JOURNAL OF APPLIED ECONOMETRICS
J. Appl. Econ. **20**: 185–207 (2005)
Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/jae.832

WHAT CAUSED THE EARLY MILLENNIUM SLOWDOWN? EVIDENCE BASED ON VECTOR AUTOREGRESSIONS

GERT PEERSMAN*
Department of Financial Economics, Ghent University, Belgium

SUMMARY

This paper uses a simple VAR for the USA and Euro area to analyse the underlying shocks of the early millennium slowdown, i.e. supply, demand, monetary policy and oil price shocks. The results of two identification strategies are compared. One is based on traditional zero restrictions and, as an alternative, an identification scheme based on more recent sign restrictions is proposed. The main conclusion is that the recent slowdown is caused by a combination of several shocks: negative aggregate supply and aggregate spending shocks, the increase of oil prices in 1999, and restrictive monetary policy in 2000. These shocks are more pronounced in the USA than the Euro area. The results are somewhat different depending on the identification strategy. It is illustrated that traditional zero restrictions can have an influence on the estimated impact of certain shocks.

1. INTRODUCTION

Between 1994 and the middle of 2000, annual real GDP growth of industrialized countries was on average more than 3%. This was even 3.9% in the United States. At the same time, inflation was historically very low: on average less than 2%. Activity weakened at the end of 2000 and most industrialized countries experienced negative growth by the end of 2001. In this paper, we analyse the underlying sources of this slowdown and the preceding expansion by estimating a simple four-variable VAR for the USA and the Euro area for the sample period 1980Q1–2002Q2. Two different identification strategies are used. One is based on traditional zero contemporaneous and long-run restrictions and, as an alternative, we propose an identification scheme based on more recent sign restrictions. In contrast to a lot of previous recessions, the fluctuations in both areas did not have an obvious cause. Overall, we find that the slowdown was caused by a combination of several shocks: negative supply and demand shocks (the latter especially between 2001Q2 and 2001Q4), the increase of oil prices in 1999, and restrictive monetary policy in 2000. These shocks were more pronounced in the USA than the Euro area. We also show that the results are somewhat different depending on the identification strategy, especially with respect to the effects of oil price and monetary policy shocks in explaining the recession. The former shocks were much more important with traditional restrictions and the latter with sign restrictions.

Since the seminal work of Sims (1980), VARs are often used as a tool for analysing underlying disturbances in explaining recessions, as in Blanchard (1993) and Walsh (1993), each of whom analyse the 1990–1991 recession in the USA. Blanchard (1993) estimates a VAR on the components of GDP and finds that the recession was associated with large negative consumption shocks. Walsh (1993) analyses aggregate supply, aggregate spending, money demand and money

* Correspondence to: Gert Peersman, Department of Financial Economics, Ghent University, W. Wilsonplein 5D, B-9000 Ghent, Belgium. E-mail: gert.peersman@ugent.be

Received 15 May 2003
Revised 25 June 2004

supply disturbances. His results suggest that the downturn was due to restrictive monetary policy and negative aggregate spending factors. In contrast to these papers, we analyse the recent slowdown. Moreover, a comparison is made between the USA and the Euro area.

Within this VAR framework, we identify four types of underlying disturbances, i.e. an oil price, aggregate supply, aggregate demand (spending) and monetary policy shock. In order to identify these shocks, we use two alternative strategies. The first is based on conventional zero contemporaneous and long-run restrictions. We use an extended version of the Gali (1992) and Gerlach and Smets (1995) identification strategy. The model is closely related to the latter. The difference, however, is that we add an oil price shock. Since we are considering large and relatively closed economies, we do not have problems in modelling the exchange rate, a critique often mentioned regarding the Gerlach and Smets (1995) model for some of the more open countries.

The second identification strategy is based on more recent sign restrictions, pioneered by Faust (1998), Uhlig (1999) and Canova and De Nicoló (2002, 2003). The advantage of this agnostic identification procedure is that we do not have to impose zero constraints on the contemporaneous impact matrix or the long-run effects of the shocks. Short-run restrictions are typically not based on theoretical considerations, and long-run restrictions, as shown by Faust and Leeper (1997), can be highly misleading. In contrast, the agnostic approach only makes explicit use of restrictions that researchers often use implicitly. In their analysis, researchers experiment with the model specification until the results look reasonable. For example, according to conventional wisdom, a restrictive monetary policy shock is expected to have a negative impact on prices and a temporary effect on output. This *a priori* theorizing is made more explicit with sign restrictions, and at the same time, no additional short and long-run conditions are necessary. In contrast to Faust (1998), Uhlig (1999) and Canova and De Nicoló (2002), we not only identify monetary policy shocks, but a full set of shocks (oil price, supply, demand and monetary policy). The identification of additional shocks should also help to identify the monetary policy shock. Canova and De Nicoló (2003) also identify supply, demand and monetary policy shocks in the G-7 countries, but their restrictions are based on the sign of the cross-correlations of the impulse responses, while ours are only based on the sign of impulse response functions themselves. The latter is somewhat less stringent. Using these alternative restrictions, we show in this paper that traditional zero constraints can have an influence on the estimated impact of certain shocks. In particular, we find a higher contribution of monetary policy shocks in explaining the recent slowdown with sign restrictions, while oil price shocks were more important with conventional restrictions.

The rest of the paper is structured as follows. In Section 2, we present the VAR model and the results of impulse response analyses for both identification strategies are compared. Using the results obtained from the VAR, in Section 3 we present a decomposition of output, prices, oil prices and the interest rate in order to investigate the underlying disturbances of the early millennium slowdown. We also discuss the differences between the USA and the Euro area. Finally, Section 4 concludes.

2. A SIMPLE FOUR-VARIABLE VAR

In this section, we present the model and the results of a simple four-variable VAR. Section 2.1 discusses the basic model to estimate the VAR. The first identification strategy, based on traditional restrictions, is presented in Section 2.2. As an alternative, we discuss an identification strategy based on more recent sign restrictions in Section 2.3. A detailed comparison between both approaches is done in Section 2.4, based on a simulation exercise. Both models are then used to analyse the underlying shocks of recent fluctuations in Section 3.

2.1. The Model and Data

Consider the following specification for a vector of endogenous variables Y_t:

$$Y_t = c + \sum_{i=1}^{n} A_i Y_{t-i} + B\varepsilon_t \tag{1}$$

where c is an $(n \times 2)$ matrix of constants and linear trends, A_i is an $(n \times n)$ matrix of autoregressive coefficients and ε_t is a vector of structural disturbances. The endogenous variables, Y_t, that we include in the VAR are the first difference of oil prices (Δoil_t), output growth (Δy_t), consumer inflation (Δp_t) and the short-term nominal interest rate (s_t).[1] These variables are assumed to be a covariance stationary vector process. For Δoil, Δy and Δp, we can reject the hypothesis of the existence of a unit root at the 10% level (using augmented Dickey–Fuller and Phillips–Perron tests). We cannot, however, reject the hypothesis of a unit root in s in both areas. Given the low power of these tests in relatively small data sets, we follow Gali (1992) and Gerlach and Smets (1995) and assume that s is stationary since the nominal rate cannot have a unit root when both the real rate (for theoretical reasons) and inflation are stationary. Plots of these linearly detrended series indicate no evidence of non-stationarity. Using these four variables, the VAR is estimated for the sample period 1980Q1–2002Q2, with three lags.[2]

Within this framework, we identify four types of underlying disturbances, respectively an oil price, aggregate supply, aggregate demand (spending) and monetary policy shock: $\varepsilon_t' = [\varepsilon_t^{oil} \quad \varepsilon_t^{s} \quad \varepsilon_t^{d} \quad \varepsilon_t^{m}]$. In order to identify these shocks, we use two different identification procedures. The first is based on traditional zero contemporaneous and long-run restrictions, and is discussed in the next subsection. As an alternative, we present the results based on sign restrictions in Section 2.3.

2.2. Traditional Identification Strategy

For the traditional identification strategy, we use an extended version of the Gali (1992) and Gerlach and Smets (1995) strategy. They use a mixture of short-run and long-run restrictions. In the empirical VAR literature, there also exist alternative conventional identification strategies (e.g. King *et al.*, 1991; Shapiro and Watson, 1988). We select, however, the restrictions discussed below because the identified shocks correspond to the shocks identified with sign conditions in Section 2.3. Moreover, they are generally accepted and commonly applied in other research papers.[3]

---

[1] Data are obtained from the Bank of England database. We use the three-month nominal interest rate as the monetary policy instrument in order to simplify comparisons between the USA and the Euro area. Using the federal funds rate in the USA has hardly any effect on the results.

[2] Initially, we began with a larger sample period starting in the 1970s. Several tests, however, indicate that there is a structural break for the interest rate equation around 1980. We do not have any stability problems in our final sample periods. Lag length is determined by standard likelihood ratio tests and AIC information criteria. LM and Ljung–Box Q tests reject the hypothesis of no serial correlation at lag 5 for the oil price equation in both VARs, but not for the other equations.

[3] The robustness of our conclusions with respect to alternative traditional identification strategies is an interesting exercise, but beyond the scope of this paper.

We assume that there is a contemporaneous impact of an oil price shock on all the other variables in the system, but no immediate impact of the other shocks on oil prices.[4] The assumption of exogenous contemporaneous oil price movements is commonly used in the empirical VAR literature (e.g. Sims, 1992) but is very restrictive. In the next subsection, we analyse the robustness of this assumption by using sign restrictions.

Following Blanchard and Quah (1989), Gali (1992) and Gerlach and Smets (1995), we rely on a vertical long-run Philips curve to assume that demand and monetary policy shocks have no long-run impact on the level of real output. Supply shocks are thus associated with permanent shocks to output. One may argue that even demand disturbances can have a long-run impact on output, but those long-run effects are typically assumed to be small compared to those of supply disturbances and are assumed not to affect the estimates. Using this approach, demand and monetary policy shocks with permanent effects are therefore labelled as supply shocks. Again, this long-run neutrality is relaxed when we use sign constraints as an alternative.

In order to discriminate between aggregate demand and monetary policy shocks, we follow Bernanke and Blinder (1992) and use the restriction that monetary policy shocks have no contemporaneous effect on output. The aggregate demand shocks are also often called aggregate spending or IS shocks. Monetary policy shocks are shocks with a temporary effect on output, and are a combination of monetary policy, money demand and possibly exchange rate shocks, as long as these shocks have an influence on the short-term interest rate. However, monetary policy shocks should be the main underlying source. The zero contemporaneous effects of a monetary policy shock on output are also relaxed in the next subsection.

