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COMPARING SHOCKS AND FRICTIONS IN US AND EURO AREA BUSINESS CYCLES: A BAYESIAN DSGE APPROACH

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ABSTRACT

Comparing Shocks and Frictions in US and Euro Area Business Cycles: A Bayesian DSGE Approach*

This Paper estimates a DSGE model with many types of shocks and frictions for both the US and the euro area economy over a common sample period (1974-2002). The structural estimation methodology allows us to investigate whether differences in business cycle behaviour are due to differences in the type of shocks that affect the two economies, differences in the propagation mechanism of those shocks or differences in the way the central bank responds to those economic developments. Our main conclusion is that each of those characteristics is remarkably similar across both currency areas.

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1. Introduction

The creation of a single currency, the euro, in twelve of the fifteen countries of the European Union in January 1999 has greatly stimulated the analysis of aggregate macro-economic developments in the new currency area.[1] Obviously, because this aggregate analysis necessarily relies to a large extent on a sample period before the actual establishment of EMU, the conclusions that can be drawn from such an analysis should be treated with sufficient caution. However, one of the robust and somewhat surprising findings has been that in many cases the business cycle behaviour of aggregate euro area macro variables such as output, inflation and interest rates has been very similar to that observed in the United States, another large currency area. For example, Agresti and Mojon (2002) compare the cyclical time series properties of the main macro-economic time series and their comovement with output in the euro area with those in the United States following the methodology of Stock and Watson (2000). They find that the variances and cross-covariances show very similar patterns in both areas. Similarly, Peersman and Smets (2002) analyse the effects of monetary policy shocks in an identified Vector Autoregression for the euro area and show that the impulse responses are very similar to those found in the United States. A final example is the work by Gali and Gertler (1999) and Gali, Gertler and Lopez-Salido (2001) and Leigh and Malley (2002), who estimate structural New-Keynesian Phillips curves for the euro area and the US and find again that the estimated parameters, including the degree of price stickiness, is comparable in both areas.

Building on our previous work (Smets and Wouters, 2003a and b), this paper provides further evidence of the similarities and differences in the structural characteristics of the economy in the two largest currency areas in the world by estimating a fully specified dynamic stochastic general-equilibrium (DSGE) model for both areas over the same sample period. The model used is the one developed in Smets and Wouters (2003b). Following Christiano, Eichenbaum and Evans (2001), Altig, Christiano, Eichenbaum and Linde (2003) and Smets and Wouters (2003a), it features a relatively large number of shocks and frictions, which are designed to capture the time series properties of the main macro-economic data. The frictions include sticky nominal price and wage setting that allows for backward indexation, habit formation in consumption and adjustment costs in investment that create hump-shaped reaction profiles in aggregate demand, and variable capital utilisation and fixed costs in production that generate an elastic supply and smooth marginal cost responses to various structural shocks. The dynamics is driven by ten orthogonal shocks including productivity, labour supply, investment, preference, cost-push and monetary policy shocks. The DSGE model is estimated for the euro area and the United States separately with Bayesian econometric techniques and using seven key macro-economic data series: real GDP, consumption, investment, prices, real wages, employment and the nominal interest rate. The baseline estimation period is from 1974 till 2002. However, in order to investigate the stability of the results we also estimate the model over a shorter sample period from 1983 to 2002.

One advantage of our structural methodology over some of the approaches mentioned above is that we are able to directly compare both the structural parameters and the sources of business cycle

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[1] The main data set used for this analysis has been developed in Fagan et al (2000).

developments across the two currency areas. This allows us to investigate whether differences in business cycle behaviour are due to differences in the type of shocks that affect the economy, differences in the propagation mechanism of those shocks or differences in the way the central bank responds to those economic developments. Of course, the more structure is imposed on the estimated model, the more the results will be coloured by the selected theoretical specification. Therefore, it is important to have a theoretical structure that is not strongly rejected by the data. As shown in Smets and Wouters (2003a and b), the model that is used in this paper has a marginal likelihood that is comparable or greater than that of unconstrained or simple Bayesian VARs[2].

Our main conclusion is that it is indeed difficult to detect significant differences in either the structure of the economy or the sources of business cycle fluctuations across the two currency areas. Differences in actual business cycle developments are mainly due to similar types of shocks affecting the two economies at different times. Regarding the sources of business cycle fluctuations our main result is very similar to the one found in Shapiro and Watson (1989). While “demand” and monetary policy shocks play some role in the short run, it is mainly productivity and labour supply shocks that drive output developments at business cycle frequencies. This is true in both the euro area and the United States. Regarding the structure of the economy, we find that in both economies a substantial degree of nominal and real frictions are necessary to capture the dynamics of the main macro variables discussed above. We estimate considerable nominal rigidities in both goods and labour markets. If anything, we find that nominal wage rigidity is greater in the US than in the euro area. Also the real frictions such as the degree of habit persistence, the costs of adjustment in investment, variable capacity utilisation and fixed costs in production are estimated to be significant and comparable in size in the two areas. Finally, we find no evidence of significant differences in the way monetary authorities have responded to output and inflation developments. Short-term interest rates respond somewhat stronger and faster to changes in the output gap and inflation in the US, but they are more persistent in the euro area.

The rest of the paper is structured as follows. Section 2 describes the linearised version of the model that we estimate. For a description of the estimation methodology we refer to Smets and Wouters (2003a). We compare the parameter estimates and the sources of business cycle fluctuations in both currency areas in Sections 3 and 4 respectively. Section 5 discusses the propagation of some of the main structural shocks in both currency areas and Section 6 concludes the analysis by providing a short interpretation of the three boom and recession episodes in both areas. Finally, Section 7 contains the main conclusions.

2. The linearised DSGE model

In this Section, we describe the log-linearised DSGE model that we subsequently estimate using both euro area and US data. For a discussion of the micro-foundations of the model we refer to Smets and Wouters (2003b) The ^ above a variable denotes log deviations from steady state.

The dynamics of aggregate *consumption* is given by:

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[2] See Schorfheide (2000) for a discussion of the model evaluation methods based on the marginal likelihood concept within a Bayesian approach.

(1) $$\hat{C}_t = \frac{h}{1+h}\hat{C}_{t-1} + \frac{1}{1+h}E_t\hat{C}_{t+1} + \frac{(\sigma_c - 1)}{\sigma_c(1+\lambda_w)(1+h)}(\hat{l}_t - \hat{l}_{t+1}) - \frac{1-h}{(1+h)\sigma_c}(\hat{R}_t - E_t\hat{\pi}_{t+1}) + \frac{1-h}{(1+h)\sigma_c}(\hat{\varepsilon}_t^b)$$

Consumption $\hat{C}_t$ depends on the ex-ante real interest rate $(\hat{R}_t - E_t\hat{\pi}_{t+1})$ and, with external habit formation, on a weighted average of past and expected future consumption. When $h = 0$, only the traditional forward-looking term is maintained. In addition, due to the non-separability of the utility function , consumption will also depend on expected employment growth $(\hat{l}_{t+1} - \hat{l}_t)$. When the elasticity of intertemporal substitution (for constant labour) is smaller than one $(\sigma_c > 1)$, consumption and labour supply are complements. Finally, $\hat{\varepsilon}_t^b$ represents a preference shock affecting the discount rate that determines the intertemporal substitution decisions of households. This shock is assumed to follow a first-order autoregressive process with an IID-Normal error term: $\varepsilon_t^b = \rho_b \varepsilon_{t-1}^b + \eta_t^b$.

The *investment equation* is given by:

(2) $$\hat{I}_t = \frac{1}{1+\beta}\hat{I}_{t-1} + \frac{\beta}{1+\beta}E_t\hat{I}_{t+1} + \frac{1/\varphi}{1+\beta}\hat{Q}_t + \hat{\varepsilon}_t^I$$

where $\varphi = \overline{S}''$ depends on the adjustment cost function (S) and β is the discount factor applied by the households. As discussed in CEE (2001), modelling the capital adjustment costs as a function of the change in investment rather than its level introduces additional dynamics in the investment equation, which is useful in capturing the hump-shaped response of investment to various shocks including monetary policy shocks. A positive shock to the investment-specific technology, $\hat{\varepsilon}_t^I$, increases investment in the same way as an increase in the value of the existing capital stock $\hat{Q}_t$. This investment shock is also assumed to follow a first-order autoregressive process with an IID-Normal error term: $\varepsilon_t^I = \rho_I \varepsilon_{t-1}^I + \eta_t^I$

The corresponding *Q equation* is given by:

(3) $$\hat{Q}_t = -(\hat{R}_t - \hat{\pi}_{t+1}) + \frac{1-\tau}{1-\tau+\bar{r}^k}E_t\,\hat{Q}_{t+1} + \frac{\bar{r}^k}{1-\tau+\bar{r}^k}E_t\,\hat{r}_{t+1}^k + \eta_t^Q$$

where τ stands for the depreciation rate and $\bar{r}^k$ for the rental rate of capital so that $\beta = 1/(1-\tau+\bar{r}^k)$. The current value of the capital stock depends negatively on the ex-ante real interest rate, and positively on its expected future value and the expected rental rate. The introduction of a shock to the required rate of return on equity investment, η_t^Q, is meant as a shortcut to capture changes in the cost of capital that may be due to stochastic variations in the external finance premium.[3] We assume that this equity premium shock follows an IID-Normal process. In a fully-fledged model, the production of capital goods and the associated investment process could be modelled in a separate sector. In such a case, imperfect information between the capital producing borrowers and the financial intermediaries could give rise to a stochastic external finance premium. For example, in Bernanke, Gertler and Gilchrist (1998), the

[3] This is the only shock that is not directly related to the structure of the economy.

deviation from the perfect capital market assumptions generates deviations between the return on financial assets and equity that are related to the net worth position of the firms in their model. Here, we implicitly assume that the deviation between the two returns can be captured by a stochastic shock, whereas the steady-state distortion due to such informational frictions is zero.[4]

The *capital accumulation equation* becomes a function not only of the flow of investment but also of the relative efficiency of these investment expenditures as captured by the investment-specific technology shock:

(4) $$\hat{K}_t = (1-\tau)\hat{K}_{t-1} + \tau\hat{I}_{t-1} + \tau\,\hat{\varepsilon}^I_{t-1}$$

With partial indexation to lagged inflation, the *inflation equation* becomes a more general specification of the standard new-Keynesian Phillips curve:

