables 2-5 present the forecast-error variance decompositions for GDP and unemployment in US, Germany, UK and Norway respectively. The identification restriction that aggregate demand disturbances have no long run effect on GDP, implies that as the forecast horizon reaches infinity, 100 pct. of the variation in GDP is explained by aggregate supply and real oil price shocks. However, at shorter horizons, the relative contributions of aggregate demand, supply and oil price disturbances to GDP fluctuations are unrestricted.

Table 2. Variance Decomposition of GDP and Unemployment in US

	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
2	69.8	1.4	28.8	80.5	0.4	19.0
3	58.0	3.9	38.1	86.2	1.5	12.4
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
24	16.4	23.4	60.1	85.9	2.3	11.8
40	11.3	26.3	62.4	85.9	2.3	11.8

Real oil price shocks have only an initial small effect on output. However, after three to four years, oil price shocks explain about 20 pct. of output fluctuations in the US, increasing to 25 pct. after ten years. In UK, the effect is largest after two years, where 10 pct. of output fluctuations are explained by oil price movements. The effect in Germany is smaller, and less than 8 pct. of output movements are explained by oil price shocks after three years. In Norway, oil price shocks have a positive long run effect on output that increases over time, and from three years and onwards, about 5 pct. of output movements are explained by oil price shocks. Oil price shocks have little importance in explaining unemployment fluctuations in all countries the first year, but after three years, 2-5 pct. of unemployment fluctuations are explained by oil price shocks. The effect is largest in Germany.

Table 3. 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
2	33.6	0.6	65.7	98.8	0.2	1.0
3	35.6	0.9	63.5	98.4	0.1	1.5
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
24	33.1	5.8	61.0	90.6	5.2	4.2
40	25.6	5.9	68.4	90.4	5.4	4.2

In the short term, aggregate demand disturbances contribute to most of the variation in output in US, UK and Norway, with 60-90 pct. of the variation in GDP explained by aggregate demand shocks initially. The relative contribution of aggregate demand disturbance thereafter declines gradually as expected. Aggregate demand shocks play the most important role in explaining unemployment fluctuations the first year in all countries except in UK, where aggregate supply shocks are more important. After two to three years, aggregate demand shocks explain about 70-90 pct. of unemployment variation in Norway, US and Germany and about 40 pct. of the variation in unemployment in UK.

Aggregate supply disturbances explain about 15-40 pct. of the variation in GDP in US, UK and Norway the first quarter, whereas in Germany 75 pct. of output fluctuations are explained initially by aggregate supply disturbances. Thereafter aggregate supply disturbances become more important, and after ten years, supply disturbances explain about 60-70 pct. of output fluctuations in US and Germany, and about 80 pct. of output fluctuations in UK and Norway.

Table 4. Variance Decomposition of GDP and Unemployment in 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
2	87.1	2.4	10.4	9.3	0.9	89.8
3	85.0	2.2	12.9	13.7	1.5	84.7
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
24	14.9	5.2	79.9	38.1	3.9	58.0
40	10.1	4.7	85.1	38.2	4.0	57.8

To conclude this section, I summarise the main findings up to now. The responses of output and unemployment to demand disturbances (temporary shocks) in US, UK and Norway, seem consistent with what a Keynesian approach to business cycles would have predicted (cf. section 3). Demand disturbances are the most important factor behind output fluctuations in the short run, but eventually prices and wages adjust to restore equilibrium.

Table 5. 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
2	53.9	0.2	45.9	51.5	1.8	46.7
3	54.6	0.3	45.1	56.5	2.9	40.6
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
24	15.2	4.9	79.9	70.8	2.0	27.2
40	9.7	5.1	85.2	70.8	2.0	27.2

The initial increase in both output and unemployment after supply disturbances (permanent shocks) seen most clearly in US, UK and Norway, indicate again that there may be nominal and real rigidities present in these countries. Productivity shocks increase output, but with a rigid nominal price level, aggregate demand fails to increase with enough to prevent unemployment from rising (cf. Blanchard and Quah 1989 p. 663). When prices and wages eventually adjust, unemployment falls gradually back to its equilibrium level.

In the real business cycle view, supply disturbances (technology changes), are the driving force behind short term economic fluctuations (e.g. Kydland and Prescott 1982). Prices are flexible and economic fluctuations will reflect changes in agents behaviour to stochastic shocks as technology. In these models, policy changes have no effect on output, as agents are rational and anticipate prices. In Germany, "supply disturbances" are more important than "demand disturbances" in explaining output fluctuations in the short term, and indicate that a real business cycle view may be applicable. Recall also that although demand disturbances are most important in US, UK and Norway in the short run, after two years, supply shocks (permanent shocks) explain between 40 and 60 pct. of output fluctuations, and are therefore also important contributors for the business cycles in the medium term.

In Germany, US and UK, GDP declined temporary after an oil price shock, and in US, the effect remained negative also in the long run. However, in Norway, GDP actually increased in response to oil price shocks. Why should output in US respond more negatively to an oil price shock than output in Germany (and UK), and why do Norway and 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 low production dependence of oil, 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 e.g. Lehment 1982, Fieleke 1988 and Nandakumar 1988 for discussions). Raasche and Tattom (1981) suggest that as Germany has traditionally had higher duty on oil prices than US, it may therefore have replaced oil as an energy source in some of the industry with nuclear power or coal. Especially, between 1973 and 1979, consumption of crude petroleum per capita declined slightly in Germany, whereas in US, consumption of crude petroleum per capita increased. Total import of crude petroleum also declined slightly between 1973 and 1979 in Germany, but increased in US, (cf. UN Yearbook of World Energy Statistics).

The fact that in UK output decreased, whereas in Norway, output actually increased in response to an oil price shock, emphasises how two countries that are self sufficient with oil resources can react very differently to oil price shocks, at least in the short term. These results are also consistent with the findings in Mork et al. (1994). Although the oil sector plays a much larger role in Norway than in UK, macroeconomic policy has also been conducted very differently in light of the two major oil price shocks in Norway and UK[14]. In Norway, the oil price increases raised the net national wealth, allowing the government to follow an expansionary fiscal policy during the latter part of the 1970s and early in the 1980s. UK was self sufficient with oil resources when the second oil price shocks occurred, but fiscal and monetary policies have remained relatively tight during the 1980s, aimed primarily at combating the high inflation rates in that period. Also, with factory closures and rapidly increasing unemployment rates from 1979 in UK, much of the revenues from the increased oil prices went into social security in addition to payment of existing external debts.

The VAR model estimated above, implies that if oil price increases decrease output, oil price decreases will increase output. However, some authors like Mork et al. (1994), argue that oil price increases and decreases have had asymmetric effects on output growth in several countries like Germany and US, (although maybe not in Norway and UK)[15]. Rather than investigating whether oil price increases and decreases have symmetric effects, I finally investigate whether the effects of oil price changes have been stable over time. I divide the sample into three periods, 1960-1971, 1972-1981 and 1982-1994, and reestimate the model for US for each of the three periods. In the first period, oil prices have been relatively stable, the second period is dominated by two huge oil price increases, whereas in the third period, oil prices have fallen dramatically interrupted only by the 1990 Persian Gulf War. The impulse response functions and variance decompositions are seen in appendix E.

From 1960 to 1971, adverse oil price shocks have negative effects on output in US, explaining approximately 5-10 pct. of output variation. This is also consistent with Hamilton (1983), who found

[14] By 1980, oil and gas accounted for almost 10 pct. of GDP in Norway and 5 pct. of GDP in UK, whereas by 1993, almost 20 pct. of GDP was generated in the oil sector in Norway, but in UK, oil and gas accounted for only 2 pct. of GDP.
[15] Mork et. al. (1994) distinguish between oil price decreases and oil price increases and analyse the effects of these oil price changes through bivariate and multivariate correlations in a reduced-form macroeconomic model.

a significant negative correlation between oil prices and output in US all the way back to the World War II. Oil price shocks have approximately zero effect on unemployment in this period. From 1972-1981, the two oil price shocks dominate output movements, and more than 50 pct. of output variation is explained by oil price shocks. Oil price shocks explain approximately 15 pct. of the variation in unemployment, and unemployment increases with 0.1-0.2 pct. points after two years. From 1982 to 1994, oil price shocks have almost no effect on GDP and unemployment, explaining less than 2 pct. of output and unemployment variation.

Hence, oil price disturbances have had adverse effects on output in US during the 1960s, 1970s and early 1980s, although during the middle/late 1980s and early 1990s (where oil prices have mostly fallen, except during the Persian Gulf war), the effect of an adverse oil price shock is most likely zero. However, these results should be interpreted as illustrations rather than formal analysis, as each sample investigated is small (10 years), and will be dominated by the extreme values in this period. Finally, demand and supply shocks are more stable, and except for the 1970's when oil price shocks dominate, demand and supply shocks play constant roles during the 1960's, 1980's and 1990's.