These conditions are sufficient to fully identify the model, and the impulse response functions to an oil price, aggregate supply, aggregate demand and monetary policy shock are presented in Figure 1a and b for the USA and the Euro area, respectively, together with 84th and 16th percentile error bands based on 1000 Monte Carlo draws.[5] The results are as expected and consistent with theory. In addition, there are only a few differences between both areas. There is a permanent effect of an oil price shock (first rows of the figures) on the level of output and prices, and the interest rate temporarily increases to offset the inflationary pressures. The pass-through of an oil price shock is much faster for prices than the pass-through for output, as the latter only starts falling after approximately 4 quarters. The output effects are also somewhat stronger in the USA than the Euro area. In general, we find very similar output and price patterns after a supply shock (second rows). This illustrates the fact that oil price shocks are also reflected in a shift of the aggregate supply curve, which is standard in the literature. The impact of both shocks on output and prices is, however, only complete after 12–16 quarters.

After a positive aggregate spending shock (third rows), output immediately increases and gradually returns to baseline. There is a permanent increase of the price level and a temporary increase of the nominal interest rate. An unexpected rise in the interest rate (monetary policy shock, rows four) leads to a decrease in GDP, with a maximum impact after 4–6 quarters, and a gradual decrease in prices. This is consistent with the results of most of the empirical literature on the effects of monetary policy shocks in both areas.[6] The size of a monetary policy shock is more than double in the USA: 70 basis points increase of the short-term interest rate relative to a

[4] For the implementation of the restrictions, we refer to the CEPR Discussion Paper No. 4087 version of this paper.
[5] Error bands are calculated as suggested by Sims and Zha (1999), which is a Bayesian approach. The full line is the median impulse response function from the posterior distribution.
[6] For example, Christiano *et al*. (1998) for the USA and Peersman and Smets (2001) for the Euro area.

30 basis points increase in the Euro area. The monetary policy reaction function to this monetary policy shock is, on the other hand, much smoother in the Euro area. This results in a similar impact on the price level, but a stronger impact on output in the USA. The impact of an aggregate supply shock on oil prices is insignificant in both regions, while oil prices rise after a positive demand shock and fall after a restrictive monetary policy shock in the USA. For the Euro area, we only find a decline after a monetary policy shock, but an insignificant effect after aggregate demand shocks. This illustrates that oil prices do react to other shocks and might suggest that the contemporaneous zero constraints are to stringent. This is analysed in more detail in the next section. Generally, these results are very similar to the existing empirical evidence.

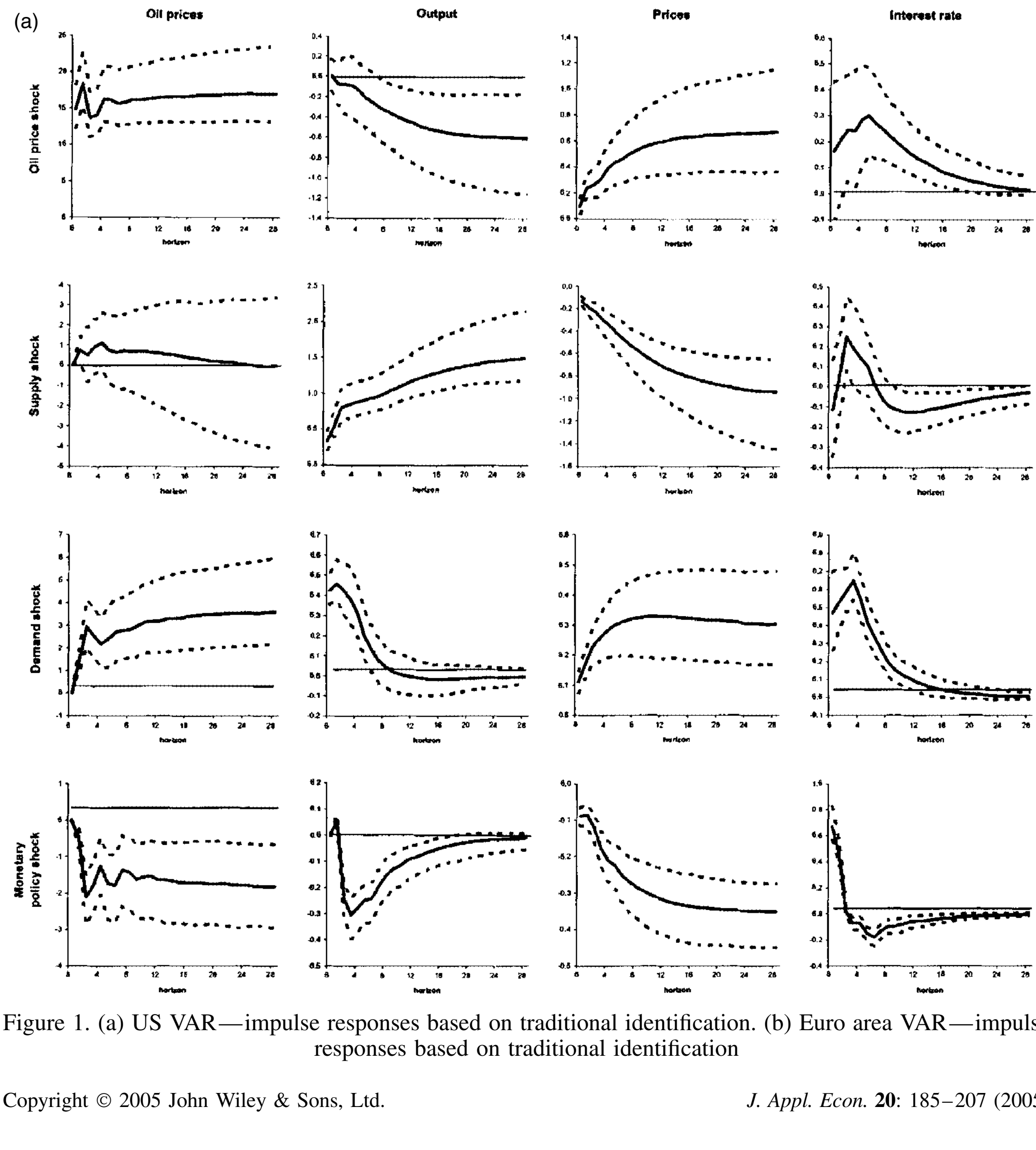

Figure 1. (a) US VAR—impulse responses based on traditional identification. (b) Euro area VAR—impulse responses based on traditional identification

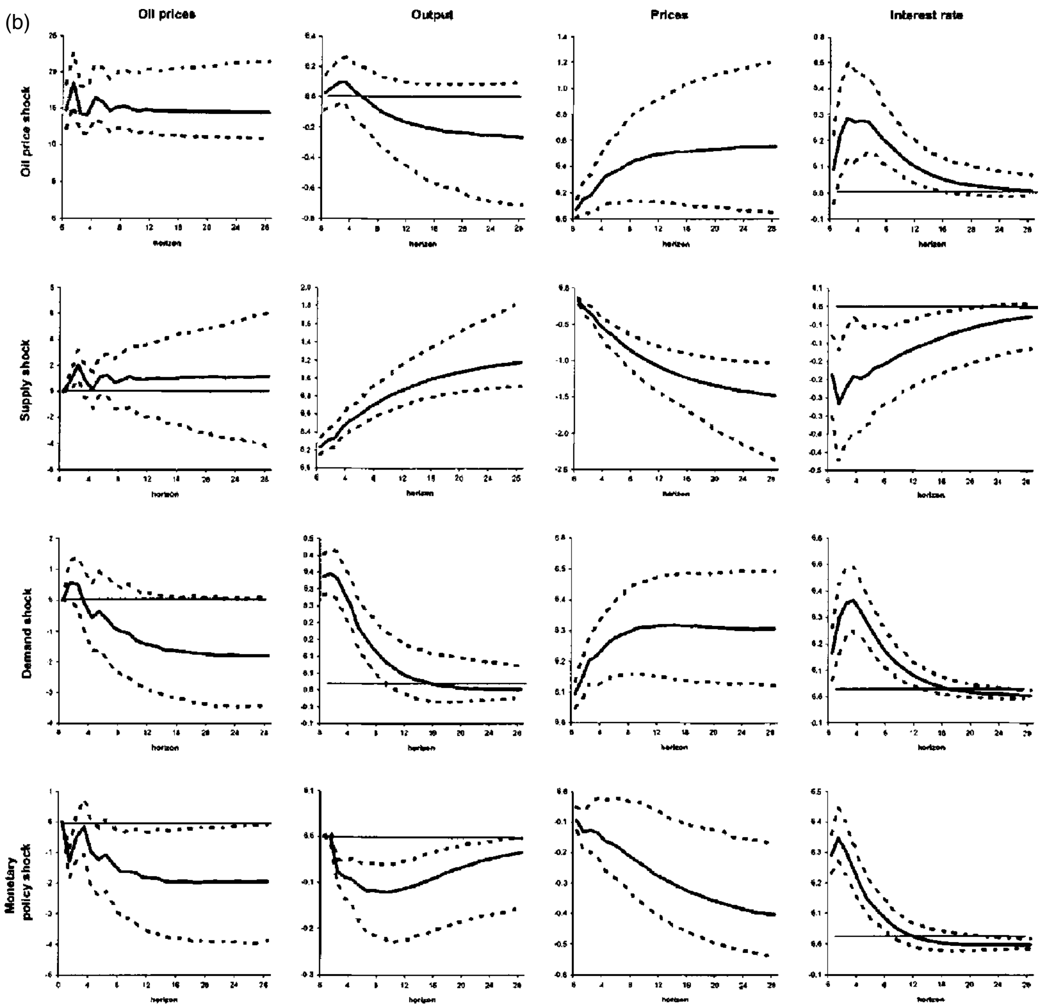

Figure 1. (*Continued*)

2.3. Identification Based on Sign Restrictions

In this section, we discuss the robustness of the above results if we use an alternative identification strategy. As already mentioned, some of the zero short-run restrictions are very stringent and not based on theoretical considerations. The assumption that the oil price is contemporaneously exogenous could be questionable, since it is a financial variable. On the other hand, ordering the oil price last, i.e. allowing for an immediate impact of the other shocks on the oil price, but assuming that there is no contemporaneous impact of oil price shocks on other variables, is even more stringent. This would imply that the general price level does not immediately react to a shift in oil prices, the latter being part of it. Similarly, assuming a zero contemporaneous impact of a monetary policy shock on output is inconsistent with a large class of general equilibrium monetary models (Canova and Pina, 1999).

Long-run restrictions are often better justified by theory. Nevertheless, some equilibrium growth models (for example, many overlapping generations models) allow for permanent effects of aggregate demand and monetary policy shocks on output because they can affect the steady-state level of capital (Gali, 1992). Furthermore, relying on long-run conditions can be highly misleading. Faust and Leeper (1997) show that substantial distortions are possible due to small sample biases and measurement errors when using these type of restrictions.