(5) $$\hat{\pi}_t - \overline{\pi}_t = \frac{\beta}{1+\beta\gamma_p}(E_t\hat{\pi}_{t+1} - \overline{\pi}_t) + \frac{\gamma_p}{1+\beta\gamma_p}(\hat{\pi}_{t-1} - \overline{\pi}_t) + \frac{1}{1+\beta\gamma_p}\frac{(1-\beta\xi_p)(1-\xi_p)}{\xi_p}\left[\alpha\hat{r}^k_t + (1-\alpha)\hat{w}_t - \hat{\varepsilon}^a_t - (1-\alpha)\gamma t\right] + \eta^p_t$$

The deviation of inflation $\hat{\pi}_t$ from the target inflation rate $\overline{\pi}_t$ depends on past and expected future inflation deviations and on the current marginal cost, which itself is a function of the rental rate on capital, the real wage $\hat{w}_t$ and the productivity process, that is composed of a deterministic trend in labour efficiency γ and a stochastic component ε^a_t, which is assumed to follow a first-order autoregressive process: $\varepsilon^a_t = \rho_a\varepsilon^a_{t-1} + \eta^a_t$. η^p_t is a IID-Normal price mark-up shock. When the degree of indexation to past inflation is zero ($\gamma_p = 0$), this equation reverts to the standard purely forward-looking Phillips curve. By assuming that all prices are still indexed to the inflation objective in that case, this Phillips curve will be vertical. Announcements of changes in the inflation objective will be completely neutral even in the short run. This is based on the strong assumptions that indexation habits will adjust immediately to the new inflation objective. With $\gamma_p > 0$, the degree of indexation to lagged inflation determines how backward looking the inflation process is or, in other words, how much exogenous persistence there is in the inflation process. The elasticity of inflation with respect to changes in the marginal cost depends mainly on the degree of price stickiness. When all prices are flexible ($\xi_p = 0$) and the price-mark-up shock is zero, this equation reduces to the normal condition that in a flexible price economy the real marginal cost should equal one.

Similarly, the indexation of nominal wages results in the following real wage equation:

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[4] For alternative interpretations of this equity premium shock and an analysis of optimal monetary policy in the presence of such shocks, see Dupor (2001).

(6)
$$\hat{w}_t = \frac{\beta}{1+\beta}E_t\hat{w}_{t+1} + \frac{1}{1+\beta}\hat{w}_{t-1} + \frac{\beta}{1+\beta}(E_t\hat{\pi}_{t+1} - \overline{\pi}_t) - \frac{1+\beta\gamma_w}{1+\beta}(\hat{\pi}_t - \overline{\pi}_t) + \frac{\gamma_w}{1+\beta}(\hat{\pi}_{t-1} - \overline{\pi}_t)$$
$$- \frac{1}{1+\beta}\frac{(1-\beta\xi_w)(1-\xi_w)}{(1+\frac{(1+\lambda_w)\sigma_L}{\lambda_w})\xi_w}\left[\hat{w}_t - \sigma_L\hat{L}_t - \frac{1}{1-h}(\hat{C}_t - h\hat{C}_{t-1}) + \hat{\varepsilon}_t^L\right] + \eta_t^w$$

The real wage $\hat{w}_t$ is a function of expected and past real wages and the expected, current and past inflation rate where the relative weight depends on the degree of indexation γ_w to lagged inflation of the non-optimised wages. When $\gamma_w = 0$, real wages do not depend on the lagged inflation rate. There is a negative effect of the deviation of the actual real wage from the wage that would prevail in a flexible labour market. The size of this effect will be greater, the smaller the degree of wage stickiness (ξ_w), the lower the demand elasticity for labour (higher mark-up λ_w) and the lower the inverse elasticity of labour supply (σ_l) or the flatter the labour supply curve. ε_t^L is a preference shock representing a shock to the labour supply and is assumed to follow a first-order autoregressive process with an IID-Normal error term: $\varepsilon_t^L = \rho_L\varepsilon_{t-1}^L + \eta_t^L$. In contrast, η_t^w is assumed to be an IID-Normal wage mark-up shock.

The equalisation of marginal cost implies that, for a given installed capital stock, *labour demand* depends negatively on the real wage (with a unit elasticity) and positively on the rental rate of capital:

(7) $$\hat{L}_t = -\hat{w}_t + (1+\psi)\hat{r}_t^k + \hat{K}_{t-1}$$

where $\psi = \frac{\psi'(1)}{\psi''(1)}$ is the inverse of the elasticity of the capital utilisation cost function.

The *goods market equilibrium condition* can be written as:

(8)
$$\hat{Y}_t = (1-\tau k_y - g_y)\hat{C}_t + \tau k_y\hat{I}_t + g_y\varepsilon_t^G$$
$$= \phi\hat{\varepsilon}_t^a + \phi\alpha\hat{K}_{t-1} + \phi\alpha\psi\hat{r}_t^k + \phi(1-\alpha)(\hat{L}_t + \gamma t) - (\phi-1)\gamma t$$

where k_y is the steady state capital-output ratio, g_y the steady-state government spending-output ratio and ϕ is one plus the share of the fixed cost in production. We assume that the government spending shock follows a first-order autoregressive process with an IID-Normal error term: $\varepsilon_t^G = \rho_G\varepsilon_{t-1}^G + \eta_t^G$.

Finally, the model is closed by adding the following empirical monetary policy reaction function:

(9)
$$\hat{R}_t = \overline{\pi}_t + \rho(\hat{R}_{t-1} - \overline{\pi}_{t-1}) + (1-\rho)\{r_\pi(\hat{\pi}_{t-1} - \overline{\pi}_{t-1}) + r_Y(\hat{Y}_{t-1} - \hat{Y}_{t-1}^p)\} +$$
$$r_{\Delta\pi}\left[(\hat{\pi}_t - \overline{\pi}_t) - (\hat{\pi}_{t-1} - \overline{\pi}_{t-1})\right] + r_{\Delta y}\left[(\hat{Y}_t - \hat{Y}_t^p) - (\hat{Y}_{t-1} - \hat{Y}_{t-1}^p)\right] + \eta_t^R$$

The monetary authorities follow a generalised Taylor rule by gradually responding to deviations of lagged inflation from an inflation objective and the lagged output gap defined as the difference between actual and potential output (Taylor, 1993). Consistently with the DSGE model, potential output is defined as the level of output that would prevail under flexible price and wages in the absence of the three "cost-push" shocks.[5] The parameter ρ captures the degree of interest rate smoothing. In addition, there is also a

[5] In practical terms, we expand the model consisting of equations (2) to (9) with a flexible-price-and-wage version in order to calculate the model-consistent output gap.

short-run feedback from the current changes in inflation and the output gap. Finally, we assume that there are two monetary policy shocks: one is a temporary IID-Normal interest rate shock (η_t^R) also denoted a monetary policy shock; the other is a permanent shock to the inflation objective ($\bar{\pi}_t$) which is assumed to follow a non-stationary process ($\bar{\pi}_t = \bar{\pi}_{t-1} + \eta_t^{\pi}$). The dynamic specification of the reaction function is such that changes in the inflation objective are immediately and without cost reflected in actual inflation and the interest rate if there is no exogenous persistence in the inflation process. In the empirical exercise, we assume that this policy rule together with the process for the stochastic shocks is able to describe the behaviour of monetary authorities over the sample period. Especially for the euro area this is a strong assumption because there was no unified monetary policy during most of the period under investigation. But even for the US, the hypothesis of a stable monetary policy rule over the sample period is frequently rejected in the literature and should be tested empirically. However, the presence of two types of monetary policy shocks distinguishes our exercise from many other studies on this topic.

Equations (1) to (9) determine the nine endogenous variables: $\hat{\pi}_t$, $\hat{w}_t$, $\hat{K}_{t-1}$, $\hat{Q}_t$, $\hat{I}_t$, $\hat{C}_t$, $\hat{R}_t$, $\hat{r}_t^k$, $\hat{L}_t$ of our model. The stochastic behaviour of the system of linear rational expectations equations is driven by ten exogenous shock variables: five shocks arising from technology and preferences (ε_t^a, ε_t^I, ε_t^b, ε_t^L, ε_t^G) which are assumed to follow an AR(1) process, three "cost-push" shocks (η_t^w, η_t^p and η_t^Q) which are assumed to follow a white-noise process and two monetary policy shocks ($\bar{\pi}_t$ and η_t^R).

3. Comparing the parameter estimates

We estimate equations (1) to (9) for the US and the euro area separately using seven key macro-economic time series: output, consumption, investment, hours worked, real wages, prices and a short-term interest rate. The Bayesian estimation methodology is extensively discussed in Smets and Wouters (2003a).

3.1 The prior distribution of the parameters

The Bayesian estimation methodology requires the specification of prior distributions over the 32 structural parameters of the log-linear DSGE model. The first set of columns in Table 1 summarises those prior distributions. We assumed the same prior for both countries and for both periods for which the model is estimated. The priors on the standard error and the persistence of the exogenous stochastic processes are harmonised as much as possible. The standard errors of the innovations are assumed to follow an Inverse-Gamma distribution with a mean of 0.25 (0.05 for the permanent inflation objective shock) and two degrees of freedom corresponding to a rather loose prior. The persistence parameters of the AR(1) processes are assumed to follow a Beta distribution with mean of 0.85 and standard deviation of 0.1. The three mark-up shocks to prices, wages and equity prices are assumed to be IID white noise processes. The deterministic growth rate in technology is assumed to be Normal-distributed with mean 0.4 (quarterly growth rate) and standard deviation 0.1.

Five parameters are restricted to a point value prior to the estimation process. The discount rate is set at 0.99, the depreciation rate is set at 0.025 (both on a quarterly basis). For the US, the share of consumption and investment are set at 0.65 and 0.17 and the capital income share in the Cobb Douglas production function is fixed at 0.24. For the euro area, the consumption and investment shares are respectively 0.6 and 0.22 and the production parameter is 0.3. These values are in line with historical averages for the series used and guarantee a steady state growth path. These parameters are hard to estimate unless the means of the time series are taken into account in the estimation process.

The parameters describing the monetary policy rule are based on a standard Taylor rule: the long run reaction coefficient to inflation and the output-gap are described by a Normal distribution with mean 1.5 and 0.125 (corresponding to 0.5 for annual rates) and standard errors 0.1 and 0.05. The persistence of the policy rule, determined by the coefficient on the lagged interest rate, is assumed to be Normal distributed around 0.75 with a standard error of 0.1. The prior on the short run reaction coefficients to inflation and output-gap changes reflect the assumptions of a gradual adjustment towards the long run.