6. Specific episodes

Above I investigated the responses of output to aggregate demand, supply and oil price shocks on average over the whole (or sub) periods. The moving average representation in (12) also implies that I can focus on specific historical periods, by computing the forecast errors in output using a weighted average of the estimated shocks. The weights are given by the impulse responses in (12). The decomposition is based on the following partition:

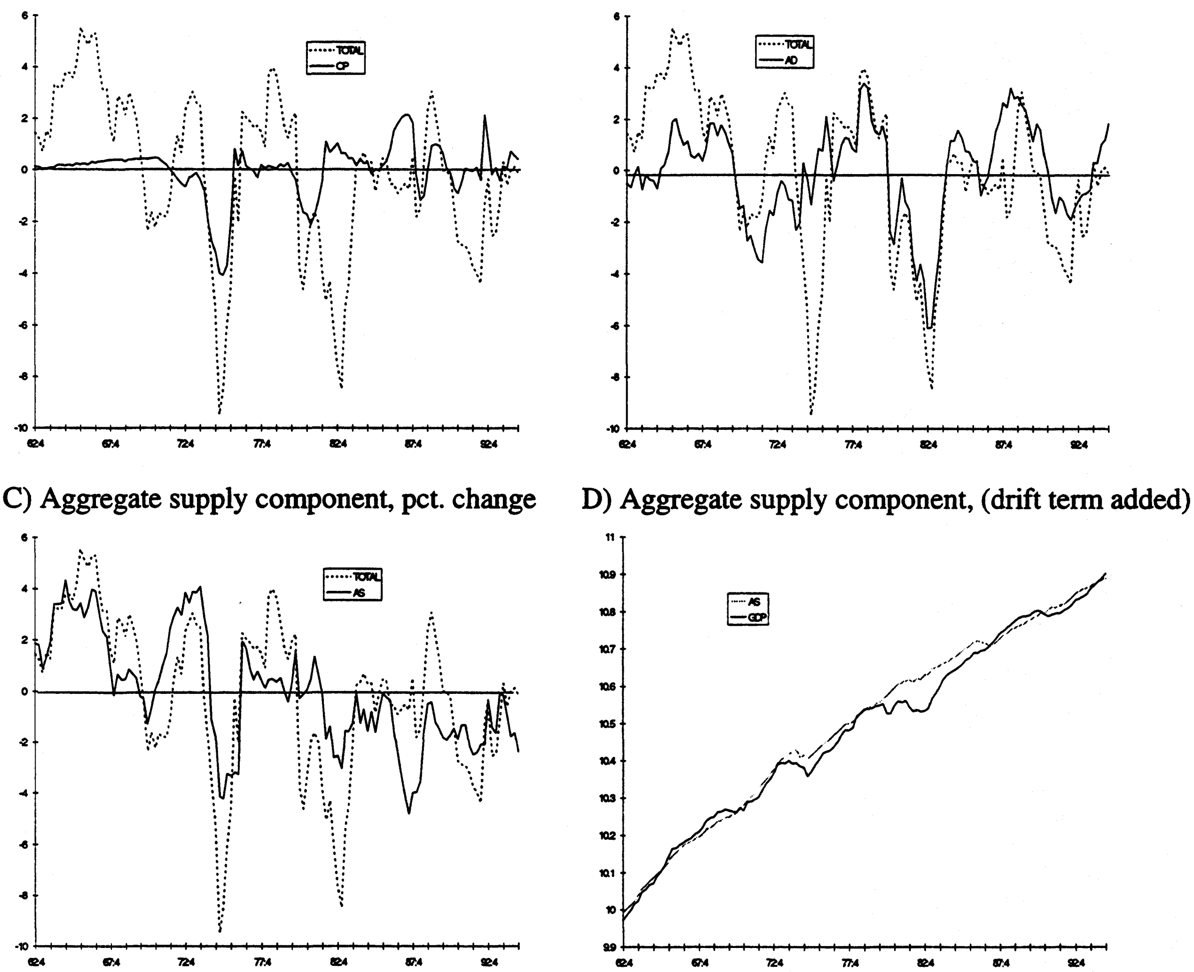
$$(17) \quad z_{t+j} = \sum_{s=0}^{j-1} D_s \varepsilon_{t+j-s} + \sum_{s=j}^{\infty} D_s \varepsilon_{t+j-s}$$

The first sum represents the part of z_{t+j} that is due to innovations in period t+1 to t+j. The second sum is the forecast (base projection) of z_{t+j}, based upon information given at time t. The gap between each data series and its base projection, can be assessed in terms of the contributions of the different shocks for the forecast error in each variable in the analysis. The results are presented in figure 3-6 for US, Germany, UK and Norway respectively. In panel A-C in each figure, I plot the total forecast error in output together with the forecast error that is due to oil price shocks, demand shocks and supply shocks respectively for each country. As the variables are in logarithms, these plots can be interpreted as pct. deviation from a trend. In panel D, 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). Table 6-9 summarise the values for the forecast errors of output due to each shock in the years 1974/1975 and 1979/1980.

The decomposition in (17) allows me to interpret economic fluctuations in terms of the different shocks that have hit the economy. For all countries, the shocks identified (demand, supply and oil price shocks) will be interpreted and assessed in terms of actual episodes that occurred in the periods examined. I first note that the output fluctuations implied by the (sum of the) different shocks in each country, correspond well with the common concepts of classical business cycles documented by the National Bureau of Economic Research (NBER) for US (the so-called business cycle chronologies), and by e.g. Artis et al. (1995) for some other European countries, (although Artis et al. 1995 refer to industrial production)[16].

[16] The NBER dates peaks and troughs of general economic activity in the US, with peaks preceded by periods of expansion and troughs preceded by periods of contractions.

Figure 3. Forecast Error Decompositions for GDP in United States



A) Oil price component, pct. change

B) Aggregate demand component, pct. change

C) Aggregate supply component, pct. change

D) Aggregate supply component, (drift term added)

The high growth rates in the *US* during most of the 1960s, seem to be mainly driven by positive supply shocks. Output do not fluctuate much during this period, and the variation in output seems to be characterised as slowly changing growth rates around a rising trend, rather than recurrent output fluctuations. This can be seen from figure 3D, where output is either below the supply potential (1960-1965), or above the supply potential (1965-1970)[17]. From about the time of the first oil price shock, output starts to fluctuate more violently. The recession from 1974-1976, was at first dominated by negative oil price shocks, but from the end of 1975, both adverse oil price shocks and negative supply shocks prolonged the recession, (see table 6). Recall that the jump upwards in the level of the trend in the unemployment rate in 1974 (cf. section 5.1), occurred at the same time as the supply potential and output fell down (cf. figure 3D). Several economists have argued that the long-run patterns of growth changed in the middle 1970s, and e.g. Sachs (1982) noted that behind the cyclical changes in 1973, was a more fundamental sharp decline in labour productivity growth.

With rising unemployment rates in 1973/1974, macroeconomic policies turned accommodating, and from 1977, demand shocks contributed positively towards the boom in the late 1970s (cf. figure 3B). From 1980, oil price shocks triggered off a new recession, but the recession was short and lasted initially only for a year. However, the government started to follow tight monetary policies, (although

[17] A similar picture is drawn in Dornbusch and Fischer (1994, pp. 446-447), where the trend (or potential output) is defined as the full employment (Okun) output.

expansionary fiscal policies) and from 1981, negative demand shocks pushed the economy into a prolonged recession that lasted almost until 1984. In contrast to the previous recession (1974-1976), aggregate supply shocks play almost no role for the 1980-1984 recession, which can also be confirmed in figure 3D, where output clearly lies below its supply potential during this period. The dating of these cycles correspond well with NBER chronology, which interprets the early 1980s into two cycles; the economy is at a bottom of a cycle (trough) in July 1980, thereafter the economy is recovering and reaches a cyclical peak in July 1981, before it contracts until the next trough in December 1982.

Table 6. Forecast Error Decomposition for GDP in United States, 1974/1975 and 1979/1980[1]

	AD-shock	OP-shock	AS-shock	GDP
74Q1-74Q2	-2.2	-1.4	2.5	-1.1
74Q3-74Q4	0.0	-3.0	-1.5	-4.5
75Q1-75Q2	-0.8	-4.0	-4.2	-9.0
75Q3-75Q4	0.8	-2.9	-3.3	-5.4
79Q1-79Q2	1.7	0.2	0.3	2.2
79Q3-79Q4	1.6	0.1	-0.1	1.6
80Q1-80Q2	-0.6	-0.8	0.6	-0.8
80Q3-80Q4	-2.2	-1.7	0.0	-4.0

1) AD = Aggregate Demand shock, OP= Oil price shock, AS = Aggregate supply shock.

Blanchard and Quah (1989) argued that the two recessions of 1974-1975 and 1979-1980, were attributed to equally proportions of adverse supply and adverse demand shocks. By including oil price shocks directly into the VAR, I have found that whereas supply disturbances (shocks with permanent effect on output other than oil price shocks) have had an important role in explaining the latter part of the 1973-1975 recession, supply shocks play virtually no role in the 1979-1980 recession.