In order to check the robustness of our previous results, we use an alternative identification procedure that does not suffer from these problems. Faust (1998), Kieler and Saarenheimo (1998), Uhlig (1999) and Canova and De Nicoló (2002) use sign restrictions on the impulse response functions to identify a monetary policy shock. The advantage of their approach is that zero constraints on the contemporaneous impact matrix or the long-run effects of the shocks are not necessary. Instead, restrictions which are often used implicitly, consistent with the conventional view, are made more explicit. For example, a contractionary monetary policy shock leads to a fall in non-borrowed reserves, output and prices. In contrast to these papers, we not only identify monetary policy shocks, but a full set of shocks. The identification of additional shocks should also help to identify the monetary policy shock.[7]

The sign conditions that we impose are generally accepted in the theoretical literature and based on a typical aggregate demand and aggregate supply diagram, which remains the core of many macroeconomic textbooks. In addition, the restrictions are consistent with most dynamic general equilibrium models. All constraints are imposed as $\geq$ or $\leq$, which implies that a zero response is also possible.[8] We assume that after an unexpected rise of the interest rate (monetary policy shock), the response of output and prices is not positive, and there is not an immediate increase of the oil price. After a positive demand shock, we assume that the response of output and prices is not negative and there is not an immediate fall of the oil price and the interest rate. These effects are consistent with a shift of the aggregate spending or IS curve. Consequently, the difference with a monetary policy shock is the opposite sign of the interest rate response relative to output, the price level and oil prices. An unfavourable oil price shock, i.e. a rise of oil prices, does not have a positive impact on output and not a negative effect on prices. As a result, the nominal interest rate does not decrease. Following a positive supply shock, there is no fall in output. In addition, prices and the nominal interest rate do not increase. Because the oil price shock can be considered as a supply shock, the signs of normalized responses of output, prices and the interest rate are the same. However, in contrast to an oil price shock, the sign of the response of oil prices after a supply shock is uncertain. As a consequence, we do not impose a restriction on the response of oil prices after a supply shock. The data will determine the sign of this response. In order to disentangle the two shocks, we assume that the oil price shock is the shock with the largest contemporaneous impact on oil prices. All restrictions can be summarized as follows:

For output and prices, we choose the time period over which the sign restrictions are binding being equal to 4 quarters. This is consistent with the restrictions of Uhlig (2001) and Faust (1998) for monetary policy shocks. Reducing this value has hardly any influence on the results.

[7] If only monetary policy shocks are identified, impulse responses that match the restrictions of the monetary policy shock are accepted even if the responses to the other shocks are unreasonable. This is not possible if more shocks are identified because the responses to all shocks have to be consistent with the sign restrictions. The cost, of course, is that you have to impose more restrictions.

[8] For a full explanation of the methodology to implement sign restrictions and derive impulse response functions, we refer to Uhlig (1999), Canova and De Nicoló (2002) or the working paper version of this paper (CEPR Discussion Paper No. 4087).

	Oil	y	p	s
Oil price	$\geqslant 0$	$\leqslant 0$	$\geqslant 0$	$\geqslant 0$
Supply	?	$\geqslant 0$	$\leqslant 0$	$\leqslant 0$
Demand	$\geqslant 0$	$\geqslant 0$	$\geqslant 0$	$\geqslant 0$
Monetary policy	$\leqslant 0$	$\leqslant 0$	$\leqslant 0$	$\geqslant 0$

Nevertheless, we select this value in order to limit the number of plausible decompositions.[9] Also, larger values for this time period do not alter the results significantly. For the response of oil prices and the interest rate, we only impose a contemporaneous constraint, since these are financial and fully flexible variables.

Following Uhlig (1999), we use a Bayesian approach for estimation and inference, which is consistent with the method proposed by Sims and Zha (1999) and the one used in Section 2.2. Our prior and posterior belong to the normal–Wishart family, obtained from Zellner (1971) and used in the RATS manual for drawing error bands. Because there are an infinite number of admissible decompositions for each draw from the posterior when using sign restrictions, we use the following procedure. To draw the 'candidate truths' from the posterior, we take a joint draw from the posterior for the usual unrestricted normal–Wishart posterior for the VAR parameters as well as a uniform distribution for the rotation matrices.[10] We then construct impulse response functions. If all the imposed conditions of the impulse responses of the four different shocks are satisfied, we keep the draw. More specifically, the responses of the four identified shocks should be consistent with an oil price, supply, demand and monetary policy shock. Decompositions that match only the criteria of three or less shocks are rejected. This means that these draws receive zero prior weight. On average, 97 and 130 draws are needed to draw one solution that matches all the conditions for the Euro area and the USA, respectively. Based on the draws kept, we calculate statistics and report the median responses, together with the 84th and 16th percentile error bands.[11]

Impulse response functions in Figure 2a and b look very similar to the responses based on the traditional identification strategy, but there are some interesting differences. As expected, the oil price response to a supply shock is uncertain. It is insignificant in the USA and slightly positive in the Euro area. An interesting result is the reaction of oil prices to a demand and monetary policy shock. In contrast to the conventional identification strategy, we find a substantial impact of both shocks in the USA and the Euro area. The largest part of the effect is even instantaneously. This implies that the contemporaneous zero constraint for oil prices in the traditional approach is probably too stringent. Part of the demand and monetary policy shocks are then identified as oil price shocks. On the other hand, we do not find permanent effects of a monetary policy and demand shock on the level of output, which was assumed in Section 2.2. The median responses

[9] The results with fewer restrictions are available upon request.

[10] Since the shocks are mutually orthogonal, $E(\varepsilon_t \varepsilon_t') - I$, the variance–covariance matrix of equation (1) is equal to: $\Omega = BB'$. For any possible orthogonal decomposition B, we can find an infinite number of admissible decompositions of Ω, $\Omega = BQQ'B'$, where Q is any orthonormal matrix, i.e. $QQ' = I$. More specifically, $Q = \prod_{m,n} Q_{m,n}(\theta)$ with $Q_{m,n}(\theta)$ being six bivariate rotation matrices of different elements of the VAR: $\theta = \theta_1, \ldots, \theta_6$, and rows m and n are rotated by the angle θ_i. All possible decompositions can be produced by varying the six parameters θ_i in the range $[0, \pi]$. We draw from a uniform distribution $[0, \pi]$ for each θ_i.

[11] Note that the sign restrictions approach is potentially liable to the so-called 'normalization' problem, a rule of reversing signs of coefficients in equations in a particular way. See Waggoner and Zha (1997) for a discussion of this problem.

predict a small permanent effect of both shocks in the USA, but the error bands are very wide, which implies that we cannot reject long-run neutrality. The immediate effect of a monetary policy shock on output is, however, substantial. More than one-third of the total impact is estimated to occur within 1 quarter. The maximum impact of a monetary policy shock is also larger than the impact based on traditional restrictions, even though the size of the interest rate shock is smaller.[12] In the next section, we discuss the quantitative differences between both approaches in more detail for an exogenous oil price and a monetary policy shock, respectively.

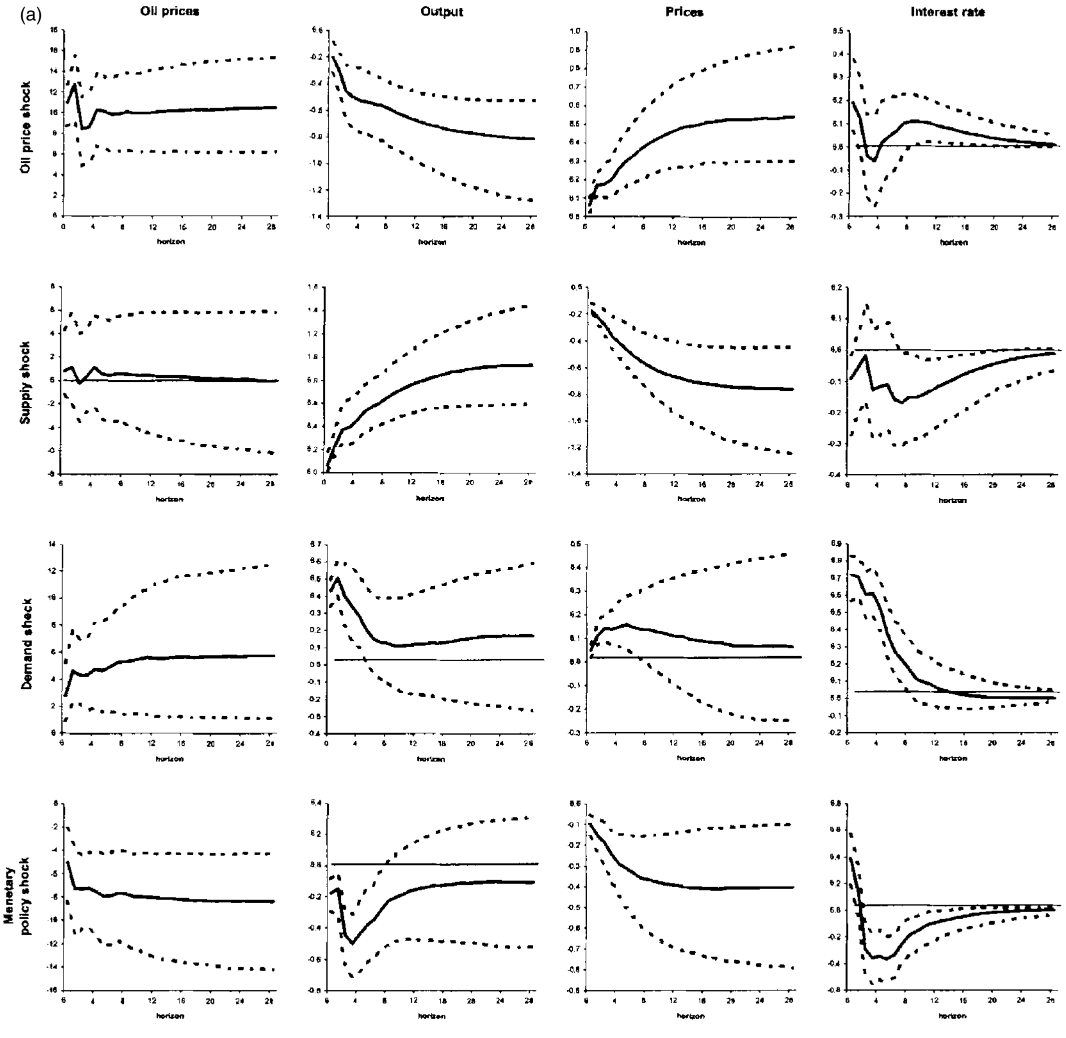

Figure 2. (a) US VAR—impulse responses based on sign restrictions. (b) Euro area VAR—impulse responses based on sign restrictions

[12] This is also reflected in the variance decompositions of output and prices (not reported in this paper). The contribution of monetary policy shocks is approximately double for both variables when using sign restrictions instead of traditional restrictions.

