PROFESSIONAL FORECASTERS AND THE REAL-TIME FORECASTING PERFORMANCE OF AN ESTIMATED NEW KEYNESIAN MODEL FOR THE EURO AREA

Frank Smets, Anders Warne and Rafael Wouters

In 2013 all ECB publications feature a motif taken from the €5 banknote.

Frank Smets
European Central Bank and KU Leuven; e-mail: frank.smets@ecb.europa.eu

Anders Warne
European Central Bank; e-mail: anders.warne@ecb.europa.eu

Rafael Wouters
National Bank of Belgium; e-mail: rafael.wouters@nbb.be

CONTENTS

ABSTRACT: This paper analyses the real-time forecasting performance of the New Keynesian DSGE model of Galí, Smets, and Wouters (2012) estimated on euro area data. It investigates to what extent forecasts of inflation, GDP growth and unemployment by professional forecasters improve the forecasting performance. We consider two approaches for conditioning on such information. Under the "noise" approach, the mean professional forecasts are assumed to be noisy indicators of the rational expectations forecasts implied by the DSGE model. Under the "news" approach, it is assumed that the forecasts reveal the presence of expected future structural shocks in line with those estimated over the past. The forecasts of the DSGE model are compared with those from a Bayesian VAR model and a random walk.

NON-TECHNICAL SUMMARY

Following the seminal work of Croushore and Stark (2001) on constructing a real-time data set for the US economy, it has become standard to use real-time data when analysing the out-of-sample forecast performance of alternative empirical macromodels. With a few exceptions much less real-time data analysis has been done on the euro area, partly because a comprehensive real-time euro area data set has only recently become available. This paper uses the ECB's real-time data base to perform two types of analysis.

First, we investigate the real-time forecasting performance of the New Keynesian DSGE model of Galí, Smets, and Wouters (2012) over the EMU period and compare it with two alternative non-structural linear models. Second, we analyse to what extent the forecasts of euro area GDP growth, inflation and unemployment by professional forecasters (from the ECB's Survey of Professional Forecasters) help improving the forecast performance of the DSGE model. We consider two interpretations. Under the "noise" interpretation, the mean professional forecasts are assumed to be noisy indicators of the rational expectations forecasts implied by the DSGE model. Under the "news" interpretation, it is assumed that the forecasts reveal the presence of expected future structural shocks in line with those estimated over the past.

Overall, we find that the DSGE model outperforms the random-walk model and has similar performance as the non-structural BVAR model. Adding one to two-year-ahead professional forecasts of real GDP growth, inflation, and the unemployment rate does not significantly improve the overall performance of the GSW model, although it does help to reduce some of the bias in the forecasts of wage growth in the news models.

1. Introduction

Following the seminal work of Croushore and Stark (2001) on constructing a real-time data set for the US economy, it has become standard to use real-time data when analysing the out-of-sample forecast performance of alternative empirical macromodels.[1] With a few exceptions much less real-time data analysis has been done on the euro area, partly because a comprehensive real-time euro area data set has only recently become available.[2] This paper uses the European Central Bank (ECB) real-time data base (RTDB)—described in Giannone, Henry, Lalik, and Modugno (2012) and available on the ECB's website—to perform two types of analysis.

First, we investigate the real-time forecasting performance of the model of Galí et al. (2012, GSW) over the EMU period and compare it with two alternative non-structural linear models. The GSW model is a version of the model by Smets and Wouters (2003, 2007) which has been shown to forecast reasonably well. It is therefore of interest to see to what extent these results are robust to the real-time nature of the underlying data in the euro area. Recently, a similar exercise on US data was performed by Edge and Gürkaynak (2010).

Second, we analyse to what extent the forecasts of euro area GDP growth, inflation and unemployment by professional forecasters (from the ECB's Survey of Professional Forecasters) help improving the forecast performance of the DSGE model. We consider two interpretations. Under the "noise" interpretation, the mean professional forecasts are assumed to be noisy indicators of the rational expectations forecasts implied by the DSGE model. Under the "news" interpretation, it is assumed that the forecasts reveal the presence of expected future structural shocks in line with those estimated over the past. This exercise is similar to the one performed by Del Negro and Schorfheide (2012) for the United States.