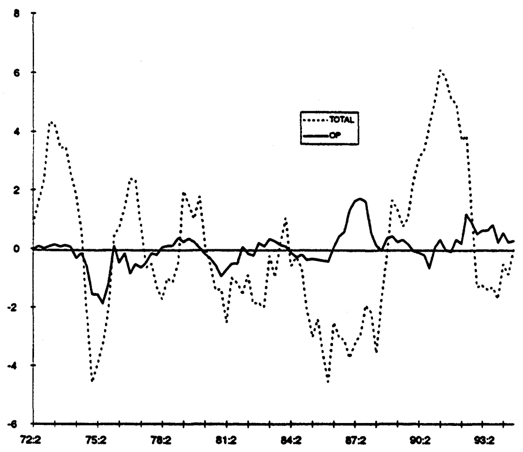
In 1986, the fall in oil prices had a positive stimulus to output growth, but the overall performance of the economy remained negative for two more years, as both demand and supply disturbances contribute negatively to output fluctuations, (this is also suggested in e.g. Shapiro and Watson 1988, and Barrell and Magnussen 1996). From 1990, the economy experiences another recession, this time, driven primarily by supply shocks. Blanchard (1993) also finds the recession in 1990-1991 to be mainly driven by shocks with permanent effects, and argues that this is why the recovery that has followed has been so sluggish. According to the NBER chronology, US has yet not seen the end of this recession, with no reported peaks after the trough in March 1991.

After the collapse of the Bretton-Woods system in 1973, *Germany* had 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, when Germany was already at the beginning of a recession (cf. figure 4B). From 1975, the recession is dominated by negative oil price shocks, but by 1976, the economy is again booming (cf. figure 4A).

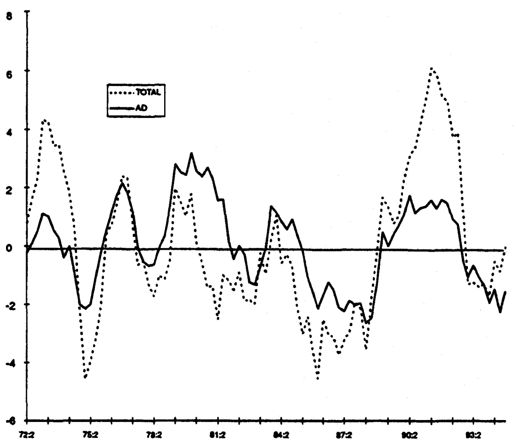
As in US, demand shocks stimulated the economy in some periods between the first and second oil price shocks, and the boom in 1978-1980 was mainly driven by an expansionary fiscal policy (as the Bonn summit in 1978 proposed that Germany should act as a locomotive to the rest of the world, cf. figure 4B). When the second oil price shock hit the economy, monetary policy was expansionary, and the economy was booming. The adverse oil price shock in 1979/1980 had only a small negative effect on the economic performance in the early 1980s, but a series of negative supply shocks eventually turn the economy into a recession (cf. table 7). In contrast to US, negative demand shocks have little or no adverse effects on output in Germany in the early 1980s, although monetary polices were quickly tightened from 1979 onwards to avoid high inflation rates. Rasche and Tatom (1981) suggest that the policy responses in Germany that avoided the high inflation rates, also minimised the real effects of energy shocks, through the appreciation of DM relative to the pricing currency in the world energy market.

Figure 4. Forecast Error Decompositions for GDP in Germany

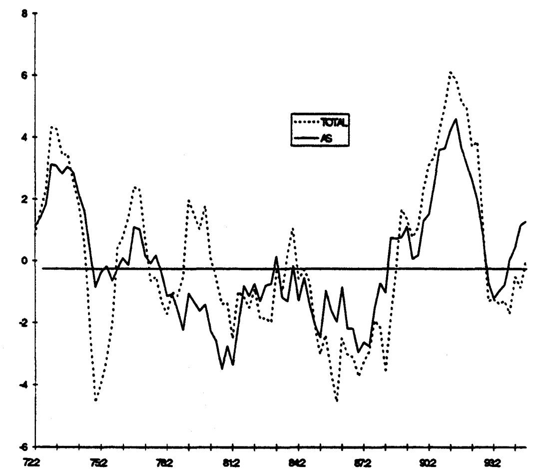
A) Oil price component, pct. change



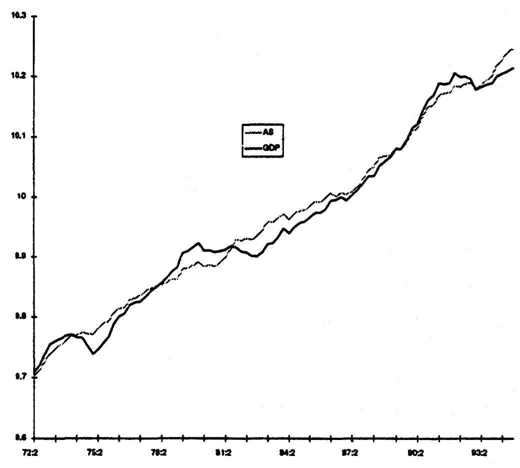
B) Aggregate demand component, pct. change



C) Aggregate supply component, pct. change



D) Aggregate supply component, (drift term added)



In table 1 we saw that despite the fact that Germany managed to maintain low inflation rates during the 1970s and 1980s, output growth was relatively weak and unemployment slowly rising, indicating a structural weakness of the German economy. Hellwig and Neumann (1987) and the discussions there, suggest that this weakness was attributed to structural rather than cyclical factors. From figure 4C and D, one can see that supply shocks contribute negatively during most of the 1980s, so output growth remains sluggish and GDP lies below its supply potential until late in the 1980s. The business cycle chronology in Artis et al. (1995) also suggests that the recovery in the German economy in the 1980s was very slow, as the trough in November 1982 was first preceded by a peak in June 1991.

Table 7. Forecast Error Decomposition for GDP in Germany, 1974/1975 and 1979/1980[1]

	AD-shock	OP-shock	AS-shock	GDP
74Q1-74Q2	-0.2	-0.1	2.5	2.2
74Q3-74Q4	-1.5	-0.4	1.0	-0.9
75Q1-75Q2	-2.1	-1.6	-0.6	-4.3
75Q3-75Q4	-0.7	-1.5	-0.4	-2.6
79Q1-79Q2	2.1	0.3	-1.6	0.7
79Q3-79Q4	2.5	0.3	-1.5	1.3
80Q1-80Q2	2.9	-0.1	-1.8	0.9
80Q3-80Q4	2.5	-0.5	-3.1	-1.0

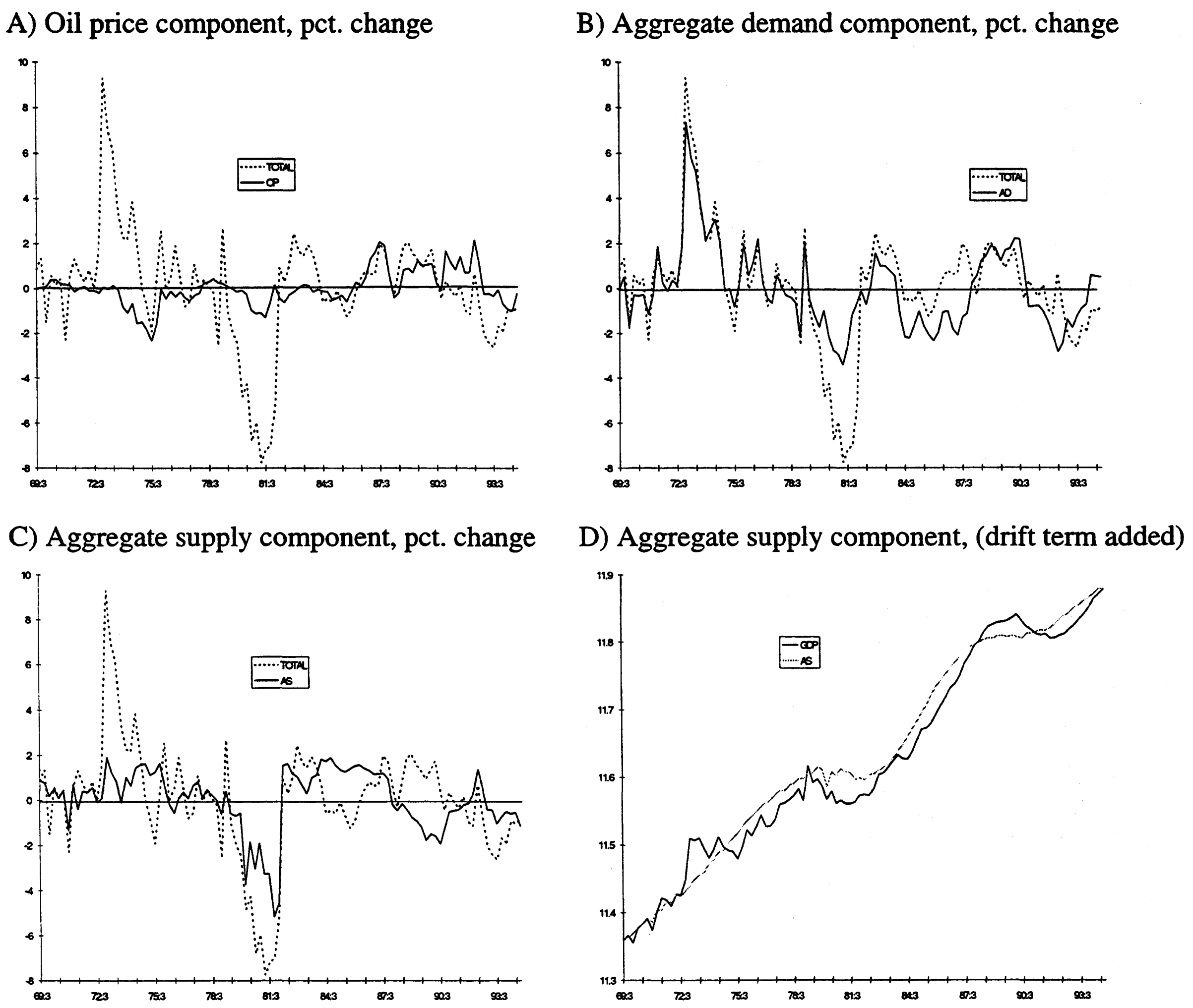
1) AD = Aggregate Demand shock, OP= Oil price shock, AS = Aggregate supply shock.