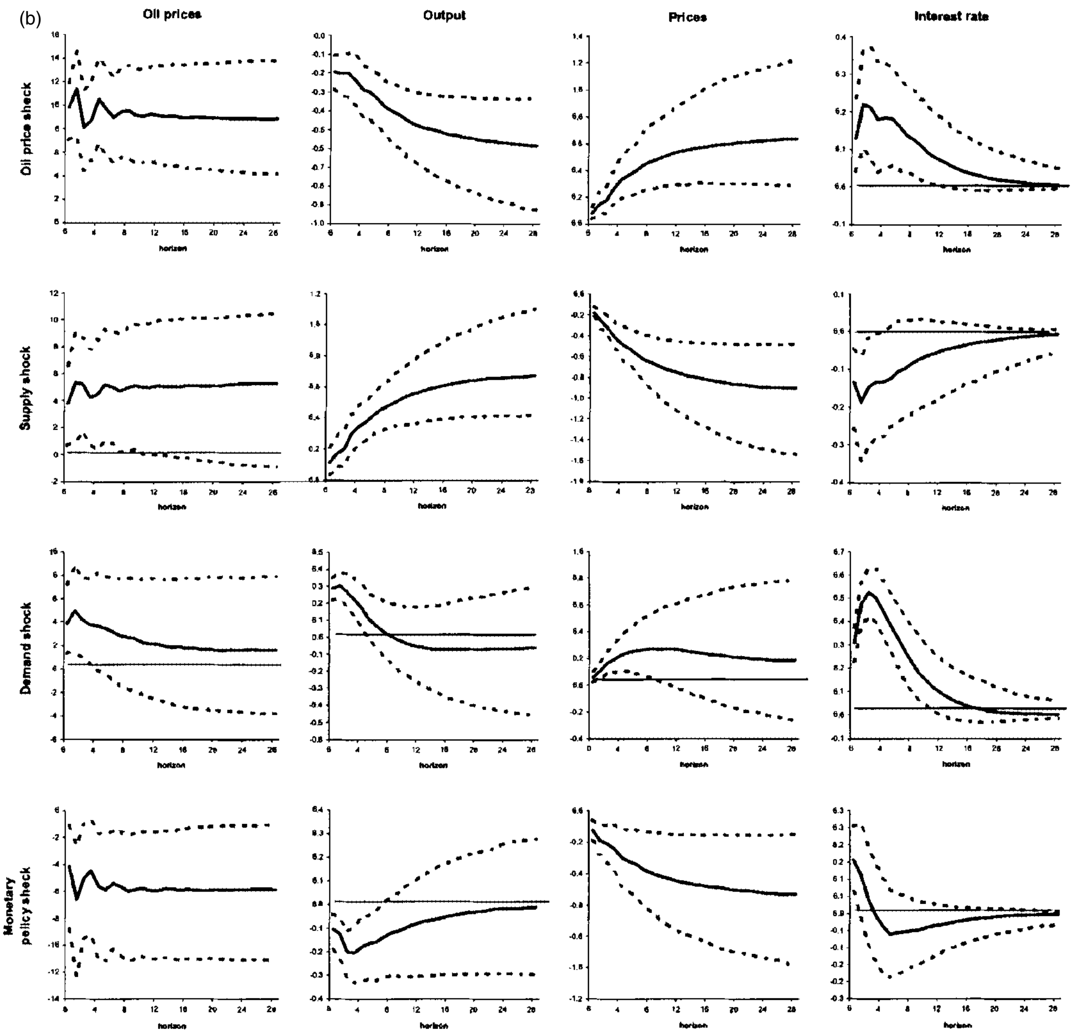

Figure 2. (*Continued*)

2.4. Comparison Between Both Approaches: A Simulation Exercise

In this section, we evaluate the quantitative importance of the differences between the impulse response functions of the two alternative identification strategies. As discussed in Section 2.3, these impulse responses look relatively similar. Figures 1 and 2 show the responses to one standard deviation shocks. The size of the estimated shocks is, however, not the same in both cases, which makes a comparison very difficult. We therefore perform a normalized simulation in this section. In particular, we compare the results of an exogenous oil price increase of 10% and an exogenous shift of the interest rate of 50 basis points. Both simulations are very relevant. Exogenous oil price movements occur very frequently. Examples are shifts of quota agreed between OPEC countries, other exogenous movements in the supply of oil, or fluctuations as a result of shifts in the risk of a war. An important issue is the impact of these shocks on the economy, in particular on output growth and inflation. The second simulation, an exogenous increase of the interest rate of 50 basis points, is very relevant in the context of the monetary transmission mechanism debate. There is still a lot of uncertainty about the exact impact of a shift in the stance of monetary policy on the real economy. We do not report the results of the comparison of aggregate supply and demand shocks because of normalization problems.[13]

The results are shown in Figure 3. The first two columns contain the impulse responses to a 10% increase of oil prices, and the last two columns the responses to a rise in the interest rate of 50 basis points. The black lines are the responses based on sign restrictions, together with 84th and 16th percentile error bands (dotted black lines). The grey line is the estimated median response based on traditional restrictions. Since the zero restrictions also match the sign restrictions in most cases, we can consider the traditional solution as one of the solutions of the sign restrictions approach.[14] The response of oil prices, prices and the interest rate to a 10% increase in oil prices is very similar across both methods. The result of the traditional approach almost always lies within the confidence bands of the sign conditions. The main difference, however, is the response of output. The effect on output is estimated to be much smaller with conventional restrictions, and lies outside the error bands. This implies that the solution obtained with conventional restrictions lies in the tails (below 16th percentile) of all possible solutions. The difference is also economically very important. A 10% rise in the oil price has, on average, a long-run negative effect on output of 0.39% and 0.18% for the USA and the Euro area, respectively, with traditional restrictions. The median response based on sign restrictions predicts, however, an impact of 0.71% and 0.60%, respectively.

The results of an exogenous interest rate rise of 50 basis points by monetary authorities are clearly different across both methods. Most responses based on conventional restrictions lie outside the error bands of the distribution of sign constraints. Specifically, the response of oil prices is much smaller in the short and the long run. In addition, and more important in the context of the monetary transmission debate, the effect on output and prices is also much smaller with traditional restrictions. The maximum impact on output in the USA and the Euro area is respectively −0.23% and −0.21% with traditional restrictions, while the impact lies between −0.40% and −0.91% in the USA, and between −0.37% and −1.06% in the Euro area with sign restrictions (median impact of respectively −0.65% and −0.64%), economically a substantial difference. The effects on prices are also much smaller with conventional restrictions. The difference with the median estimate based on sign conditions is again very high. The latter is double in the USA: −0.52% compared to −0.26% using conventional restrictions. For the Euro area, this is even −1.70% compared to −0.70%. In sum, the differences between both approaches for the impact of an exogenous oil price and monetary policy shock are substantial and economically very relevant. In the next section, we investigate whether this has implications for the analysis of the sources of the slowdown.

[13] It is not clear whether we should normalize on the contemporaneous or the long-run impact of the shocks.
[14] The only exception is the response of output to an oil price shock in the Euro area. Using traditional restrictions, the contemporaneous effect is slightly above zero. As a consequence, this solution would be rejected with sign restrictions. The effect is, however, extremely small and does not affect the main message of the results.

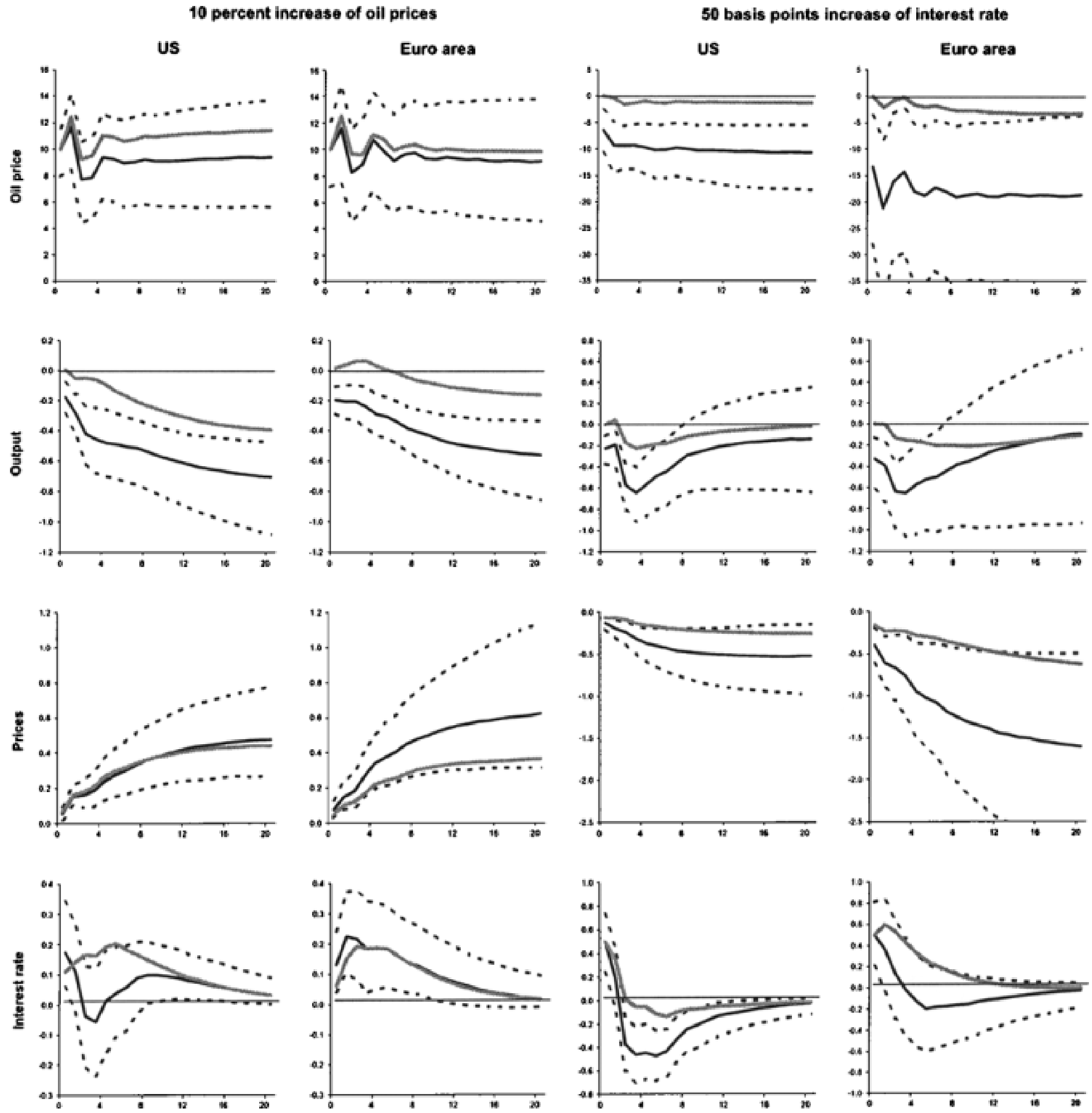

Figure 3. A comparison between both approaches—Results of a simulation

3. ANALYSIS OF THE RECENT SLOWDOWN: DECOMPOSING OUTPUT, PRICES, OIL PRICES AND THE INTEREST RATE

Based on the estimates of the previous section, we can calculate the shocks and the cumulative effects of these shocks on output, prices, oil prices and the interest rate. This means that output, prices, oil prices and the interest rate can be written as the sum of a deterministic component, the contribution of current and past oil price shocks, current and past aggregate supply shocks, current and past aggregate demand shocks, and current and past monetary policy shocks. The