The rest of the paper is structured as follows. Section 2 presents the GSW model. Section 3 presents the real-time data base including the Survey of Professional Forecasts. Section 4 discusses the full-sample estimation results of the benchmark GSW model and provides a brief comparison with the findings for United States reported in Galí et al. (2012). Section 5 contains the findings of the real-time forecast comparison exercise. Finally, Section 6 summarises the main findings and concludes.

2. The Gali-Smets-Wouters Model

2.1. Staggered Wage Setting and Wage Inflation Dynamics

This section describes the main features of the GSW model. The model is very similar to Smets and Wouters (2007, SW). One main difference is that it models the labor supply decision on the extensive margin (whether to work or not), rather than on the intensive margin (how many hours to work). The model assumes a (large) representative household with a continuum of

---

[1] See, for example, Croushore (2011) and the literature review on real-time data analysis compiled by Dean Croushore at `https://facultystaff.richmond.edu/~dcrousho/docs/realtime_lit.pdf`. For an early real-time forecasting exercise, see Diebold and Rudebusch (1991).

[2] Two exceptions are Coenen, Levin, and Wieland (2005) and Coenen and Warne (2012).

members represented by the unit square and indexed by a pair $(i, j) \in [0, 1] \times [0, 1]$. The first dimension, indexed by $i \in [0, 1]$, represents the type of labor service in which a given household member is specialized. The second dimension, indexed by $j \in [0, 1]$, determines his disutility from work. The latter is given by $\chi_t \Theta_t j^\omega$ if he is employed, zero otherwise, where $\chi_t > 0$ is an exogenous preference shifter (referred to below as a "labor supply shock"), Θ_t is an endogenous preference shifter, taken as given by each individual household and defined below, and $\omega \geq 0$ is a parameter determining the shape of the distribution of work disutilities across individuals.

Individual utility is assumed to be given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\log \widetilde{C}_t(i, j) - 1_t(i, j) \chi_t \Theta_t j^\omega \right),$$

where $\widetilde{C}_t(i, j) \equiv C_t(i, j) - h\overline{C}_{t-1}$, with $h \in [0, 1]$, and with $\overline{C}_{t-1}$ denoting (lagged) aggregate consumption (taken as given by each household), and where $1_t(i, j)$ is an indicator function taking a value equal to one if individual (i, j) is employed in period t, and zero otherwise. Thus, as in SW and related monetary DSGE models, we allow for (external) habits in consumption, indexed by h.

As in Merz (1995), full risk sharing of consumption among household members is assumed, implying $C_t(i, j) = C_t$ for all $(i, j) \in [0, 1] \times [0, 1]$ and t. Thus, we can derive the household utility as the integral over its members' utilities, that is:

$$E_0 \sum_{t=0}^{\infty} \beta^t U_t \big(C_t, \{N_t(i)\} \big) \equiv E_0 \sum_{t=0}^{\infty} \beta^t \left(\log \widetilde{C}_t - \chi_t \Theta_t \int_0^1 \int_0^{N_t(i)} j^\omega \, dj \, di \right)$$

$$= E_0 \sum_{t=0}^{\infty} \beta^t \left(\log \widetilde{C}_t - \chi_t \Theta_t \int_0^1 \frac{N_t(i)^{1+\omega}}{1 + \omega} \, di \right),$$

where $N_t(i) \in [0, 1]$ denotes the employment rate in period t among workers specialized in type i labor and $\widetilde{C}_t \equiv C_t - h\overline{C}_{t-1}$. We define the endogenous preference shifter Θ_t as follows:

$$\Theta_t \equiv \frac{Z_t}{\overline{C}_t - h\overline{C}_{t-1}},$$

where Z_t evolves over time according to the difference equation

$$Z_t = Z_{t-1}^{1-\upsilon} \left(\overline{C}_t - h\overline{C}_{t-1} \right)^\upsilon.$$

Thus Z_t can be interpreted as a "smooth" trend for (quasi-differenced) aggregate consumption. Our preference specification implies a "consumption externality" on individual labor supply: during aggregate consumption booms (i.e. when $\overline{C}_t - h\overline{C}_{t-1}$ is above its trend value Z_t), individual (as well as household-level) marginal disutility from work goes down (at any given level of employment).