The huge boom from 1989 to 1993 is both demand and supply driven. The boom is 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 plunge the economy into a (small) recession.

In *United Kingdom*, the 1970s was characterised with a series of positive demand shocks, especially in 1972/1973 under the Heath government, where the broad monetary stock exploded by over 50 pct (the Barber Boom, named after the Chancellor at the time, see e.g. Smith 1988). 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 1973/1974 led only to a temporary decline in output (see figure 5 and table 8). However inflation was rising violently in this period (cf. table 1), and when the Thatcher government took over in 1979, on of its primary aims was to reduce inflation.

The new government believed in tight monetary control to combat the high inflation rates, and one of the first tasks was to announce severe monetary policy tightening, and public expenditure cuts in the June 1979 budget, and subsequently in the March 1980 budget. The economy started to drop drastically from the end of 1979. However, in contrast to US that adopted expansionary fiscal policies, UK continued to pursue tight fiscal policies, and announced new severe budget cuts in

Figure 5. Forecast Error Decompositions for GDP in United Kingdom



March 1981. The effects on the economy were grave. Output fell drastically, especially manufacturing output, which decreased by more than 15 percent from 1979 to 1980, and unemployment rose by more than 1 million in a year.

Table 8. Forecast Error Decomposition for GDP in United Kingdom, 1974/1975 and 1979/1980[1]

	AD-shock	OP-shock	AS-shock	GDP
74Q1-74Q2	2.4	-1.0	0.8	2.2
74Q3-74Q4	2.5	-1.1	1.5	2.9
75Q1-75Q2	-0.1	-1.7	1.4	-0.4
75Q3-75Q4	-0.3	-2.0	1.4	-0.8
79Q1-79Q2	-0.1	0.2	-0.1	0.1
79Q3-79Q4	-0.9	0.0	-0.6	-1.5
80Q1-80Q2	-1.4	-0.1	-2.2	-3.6
80Q3-80Q4	-2.5	-0.6	-2.4	-5.5

1) AD = Aggregate Demand shock, OP= Oil price shock, AS = Aggregate supply shock.

The effects of these shocks can also clearly be seen in figure 5 and table 8. The oil price shock in 1980 played only a small role in the recession in UK from 1979-1983. Negative demand shocks contributed to the decline of the economy from 1979, however from 1981, negative supply shocks are mostly to blame for the severity of the recession. These negative permanent "supply shocks" may have had long lasting negative effects on the economy (see e.g. Flemming 1982 and Buiter and Miller 1983 for analyses of this specific period). In figure 5D, the supply potential shifted down drastically from 1980 onwards. The timing of this downwards shift in output, corresponds well with the timing of the break upwards in the unemployment rate in 1980Q2 (cf. section 5.1).

With positive supply shocks (from e.g. productivity growth), the economy recovers after 1982 (cf. figure 5). Matthews and Minford (1987) also argue that once supply side policies were introduced by the government, it had significant effects on productivity growth. From 1987 to 1991, UK experiences a demand led boom. Positive demand shocks (from an increase in real spendings) drive output above its supply potential, but from 1991, demand shocks again contribute negatively to output movements.

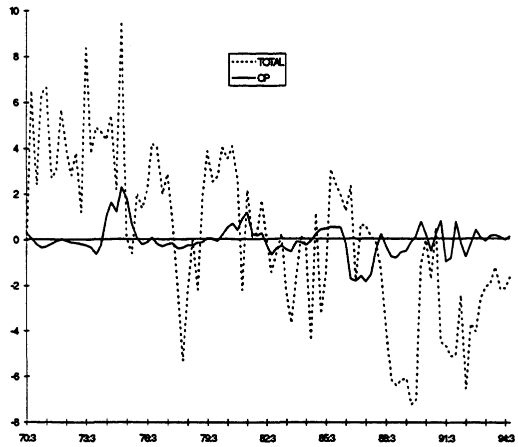
In section 5.2, adverse oil price shocks were found to have positive effect on output in *Norway*. This is understood more clearly by examining figure 6A. The adverse oil price shocks in 1973/1974 have huge positive effects on output in Norway until 1976. The oil price shocks in 1979/1980 have much less effects on the economy, although they contribute positively to output movements until 1982. The subsequent fall in oil prices in 1986 contribute negatively to output movements from 1986 to 1988, and thereafter the effect is both positive and negative.

The first oil price shock in 1973/1974 occurred at a time when the Norwegian economy had just discovered huge oil resources in the North Sea. By 1975, Norway was ready as a producer of oil and gas. However, the prospect of increased oil revenues brought about by higher oil prices in 1973/1974, created a potential for profitable output in Norway. By the end of the 1970's, Norway was a net exporter of oil, so when the second oil price rise occurred in 1979/1980, overall national wealth increased further.

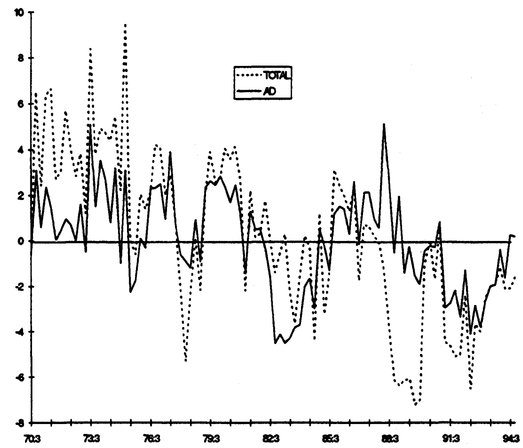
During the 1970s, demand shocks and supply shocks are also important contributors behind the good economic performance in the 1970s, and especially in the late 1970s and early 1980s, positive demand shocks are the most important factors behind the high growth rates. The positive demand shocks coincides with the expansionary fiscal policies that the government followed in this period (especially from 1974-1977).

Figure 6. Forecast Error Decompositions for GDP in Norway

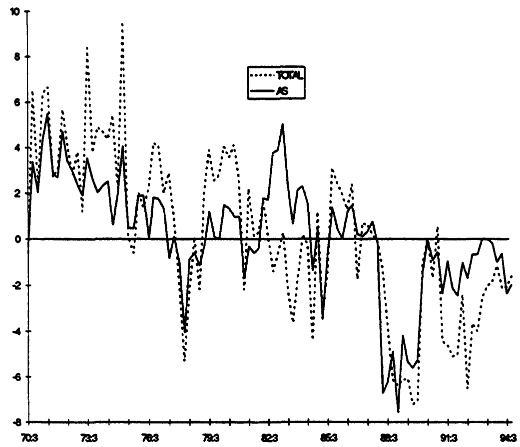
A) Oil Price component, pct. change



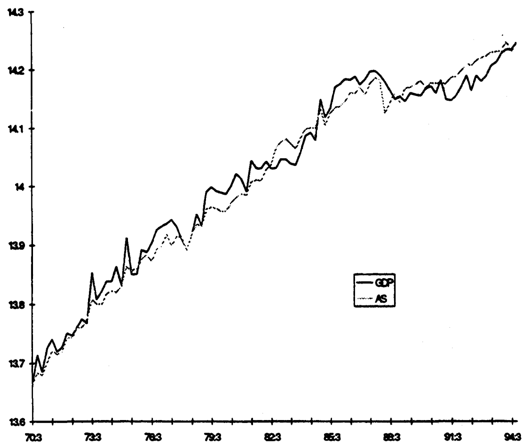
B) Aggregate demand component, pct. change



C) Aggregate supply component, pct. change



D) Aggregate supply component, (drift term added)



During the 1980s, Norway experienced two severe recessions. From figure 6, one can see that these two recessions are due to entirely different shocks. The first recession from 1982 to 1985, is primarily demand driven, and supply shocks actually contribute positively to output fluctuations in this period. The economy thereafter experiences a demand driven boom, set off primarily by the financial deregulation in 1984/1985. However, the collapse of oil prices in 1986 contribute negatively to output growth, by eroding the government of potential future income streams. From 1988, the spending boom in Norway accumulates in a severe financial crisis. GDP growth is again falling and now unemployment is also rising drastically (cf. table 1). This recession is mainly driven by negative supply shocks, although demand shocks are also negative later in this period. This can be seen in figure 6D, where the supply potential shifts down with GDP in 1988. The time of the fall in the supply potential, corresponds well with the break in the level of the trend in unemployment in 1988Q2 (cf. section 5.1).