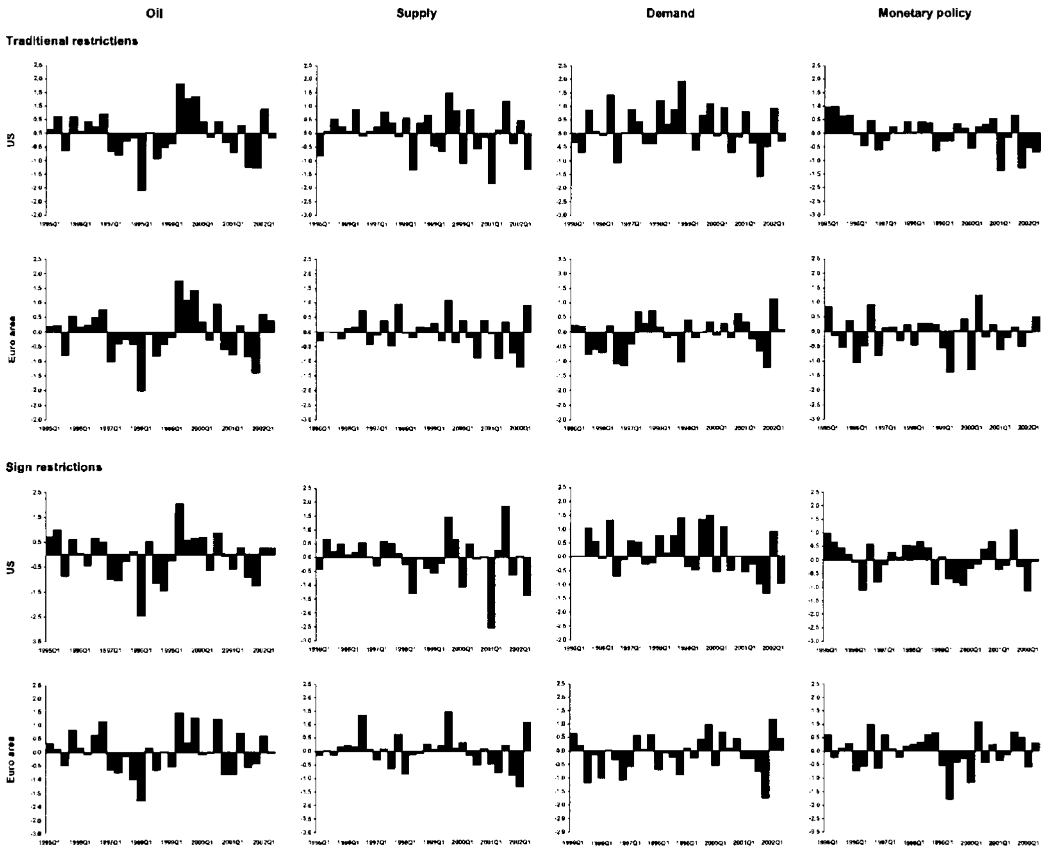

Figure 4. United States and Euro area shocks: 1995Q1–2002Q2

time series of the shocks in both areas are presented in Figure 4, and the contribution of these shocks to output, prices, oil prices and the interest rate are presented (as deviations from baseline, i.e. the deterministic component) in Figure 5a–d for the period 1995Q1–2002Q2. For reasons of legibility, we only show the median estimates.[15] In our discussion, distinction is made between the contribution to output (recent slowdown), prices and the interest rate.

3.1. The Contribution to Output

Impact of Supply Shocks

Starting in 1995, there is a continuous increase in the level of output due to positive supply shocks (typically characterized as the new economy). These results are very consistent across both identification strategies (see Figure 5a). The 'new economy' idea was clearly more a US phenomenon. Supply shocks made an accumulated positive contribution to output in the USA between 2.8% and 4.4% depending on the identification strategy, whilst this was only around 1%

[15] Figures with confidence bands are available upon request, but the conclusions are not altered. Significance is also reported in Tables I–III.

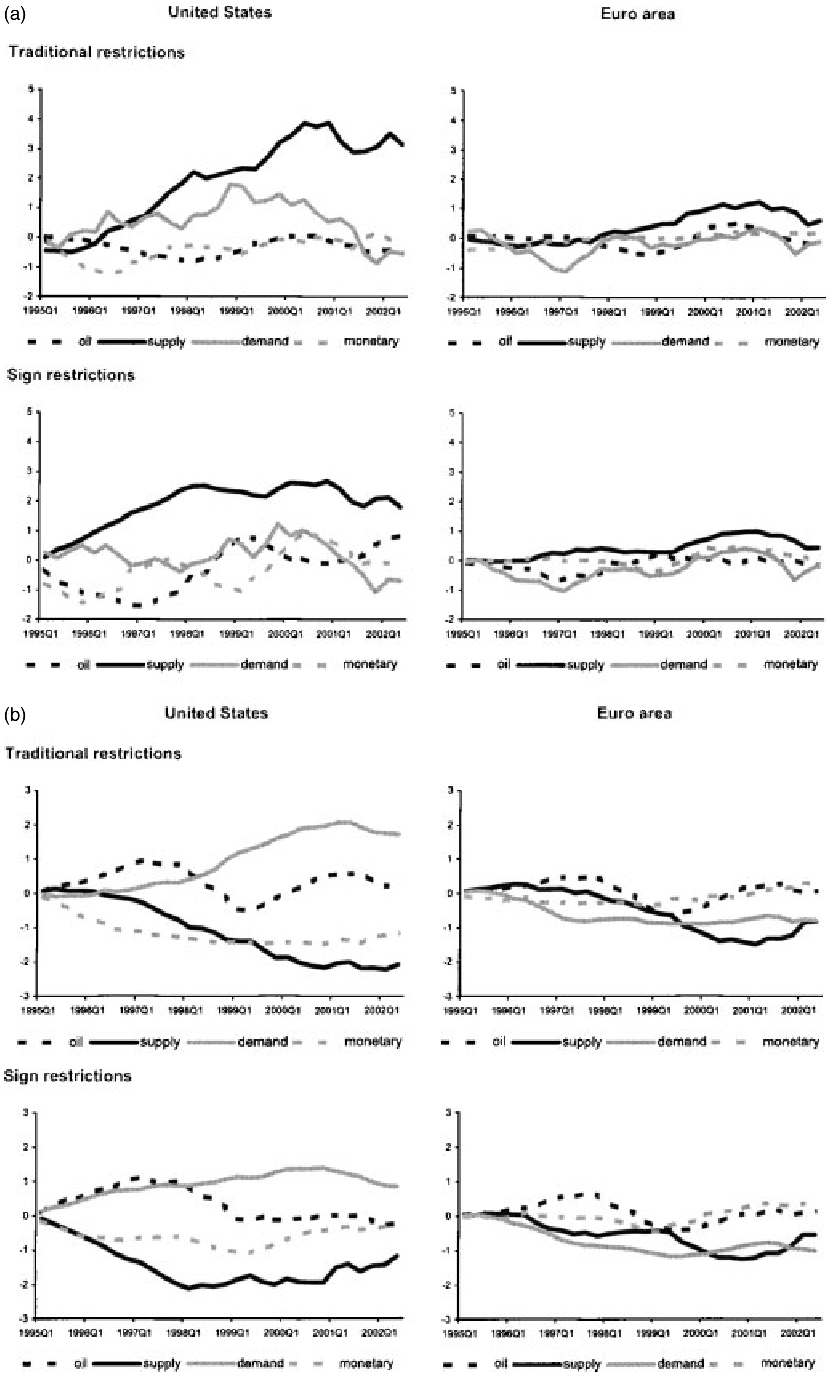

Figure 5. (a) Contribution of shocks to output. (b) Contribution of shocks to prices. (c) Contribution of shocks to oil prices. (d) Contribution of shocks to interest rates

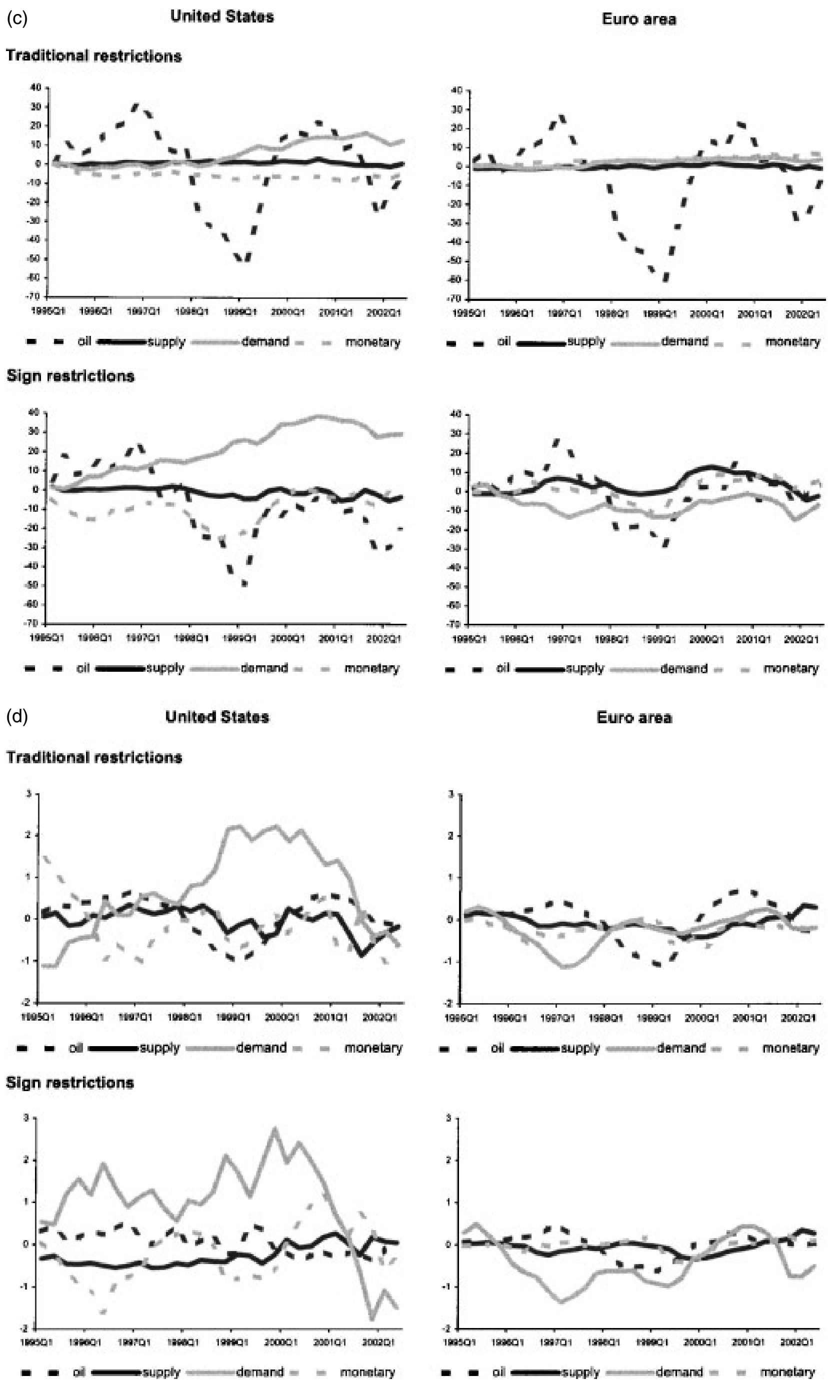

Figure 5. (*Continued*)

in the Euro area. Positive effects of supply shocks stagnate around the middle of 2000, after which there is a negative contribution of supply shocks to output until the end of 2002Q2. These shocks can partly explain the slowdown. This is also shown in Table I. This table contains the median contributions of the shocks to output *growth*. Bold figures are significant, i.e. upper and lower error bands have the same sign. Actual figures are the sum of a baseline (deterministic) component and the contribution of all shocks.[16] We find a significant negative effect of 0.94% and 0.76% in the USA between 2001Q1 and 2001Q3 for traditional and sign constraints, respectively. Also in the Euro area, the effects are significant. Output fell 0.73% or 0.50% between 2001Q2 and 2002Q1 for the traditional and sign restrictions approach, respectively (columns 6 and 7 of Table I).