The parameters of the utility function are distributed as follows. The prior on the intertemporal substitution elasticity is set at 1 (with a standard error 0.375), the habit parameter is assumed to fluctuate around 0.7 (with a standard error of 0.1) and the wage elasticity of labour supply is assumed to be around 2 (with a standard error of 0.75). The prior on the adjustment cost parameter for investment is set around 4 with standard error 2 (based on CEE 2001) and the capacity utilisation elasticity is set at 0.2 (standard error 0.1 including the 0.1 of King and Rebelo, 2000). The share of fixed costs in the production function is assumed to be distributed around 0.25 (the corresponding parameter is defined as 1.25). All these priors are described by a Normal distribution, with the exception of the habit persistence parameter, which follows a Beta distribution because it is restricted between 0 and 1.

Finally there are the parameters describing the price and wage setting. The Calvo probability is assumed to be around 0.75 for both prices and wages, corresponding to a one-year average contract length. The degree of indexation on past inflation is set at 0.75, which corresponds to a significant coefficient (0.43) on the lagged inflation terms in the linearised inflation and wage equations.

3.2 The posterior distribution of the parameters

The second and third sets of columns in Table 1 report the results of the posterior sampling. More specifically, they report the median and the 5 and 95 percentile of the estimated posterior distribution of the parameters for both the US and euro area model, estimated over two common sample periods.[6] The baseline model is estimated over the longer period from 1974:1 to 2002:2. This sample period is given by the sample size of the euro area data set. In order to increase the comparability of the US and euro area results, we also limited the US sample to the same period. In order to examine the stability of the results, Table 1 also reports the estimation results for a shorter period from 1983:1 to 2002:2. It has been argued that particularly in the United States there has been a break in the time series properties and particularly in their volatility in the early 1980s.[7] Part of this break may be related to a change in monetary policy

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[6] The posterior distribution reported in Table 1 has been generated by the Metropolis Hastings sampler (see Geweke, 1999). Time considerations restricted the sampling to 50000 draws for this exercise. Statistical tests indicate that the sampling has not completely converged. The resulting median of the distribution is very close to the estimated mode of the parameters. As this estimate does not rely on the MH sampler, we are quite confident that the main results will not be much affected by further increasing the sample.

[7] See, for example, Perez-Quiros and McConnel (2000), Stock and Watson (2002).

behaviour as, for example, argued in Clarida, Gali and Gertler (1998). Regarding the euro area, it may be argued that the convergence process to a common monetary policy only seriously started in the mid-1980s. Also in this case, it is therefore of interest to analyse to what extent the results over the longer sample period are robust with respect to the more recent period. In what follows, we will focus on the results of the longer period and comment on any important differences with the results for the shorter sample.

The overall finding of comparing the parameters across the two regions is that they are remarkably similar. As discussed in the introduction, this may not be very surprising given the recent findings of Agresti and Mojon (2002) and Peersman and Smets (2002). The finding of broad similarity across the two regions applies to both the estimated stochastic driving processes, the behavioural parameters and the policy rule. Nevertheless, there are also some interesting differences. Turning first to the estimated stochastic processes for the structural shocks, it appears that the variances of the "demand" shocks are typically significantly larger in the US than in the euro area. This is most striking for the preference shock which is almost four times as variable in the US (1.26) than in the euro area (0.31). However, the persistence of those shocks is typically lower, so that the difference in the unconditional variance of the shock variables is less striking. For example, the autoregressive parameter in the preference shock is only 0.56 in the US compared to 0.86 in the euro area. Of the three demand shocks, the government spending process is estimated to be the most persistent in both areas. Also the monetary policy shock has a larger variance in the US than in the euro area. Overall, the larger variability of the demand and monetary policy shocks becomes less striking in the shorter and more recent sample period. For example, the median standard deviation of the monetary policy shocks falls in the United States from 0.24 to 0.13, which is much closer to the relatively stable estimate of about 0.12 in the euro area. The fall in the variability of the non-systematic component of monetary policy is consistent with the findings of Boivin and Giannoni (2003), who conclude that changes in both systematic and non-systematic monetary policy have contributed to the lower variability of the US economy in the most recent period.

Regarding the other shock processes, it turns out that the variability of the productivity shock is somewhat higher in the euro area than in the United States. Compared to other estimates, the estimated standard error of the productivity shock is on the low side, but this is partly due to the introduction of variable capital utilisation as, for example, argued in King and Rebelo (2000). In both cases, the productivity process is estimated to be very persistent and close to a unit root, in particular over the whole sample period. The linear trend in productivity is estimated to be somewhat higher in the US economy (1.16 annualised) than in the euro area (0.88). Finally, the variances of the other shocks (in particular the "cost-push" shocks and the labour supply shock) do not appear to be significantly different. It is also worth noting that the innovations in the non-stationary inflation objective shock have a small, though significant standard error. When comparing those estimates with those in the more recent sample, one striking difference is the fall in the variance and the persistence of the labour supply shocks in the US.

Turning to the behavioural parameters the overall picture of similarity between both economies is confirmed. A rough measure of this similarity is that in almost all cases the median estimate of a parameter in one region falls in the estimated confidence band for the same parameter of the other region.

There are only two exceptions. Somewhat surprisingly, the Calvo parameter for wage stickiness appears to be signficantly larger in the US than in the euro area, when estimated over the whole sample period. Similarly, the indexation parameter of prices, which captures the degree of inflation persistence, is estimated to be higher in the United States than in the euro area. To the extent that in particular the former parameter is thought to capture structural rigidities in labour markets, this finding does not conform to the common wisdom that labour markets are more flexible in the United States. The average length of wage contracts is estimated to be around 5 quarters in the US, while it is close to three quarters in the euro area. Consistent with our previous findings for the euro area (Smets and Wouters, 2003a,b), we find that the Calvo parameter for price stickiness is relatively high in both the euro area and the US. This is in contrast to the results reported by Christiano, Eichenbaum and Evans (2001) and ACEL (2002), finding that the estimated degree of price stickiness in the US is relatively small and economically unimportant.[8] Our results are more in line with the findings of Gali and Gertler (1999) and Gali, Gertler and Lopez-Salido (2001). The finding that in both areas the average contract length is higher in the goods market than in the labour market is at first sight surprising. However, as discussed in Smets and Wouters (2003b) this is partly the result of our assumption that the marginal cost curve that firms face in the goods market is flat, while it is upward-sloping in the labour market. As discussed in Woodford (2003), the latter assumption creates a strategic complementarity between wage setters, which will tend to reduce the sensitivity of wages to its fundamental determinants for a given Calvo parameter. This strategic complementarity is absent in the price setting context because it is assumed that production factors move freely between individual firms so that all firms produce with the same capital/labour technology and all firms face the same marginal cost independent of the production level. As a result, a similar Calvo stickiness parameters in the wage setting process compared to the price setting problem implies a much slower response of wages to the fundamental driving forces as it is the case for prices. Comparing the estimates of those parameters with those for the shorter sample, a striking finding is that the degree of nominal wage stickiness increases quite dramatically both in terms of the Calvo parameter (around 0.9 in both areas) and in terms of the indexation parameter. As a result real wages become very sticky in the most recent period. One explanation may be that because of the more stable monetary environment since the mid eighties nominal wage contracts are set for longer periods. This interpretation is consistent with the fact that the estimated stickiness moves in the two economies in the same direction.[9] Overall, given the simple structure of the labour market model, these results should be taken with a grain of salt.

Regarding the other behavioural parameters, the estimates are in the same ballpark as our previous estimates (Smets and Wouters, 2003a,b) and broadly conform to the findings in the literature. The investment adjustment cost parameter is estimated around 6, which implies a gradual and persistent response of investment to the different shocks. The inverse of the intertemporal substitution parameter in the utility function is estimated around 1.5 for both countries. The habit parameter (around 0.60 for the

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8 Our conjecture is that the finding of limited price rigidity is partly a result of the different methodology used in CEE (2001).

9 Another possibility is that in the shorter sample, it becomes harder to distinguish between persistent labour supply shocks with a relatively low degree of wage stickiness and temporary wage mark-up shocks with a relatively high degree of wage stickiness. That some of this might be going on is suggested by the fact that in the latter period the variance of the labour supply shocks falls dramatically in favour of the temporary wage mark-up shocks.

euro area and 0.67 for the US) is estimated to be relatively on the low side compared to, for example, the estimates provided in Fuhrer (2000). The labour supply parameter in the utility functions is around 2.2, the share of fixed costs around 0.5 and the capital utilisation cost parameter is estimated around 0.3. Overall, these results appear to be robust in the shorter estimation period.

Finally, the estimated policy rules are also very similar in both economies. The long-run response to inflation is estimated around 1.5, while the long-run response to the output gap is somewhat smaller than suggested by Taylor (1993) at 0.25. The interest rate persistence is somewhat higher in the euro area, whereas the short-run response to changes in inflation and output is greater in the US. From Table 1, there does not appear to be any strong evidence that the Fed has become more reactive to inflation and output developments in the more recent period. This finding is in contrast to results in the literature which point to instability in the monetary policy rule before and after the late seventies (e.g. Clarida, Gali and Gertler, 1999). Our specification deviates, however, from most other studies in that we allow for two types of monetary policy shocks: a temporary interest rate shock and a permanent inflation objective shock. As discussed below, the inflation objective shock takes up most of the long-term trend behaviour in inflation. Our results suggest that around this non-stationary inflation objective, the short run dynamics of monetary policy does not seem to have changed much over time.

Overall, the main conclusions from the results presented in Table 1 are twofold. First, there is no strong evidence that the structure of the US and euro area economies are significantly different. Second, there is no strong evidence that this structure has significantly changed over time. If anything, the variances of the stochastic processes (in particular of the demand shocks) have fallen in the most recent period.

4. Comparing sources of business cycle fluctuations in the US and the euro area

The analysis of the previous Section suggests that the sources of business cycle movements will be broadly similar in both areas. Graphs 1 to 4 confirm this finding based on a comparison of the variance decomposition of the main macro-economic variables in both areas. The graphs report the variance decomposition of the forecast errors of output, inflation, wages and the short-term interest rate for 1, 4, 10 and 30 quarters ahead.[10]

Focusing first on the sources of output fluctuations, it is clear that in the short run (up to one year) output developments are mainly driven by “demand” shocks, in particular the government spending and preference shocks, and to a lesser extent by the monetary policy shock. In agreement with the larger variances of those shocks in the US compared to the euro area, those shocks are relatively more important in driving short-term developments in the US than in the euro area. At the one-year horizon those three shocks still account for 45% of output fluctuations in the US, while they account for 28% in the euro area.