The economy recovers somewhat by 1990, but by that time the international economy is slowing down, and now demand shocks contribute negatively to output growth until 1993. However, from 1993, demand is on a steep upturn.

Table 9. Forecast Error Decomposition for GDP in Norway, 1974/1975 and 1979/1980[1]

	AD	OP	AS	GDP
74Q1-74Q2	3.1	-0.4	2.2	4.8
74Q3-74Q4	2.0	1.4	1.6	4.9
75Q1-75Q2	1.0	1.8	3.0	5.8
75Q3-75Q4	-2.0	1.3	0.5	-0.3
79Q1-79Q2	0.7	-0.1	-0.7	-0.1
79Q3-79Q4	2.5	0.1	0.6	3.2
80Q1-80Q2	2.6	0.1	0.7	3.4
80Q3-80Q4	2.1	0.6	1.2	3.8

1) AD = Aggregate Demand shock, OP= Oil price shock, AS = Aggregate supply shock.

7. Conclusions

By using a minimum of restrictions on a VAR model, I have been able to interpretate economic fluctuations in Germany, Norway, United Kingdom and United States in terms of different shocks that have hit the economy. For all countries, the shocks identified (demand, supply and oil price shocks) are well interpreted in terms of actual episodes that occurred in the periods examined.

Demand disturbances (temporary shocks) are most important for GDP in the short run in United States, United Kingdom and Norway, although already after two to three years (at the so called business cycle frequencies), supply shocks (permanent shocks) dominate. In Germany, supply shocks play the most important role at all horizons.

In Germany, United Kingdom and United States, an adverse oil price shock has had a negative effect on output, but only in US is the effect negative also in the long run. For Norway, a small oil exporting country, an adverse oil price shock stimulates the economy, although in the long run, the effect is most likely zero. The different response in UK and Norway to an energy price shock, emphasises how two countries that are self sufficient with oil resources can react very differently to oil price shocks, especially if the governments have different priorities when deciding on macroeconomic policies.

In Germany, UK and US, the oil price shocks in 1973/1974 are among the most important factors behind the recession in the middle 1970s. The oil price shocks in 1979/1980 play a much smaller role for output movements in all countries. Negative demand disturbances (e.g. contractionary monetary policies) are much more important in explaining the severe recession in the early 1980s in UK and US (although in UK negative supply disturbances play the most important role from 1981), whereas in Germany, negative supply disturbances are mostly to blame for the poor economic performance in the 1980s.

Despite the many advantages of using a simple structural VARs, it is also subject to some limitations. Especially, 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 we will for instance not be able to distinguish between different aggregate demand shocks (like e.g. increases in money supply or fiscal policy).

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Appendix A: Data sources

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 that is measured in levels. For each country, I use total GDP or GNP, except for Norway, where I use GDP in mainland Norway (that is GDP generated in the sectors other than the oil producing sectors), which account for approximately 80 pct. of total GDP.

United States: 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, mth. average DEM/USD, (n.s.a.). Source OECD.

United Kingdom: 1966Q1-1994Q4
Gross Domestic Product, constant 1991 prices. Source: Datastream
Unemployment rate, total labour force. Source: OECD
Implicit GDP deflator. Source: OECD
Exchange rate, mth. average GBP/USD, (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, mth. avg. NOK/USD, (n.s.a.). Source OECD.

For all countries:
Nominal Oil price: Saudi Arabian Light-34, USD 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 countries national currency by the exchange rate and deflated by each countries implicit GDP deflator, except for Norway which uses the consumer price index (as oil prices may be included in the GDP deflator, as approximately 20 pct. of GDP in Norway is generated in the oil sector).

Appendix B: Model specifications-Determination of lag order and test for general serial correlation in the residuals

Table B.1 United States: Information criteria and F-tests for model reductions[1]

Lags	SC	HQ	Sequential F-tests	p-value	Direct F-tests	p-value
1	-15.09	-15.24	F(9, 297) =4.92	0.000	F(63, 311) = 1.64	0.004
2	-15.09	-15.36	F(9, 289) =2.81	0.004	F(54, 310) = 1.09	0.327
3	-14.96	-15.35	F(9, 282) =1.15	0.328	F(45, 309) = 0.76	0.867
4	-14.71	-15.22	F(9, 275) =0.16	0.997	F(36, 308) = 0.67	0.924
5	-14.39	-15.01	F(9, 267) =0.91	0.516	F(27, 304) = 0.84	0.691
6	-14.13	-14.87	F(9, 260) =1.37	0.201	F(18, 294) = 0.82	0.680
7	-13.90	-14.76	F(9, 253) =0.29	0.977	F(9, 253) = 0.29	0.977
8	-13.59	-14.57				

1) SC reports the Schwarz information criteria, HQ reports the Hannan-Quinn information criteria, sequential F-test with corresponding p-value reports the sequential model reductions (8→7,...,2→1 lags), direct F-test with corresponding p-value reports the direct model reductions (8→7, ..., 8→1 lags). All test-statistics are calculated using PcFiml 8.0 (see Doornik and Hendry 1994).

Table B.2 Germany: Information criteria and F-tests for model reductions[1]

Lags	SC	HQ	Sequential F-tests	p-value	Direct F-tests	p-value
1	-16.08	-16.27	F(9, 209) = 8.99	0.000	F(63, 203) = 2.62	0.000
2	-16.44	-16.78	F(9, 202) = 1.91	0.052	F(54, 203) = 1.46	0.033
3	-16.21	-16.69	F(9, 194) = 2.50	0.009	F(45, 202) = 1.35	0.087
4	-16.05	-16.67	F(9, 187) = 2.03	0.036	F(36, 201) = 1.05	0.395
5	-15.84	-16.61	F(9, 180) = 0.84	0.581	F(27, 199) = 0.75	0.807
6	-15.51	-16.42	F(9, 172) = 0.86	0.561	F(18, 192) = 0.72	0.789
7	-15.18	-16.24	F(9, 165) = 0.59	0.802	F(9, 165) = 0.59	0.802
8	-14.83	-16.03				

1) For a description of these tests, see table B.1.

Table B.3 United Kingdom: Information criteria and F-tests for model reductions[1]

Lags	SC	HQ	Sequential F-tests	p-value	Direct F-tests	p-value
1	-13.28	-13.46	F(9, 238) = 2.76	0.004	F(63, 239) = 1.4472	0.026
2	-13.13	-13.44	F(9, 231) = 0.84	0.581	F(54, 239) = 1.2127	0.167
3	-12.82	-13.26	F(9, 224) = 3.77	0.000	F(45, 238) = 1.2801	0.124
4	-12.77	-13.35	F(9, 216) = 0.79	0.625	F(36, 237) = 0.7038	0.897
5	-12.45	-13.17	F(9, 209) = 0.86	0.558	F(27, 234) = 0.6831	0.881
6	-12.15	-13.00	F(9, 202) = 0.81	0.606	F(18, 226) = 0.6042	0.895
7	-11.84	-12.82	F(9, 194) = 0.41	0.927	F(9, 194) = 0.4143	0.927
8	-11.50	-12.61				

1) For a description of these tests, see table B.1.

Table B.4 Norway: Information criteria and F-tests for model reductions[1]

Lags	SC	HQ	Sequential F-tests	p-value	Direct F-tests	p-value
1	-13.10	-13.28	F(9, 228) = 1.93	0.049	F(63, 227) = 1.25	0.119
2	-12.87	-13.19	F(9, 221) = 1.51	0.145	F(54, 227) = 1.13	0.261
3	-12.61	-13.07	F(9, 214) = 1.51	0.147	F(45, 226) = 1.06	0.385
4	-12.36	-12.95	F(9, 207) = 0.17	0.997	F(36, 225) = 0.95	0.559
5	-11.97	-12.70	F(9, 199) = 1.18	0.310	F(27, 222) = 1.21	0.230
6	-11.69	-12.56	F(9, 192) = 0.72	0.691	F(18, 215) = 1.21	0.254
7	-11.37	-12.37	F(9, 185) = 1.69	0.094	F(9, 185) = 1.69	0.094
8	-11.15	-12.30				

1) For a description of these tests, see table B.1.