Impact of Demand Shocks

The results for the contribution of demand shocks are also very similar for both approaches. The pattern, however, was different across both areas (see Figure 4), which is reflected in the historical contributions. In the USA, the contribution of demand shocks to output between 1996 and 2001 is always above baseline with traditional restrictions and most of the time with sign constraints. From the beginning of 2000 onwards, the contribution of demand shocks to output growth became mainly negative. Until the beginning of 2001, however, the decline was mostly due to the closing down of a positive output gap, because at the same time there were still a number of positive demand shocks (illustrated in Figure 4). These positive shocks were, however, not sufficient to offset the return to potential output (the return to potential output is visually illustrated by the impulse response functions to a demand shock in Figures 1 and 2). A sequence of negative demand shocks in 2001 turned output below its baseline level. Accordingly, output growth was respectively 1.07% and 1.21% lower in 2001 for both approaches.

For the Euro area, there were a number of negative demand shocks between 1995 and 1997 with corresponding effects on output growth, after which there was a positive trend, though very small in magnitude, until the end of 2000. In the last three quarters of 2001, output fell significantly with respectively 0.85% and 0.96% due to negative demand shocks for our two methods, which is somewhat less pronounced than the impact in the USA. In sum, negative demand shocks also made a substantial contribution to the early millennium slowdown in both areas.

Impact of Oil Price Shocks

The negative supply and demand shocks are accompanied by a negative impact of oil price shocks. The result is, however, highly influenced by the methodology used. For both methods, we find that declines in oil prices during the period 1997–1998 had positive effects on output afterwards (though larger with traditional restrictions). The figures are, on the other hand, different for the increases of oil prices in 1999 and the first quarter of 2000. With conventional methods, these rises had in 2001 a negative and highly significant impact on output growth of 0.31% in the Euro area (column 4 of Table I). The figures for the USA are similar, with a fall in output of 0.37%. The estimate of the latter is, however, insignificant. This finding is not consistent with the results obtained using alternative restrictions: the impact of oil price shocks is estimated to be negligible and insignificant. We even find a slightly positive effect on output growth in the USA at the end of 2001 and the beginning of 2002. This difference between both approaches is striking.

[16] Because we report the median estimates, the sums reported in the tables are not exact.

Table I. Decomposition of growth rates

	Actual	Baseline		Oil		Supply		Demand		Monetary	
		(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
United States											
1995	2.64	**3.05**	**3.04**	−0.06	**−1.13**	**−0.46**	**0.62**	**0.86**	**0.82**	**−0.92**	**−0.78**
1996	3.50	**2.97**	**2.97**	**−0.27**	**−0.50**	**0.70**	**0.86**	**0.51**	−0.05	**−0.51**	0.17
1997	4.34	**2.89**	**2.88**	**−0.35**	0.00	**1.05**	**0.84**	0.15	−0.29	**0.57**	**0.86**
1998	4.19	**2.81**	**2.78**	−0.03	**1.10**	**0.79**	0.49	**0.49**	0.35	0.17	−0.47
1999	4.03	**2.72**	**2.68**	**0.51**	**0.74**	**0.51**	−0.15	0.32	**0.49**	0.04	0.34
2000	3.69	**2.64**	**2.62**	0.20	**−0.56**	**1.16**	0.33	−0.47	0.18	0.20	**1.10**
2001	0.25	**2.57**	**2.55**	−0.37	0.19	**−0.66**	**−0.51**	**−1.07**	**−1.21**	−0.02	**−0.52**
2000Q1	0.63	**0.66**	**0.65**	0.07	−0.21	**0.28**	0.20	**−0.32**	**−0.35**	−0.03	**0.34**
2000Q2	1.18	**0.66**	**0.65**	0.03	0.04	**0.43**	−0.07	**0.17**	0.17	−0.09	**0.34**
2000Q3	0.14	**0.65**	**0.65**	−0.03	−0.16	−0.15	−0.06	**−0.46**	−0.18	**0.16**	−0.03
2000Q4	0.27	**0.65**	**0.64**	−0.14	0.02	**0.15**	0.11	**−0.32**	**−0.26**	−0.01	**−0.17**
2001Q1	−0.15	**0.64**	**0.64**	−0.10	0.04	**−0.60**	**−0.18**	0.05	**−0.42**	**−0.11**	−0.14
2001Q2	−0.40	**0.64**	**0.63**	−0.08	−0.01	**−0.34**	**−0.42**	**−0.30**	**−0.24**	**−0.27**	**−0.32**
2001Q3	−0.07	**0.63**	**0.63**	−0.18	**0.20**	0.00	−0.16	**−0.85**	**−0.44**	**0.35**	−0.25
2001Q4	0.68	**0.62**	**0.62**	0.01	**0.33**	0.18	**0.23**	**−0.30**	**−0.59**	**0.21**	0.11
2002Q1	1.23	**0.62**	**0.62**	0.04	**0.21**	**0.43**	0.07	**0.40**	**0.41**	**−0.26**	−0.12
2002Q2	0.28	**0.61**	**0.61**	−0.11	0.08	**−0.34**	**−0.31**	−0.10	−0.04	**0.25**	−0.06
Euro area											
1995	2.39	**2.20**	**2.16**	0.09	**−0.15**	−0.14	−0.01	0.09	0.27	**0.16**	**0.14**
1996	1.47	**2.19**	**2.16**	−0.03	**−0.29**	−0.06	0.10	**−0.76**	**−0.61**	**0.15**	0.10
1997	2.42	**2.18**	**2.17**	−0.10	−0.10	0.13	**0.25**	0.03	0.04	**0.14**	−0.06
1998	2.81	**2.16**	**2.15**	−0.36	**0.48**	**0.32**	0.04	**0.54**	0.28	**0.09**	−0.10
1999	2.72	**2.15**	**2.14**	0.27	0.15	**0.39**	0.13	−0.13	0.11	0.03	0.12
2000	3.57	**2.14**	**2.13**	**0.63**	−0.09	**0.41**	**0.46**	0.25	**0.52**	**0.14**	**0.39**
2001	1.61	**2.12**	**2.13**	**−0.31**	0.02	−0.06	−0.02	−0.10	**−0.31**	0.01	−0.07
2000Q1	0.89	**0.53**	**0.53**	**0.23**	0.07	**0.11**	0.11	0.02	−0.04	0.00	**0.19**
2000Q2	0.84	**0.53**	**0.53**	0.07	0.02	**0.15**	**0.15**	**0.11**	**0.21**	−0.02	−0.08
2000Q3	0.49	**0.53**	**0.53**	0.03	**−0.22**	−0.11	0.04	−0.06	0.05	**0.11**	**0.11**
2000Q4	0.73	**0.53**	**0.53**	−0.06	0.12	**0.13**	0.06	**0.21**	**0.12**	**−0.07**	−0.08
2001Q1	0.56	**0.53**	**0.53**	−0.11	**0.15**	**0.07**	0.01	0.09	**−0.10**	−0.01	0.01
2001Q2	0.03	**0.53**	**0.53**	**−0.11**	**−0.21**	**−0.24**	**−0.10**	**−0.12**	**−0.13**	−0.01	−0.01
2001Q3	0.16	**0.53**	**0.53**	**−0.17**	0.02	0.04	−0.01	**−0.27**	**−0.28**	0.04	**−0.07**
2001Q4	−0.23	**0.53**	**0.53**	−0.13	0.07	**−0.14**	**−0.12**	**−0.46**	**−0.55**	0.00	**−0.09**
2002Q1	0.36	**0.53**	**0.53**	**−0.08**	**−0.14**	**−0.39**	**−0.27**	**0.32**	**0.28**	−0.03	−0.03
2002Q2	0.66	**0.53**	**0.53**	−0.08	−0.03	**0.11**	0.02	0.07	**0.21**	0.03	**−0.07**

(1) Traditional restrictions.
(2) Sign restrictions.
Median estimated values based on Monte Carlo integration.
Bold figures are significant: median, upper and lower bands of estimates have the same sign.

Impact of Monetary Policy Shocks

Also for monetary policy shocks, we find a controversial result for our alternative identification methods in explaining the slowdown. For the USA and the Euro area, both methods find a significant positive contribution of monetary policy shocks to output growth in 2000 as a result of easy monetary policy in 1999. This reinforced the ongoing boom. The magnitude is, however, much larger with sign restrictions. On the other hand, restrictive monetary policy had an insignificant effect on output growth in 2001 using conventional restrictions, but central banks played an important and significant role using sign conditions: output is estimated to have fallen by 0.52%

in 2001 in the USA. The total impact in the Euro area is negative but insignificant in 2001. Nevertheless, we do find a significant effect in some individual quarters, i.e. 2001Q3, 2001Q4 and 2002Q2.

Overall, we find a very important role for aggregate demand and aggregate supply shocks in explaining the recent slowdown across both identification methods. However, it turns out that we find an important role for restrictive monetary policy in explaining the slowdown with sign restrictions, whilst we find a substantial contribution of unfavourable oil price shocks when we use conventional zero restrictions to identify the shocks. These results indicate that a lot of the effects of oil price shocks from the traditional approach are picked up by monetary policy shocks using sign conditions in explaining the slowdown, and illustrate that restricting the contemporaneous response of oil prices and output to a monetary policy shock to be zero can have a substantial influence on the results and the conclusions. This finding is consistent with the results of Section 2.4.