[10] More detailed tables of the variance decomposition, including the bounds around the median and the decomposition for the shorter sample estimation outcomes, are summarised in an appendix available upon request from the authors.

However, over the medium to long run, the contribution of the three “supply” shocks (i.e. the productivity, labour supply and the investment-specific technology shock) to output developments increases quite dramatically, while the contribution of the other shocks falls. At the 10 quarter horizon, the productivity and labour supply shocks account for 71% and 52% of output fluctuations in the euro area and the US respectively. This rises to 87 and 74% respectively at the 8 year horizon. Both shocks are about equally important. In contrast to a recent VAR analysis by Fischer (2002), the investment specific technology shock accounts for a significant, but much less important fraction of output developments at the medium to long run horizon. Overall, the relative contribution of productivity and labour supply shocks does conform to the analysis of Shapiro and Watson (1989), who use an identified VAR methodology for the US. In the medium to long run, the contribution of the other shocks (including monetary policy shocks) is rather limited. The productivity shock is also one of the main medium to long run determinants of real wages and consumption and investment. In this respect, the labour supply shock contributes relatively less to long-run movements in investment as capital is substituted for labour, whereas the investment-specific technology shock explains the relatively more of long-term movements in investment (in particular in the US).

Turning to price and wage developments (Graph 2 and 3), it is clear that the price and wage mark-up shocks are by far the most important driving forces behind short to medium-term fluctuations in both areas. However, in the long run the nominal trends in prices and interest rates are mainly driven by the inflation objective shock. It is quite striking that neither of these shocks contributes to the output developments. The limited output cost of changes in the inflation objective shock is a result of the assumption that disinflations are assumed to be perfectly perceived by the agents in the economy. A more realistic assumption would be to assume asymmetric information regarding the inflation objective as, for example, in Erceg and Levin (2001).

Finally, turning to the determinants of interest rate fluctuations (Graph 4), it is clear that in the short to medium run those are mostly driven by the demand shocks, in particular the preference shock, and the temporary monetary policy shock. As mentioned before, in the longer run also the inflation objective shock becomes an importance source of fluctuations. At the 10 quarter horizon, about 65% of interest rate fluctuations in the US and 43% of interest rate fluctuations in the euro area are driven by fundamental shocks, the rest being the results of unsystematic monetary policy.

5. Propagation of shocks in the euro area and the US

Yet another way of comparing the estimation results for the euro area and the US is to look at the impulse response functions. Graph 5 focuses on one example of each of the four types of shocks considered: a “supply” shock (productivity), a “demand” shock (preference), a “cost-push” shock (price mark-up) and a monetary policy shock (temporary interest rate shock). Overall, the similarity of the findings in both areas is again striking.

As discussed in Smets and Wouters (2003a,b), the qualitative features of the responses to a productivity shock and a monetary policy shock are very much in line with those obtained using different methodologies such as identified VARs (see, for example, Gali (1999), Francis and Ramey (2002) and

ACEL (2002) for a productivity shock and CEL (2001) and Peersman and Smets (2002) for a monetary policy shock). A robust feature of the response to a positive productivity shock in both areas is that employment falls. As in Francis and Ramey (2002), this is mostly due to the sluggish response of the demand components due to habit formation and investment adjustment costs. The deflationary effect of a positive productivity shock appears somewhat larger in the US compared to the euro area.

Turning to the preference shock, it is clear that in both regions a positive preference shock on consumption and output leads to some inflationary pressures and a partial crowding out of investment. This crowding out is, however, much less important in the US and this in spite of a larger short-term interest rate response and a higher investment interest rate elasticity. One of the factors explaining this may be the much higher persistence of the interest rate response in the euro area.

In line with the larger estimated wage stickiness in the US, real wages respond more sluggishly to the various shocks in the US than in the euro area. This is also reflected in a more persistent response of inflation to most of the shocks. For example, while, following a monetary policy shock, inflation reaches its trough after 4 quarters in the euro area, the trough is reached only after 6 quarters in the US. The higher price and wage stickiness in the US also explains why the output cost of a temporary mark-up shock is significantly larger in the US compared to the euro area.

6. Historical decomposition of the business cycles

Overall, our main finding is that the sources of the shocks, the frictions and the policy reaction functions appear to be very similar in the two economies. However, the actual macro-economic developments were at times quite different. This can partially be explained by the different timing of the shocks in the two countries. One indication of this asynchronicity is the low correlation between the structural shocks in the euro area and the US as shown in Table 3. In general, the correlation is close to zero. Two exceptions are the preference shocks and the monetary policy shocks.

In order to get a better idea of what has driven particular business cycle developments, Table 2 summarises some of the information by focusing on the contributions of the various shocks to the three main boom and recession periods in both areas.

A first interesting exercise is to compare the determinants of the output boom in the second half of the 1990s and the subsequent slowdown (last set of columns in Table 2). In the US, there does not seem to be any particular shock that has driven most of the output boom in that period. Positive contributions of about the same size came from the three supply shocks, the preference shock, relatively loose monetary policy and a positive wage mark-up shock. This analysis therefore suggests that a combination of factors was responsible for the good growth performance in the second half of the 1990s, not only favourable productivity growth. In contrast, in the euro area most of the output boom can be explained by a positive labour supply shock. Also preference, productivity and monetary policy shocks had a positive, though much more limited contribution, but the investment shock had a significant negative effect. Turning to the subsequent downturn, it appears that in the US the downturn is mostly driven by a negative preference and investment shock, while productivity developments continued to provide a positive contribution. In contrast in the euro area, productivity fell significantly only to be counteracted by a rise in the labour supply.

The strong growth expansion in the second half of the 1980s seems to have been mainly supported by a rise in the labour supply in both areas. In the euro area, this was backed up by positive developments in productivity and investment, while the opposite occurred in the US. In both areas the subsequent recession was mainly due to negative preference and investment shocks, very much like in the current downturn.

The role of monetary policy shocks in driving output booms and busts is quite limited. One exception is the recession of the early 1980s. In both areas, the monetary policy shocks were the most important source of the downturn in output in this period.

Turning to the behaviour of inflation during those boom and recession periods, it is clear from the lower row in Table 2 that in each recession period inflation falls. Consistently, with the analysis of output developments in those periods, negative preference and investment shocks are important contributors. In the euro area, there was also a major disinflation in the boom periods of 1982-1992 and 1995-2000. This disinflation is completely explained by a fall in the inflation objective.

7. Conclusions

In this paper we have estimated a DSGE model with many types of shocks and real and nominal frictions for both the US and the euro area economy over a common sample period (1974-2002). The structural estimation methodology allows us to investigate whether differences in business cycle behaviour in the two economic areas are due to differences in the type of shocks that affect the two economies, differences in the propagation mechanism of those shocks or differences in the way the central bank responds to those economic developments. Our main conclusion is that each of those characteristics is remarkably similar across both currency areas. Moreover, the identified sources of business cycle fluctuations and the estimated effects of the various shocks on the two economies conform to the empirical results obtained using identified VARs.

Of course, the comparison using empirical DSGE models performed in this paper is only a starting point. There are at least two interesting avenues for future research, which will also serve to examine the robustness of our results. First, we need to look at alternative models with different and richer goods, labour and financial market structures. Imposing a relatively simple, identical structure in each of the two economies may bias the results against finding significant differences. Second, we have treated each of the two economies as two separate closed economies. Given the limited importance of bilateral trade between the two areas, this may be a reasonable first approximation. Recent experience has, however, suggests that the linkages between the two blocs are stronger than may have been expected on the basis of trade links only. Linking the two economies in a well-specified two-country model will allow us to examine those transmission channels and their effects on the estimated parameters of the model.

Data appendix

For the US, consumption, investment and GDP are taken from the US Department of Commerce - Bureau of Economic Analysis databank. Real Gross Domestic Product is expressed in Billions of Chained 1996 Dollars. Nominal Personal Consumption Expenditures and Fixed Private Domestic Investment are deflated with the GDP-deflator.[11] Inflation is the first difference of the log Implicit Price Deflator of the GDP series.

Hours and wages are taken from the Bureau of Labour Statistics (hours and hourly compensation for the NFB sector for all persons). Hourly compensation is divided by the GDP price deflator to get the real wage variable. Hours are adjusted to take into account the limited coverage of the NFB sector compared to GDP. The index of average hours for the NFB sector is multiplied with civilian employment (16 years and over). The aggregate real variables are expressed per capita by dividing with the population over 16. All series are seasonally adjusted. The interest rate is the Federal Funds Rate.

For the euro area, all data are taken from the AWM database from the ECB (see Fagan et al, 2000). Investment includes both private and public investment expenditures. Real variables are deflated with their own deflator. Inflation is calculated as the first difference of the log GDP deflator. In the absence of data on hours worked, we use total employment data for the euro area. As explained in Smets and Wouters (2003a), we therefore use for the euro area model an auxiliary observation equation linking labour services in the model and observed employment based on a Calvo mechanism for the hiring decision of firms. The series are updated for the most recent period using growth rates for the corresponding series published in the Monthly Bulletin of the ECB.

Consumption, investment, GDP, wages and hours/employment are expressed in 100xlog. The interest rate and inflation rate are expressed on a quarterly basis corresponding with their appearance in the model (in the graphs the series are translated on an annual basis).

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[11] We follow Altig, Christiano, Eichenbaum and Linde (2002) here. This approach avoids the positive trend in the investment share of output that results from the decline in the relative investment expenditures deflator. A fully specified model would start from a two-sector model allowing for a separate trend in technological progress in the investment good sector. In such a two-sector model, the relative price of investment and consumption goods can be used to identify the investment specific technological progress. In our one sector model, it was difficult to identify a separate deterministic trend in investment specific technology. However, there are significant short run shocks around this trend that influence investment in the short and medium run.

References

Agresti, A.-M. and B. Mojon (2001), "Some stylised facts on the euro area business cycle", ECB Working Paper Series, no. 95, Dec. 2001.

Altig D., Christiano L.J., Eichenbaum M. and Jesper Linde (2002), “Technology Shocks and Aggregate Fluctuations”, Preliminary version.

Bernanke, B., Gertler, M. and S. Gilchrist (1998), “The financial accelerator in a quantitative business cycle framework”, NBER Working Paper Series No. 6455.

Boivin, J. and M.P. Giannoni (2002), "Has Monetary Policy Become More Effective", Working Paper, Columbia University.

Christiano, L.J., Eichenbaum, M. and C. Evans (2001), “Nominal rigidities and the dynamic effects of a shock to monetary policy”, May 2001.

Clarida, R., Gali, J. and M. Gertler (1998), “Monetary policy rules in practice: Some international evidence”, European Economic Review, 42, 6, 1033-67.