Table B.5 Ljung-Box Q-statistics (marginal significance level)[1]

	Lags	Δy	p-value	Δo	p-value	u	p-value
US	3	Q(8) = 5.33	0.72	Q(8) = 5.60	0.69	Q(8) = 9.37	0.31
		Q(24)=25.96	0.41	Q(24)=18.03	0.80	Q(24)=24.97	0.41
GERMANY	5	Q(8) = 7.75	0.46	Q(8) =22.19	0.97	Q(8) = 4.95	0.76
		Q(24)=29.91	0.19	Q(24)=12.72	0.97	Q(24)=16.61	0.86
UK	6	Q(8) = 2.24	0.97	Q(8) = 1.24	0.99	Q(8) = 2.14	0.98
		Q(24)=10.97	0.99	Q(24)=14.06	0.95	Q(24)=10.14	0.99
NORWAY	6	Q(8) = 4.28	0.83	Q(8) = 1.57	0.99	Q(8) = 0.69	0.99
		Q(24)=19.50	0.72	Q(24)=14.00	0.95	Q(24)=16.82	0.86

1) The Ljung-Box Q-statistic is treated as a chi-square with M degrees of freedom, where M is the number of autocorrelations given in parenthesis. The p-value, reports the marginal significance level.

Appendix C: Tests for unit root and cointegration

Tests for unit roots and cointegration are presented below. To determine whether the underlying process of a series is difference stationary or trend-stationary, I estimate the now well known augmented Dickey Fuller (ADF) regression. A test for unit root when a x-series follows an AR(p+1) process and allowing for both a constant and a time trend in the regression model, can be carried out by testing $\mu=0$, versus the alternative that $\mu<0$ in:

(C.1)

$$x_t = \alpha_0 + \alpha_1 t + \sum_{j=1}^{p+1} \phi_j x_{t-j} + \varepsilon_t$$

or

$$\Delta x_t = \alpha_0 + \alpha_1 t + \mu x_{t-1} + \sum_{j=1}^{p} \gamma_j \Delta x_{t-j} + \varepsilon_t$$

where $\mu = \sum_{j=1}^{p+1} \phi_j - 1$ and $\gamma_j = -\sum_{k=j+1}^{p} \phi_k$, j = 1,2, ...p and ε_t is assumed to be i.i.d. Gaussian with mean zero and a positive definite covariance matrix. The asymptotic ADF distribution can be obtained by Fuller (1976). As the results of the unit-root tests will be sensitive to the serial dependence in the error term, higher order AR lags may be most appropriate for capturing the serial correlation in the data. With quarterly data, it seems therefore reasonable to perform ADF tests using between 4 and 8 lags. The results using 8 AR lags are reported in table C.1. However, the conclusions there are unchanged using any lag length from 4 to 8 lags, except for US where, using 4 lags, I can reject the hypothesis that GDP is I(1) at the 10 pct. level, and for UK, using 7 lags, I can reject the hypothesis that GDP is I(1) at the 5 pct. level. However based on any other lag length, there is overwhelming evidence that GDP is I(1) in both countries, and without the assumption that GDP is I(1), the whole exercise of defining shocks that have permanent effects on GDP will be meaningless.

I now expand the ADF tests against the trend-stationary alternative by allowing the unemployment series to have a structural shift/break in the trend. I follow Zivot and Andrews (1992) that treat the possible break point as unknown in the time series. The testing strategy is to test the null hypothesis of a unit root against the alternative hypothesis that unemployment is stationary around a deterministic time trend with a one time change occurring at an unknown point in time. Following the notation in Zivot and Andrews (1992), the change in the trend is either modelled as a single change in the level of the trend (case A below), as a single change in the growth rate of the trend (case B below), or both changes at the same time (case C below). The test is computed sequentially using the full sample. To test for a unit root versus the alternative of a change in the trend can now be estimated by expanding on the ADF regression above:

(C.2)

$$x_t = \alpha_0 + \alpha_1 t + \alpha_2 DU_t(k) + \sum_{j=1}^{p+1} \phi_j x_{t-j} + \varepsilon_t$$

or

$$\Delta x_t = \alpha_0 + \alpha_1 t + \alpha_2 DU_t(k) + \mu x_{t-1} + \sum_{j=1}^{p} \gamma_j \Delta x_{t-j} + \varepsilon_t$$

where $\mu = \sum_{j=1}^{p+1} \phi_j - 1$ and $\gamma_j = -\sum_{k=j+1}^{p} \phi_k$, j = 1,2, ...p, $DU_t(k)$ is a dummy variable that captures the possible change in the trend at period k and ε_t is assumed to be i.i.d. Gaussian with mean zero and a positive definite covariance matrix. In case (A) (change in the level of the trend), $DU_t(k)$ is specified as:

$$(A)\ DU_t(k) = 1 \text{ if } t\rangle k, \text{ 0 otherwise.}$$

in case (B) (change in slope of the trend), $DU_t(k)$ is specified as:

$$(B)\ DU_t(k) = t - k \text{ if } t\rangle k, \text{ 0 otherwise.}$$

whereas in case (C) I assume both a change in the level and the slope of the trend.

For each of the cases A, B and C, I compute; $t^i_{ADF\text{-}min} \equiv \min_{ko \leq k \leq T-ko} t(k)_{ADF}$ for i = A, B, C, that is the minimal t_{ADF} value over all sequentially computed t_{ADF} statistics. The finite sample critical values and the empirical size and nominal power of the test statistics described above, are established by Monte Carlo simulation in Zivot and Andrews (1992). The test results are presented in table C.2.

To test for cointegration between the variables in the model, I use the Johansen Maximum Likelihood Procedure, see Johansen (1988, 1991). Rewriting z_t as a cointegrated formula, $w_t = (y_t, o_t, u_t)'$, where u_t is the unemployment rate adjusted for the structural break, the error-correction form is equal to:

$$\text{(C.3)} \qquad \Delta w_t = u + \sum_{i=1}^{k} \Gamma_i \Delta w_{t-1} + \alpha\beta' z_{t-1} + \varepsilon_t$$

where ε_t is assumed to be i.i.d. Gaussian with mean zero and a positive definite covariance matrix. The assumption of cointegration is formulated as a reduced rank of the total impact multiplier $\alpha\beta'$, where α and β are p x r matrices of rank r, where $0<p<r$. The number of lags included in (C.3) are set equal to the number of lags used in the VAR models in the analysis. That is, for US I use three lags, for Germany I use five lags and for Norway and UK I use six lags.

The trace statistics indicate that there is no evidence of cointegration at the 5 pct. level in US and Norway, but in Germany and UK, the trace statistics reject the null hypothesis of no cointegrating vector at the 5 pct level (but not at the 1 pct. level). However, adjusted for degrees of freedom as the sample is small (see Reimers 1992), the trace statistics can not reject the null hypothesis of no cointegration even at the 5 pct. level.

The assumption that u_t is stationary, nevertheless implies that w_t is in fact cointegrated with a cointegrator vector (0,0,1). Testing this restriction that there are only nonzero elements on the stationary variables in the cointegrating vector is trivial and add nothing to the analysis above (see the discussion in Quah 1995), except being a further check on whether u_t is stationary. Nevertheless, imposing one cointegrating vector, in none of the countries can I reject the hypothesis that if w_t is cointegrated, it is cointegrated with cointegrating vector (0,0,1), hence u_t is stationary. Finally, I have also examined the restriction that y_t and o_t are cointegrated, that is, $y_t - o_t \sim I(0)$. Imposing again one cointegrating vector, I can reject this restriction in all countries. These results are reported in table C.4.

Table C.1. Augmented Dickey Fuller unit-root tests[1]

	y	o	u	Δy	Δo	Δu
US	-2.68	-1.07	-1.94	-3.82***	-3.51***	-3.73***
GERMANY	-2.25	-1.41	-2.35	-3.08**	-2.87*	-2.57
UK	-3.14	-1.13	-1.71	-3.19***	-3.17***	-3.50***
NORWAY	-1.98	-1.26	-2.29	-3.03**	-3.17***	-3.05**

1) The critical values for the full sample Augmented Dickey Fuller statistic was taken from Table 8.5.2 in Fuller (1976) table 8.5.2 p 373. A time trend and a constant are included in the regression of the level of y, o and u, whereas in the regression using first differences, a constant (but no time trend) is included in the regression.
* Rejection of the unit-root hypothesis at the 10 pct. level
** Rejection of the unit-root hypothesis at the 5 pct. level
*** Rejection of the unit-root hypothesis at the 2.5 pct. level

Table C.2. Sequential unit-roots test for Unemployment[1]

Series	Model	Period	Minimum t-statistics
US	A,C	1974Q3	-4.36
GERMANY	B	1985Q3	-4.36*
UK	C	1980Q2	-4.92*
NORWAY	A	1988Q2	-4.92**

1) The critical values for the Sequential test statistics were taken from Zivot and Andrews (1992, p256-257). The 10 pct. (5 pct.) 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 the growth rate), is -4.82 (-5.08).
* Rejection of the unit-root hypothesis at the 10 pct. level
** Rejection of the unit-root hypothesis at the 5 pct. level

Table C.3. Johansen Maximum Likelihood Procedure, Trace tests[1]

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

1) 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).