The previous specification generalizes the preferences assumed in SW by allowing for an exogenous labor supply shock, χ_t, and by introducing the endogenous shifter Θ_t, just described. The main role of the latter is to reconcile the existence of a long-run balanced growth path with

an arbitrarily small *short-term* wealth effect. The latter's importance is determined by the size of parameter $\upsilon \in [0,1]$. As discussed in detail in GSW, that feature is needed in order to match the joint behavior of the labor force, consumption and the wage over the business cycle.

Note that under the previous preferences, the household-relevant marginal rate of substitution between consumption and employment for type i workers in period t is given by:

$$MRS_t(i) \equiv -\frac{U_{n(i),t}}{U_{c,t}}$$

$$= \chi_t \Theta_t \widetilde{C}_t N_t(i)^\omega$$

$$= \chi_t Z_t N_t(i)^\omega,$$

where the last equality is satisfied in a symmetric equilibrium with $\overline{C}_t = C_t$.

Using lower case letters to denote the natural logarithms of the original variables, we can derive the average (log) marginal rate of substitution $mrs_t \equiv \int_0^1 mrs_t(i)di$ by integrating over all labor types:

$$mrs_t = z_t + \omega n_t + \xi_t,$$

where $n_t \equiv \int_0^1 n_t(i)di$ is (log) aggregate employment and $\xi_t \equiv \log \chi_t$.

We assume nominal wages are set by "unions", each of which represents the workers specialized in a given type of labor, and acting in an uncoordinated way. As in Erceg, Henderson, and Levin (2000), and following the formalism of Calvo (1983), we assume that the nominal wage for a labor service of a given type can only be reset with probability $1 - \theta_w$ each period. That probability is independent of the time elapsed since the wage for that labor type was last reset, in addition to being independent across labor types. Thus, and by the law of large numbers, a fraction of workers θ_w do not reoptimize their wage in any given period, making that parameter a natural index of nominal wage rigidities. Furthermore, all those who reoptimize their wage choose an identical wage, denoted by W_t^*, since they face an identical problem. Partial wage indexation between re-optimization periods is allowed for, by making the nominal wage adjust mechanically in proportion to past price inflation. Formally, and letting $W_{t+k|t}$ denote the nominal wage in period $t + k$ for workers who last reoptimized their wage in period t, we assume

$$W_{t+k|t} = W_{t+k-1|t}\Pi^x \left(\Pi_{t-1}^p\right)^{\gamma_w} \left(\Pi^p\right)^{1-\gamma_w},$$

for $k = 1,2,3,\ldots$, $W_{t|t} = W_t^*$, and where $\pi_t \equiv P_t/P_{t-1}$ denotes the (gross) rate of price inflation, Π^p is its corresponding steady state value, Π^x is the steady state (gross) growth rate of productivity, and $\gamma_w \in [0,1]$ measures the degree of wage indexation to past inflation.

When reoptimizing their wage in period t, workers (or the union representing them) choose a wage W_t^* *in order to maximize their respective households utility* (as opposed to their individual utility), subject to the usual sequence of household flow budget constraints, as well as a sequence of isoelastic demand schedules of the form

$$N_{t+k|t} = \left(W_{t+k|t}/W_{t+k}\right)^{-\epsilon_{w,t}} N_{t+k},$$

where $N_{t+k|t}$ denotes period $t+k$ employment among workers whose wage was last reoptimized in period t, and where $\epsilon_{w,t}$ is the period t wage elasticity of the relevant labor demand schedule.[3] We assume that elasticity varies exogenously over time, thus leading to changes in workers' market power.

The first order condition associated with the wage-setting problem can be written as:

$$\sum_{k=0}^{\infty}(\beta\theta_w)^k E_t\left\{\left(\frac{N_{t+k|t}}{C_{t+k}}\right)\left(\frac{W_{t+k|t}^*}{P_{t+k}} - \mathcal{M}_{w,t+k}^n MRS_{t+k|t}\right)\right\} = 0, \tag{1}$$

where, in a symmetric equilibrium, $MRS_{t+k|t} \equiv \chi_t Z_t N_{t+k|t}^\omega$ is the relevant marginal rate of substitution between consumption and employment in period $t+k$, and $\mathcal{M}_{w,t}^n \equiv \epsilon_{w,t}/(\epsilon_{w,t}-1)$ is the natural (or desired) wage markup in period t, i.e. the one that would obtain under flexible wages.