Clarida, R., Gali, J. and M. Gertler (1999), “The science of monetary policy: a new Keynesian Perspective”, Journal of Economic Literature, 37:4, p. 1661-1707.

Dupor, W. (2001), “Nominal price versus asset price stabilisation”, mimeo.

Erceg, C. and A. Levin (2001), “Imperfect credibility and inflation persistence”, Board of Governors of the Federal Reserve System, Finance and Economics Discussion Series, no. 45.

Fagan, G., Henry, J. and R. Mestre (2001), “An area-wide model (AWM) for the euro area”, ECB Working Paper Series No. 42.

Fisher J.D.M. (2002), “Technology Shocks Matter”, Federal Reserve Bank of Chicago WP 14.

Francis, N. and V. Ramey (2001), “Is the technology-driven real business cycle hypothesis dead? Shocks and aggregate fluctuations revisited”, mimeo, University of California, San Diego.

Fuhrer J. (2000), “Optimal monetary policy in a model with habit formation”, American Economic Review, 90:3, p. 367-390.

Gali, J. (1999), “Technology, employment, and the business cycle: do technology shocks explain aggregate fluctuations?”, American Economic Review, 89:1, p. 249-271..

Gali, J. and M. Gertler (1999), "Inflation Dynamics: A Structural Econometric Analysis", Journal of Monetary Economics, Vol. 37, no. 4, 195-222.

Gali, J., Gertler, M. and Lopez-Salido D. (2001), “European inflation dynamics”, European Economic Review, 45 (7), June 2001, 1121-1150

Geweke, J. (1998), “Using simulation methods for Bayesian econometric models: inference, development and communication”, mimeo, University of Minnesota and Federal Reserve Bank of Minneapolis.

King, R.G. and S. Rebelo (2000), "Resuscitating real business cycles", NBER Working Paper Series 7534

Leith, C. and J. Malley (2002), "Estimated General Equilibirum models for the evaluation of Monetary Policy in the US and Europe", CESinfo Working Paper, no. 699.

McConnel, M.M. and G. Perez-Quiros (2000), "Output Fluctuations in the United States: What has Changed Since the Early 1980s?", American Economic Review, 90(5), 1464-1976.

Peersman, G. and F. Smets (2001), “The monetary transmission mechanism in the euro area”, ECB Working Paper 91, December 2001.

Schorfheide, F. (2000), "Loss Function-based Evaluation of DSGE Models", Journal of Applied Econometrics, 15(6), p. 645-670.

Shapiro, M.D. and J. Watson (1989), “Sources of Business Cycle Fluctuations”, NBER Macroeconomics Annual, 1988, p. 111-148.

Smets, F. and R. Wouters (2003a), “An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area”, Forthcoming, Journal of European Economic Association.

Smets, F. and R. Wouters (2003b), “Shocks and frictions in US business cycle fluctuations: A Bayesian DSGE Approach”, mimeo.

Stock, J.H. and M.W. Watson (2000), "Business Cycle Fluctuations in US Macroeconomic Time Series", in B. Taylor and Woodford M., eds. Handbook of Macroeconomics, Volume I.

Stock, J. and M.W. Watson (2002), "Has the Business Cycle Changed and Why?", NBER Working Paper Series, no. 9127.

Taylor, J. (1993), “Discretion versus policy rules in practice”, Carnegie-Rochester Conference Series on Public Policy 39, 195-214.

Woodford, M. (2003), "Optimising Models with Nominal Rigidities", in Interest and Prices, Princeton University.

Table 1: Prior and posterior distribution for the parameters

	Prior distribution			Posterior distribution (generated by MH algorithm)											
				EA 1974:1 - 2002:2			US 1974:1 - 2002:2			EA 1983:1 - 2002:2			US 1983:1 - 2002:2		
	type	mean	st. error	5%	median	95%	5%	median	95%	5%	median	95%	5%	median	95%
s productivity shock	inv g.	0.25	2	0.4709	0.5720	0.7116	0.3701	0.4096	0.4577	0.4635	0.5892	0.7727	0.3150	0.3613	0.4137
s inflation obj. shock	inv g.	0.05	2	0.0747	0.0989	0.1243	0.0313	0.0555	0.0907	0.0345	0.0507	0.0757	0.0409	0.0680	0.0929
s cons.pref. shock	inv g.	0.25	2	0.2029	0.3198	0.4952	0.6380	1.2620	2.0705	0.1775	0.2926	0.5182	0.1868	0.2890	0.4666
s gov.spending shock	inv g.	0.25	2	0.3292	0.3685	0.4188	0.4911	0.5496	0.6155	0.2854	0.3277	0.3792	0.3760	0.4249	0.4882
s labour supply shock	inv g.	0.25	2	1.5634	2.2292	3.1007	1.5205	2.4151	3.4706	0.1876	1.5819	3.3220	0.1458	0.3369	0.8593
s investment shock	inv g.	0.25	2	0.0980	0.1312	0.1960	0.1669	0.2720	0.4706	0.1017	0.1434	0.2152	0.1343	0.2028	0.3116
s interest rate shock	inv g.	0.25	2	0.1132	0.1369	0.1627	0.2172	0.2494	0.2969	0.0887	0.1163	0.1472	0.1150	0.1385	0.1651
s equity premium shock	inv g.	0.25	2	0.4816	0.5833	0.6866	0.3860	0.6846	0.9078	0.4058	0.5312	0.6617	0.2600	0.4865	0.6436
s price mark-up shock	inv g.	0.25	2	0.1725	0.1958	0.2234	0.1494	0.1694	0.1946	0.1501	0.1743	0.2036	0.1188	0.1373	0.1616
s wage mark-up shock	inv g.	0.25	2	0.2307	0.2634	0.2987	0.2441	0.2796	0.3156	0.2392	0.2786	0.3248	0.2870	0.3267	0.3771
r productivity shock	beta	0.85	0.1	0.9843	0.9910	0.9960	0.9822	0.9948	0.9986	0.9050	0.9438	0.9759	0.8967	0.9519	0.9889
r inflation obj. shock	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
r cons.pref. shock	beta	0.85	0.1	0.8047	0.8694	0.9122	0.3786	0.5608	0.7357	0.7863	0.8542	0.9000	0.6980	0.7930	0.8635
r gov. spending shock	beta	0.85	0.1	0.9712	0.9820	0.9889	0.9388	0.9771	0.9977	0.9698	0.9823	0.9888	0.9756	0.9937	0.9985
r labour supply shock	beta	0.85	0.1	0.9769	0.9902	0.9968	0.9685	0.9850	0.9939	0.9250	0.9617	0.9863	0.6916	0.8913	0.9748
r investment shock	beta	0.85	0.1	0.7448	0.8642	0.9302	0.6526	0.7936	0.8881	0.7860	0.8844	0.9510	0.7194	0.8300	0.9166
investment adj cost	normal	4	1.5	5.4677	7.2001	9.0191	4.2469	5.9762	7.8685	4.3239	6.1306	8.1039	4.0239	5.9448	7.8473
s consumption utility	normal	1	0.375	1.2531	1.6586	2.3018	1.0178	1.4412	1.9823	0.8973	1.2612	1.6406	0.6959	1.3253	1.8874
h consumption habit	beta	0.7	0.1	0.5032	0.6002	0.6902	0.5276	0.6783	0.7612	0.4282	0.5680	0.6993	0.3443	0.4755	0.6632
s labour utility	normal	2	0.75	1.1464	2.0812	3.1370	1.4857	2.4365	3.2809	1.3301	2.3201	3.3588	1.8587	2.7292	3.7554
fixed cost	normal	1.25	0.125	1.4536	1.5885	1.7332	1.3624	1.4706	1.5834	1.1840	1.3379	1.5007	1.1875	1.3365	1.4882
capital util. adj.cost	normal	0.2	0.075	0.1985	0.3008	0.4144	0.2143	0.3265	0.4299	0.1407	0.2429	0.3592	0.1949	0.2992	0.4065
calvo wages	beta	0.75	0.05	0.6151	0.6909	0.7596	0.7292	0.7940	0.8549	0.8570	0.9165	0.9392	0.8668	0.8940	0.9180
calvo prices	beta	0.75	0.05	0.8825	0.9039	0.9255	0.8511	0.8842	0.9158	0.8758	0.8971	0.9169	0.8992	0.9184	0.9364
indexation wages	beta	0.75	0.15	0.3510	0.5804	0.8359	0.3948	0.6555	0.8797	0.7188	0.8954	0.9712	0.5280	0.7842	0.9340
indexation prices	beta	0.75	0.15	0.1679	0.3019	0.4437	0.4891	0.6804	0.8509	0.1685	0.2879	0.4297	0.1978	0.3739	0.6118
r inflation	normal	1.5	0.1	1.2921	1.4857	1.6439	1.2359	1.4144	1.6044	1.2676	1.4230	1.5785	1.2855	1.4488	1.6121
r d(inflation)	normal	0.3	0.1	0.0536	0.1248	0.2006	0.1373	0.2432	0.3489	0.0637	0.1468	0.2294	0.0621	0.1557	0.2633
r lagged interest rate	beta	0.75	0.05	0.8729	0.9011	0.9301	0.8068	0.8457	0.8851	0.7998	0.8682	0.9143	0.8271	0.8634	0.8948
r output	normal	0.125	0.05	0.0305	0.0709	0.1175	0.0290	0.0641	0.1245	0.0468	0.1002	0.1584	0.0355	0.0705	0.1189
r d(output)	normal	0.0625	0.05	0.0967	0.1459	0.2038	0.1987	0.2574	0.3311	0.0866	0.1333	0.1972	0.1441	0.1917	0.2504
calvo employment	normal	0.5	0.1	0.5105	0.5839	0.6518	-	-	-	0.5131	0.5942	0.6637	-	-	-
trend	normal	0.4	0.1	0.1682	0.2243	0.2938	0.2578	0.2983	0.3730	0.2806	0.3500	0.4098	0.3613	0.4171	0.4375

* For the Inverted Gamma function the degrees of freedom are indicated.