Table C.4. Test of Restrictions on Cointegrated vectors

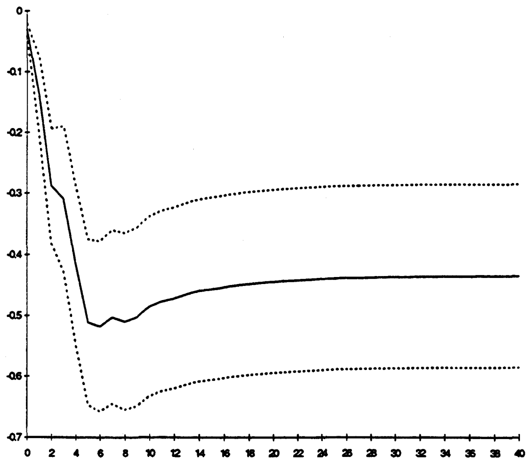
	Cointegrated vector (0, 0, 1) u_t~I (0)		Cointegrated vector (1, -1, 0) $y_t - o_t$~ I (0)	
	LR-test	p-value	LR-test	p-value
US	4.56	0.10	7.25	0.02
GERMANY	2.03	0.36	9.12	0.01
UK	3.19	0.20	23.50	0.00
NORWAY	0.32	0.85	10.93	0.00

1) All test-statistics are calculated using PcFiml 8.0 (see Doornik and Hendry 1994). The limiting distribution of the LR test is $\chi^2(2)$.

Appendix D: Impulse Response Functions with one standard error band

Figure D.1. USA, response to oil price shock

A) GDP



B) Unemployment

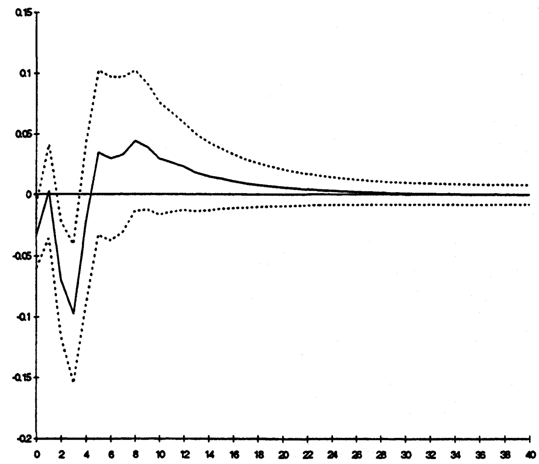
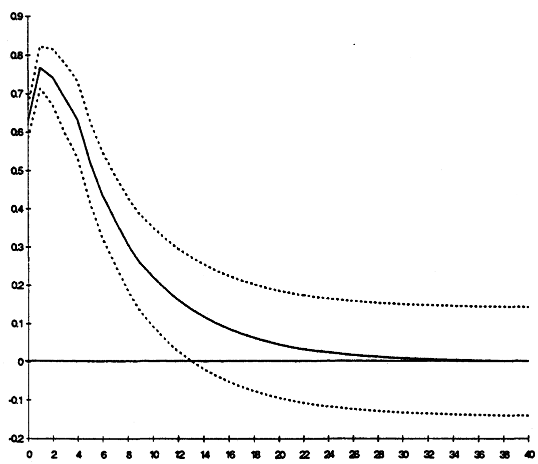


Figure D.2. USA, response to aggregate demand shock

A) GDP



B) Unemployment

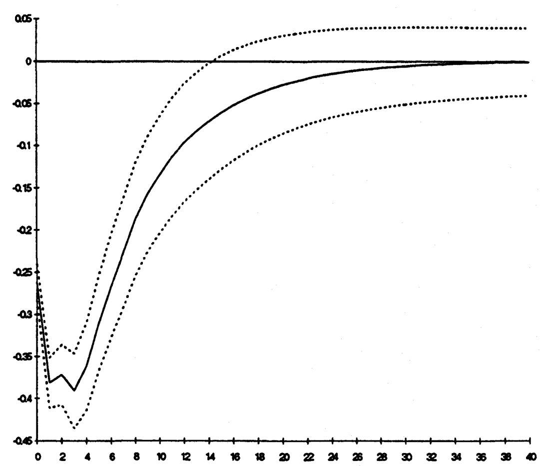
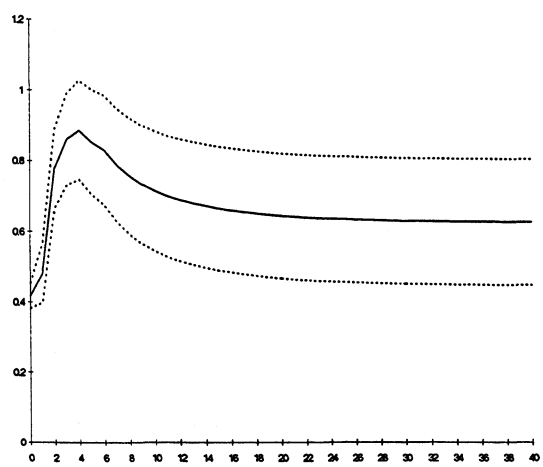