Under the above assumptions, we can write the aggregate wage index:

$$W_t \equiv \left(\int_0^1 W_t(i)^{1-\epsilon_{w,t}} di\right)^{1/(1-\epsilon_{w,t})},$$

as follows:

$$W_t \equiv \left[\theta_w\left(W_{t-1}\Pi^x(\pi_{t-1})^{\gamma_w}(\Pi^p)^{1-\gamma_w}\right)^{1-\epsilon_{w,t}} + (1-\theta_w)(W_t^*)^{1-\epsilon_{w,t}}\right]^{1/(1-\epsilon_{w,t})}. \tag{2}$$

Log-linearizing (1) and (2) around a perfect foresight steady state and combining the resulting expressions, allows us to derive (after some algebra) the following equation for wage inflation $\Delta w_t \equiv w_t - w_{t-1}$:

$$\Delta w_t = \alpha_w + \gamma_w\pi_{t-1} + \beta E_t\{\Delta w_{t+1} - \gamma_w\pi_t\} - \left[\frac{(1-\beta\theta_w)(1-\theta_w)}{\theta_w(1+\epsilon_w\omega)}\right](\mu_{w,t} - \mu_{w,t}^n), \tag{3}$$

where $\alpha_w = (1-\beta)[(1-\gamma)\pi^p + \pi^x]$. The (log) natural wage markup is given by

$$\mu_{w,t}^n \equiv \log\mathcal{M}_{w,t}^n,$$

while

$$\mu_{w,t} \equiv (w_t - p_t) - mrs_t, \tag{4}$$

is the (log) average wage markup, i.e. the log deviation between the average real wage and the average marginal rate of substitution. As equation (3) makes clear, variations in wage inflation above and beyond those resulting from indexation to past price inflation are driven by deviations of average wage markup from its natural level, because those deviations generate pressure on workers currently setting wages to adjust those wages in one direction or another.

2.2. INTRODUCING UNEMPLOYMENT

Consider an individual specialized in type i labor and with disutility of work $\chi_t\Theta_t j^\omega$. Using household *welfare* as a criterion, and taking as given *current labor market conditions* (as

---

[3] Details of the derivation of the optimal wage setting condition can be found in Erceg et al. (2000).

summarized by the prevailing wage for his labor type), that individual will find it optimal to participate in the labor market in period t if and only if

$$\left(\frac{1}{\widetilde{C}_t}\right)\left(\frac{W_t(i)}{P_t}\right) \geq \chi_t \Theta_t j^\omega.$$

Evaluating the previous condition at the symmetric equilibrium, and letting the marginal supplier of type i labor be denoted by $L_t(i)$, we have:

$$\frac{W_t(i)}{P_t} = \chi_t Z_t L_t(i)^\omega.$$

Taking logs and integrating over i we obtain

$$w_t - p_t = z_t + \omega l_t + \xi_t, \tag{5}$$

where $l_t \equiv \int_0^1 l_t(i)di$ can be interpreted as the (log) aggregate participation or labor force.

Following Galí (2011a,b), we define the *unemployment rate u_t* as:

$$u_t \equiv l_t - n_t. \tag{6}$$

Note that under our assumptions, the unemployed thus defined include all the individuals who *would like to be working* (given current labor market conditions, and while internalizing the benefits that this will bring to their households) *but are not currently employed.* It is in that sense that one can view unemployment as involuntary.

Combining (4) with (5) and (6), the following simple linear relation between the average wage markup and the unemployment rate can be derived:

$$\mu_{w,t} = \omega u_t. \tag{7}$$

Finally, combining (3) and (7) we obtain an equation relating wage inflation to price inflation, the unemployment rate and the wage markup:

$$\Delta w_t = \alpha_w + \gamma_w \pi_{t-1} + \beta E_t\{\Delta w_{t+1} - \gamma_w \pi_t\} - \left[\frac{(1-\beta\theta_w)(1-\theta_w)}{\theta_w(1+\epsilon_w\omega)}\right](\omega u_t - \mu_{w,t}^n). \tag{8}$$

Note that in contrast with the representation of the wage equation found in SW and related papers, the error term in (8) captures exclusively shocks to the wage markup, and *not* preference shocks (even though the latter have been allowed for in our model). That feature, made possible by reformulating the wage equation in terms of the (observable) unemployment rate, allows us to overcome the identification problem raised by Chari, Kehoe, and McGrattan (2009) in their critique of New Keynesian models.