3.2. The Contribution to Prices and Oil Prices

Between 1996 and 2000, also often called the new economy period, the inflation rate was in the USA on average around 0.3–0.4% lower due to positive supply shocks. This effect was somewhat less favourable in the Euro area, at approximately 0.25% per year. This favourable contribution, however, stagnated in 2001 and became unfavourable in 2002. This is shown in Figure 5b and Table II. The table contains the decompositions of inflation rates. Columns 6 and 7 show the contribution of supply shocks. In addition to the supply shocks, favourable oil price shocks in 1997 and 1998 also significantly reduced the inflation rate in 1998 and 1999 in the USA and the Euro area for both methodologies. Conversely, and consistent with the results for output, unfavourable oil price shocks made a considerable upward contribution to the inflation rate in 2000 and the beginning of 2001 with conventional restrictions, but there was hardly any contribution using sign restrictions. As a result of subsequent positive demand shocks between 1995 and the end of 2000 in the USA, inflation was on average more than 0.3% higher during that period. The large negative demand shocks in 2001 had, on the other hand, significant deflationary effects between 2001Q3 and 2002Q2. In the Euro area, demand shocks only had an upward effect on inflation in 2000 and the beginning of 2001. Finally, inflation was in both areas higher in 2000 and 2001 as a result of a slow pass-through of easy monetary policy in 1999.

The contribution of the shocks to the oil price level is a nice illustration of different results obtained from both identification procedures (Figure 5c). The total rise of oil prices relative to baseline of about 80% in 1999 and 2000 is almost completely due to oil price shocks with the traditional approach. With sign conditions, this is approximately 40% less, which is the cause of a more modest impact of oil shocks in explaining the recent slowdown found in Section 3.1. In contrast, demand and monetary policy shocks also had a substantial impact on the rise of oil prices in 1999 and 2000. The latter two shocks can explain around 40% of the boost in oil prices. To summarize, recent oil price fluctuations are largely explained as an endogenous reaction to demand and monetary policy shocks with sign restrictions, but as exogenous oil price shocks when using traditional restrictions.[17]

[17] These contradicting results for oil price shocks between both approaches are not found for the early 1990s recession, as discussed in the extended working paper version of this paper.

Table II. Decomposition of inflation

	Actual	Baseline		Oil		Supply		Demand		Monetary	
		(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
United States											
1995	2.27	**2.48**	**2.48**	**0.30**	**0.51**	0.11	**−0.62**	−0.10	0.43	**−0.51**	**−0.54**
1996	2.12	**2.34**	**2.33**	**0.42**	**0.47**	−0.16	**−0.74**	0.13	**0.38**	**−0.59**	**−0.38**
1997	1.93	**2.20**	**2.20**	**0.26**	0.17	**−0.48**	**−0.64**	0.19	0.13	**−0.26**	0.02
1998	1.06	**2.06**	**2.05**	**−0.68**	**−0.45**	**−0.54**	−0.33	**0.37**	0.12	−0.18	−0.24
1999	1.63	**1.93**	**1.91**	**−0.58**	**−0.61**	**−0.42**	0.12	**0.71**	0.24	−0.06	−0.02
2000	2.51	**1.79**	**1.75**	**0.65**	0.03	**−0.49**	−0.09	**0.50**	0.26	0.00	**0.42**
2001	2.01	**1.65**	**1.61**	**0.22**	0.02	−0.08	**0.37**	0.10	−0.20	0.07	0.14
2000Q1	0.84	**0.45**	**0.44**	**0.18**	0.00	0.00	**0.13**	**0.13**	0.11	**0.06**	**0.13**
2000Q2	0.56	**0.44**	**0.43**	**0.16**	0.03	**−0.20**	−0.08	**0.18**	0.02	−0.03	**0.13**
2000Q3	0.52	**0.43**	**0.42**	**0.17**	−0.01	**−0.09**	−0.01	0.02	0.02	−0.03	0.07
2000Q4	0.55	**0.42**	**0.41**	**0.17**	**0.09**	**−0.07**	0.00	0.04	0.02	−0.02	0.01
2001Q1	0.82	**0.41**	**0.40**	0.02	0.00	**0.13**	**0.41**	**0.11**	−0.07	**0.13**	0.07
2001Q2	0.45	**0.41**	**0.39**	0.03	−0.03	0.02	0.09	0.02	−0.08	−0.03	0.04
2001Q3	−0.02	**0.40**	**0.38**	0.00	0.01	**−0.19**	**−0.20**	**−0.15**	**−0.11**	**−0.07**	**−0.09**
2001Q4	0.20	**0.39**	**0.37**	**−0.25**	**−0.14**	0.01	**0.14**	**−0.13**	**−0.17**	**0.17**	0.00
2002Q1	0.27	**0.38**	**0.36**	**−0.11**	**−0.12**	−0.05	0.02	−0.02	**−0.11**	**0.06**	**0.10**
2002Q2	0.62	**0.37**	**0.35**	**0.07**	0.04	**0.13**	**0.23**	−0.03	−0.05	**0.07**	0.03
Euro area											
1995	3.08	**3.00**	**3.04**	0.10	0.06	0.14	0.03	0.05	−0.04	**−0.22**	0.00
1996	2.63	**2.78**	**2.82**	**0.18**	**0.25**	0.05	**−0.17**	**−0.34**	**−0.29**	−0.06	0.06
1997	2.03	**2.57**	**2.60**	**0.17**	**0.31**	−0.16	**−0.36**	**−0.47**	**−0.42**	−0.09	−0.03
1998	1.50	**2.37**	**2.39**	**−0.54**	**−0.44**	−0.32	0.01	0.00	−0.18	−0.02	**−0.16**
1999	1.17	**2.16**	**2.17**	**−0.54**	**−0.53**	**−0.45**	**−0.18**	−0.10	−0.18	0.09	0.01
2000	2.14	**1.95**	**1.95**	**0.49**	0.22	**−0.50**	**−0.53**	0.05	0.11	0.11	**0.31**
2001	2.40	**1.74**	**1.73**	**0.27**	**0.19**	0.00	0.09	**0.10**	0.12	**0.20**	**0.21**
2000Q1	0.65	**0.49**	**0.49**	**0.17**	**0.10**	**−0.14**	**−0.16**	0.01	0.02	**0.13**	**0.19**
2000Q2	0.49	**0.48**	**0.48**	**0.16**	0.05	**−0.16**	**−0.15**	0.03	**0.07**	−0.03	0.01
2000Q3	0.70	**0.46**	**0.46**	**0.20**	**0.17**	0.04	−0.03	0.00	0.03	−0.01	0.03
2000Q4	0.63	**0.45**	**0.45**	**0.14**	**0.08**	**−0.08**	**−0.05**	**0.07**	**0.09**	0.02	0.05
2001Q1	0.58	**0.44**	**0.43**	0.01	−0.04	**−0.07**	0.02	**0.06**	0.04	**0.12**	**0.12**
2001Q2	0.80	**0.42**	**0.42**	**0.06**	**0.12**	**0.16**	**0.13**	**0.05**	0.03	**0.07**	**0.07**
2001Q3	0.40	**0.41**	**0.40**	0.03	0.03	−0.01	0.01	**−0.04**	−0.03	0.00	−0.03
2001Q4	0.29	**0.40**	**0.39**	**−0.16**	**−0.11**	**0.11**	**0.17**	**−0.12**	**−0.12**	0.06	−0.04
2002Q1	0.86	**0.38**	**0.38**	**−0.08**	0.04	**0.37**	**0.35**	**0.06**	−0.04	**0.11**	0.07
2002Q2	0.40	**0.37**	**0.37**	0.03	**0.05**	0.03	0.00	−0.01	−0.04	−0.03	0.00

(1) Traditional restrictions.
(2) Sign restrictions.
Median estimated values based on Monte Carlo integration.
Bold figures are significant: median, upper and lower bands of estimates have the same sign.

3.3. The Contribution to the Interest Rate

The level of the interest rate can be decomposed into three main components: a baseline part, the endogenous reaction to other shocks (supply, demand and oil price shocks), and the contribution of exogenous monetary policy disturbances. The contributions of the shocks to the interest rate are presented in Table III and Figure 5d. The relatively small response of the interest rate to supply shocks, found in Section 2, results in modest fluctuations of the interest rate due to these shocks in the period under investigation for both identification procedures. The reactions of monetary authorities to oil price shocks are different between our two alternative methods. We hardly find a

Table III. Decomposition of interest rate

	Actual	Baseline		Oil		Supply		Demand		Monetary	
		(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
United States											
1995	5.92	**5.45**	**5.44**	**0.30**	0.26	−0.01	**−0.38**	**−0.82**	0.91	**0.91**	−0.41
1996	5.39	**5.17**	**5.18**	**0.52**	0.35	0.17	**−0.49**	0.06	**1.34**	**−0.64**	**−1.11**
1997	5.62	**4.88**	**4.87**	**0.38**	0.19	0.22	**−0.49**	0.50	**0.96**	**−0.44**	−0.06
1998	5.47	**4.60**	**4.57**	−0.52	−0.01	0.06	−0.39	**1.24**	**1.34**	−0.01	−0.09
1999	5.33	**4.32**	**4.25**	**−0.63**	0.15	−0.24	−0.31	**2.15**	**1.86**	−0.31	**−0.73**
2000	6.46	**4.04**	**3.95**	0.36	−0.24	0.10	0.05	**1.75**	**1.95**	0.12	**0.65**
2001	3.69	**3.77**	**3.70**	0.31	−0.28	**−0.43**	0.10	**0.48**	−0.39	−0.39	**0.48**
2000Q1	6.03	**4.14**	**4.06**	0.07	−0.17	0.26	0.11	**1.87**	**1.95**	−0.33	0.02
2000Q2	6.57	**4.07**	**3.99**	0.27	−0.38	0.07	−0.08	**2.14**	**2.42**	−0.09	0.50
2000Q3	6.63	**4.00**	**3.92**	0.52	−0.25	−0.02	−0.04	**1.71**	**1.98**	**0.34**	**0.90**
2000Q4	6.59	**3.93**	**3.86**	**0.61**	−0.17	0.14	0.18	**1.30**	**1.47**	**0.54**	**1.18**
2001Q1	5.26	**3.87**	**3.81**	**0.53**	−0.31	0.12	0.27	**1.40**	**0.69**	**−0.63**	**0.68**
2001Q2	4.10	**3.80**	**3.74**	**0.49**	−0.19	−0.36	0.04	**0.96**	0.21	**−0.72**	0.25
2001Q3	3.35	**3.73**	**3.67**	0.27	−0.21	**−0.87**	−0.24	−0.04	−0.64	0.29	**0.74**
2001Q4	2.06	**3.66**	**3.59**	−0.04	**−0.38**	**−0.56**	0.18	−0.40	**−1.76**	−0.53	0.38
2002Q1	1.83	**3.60**	**3.52**	−0.08	−0.13	−0.32	0.08	−0.30	**−1.08**	**−1.02**	**−0.62**
2002Q2	1.83	**3.52**	**3.44**	−0.15	0.14	−0.18	0.05	**−0.61**	**−1.50**	**−0.69**	−0.30
Euro area											
1995	7.00	**6.62**	**6.68**	**0.14**	0.08	0.15	0.04	**0.18**	0.23	−0.04	0.01
1996	5.29	**6.17**	**6.23**	**0.26**	**0.24**	−0.05	**−0.12**	**−0.54**	**−0.75**	**−0.41**	−0.06
1997	4.53	**5.73**	**5.78**	**0.23**	0.16	−0.12	−0.10	**−0.92**	**−1.07**	**−0.25**	0.02
1998	4.13	**5.28**	**5.33**	**−0.66**	**−0.46**	−0.15	0.01	−0.12	**−0.68**	−0.09	0.09
1999	3.11	**4.85**	**4.88**	**−0.66**	−0.35	**−0.33**	**−0.21**	**−0.28**	**−0.76**	**−0.39**	**−0.28**
2000	4.43	**4.39**	**4.43**	**0.53**	0.16	−0.23	−0.20	−0.03	0.12	−0.24	−0.05
2001	4.26	**3.96**	**3.99**	**0.35**	0.06	0.01	0.06	0.10	−0.01	**−0.19**	0.10
2000Q1	3.62	**4.56**	**4.60**	0.27	0.05	**−0.41**	**−0.32**	−0.16	−0.21	**−0.64**	**−0.34**
2000Q2	4.31	**4.45**	**4.49**	**0.47**	0.08	**−0.33**	−0.25	−0.05	0.07	−0.26	−0.01
2000Q3	4.78	**4.34**	**4.38**	**0.63**	**0.26**	−0.12	−0.15	0.00	0.23	−0.10	0.03
2000Q4	5.03	**4.22**	**4.27**	**0.73**	**0.29**	−0.08	−0.10	0.10	**0.43**	0.01	0.07
2001Q1	4.75	**4.12**	**4.16**	**0.63**	0.09	−0.14	−0.04	0.22	**0.43**	−0.13	0.03
2001Q2	4.59	**4.01**	**4.04**	**0.45**	0.07	0.03	0.08	**0.25**	**0.29**	−0.19	0.03
2001Q3	4.27	**3.90**	**3.93**	**0.30**	0.10	0.06	0.08	**0.13**	−0.03	−0.15	0.14
2001Q4	3.44	**3.78**	**3.82**	0.04	0.02	0.06	0.15	−0.19	**−0.75**	−0.25	**0.21**
2002Q1	3.36	**3.67**	**3.70**	−0.25	−0.01	**0.34**	**0.34**	−0.23	**−0.76**	−0.19	0.08
2002Q2	3.44	**3.56**	**3.60**	**−0.27**	0.03	**0.30**	0.27	−0.19	**−0.51**	0.01	0.09