Table 2: Historical decomposition of output and inflation for booms and recessions

Historical decomposition of output during the three economic upturns and recessions

	euro area 75:1-80:1	US 75:1-80:1	euro area 80:1-82:4	US 80:1-82:4	euro area 82:4-92:1	US 82:4-90:1	euro area 92:1-93:2	US 90:1-91:4	euro area 95:1-00:2	US 95:1-00:2	euro area 00:1-02:2	US 00:1-02:2
productivity shock	4.87	-1.72	-0.27	-0.38	4.96	-2.03	1.08	0.96	0.60	1.34	-2.79	2.49
labour supply shock	-0.42	0.49	0.65	-1.06	9.53	11.05	-0.74	-0.42	7.33	1.52	2.44	0.11
investment shock	2.26	3.61	1.61	0.42	2.57	-2.15	-1.59	-2.20	-2.33	1.31	-0.90	-2.64
preference shock	2.76	2.67	-1.71	0.01	0.08	0.46	-1.29	-1.76	1.58	1.17	-0.15	-1.68
gov. spending shock	1.15	-0.91	0.33	-0.66	-0.06	2.47	0.68	0.72	-0.28	-0.18	0.89	0.17
interest rate shock	1.53	-0.68	-3.02	-5.16	-1.73	1.66	-0.77	0.06	1.10	1.21	1.00	-0.47
inflation objective shock	-0.03	-0.08	0.07	-0.01	0.01	-0.06	0.02	0.01	-0.03	-0.04	0.00	-0.01
equity markup shock	0.42	0.90	-0.27	-0.42	0.42	0.29	-0.46	-0.47	-0.11	0.07	-0.31	-0.39
price markup shock	0.55	1.41	0.13	-0.72	-0.03	0.82	0.21	-1.09	-0.31	0.78	-0.10	0.93
wage markup shock	-0.36	-0.39	0.00	-0.25	0.30	0.63	-0.12	0.36	0.14	1.11	0.06	-1.06
trend (and initial state)	5.14	6.65	2.85	3.63	10.28	9.48	1.36	2.27	5.53	6.73	2.05	2.55
growth over the period	17.86	11.94	0.38	-4.61	26.32	22.61	-1.61	-1.56	13.23	15.01	2.19	-0.02

Historical decomposition of inflation during the three economic upturns and recessions

	euro area 75:1-80:1	US 75:1-80:1	euro area 80:1-82:4	US 80:1-82:4	euro area 82:4-92:1	US 82:4-90:1	euro area 92:1-93:2	US 90:1-91:4	euro area 95:1-00:2	US 95:1-00:2	euro area 00:1-02:2	US 00:1-02:2
productivity shock	-0.69	0.26	-0.01	-0.87	-0.77	0.38	-0.32	-0.08	0.55	-0.62	0.01	-1.02
labour supply shock	-0.15	-0.40	0.01	0.13	-0.15	-0.85	0.00	-0.16	-0.46	0.17	-0.01	-0.01
investment shock	1.36	1.32	-0.05	-0.09	0.18	-1.41	-0.98	-0.68	-0.21	0.71	-0.22	-1.18
preference shock	1.29	0.34	-0.09	0.63	0.56	0.09	-0.48	-0.83	0.00	0.55	0.05	-0.40
gov. spending shock	0.13	-0.24	0.10	0.00	0.07	0.39	0.16	-0.14	-0.03	-0.05	0.18	0.00
interest rate shock	0.23	-0.21	-1.20	-3.91	-0.36	1.22	-0.04	0.68	0.53	0.72	0.39	-0.26
inflation objective shock	-3.55	0.30	-0.88	0.13	-3.68	-0.75	-0.20	-0.28	-1.36	-0.56	-0.47	-0.40
equity markup shock	0.04	0.10	0.00	0.01	0.02	-0.04	-0.08	-0.14	-0.02	0.06	-0.02	-0.07
price markup shock	1.62	-1.51	-1.47	-1.17	0.24	2.41	0.82	-2.21	-0.38	-2.58	-0.52	2.42
wage markup shock	0.14	-0.26	-0.08	0.40	0.10	-1.22	0.00	1.18	0.04	1.71	-0.05	-0.88
trend (and initial state)	0.73	0.08	0.03	0.03	0.09	0.04	0.00	0.01	-0.04	0.00	-0.02	0.00
growth over the period	1.16	-0.23	-3.64	-4.71	-3.70	0.27	-1.11	-2.65	-1.36	0.10	-0.68	-1.80

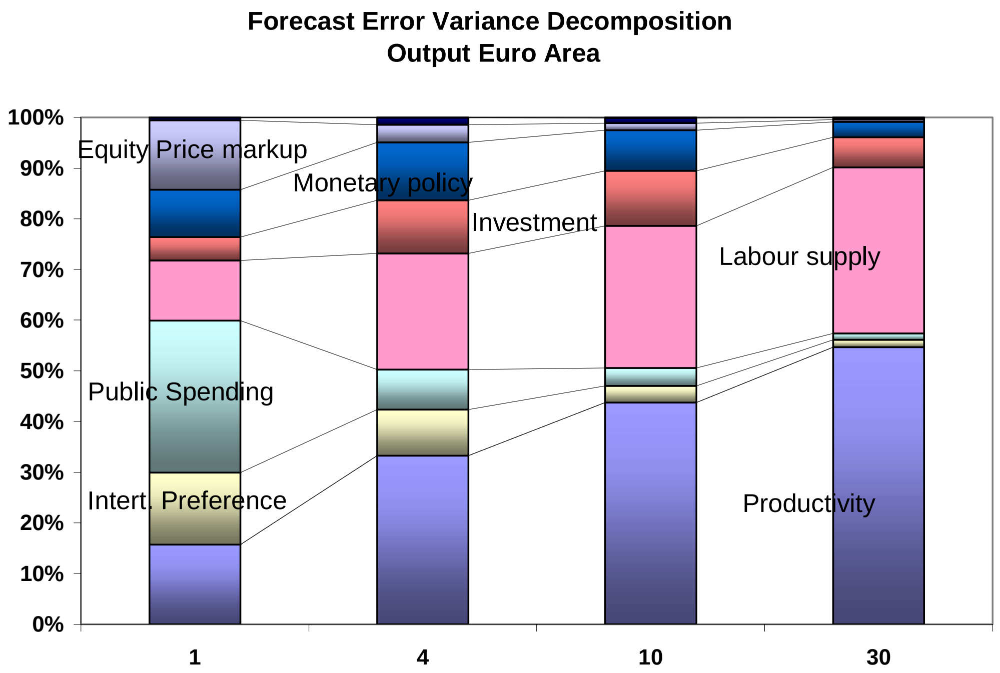
Table 3:

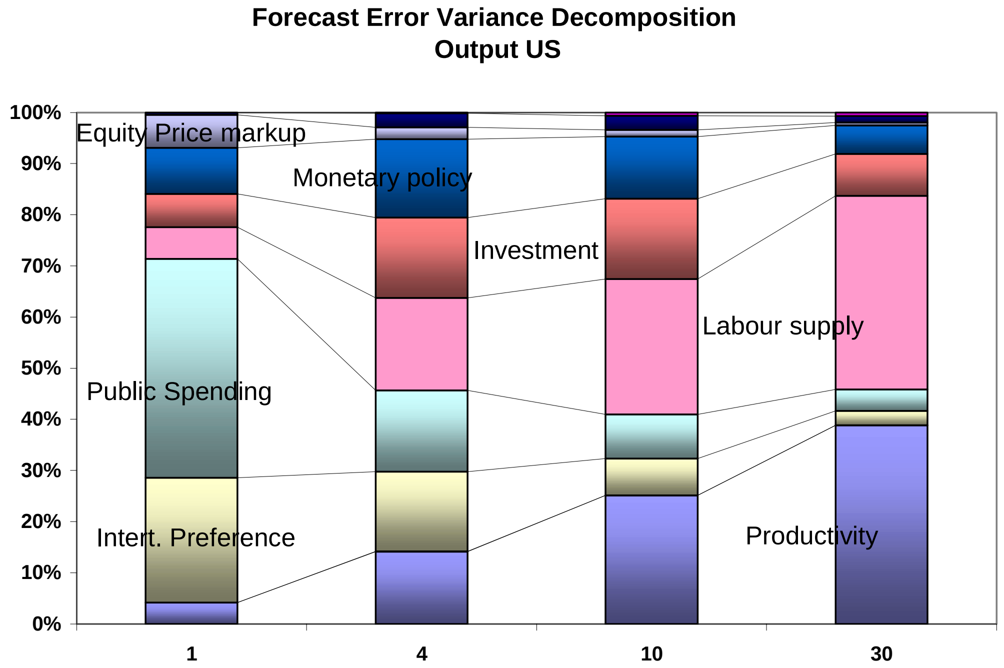
Correlation between euro area and US innovations

	1974:1 - 2002:2	(yearly average)	1983:1 - 2002:2	(yearly average)
productivity shock	0.00	-0.22	0.05	-0.22
labour supply shock	0.12	0.13	-0.14	-0.36
investment shock	0.17	0.19	0.07	-0.01
preference shock	0.16	0.43	-0.01	0.19
gov. spending shock	0.02	0.01	0.04	0.02
interest rate shock	0.45	0.68	0.19	0.27
inflation objective shock	0.11	0.01	0.14	0.27
equity markup shock	0.15	0.30	0.12	0.25
price markup shock	-0.08	0.06	-0.05	-0.05
wage markup shock	0.03	0.17	0.04	0.10

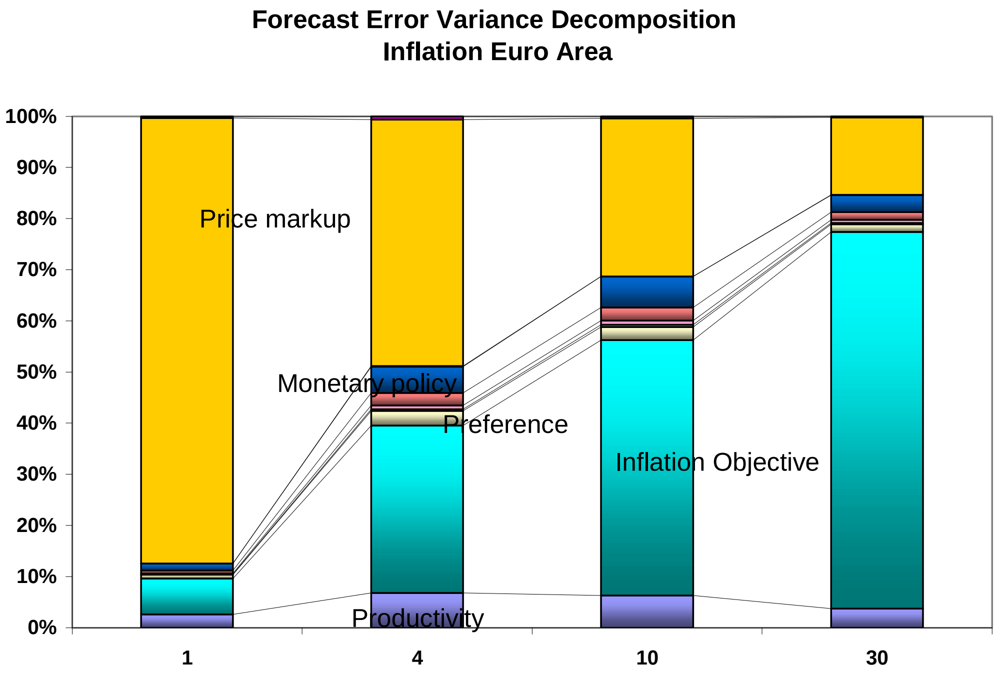
Innovations based on the two-sided kalman filter best estimates of the innovations