Finally, note that we can define the *natural* rate of unemployment, u_t^n, as the unemployment rate that would prevail in the absence of nominal wage rigidities. Under our assumptions, that natural rate will vary exogenously in proportion to the natural wage markup, and can be

determined using the simple relation:

$$\mu^n_{w,t} = \omega u^n_t. \tag{9}$$

2.3. The Rest of the Model

The remaining equations describing the log-linearized equilibrium conditions of the model are identical to a particular case of the specification in SW (2007), corresponding to logarithmic consumption utility. In addition to the wage markup and labor supply shocks discussed above, the model includes six additional shocks: a neutral, factor-augmenting productivity shock $(\widehat{\varepsilon}^a_t)$, a price markup shock $(\widehat{\varepsilon}^p_t)$; a risk premium shock $(\widehat{\varepsilon}^b_t)$, an exogenous spending shock $(\widehat{\varepsilon}^g_t)$, an investment-specific technology shock $(\widehat{\varepsilon}^q_t)$, and a monetary policy shock $(\widehat{\varepsilon}^r_t)$.

- Consumption Euler equation:

$$\widehat{c}_t = c_1 E_t\left[\widehat{c}_{t+1}\right] + \left(1 - c_1\right)\widehat{c}_{t-1} - c_2\left(\widehat{r}_t - E_t\widehat{\pi}_{t+1} - \widehat{\varepsilon}^b_t\right),$$

with $c_1 = 1/(1 + (h/\tau))$, $c_2 = (1 - (h/\tau))/(1 + (h/\tau))$, where h is the external habit parameter, τ is the trend growth rate, and $\widehat{\varepsilon}^b_t$ is the exogenous AR(1) risk premium process.

- Investment Euler equation:

$$\widehat{i}_t = i_1\widehat{i}_{t-1} + \left(1 - i_1\right)E_t\widehat{i}_{t+1} + i_2\widehat{q}^k_t + \widehat{\varepsilon}^q_t,$$

with $i_1 = 1/(1 + \beta)$, $i_2 = i_1/(\tau^2\varphi)$ where β is the discount factor, φ is the elasticity of the capital adjustment cost function, and $\widehat{\varepsilon}^q_t$ is the exogenous AR(1) process for the investment-specific technology.

- Value of the capital stock:

$$\widehat{q}^k_t = -\left(\widehat{r}_t - E_t\widehat{\pi}_{t+1} - \widehat{\varepsilon}^b_t\right) + q_1 E_t\widehat{r}^k_{t+1} + \left(1 - q_1\right)E_t\widehat{q}^k_{t+1},$$

with $q_1 = r^k/(r^k + (1 - \delta))$, where r^k is the steady-state rental rate to capital, and δ the depreciation rate.

- Aggregate demand equals aggregate supply:

$$\widehat{y}_t = c_y\widehat{c}_t + i_y\widehat{i}_t + v_y\widehat{v}_t + \widehat{\varepsilon}^g_t,$$
$$= \phi_p\left(\alpha\widehat{k}_t + \left(1 - \alpha\right)\widehat{n}_t + \widehat{\varepsilon}^a_t\right),$$

where $c_y = 1 - i_y - g_y$ is the steady-state consumption-output ratio, g_y the steady-state exogenous spending to output ratio, $i_y = (\tau + \delta - 1)k_y$ is the steady-state investment-output ratio, k_y the steady-state capital-output ratio, and $v_y = r^k k_y$. The parameter ϕ_p reflects the fixed costs in production, which is assumed to correspond to the price

markup in steady state, while $\widehat{\varepsilon}_t^g$ and $\widehat{\varepsilon}_t^a$ are the AR(1) processes representing exogenous demand components and the TFP process.[4]