Figure D.3. USA, response to aggregate supply shock

A) GDP



B) Unemployment

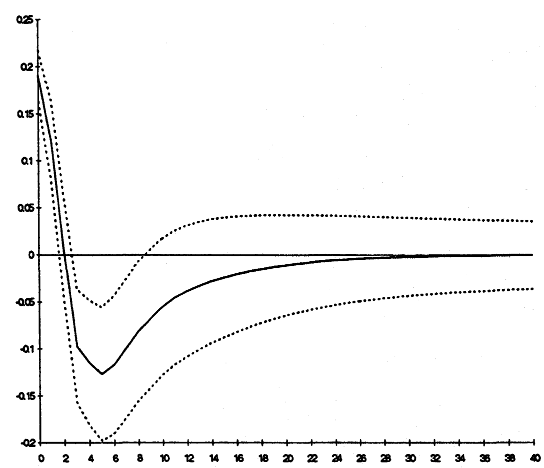


Figure D.4. Germany, response to oil price shock

A) GDP B) Unemployment

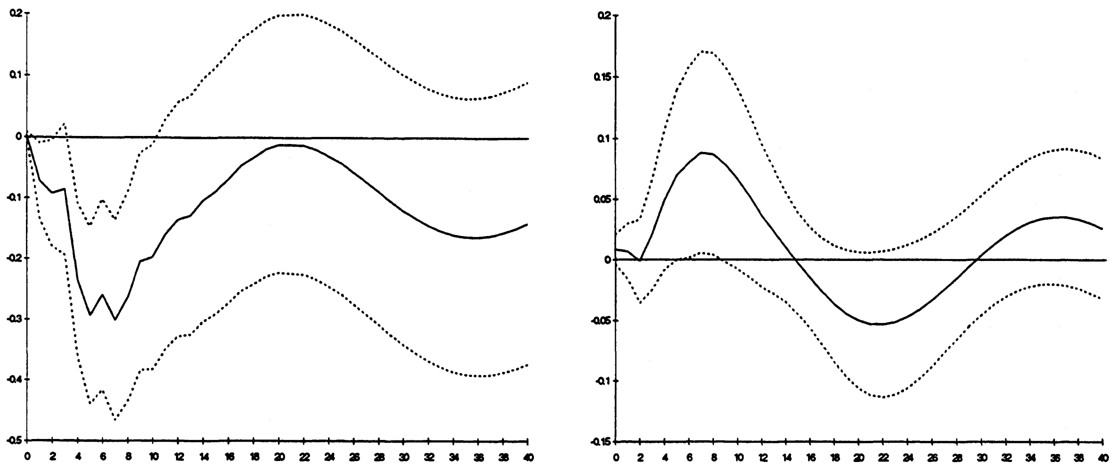


Figure D.5. United Kingdom, response to oil price shock

A) GDP B) Unemployment

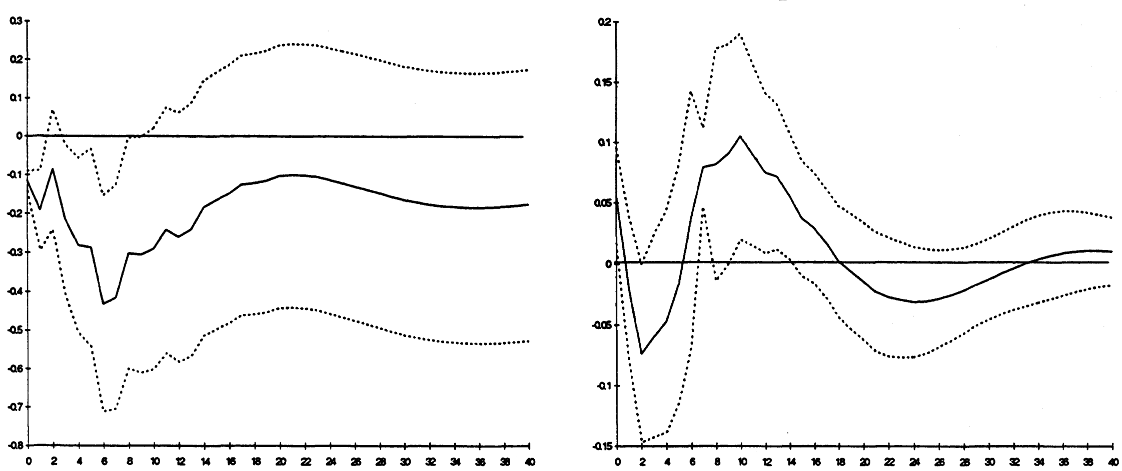
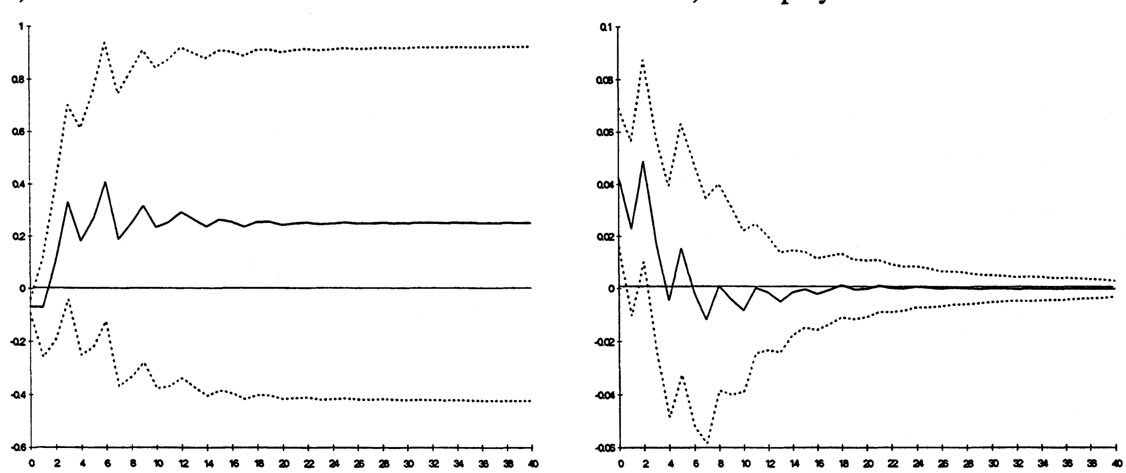


Figure D.6. Norway, response to oil price shock

A) GDP B) Unemployment

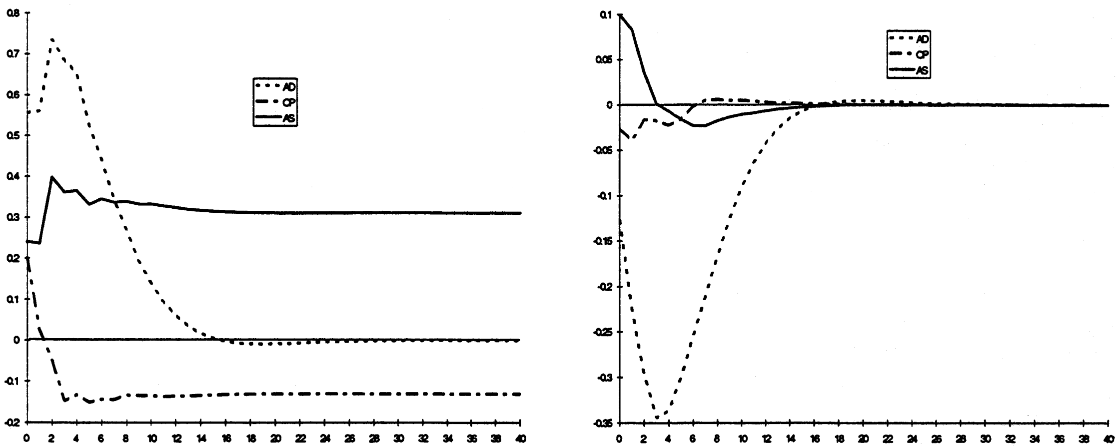


Appendix E: Impulse responses and variance decompositions in United States, 1960-1971, 1972-1981 and 1982-1994

1960-1971

Figure E.1. Impulse Response Functions:[1]

A) GDP **B) Unemployment**



1) AD = Aggregate Demand shock, OP = Oil Price shock, AS = Aggregate Supply shock.

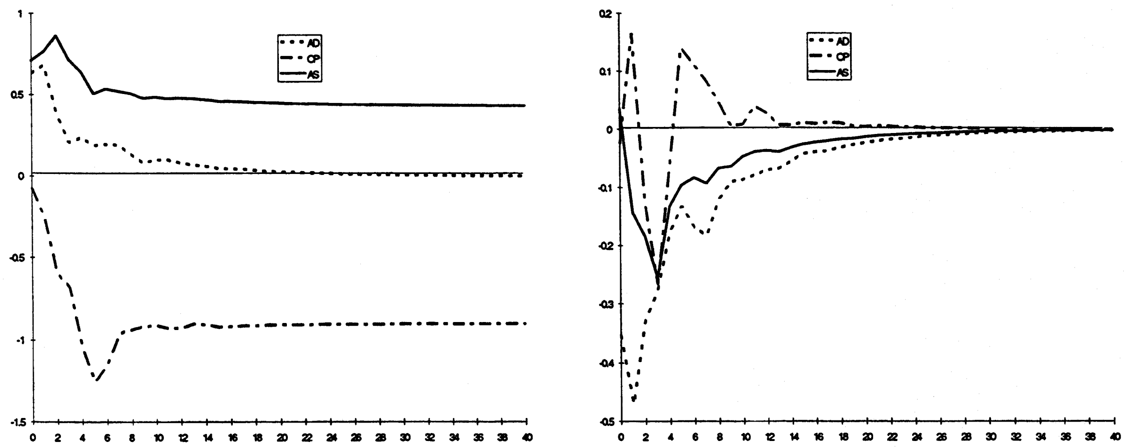
Table E.1. Variance Decomposition of GDP and Unemployment

	GDP			Unemployment		
Quarters	AD-shock	OP-shock	AS-shock	AD-shock	OP-shock	AS-shock
1	75.8	10.0	14.2	60.3	2.6	37.1
8	70.1	4.3	25.7	96.3	0.6	3.1
16	56.6	6.3	37.1	96.4	0.6	3.0
40	36.4	9.4	54.3	96.4	0.6	3.0

1972-1981

Figure E.2. Impulse Response Functions:[1]

A) GDP **B) Unemployment**



1) AD = Aggregate Demand shock, OP = Oil Price shock, AS = Aggregate Supply shock.

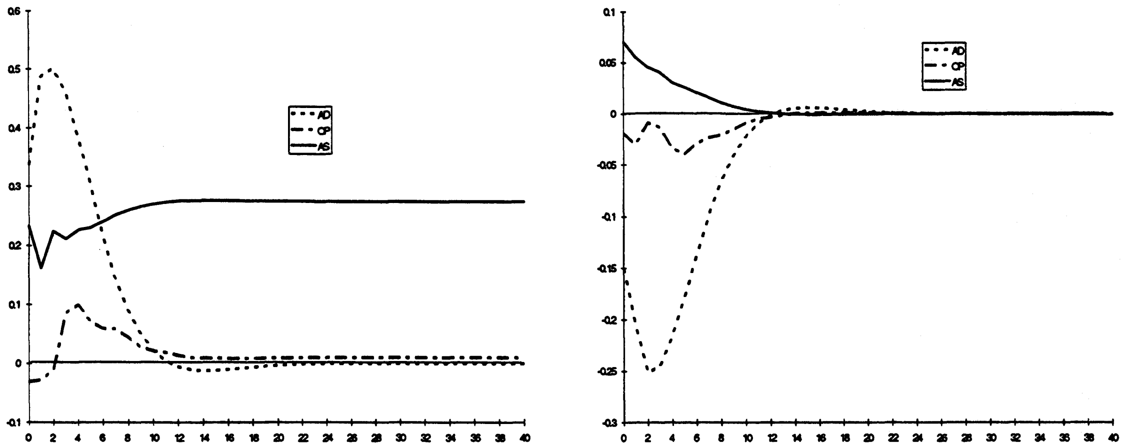
Table E.2. Variance Decomposition of GDP and Unemployment

	GDP			Unemployment		
Quarters	AD-shock	OP-shock	AS-shock	AD-shock	OP-shock	AS-shock
1	44.0	0.6	55.4	98.5	0.5	1.0
8	10.5	56.9	32.6	66.6	16.4	17.0
16	6.3	66.0	27.7	66.8	15.8	17.4
40	2.9	74.2	23.0	66.8	15.8	17.4

1982-1994

Figure E.3. Impulse Response Functions[1]

A) GDP **B) Unemployment**



1) AD = Aggregate Demand shock, OP = Oil Price shock, AS = Aggregate Supply shock.

Table E.3. Variance Decomposition of GDP and Unemployment

	GDP			Unemployment		
Quarters	AD-shock	OP-shock	AS-shock	AD-shock	OP-shock	AS-shock
1	67.2	0.6	32.2	80.9	1.3	17.8
8	69.3	2.0	28.7	93.7	1.9	4.4
16	50.7	1.6	47.7	93.6	2.0	4.4
40	28.0	0.9	71.1	93.6	2.0	4.4

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ISSN 0803-074X

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