Graph 1:


Forecast Error Variance Decomposition
Output Euro Area
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
4
10
30
Equity Price markup
Monetary policy
Investment
Labour supply
Public Spending
Intert. Preference
Productivity


Forecast Error Variance Decomposition
Output US
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1
4
10
30
Equity Price markup
Monetary policy
Investment
Labour supply
Public Spending
Intert. Preference
Productivity

Graph 2:


Forecast Error Variance Decomposition
Inflation Euro Area
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
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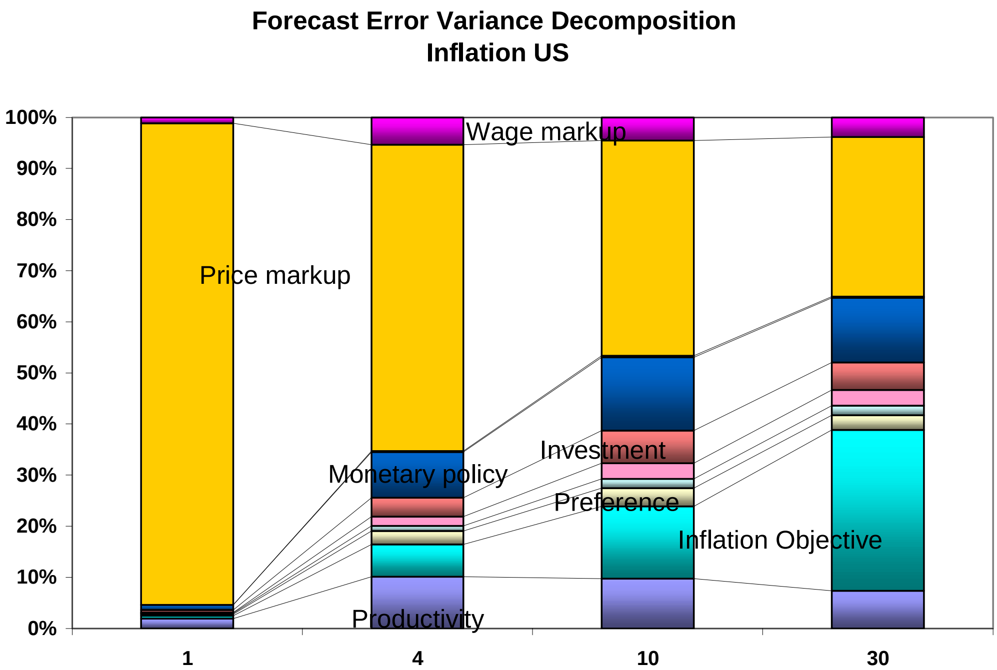
Monetary policy
Preference
Inflation Objective
Productivity
1
4
10
30


Forecast Error Variance Decomposition
Inflation US
100%
90%
80%
70%
60%
50%
40%
30%
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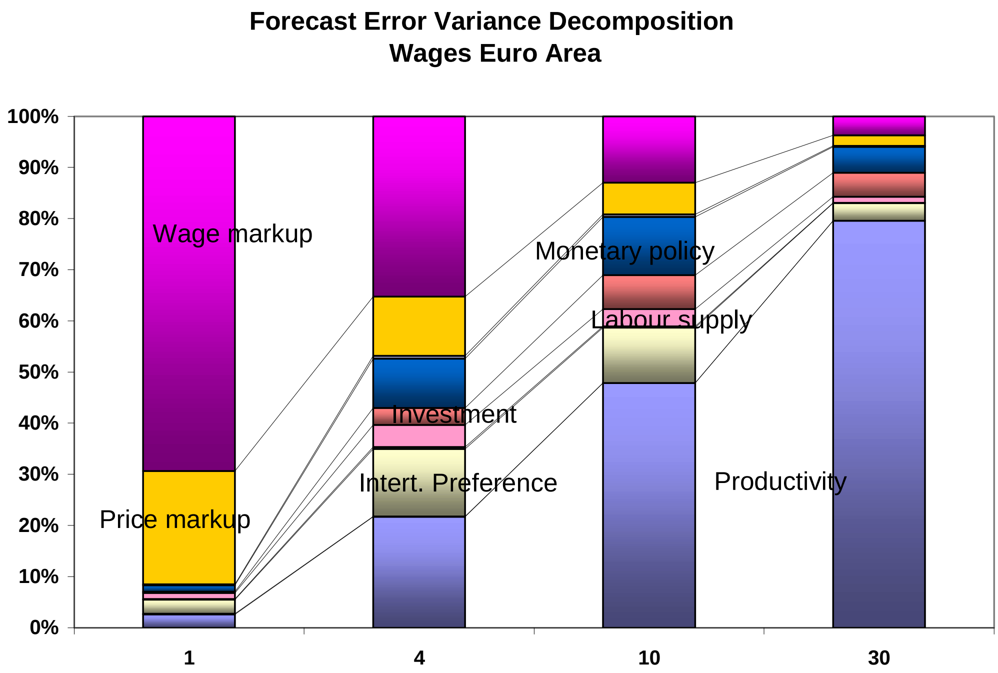
10%
0%
Wage markup
Price markup
Investment
Monetary policy
Preference
Inflation Objective
Productivity
1
4
10
30

Graph 3:


Forecast Error Variance Decomposition
Wages Euro Area
100%
90%
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0%
Wage markup
Monetary policy
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Intert. Preference
Productivity
Price markup
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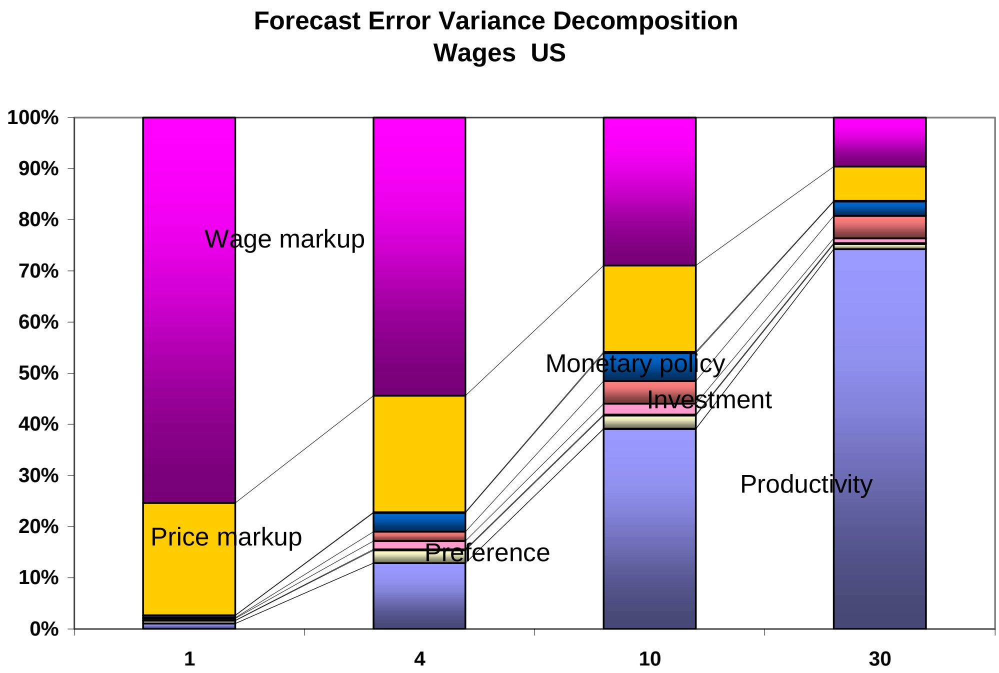
Forecast Error Variance Decomposition
Wages US
100%
90%
80%
70%
60%
50%
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10%
0%
Wage markup
Monetary policy
Investment
Productivity
Price markup
Preference
1
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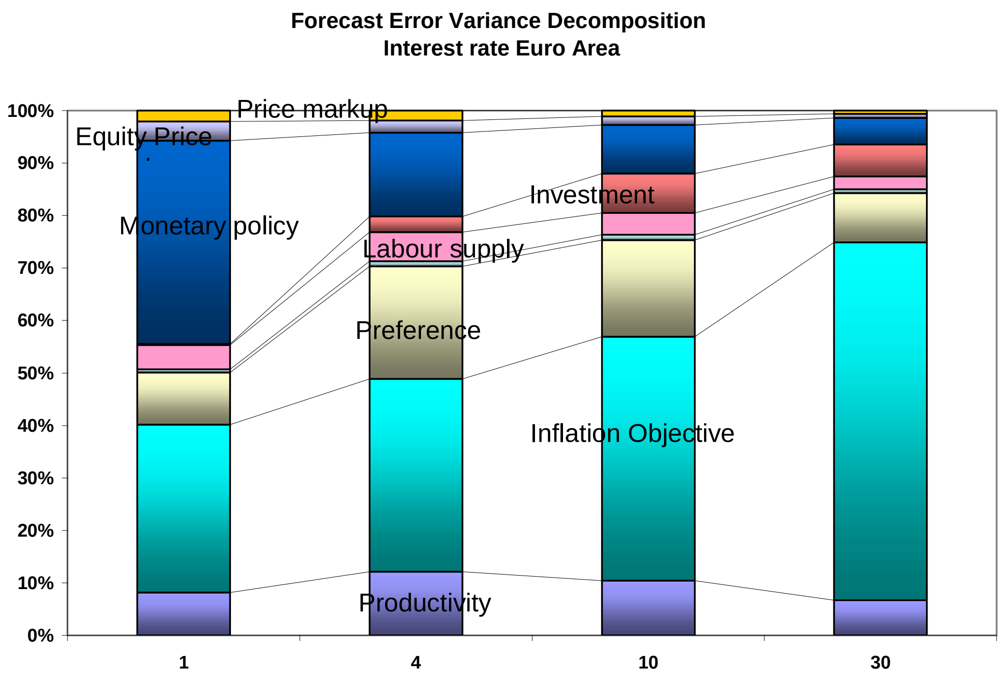
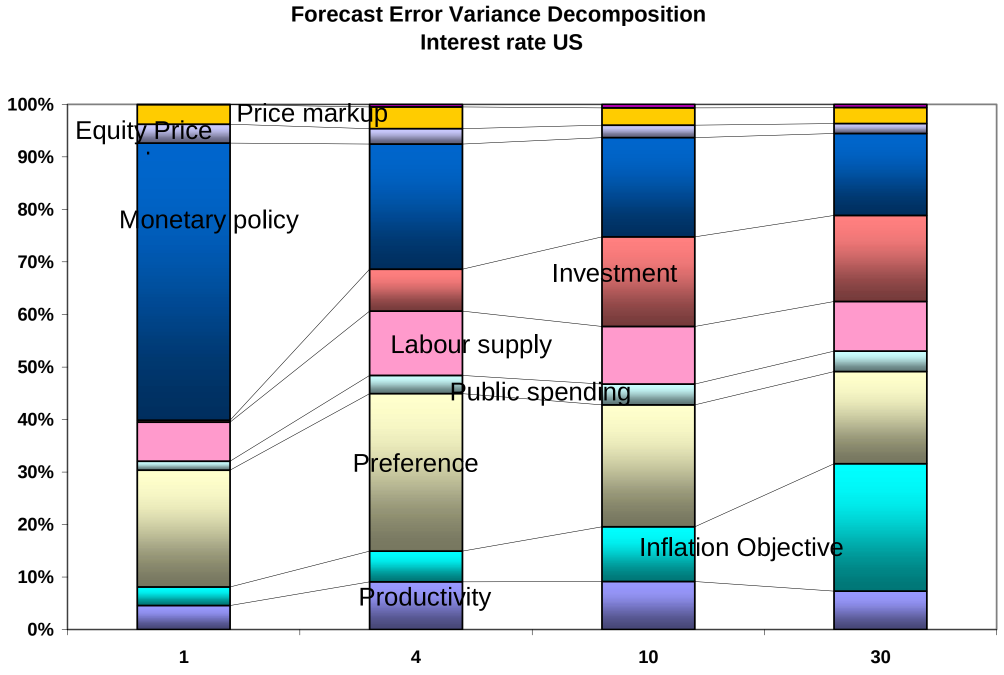
Graph 4:


Forecast Error Variance Decomposition
Interest rate Euro Area
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Price markup
Equity Price
Monetary policy
Investment
Labour supply
Preference
Inflation Objective
Productivity
1
4
10
30


Forecast Error Variance Decomposition
Interest rate US
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Price markup
Equity Price
Monetary policy
Investment
Labour supply
Public spending
Preference
Inflation Objective
Productivity
1
4
10
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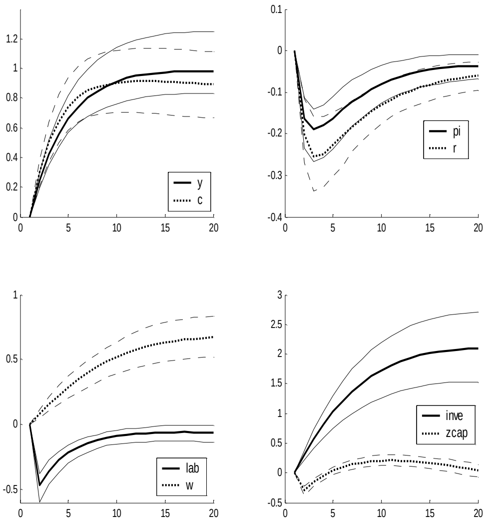
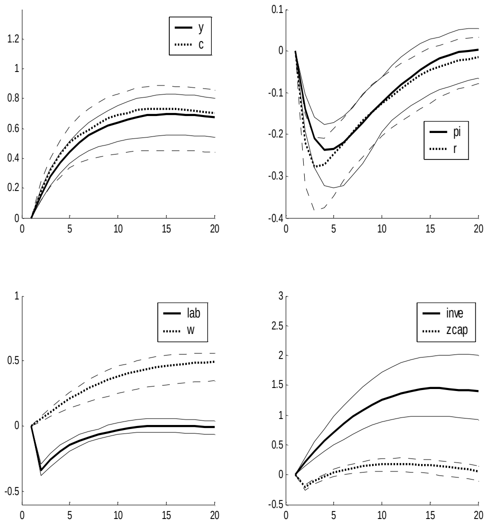
Graph 5: Comparison of the impulse response functions

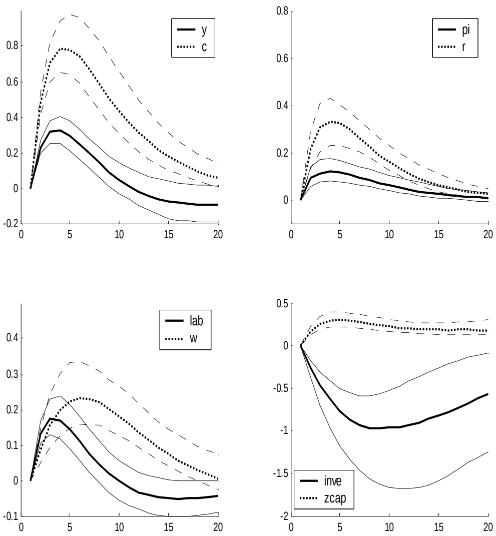
Productivity shock

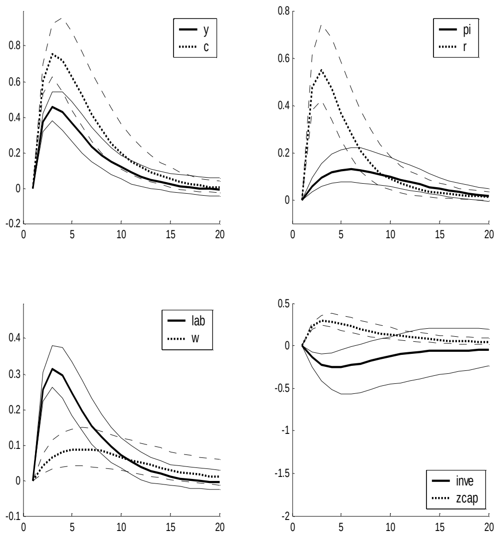




Euro area **United States**

Preference shock

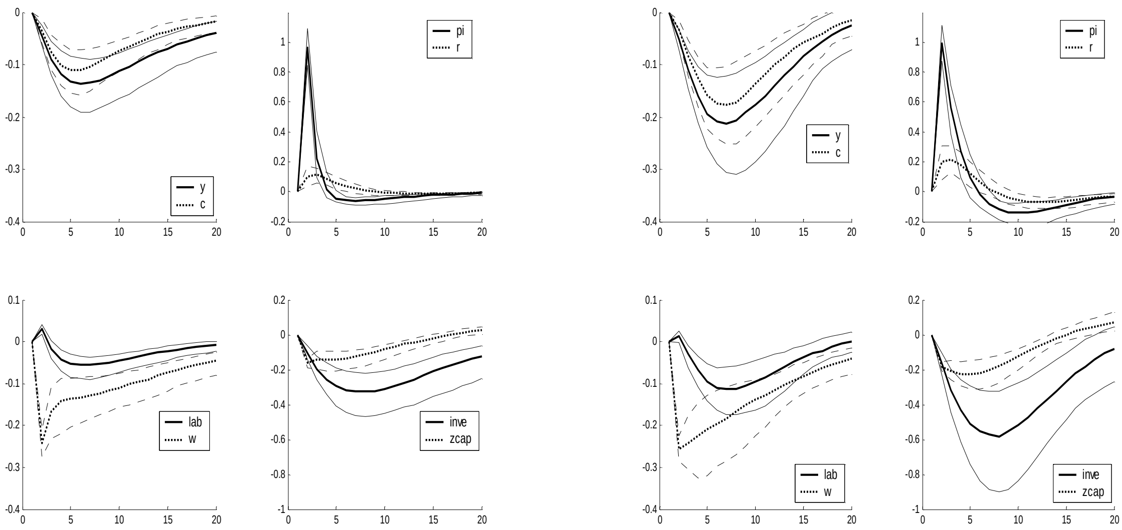




Euro area **United States**

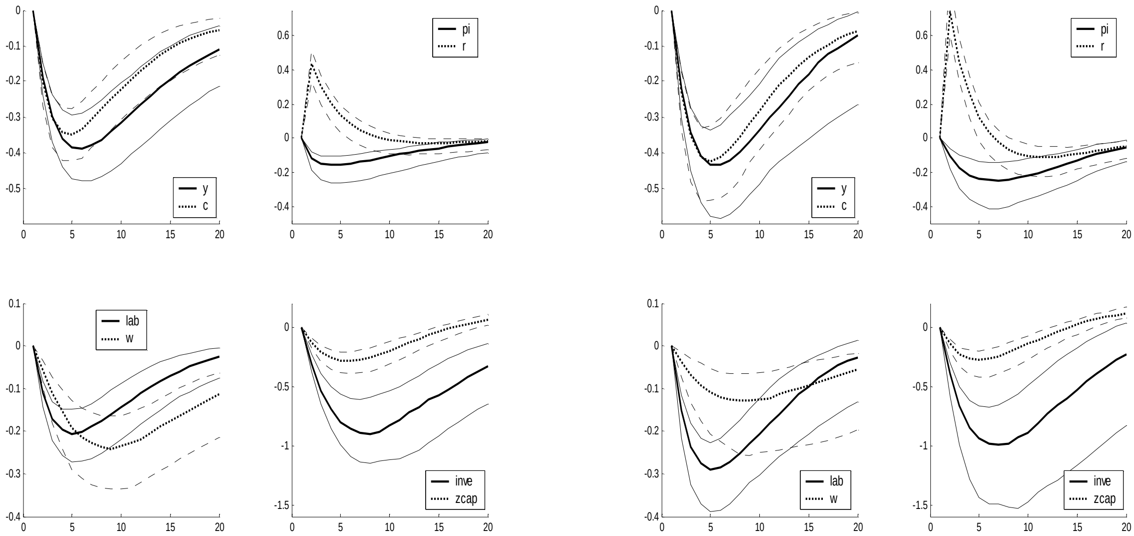
Graph 5continued: Comparison of the impulse response functions

Price mark up shock



Euro area **United States**

Interest rate shock



Euro area **United States**