- Price-setting under the Calvo model with indexation:

$$\widehat{\pi}_t - \gamma_p \widehat{\pi}_{t-1} = \pi_1 \left(E_t \widehat{\pi}_{t+1} - \gamma_p \widehat{\pi}_t \right) - \pi_2 \left(\widehat{\mu}_{p,t} - \widehat{\mu}_{p,t}^n \right),$$

with $\pi_1 = \beta$, $\pi_2 = (1 - \xi_p\beta)(1 - \xi_p)/[\xi_p(1 + (\phi_p - 1)\varepsilon_p)]$, with θ_p and γ_p respectively the probability and indexation of the Calvo model, and ε_p the curvature of the aggregator function. The average price markup $\widehat{\mu}_{p,t}$ is equal to the inverse of the real marginal cost $\widehat{mc}_t = (1 - \alpha)(\widehat{w}_t - \widehat{p}_t) + \alpha \widehat{r}_t^k + \widehat{\varepsilon}_t^a$. The natural price markup is $100\widehat{\varepsilon}_t^p$, i.e. proportional to the price markup shocks.

- Average and natural wage markups and unemployment:

$$\widehat{\mu}_{w,t} = \widehat{w}_t - \widehat{p}_t + \widehat{z}_t + \widehat{\varepsilon}_t^s + \omega \widehat{n}_t,$$
$$= \omega \widehat{u}_t.$$
$$\widehat{\mu}_{w,t}^n = 100\widehat{\varepsilon}_t^w,$$
$$= \omega \widehat{u}_t^n.$$
$$\widehat{z}_t = \left(1 - \upsilon\right)\widehat{z}_{t-1} + \frac{\upsilon}{1 - (h/\tau)} \left[\widehat{c}_t - \frac{h}{\tau}\widehat{c}_{t-1} \right],$$

while $\widehat{\varepsilon}_t^s$ is an AR(1) process representing an exogenous labor supply shock. The labor force is given by $\widehat{l}_t = \widehat{n}_t - \widehat{u}_t$.

- Capital accumulation equation:

$$\widehat{\overline{k}}_t = \kappa_1 \widehat{\overline{k}}_{t-1} + \left(1 - \kappa_1\right)\widehat{i}_t + \kappa_2 \widehat{\varepsilon}_t^q,$$

with $\kappa_1 = (1 - \delta)/\tau$, and $\kappa_2 = (\tau + \delta - 1)(1 + \beta)\tau\varphi$. Capital services used in production is defined as: $\widehat{k}_t = \widehat{v}_t + \widehat{\overline{k}}_{t-1}$.

- Optimal capital utilisation condition:

$$\widehat{v}_t = \frac{1 - \psi}{\psi}\widehat{r}_t^k,$$

where ψ is the elasticity of the capital utilisation cost function.

- Optimal capital/labor input condition:

$$\widehat{k}_t = \widehat{w}_t - \widehat{p}_t - \widehat{r}_t^k + \widehat{n}_t.$$

- Monetary policy rule:

$$\widehat{r}_t = \rho_R \widehat{r}_{t-1} + \left(1 - \rho_R\right)\left(r_\pi \widehat{\pi}_t + r_y \widehat{y}_t^{\text{gap}} + r_{\Delta y}\Delta \widehat{y}_t^{\text{gap}}\right) + \widehat{\varepsilon}_t^r,$$

with $y_t^{\text{gap}} = \widehat{y}_t - \widehat{y}_t^{\text{flex}}$, the difference between actual output and the output in the flexible price and wage economy, i.e. in the absence of distorting price and wage markup shocks.

---

[4] The innovation of the TPF process enters the process describing exogenous spending with the parameter ρ_{ga}; see Table 2 in Section 4.