(1) Traditional restrictions.
(2) Sign restrictions.
Median estimated values based on Monte Carlo Integration.
Bold figures are significant: median, upper and lower bands of estimates have the same sign.

significant influence between 1995 and 2002 with sign restrictions. There is only an upward effect in 1996 and a downward effect in 1998 in the Euro area which is significant. However, using traditional restrictions, interest rates were significantly higher between 1995 and 1997, significantly lower in 1998 and 1999, and again higher in 2000 and 2001 as a consequence of oil price shocks (Table III, column 4). Similar effects occurred in the USA.

Aggregate spending shocks had a substantive impact on monetary policy behaviour. In order to stabilize the effects of demand shocks, the Fed had to set the interest rate significantly above or below baseline, with peaks of +2.14% and +2.42% in 2000Q2 and troughs of −0.61% in

2002Q2 and −1.76% in 2001Q4 for conventional and sign restrictions, respectively. The impact on interest rate fluctuations was more moderate in the Euro area. Following a number of negative demand shocks, interest rates were significantly lower between 1996 and 1999, significantly higher at the end of 2000, and again significantly lower by the end of 2001 and the beginning of 2002.

Considering monetary policy shocks, differences are found between our two identification strategies. Monetary policy in the USA was rather stimulating until the beginning of 2000. The contribution of monetary policy shocks to the level of the interest rate was most of the time negative (Figure 5d and columns 10 and 11 in Table III), which reinforced the ongoing boom in the USA. This effect is more pronounced with sign restrictions. Conversely, monetary policy became very restrictive by the end of 2000. In 2000Q4, the interest rate was respectively 54 and 118 basis points above an average policy rule for our two alternative identification procedures. Assessing the stance of monetary policy in 2001, we find conflicting results between our two approaches. Monetary policy is estimated to have been expansionary with traditional restrictions and restrictive with sign conditions. On the other hand, both methods find again a relatively weak stance of monetary policy in the first two quarters of 2002. These findings about the stance of monetary policy in the USA are somewhat in contrast with the results of Uhlig (2001). He finds that the Fed monetary policy stance was relatively neutral in 2000 and 2001.[18]

In the Euro area, policy became stimulating in 1999, after the introduction of the Euro. European Central Bank interest rates were always below an average policy rule until the middle of 2000. From the middle of 2000 onwards, in contrast to the USA, monetary policy was always relatively neutral in the Euro area. We did find, however, a significant negative effect on output growth in 2001Q3 and Q4 using sign restrictions in Section 3.1. This is mainly the result of reversed effects of past stimulating shocks following long-run neutrality of monetary policy on the level of output.

4. CONCLUSIONS

In this paper, we have analysed the underlying sources of the early millennium slowdown using a simple four-variable VAR for the USA and the Euro area. Within this VAR, we identified four shocks, i.e. supply, demand, monetary policy and oil price shocks, based upon two different identification strategies. One is based on traditional zero contemporaneous and long-run constraints, and we proposed an alternative based on more recent sign restrictions. We find that the early millennium slowdown is caused by a combination of several shocks. Across both methodologies, we find an important role for negative aggregate spending shocks. In addition, there were negative aggregate supply shocks, negative effects of restrictive monetary policy in 2000, and a negative impact of oil price increases in 1999. The magnitude of the latter two is different between both approaches. We find an important role for oil price shocks with conventional restrictions and for monetary policy shocks using sign conditions. The effects of the shocks are more pronounced in the USA than the Euro area.

Our results also indicate that we should be careful in interpreting results based upon zero restrictions. Even if the impulse responses look similar, historical decompositions (or variance decompositions) could be different. Imposing zero constraints can have a significant influence

[18] This difference in the results might be due to the fact that Uhlig (2001) only identifies monetary policy shocks while we identify a full set of shocks.

on the identified shocks. We have provided evidence that ordering oil prices first in a recursive ordering of the variables to identify the shocks, i.e. a zero contemporaneous impact of all other shocks on oil prices, might be too stringent. With our alternative approach, oil price fluctuations do react substantially to demand and monetary policy shocks within 1 quarter. In addition, we also find evidence that restricting the immediate impact of monetary policy shocks to be zero can significantly underestimate the impact.

To do the analysis, we have only applied one particular traditional identification strategy which is commonly accepted and used in the literature. An interesting exercise, which is beyond the scope of this paper, would be to check the robustness of the results when alternative conventional and sign restrictions are used. Indeed, Farrant and Peersman (2003) and Peersman and Straub (2003) do show that there is also a remarkable difference between both approaches when respectively exchange rate shocks and technology shocks are identified.

ACKNOWLEDGEMENTS

The paper was written while the author was affiliated with the Bank of England. I thank the editors, two anonymous referees, Andrew Bailey, Fabio Canova, Freddy Heylen, Katharine Neiss, Gabriel Sterne, participants at the EEA annual conference in Venice, CEPR workshop in Madrid, Tinbergen conference in Rotterdam, ES summer meeting in Evanston, CEPR/ESI conference in Frankfurt and seminar participants at the Bank of England and European University Institute for comments on an earlier draft of the paper. In particular, I am very grateful to Fabio Canova for useful discussions and comments on the methodology.

REFERENCES

Bernanke B, Blinder A. 1992. The Federal Funds rate and the channels of monetary transmission. *American Economic Review* **82**: 901–921.
Blanchard O. 1993. Consumption and the recession of 1990–1991. *American Economic Review Papers and Proceedings* 270–274.
Blanchard O, Quah D. 1989. The dynamic effects of aggregate demand and supply disturbances. *American Economic Review* **79**: 655–673.
Canova F, De Nicoló G. 2002. Monetary disturbances matter for business fluctuations in the G-7. *Journal of Monetary Economics* **49**: 1131–1159.
Canova F, De Nicoló G. 2003. On the sources of business cycles in the G-7. *Journal of International Economics* **59**: 77–100.
Canova F, Pina J. 1999. Monetary policy misspecification in VAR models. CEPR Working Paper, 2333.
Christiano L, Eichenbaum M, Evans C. 1998. Monetary policy shocks: what have we learned and to what end. NBER Working Paper Series, 6400.
Farrant K, Peersman G. 2003. Is the exchange rate a shock absorber or source of shocks? New empirical evidence. Manuscript.
Faust J. 1998. The robustness of identified VAR conclusions about money. *Carnegie-Rochester Conference Series in Public Policy* **49**: 207–244.
Faust J, Leeper E. 1997. When do long-run identifying restrictions give reliable results? *Journal of Business and Economic Statistics* **15**(3): 345–353.
Gali J. 1992. How well does the IS–LM model fit postwar US data? *Quarterly Journal of Economics* 709–738.
Gerlach S, Smets F. 1995. The monetary transmission mechanism: evidence from the G7 countries. CEPR Discussion Paper, 1219.

Kieler M, Saarenheimo T. 1998. Differences in monetary policy transmission? A case not closed. European Commission Economic Papers, 132.
King R, Plosser C, Stock J, Watson M. 1991. Stochastic trends and economic fluctuations. *American Economic Review* **81**: 819–840.
Peersman G, Smets F. 2001. The monetary transmission mechanism in the Euro area: more evidence from VAR analysis. European Central Bank Working Paper Series, 91.
Peersman G, Straub R. 2003. Technology shocks and robust sign restrictions in a Euro area SVAR. Manuscript.
Shapiro M, Watson M. 1988. Sources of business cycles fluctuations. In *NBER Macroeconomics Annual*, pp. 111–148.
Sims C. 1980. Macroeconomics and reality. *Econometrica* **48**(1): 1–48.
Sims C. 1992. Interpreting the macro economic time series facts: the effects of monetary policy. *European Economic Review* **36**: 975–1011.
Sims C, Zha T. 1999. Error bands for impulse responses. *Econometrica* **67**(5): 1113–1155.
Uhlig H. 1999. What are the effects of monetary policy: results from an agnostic identification approach. Tilburg University Working Paper, 9928.
Uhlig H. 2001. Did the FED surprise the market in 2001? Tilburg University Center for Economic Research Discussion Paper, No. 2001–88.
Waggoner D, Zha T. 1997. Normalization, probability distribution, and impulse responses. Federal Reserve Bank of Atlanta Working Paper, 97–11.
Walsh C. 1993. What caused the 1990–1991 recession? *Federal Reserve Board of San Francisco Economic Review* **2**: 33–48.
Zellner A. 1971. *An Introduction to Bayesian Inference in Econometrics*. John Wiley and Sons: New York.