As productivity is written in terms of hours worked, we also introduce an auxiliary equation to link from observed total employment ($\widehat{e}_t$) to unobserved hours worked as in SW (2003):

$$\widehat{e}_t - \widehat{e}_{t-1} = E_t\widehat{e}_{t+1} - \widehat{e}_t + \frac{\left(1 - \beta\xi_n\right)\left(1 - \xi_n\right)}{\xi_n}\left(\widehat{e}_t - \widehat{n}_t\right).$$

The model is consistent with a balanced steady-state growth path, driven by deterministic labor augmenting trend growth. The observed variables for the euro area are given by quarterly data on the log of real (y_t), the log of real private consumption (c_t), the log of real total investment (i_t), the log of the GDP deflator ($p_{y,t}$), the log of real wages $w_t - p_{y,t}$, the log of total employment (e_t), the unemployment rate (u_t), and the short-term nominal interest rate (r_t). With all variables except the unemployment rate and the interest rate being measured in first differences, the measurement equations for the euro area are given by:

$$
\begin{bmatrix}
\Delta y_t \\
\Delta c_t \\
\Delta i_t \\
\pi_{y,t} \\
\Delta w_t - \pi_{y,t} \\
\Delta e_t \\
u_t \\
r_t
\end{bmatrix}
=
\begin{bmatrix}
\bar{\tau} + \bar{e} \\
\bar{\tau} + \bar{e} \\
\bar{\tau} + \bar{e} \\
\bar{\pi} \\
\bar{\tau} \\
\bar{e} \\
\bar{u} \\
4\bar{r}
\end{bmatrix}
+
\begin{bmatrix}
\Delta\widehat{y}_t \\
\Delta\widehat{c}_t \\
\Delta\widehat{i}_t \\
\widehat{\pi}_t \\
\Delta\widehat{w}_t - \Delta\widehat{\pi}_t \\
\Delta\widehat{e}_t \\
\widehat{u}_t \\
4\widehat{r}_t
\end{bmatrix},
\tag{10}
$$

where $\widehat{u}_t = \widehat{l}_t - \widehat{e}_t$. The steady-state parameters are determined as

$$\bar{\tau} = 100\left(\tau - 1\right), \qquad \bar{\pi} = 100\left(\pi - 1\right), \qquad \bar{r} = 100\left(\frac{\pi\tau}{\beta} - 1\right), \qquad \bar{u} = 100\left(\frac{\phi_w - 1}{\omega}\right),$$

where $(\phi_w - 1)$ is the steady-state labor market markup, π is steady-state inflation, while $\bar{e}$ reflects steady-state labour force growth and is added to the real variables that are not measured in per capita terms.

The following parameters are not identified by the estimation procedure and therefore calibrated: $g_y = 0.18$, $\delta = 0.025$, and $\varepsilon_p = 10$.

3. The Euro Area RTDB and the SPF

Following Galí et al. (2012), we estimate the DSGE model using eight macroeconomic time series for the euro area: real GDP, consumption, investment, employment, unit labor costs, GDP deflator inflation, the Euribor rate and the unemployment rate, with the first five log differenced. Real-time vintages of these data are available for downloading from the ECB's Statistical Data Warehouse and described in Giannone et al. (2012).[5] The frequency of the

---

[5] See also the detailed information about the RTDB in Giannone, Henry, Lalik, and Modugno (2010).

vintages is monthly corresponding to their publication in the ECB's Monthly Bulletin and the first vintage starts in January 2001. The latest available vintage we use in this paper is March 2011.

Table 1 presents the time flow of data releases available for the euro area Real-Time Data Base (RTDB) and the Survey of Professional Forecasters (SPF).[6] We take the vintage of the last month of the quarter, in order to convert the monthly vintages into a quarterly vintage. As is clear from the Table, this implies that monthly unemployment and HICP inflation are available for the first month of the quarter, whereas the monthly interest rate is available for the first and second month of the quarter. As we need the full quarter of monthly observations to construct the quarterly observation, we ignore the partial information available during the quarter. This implies that quarterly unemployment, HICP inflation and the interest rate are observed with a one quarter lag. Using the vintage of the last month in the quarter implies that the quarterly series are also typically available with one lag, with the exception of employment and wage compensation which are only available with a two quarter lag. In the forecasting exercises of Section 5, we will use the method of Waggoner and Zha (1999) to "nowcast" employment and wages based on information during the same quarter on real GDP and the other variables.[7]

Each monthly data vintage from the RTDB typically only covers data starting in the mid 1990s. To extend the real-time data backwards, we make use of updates of the quarterly database constructed for estimating the Area-Wide Model (AWM). Since 2000 the AWM database is updated annually; see Fagan, Henry, and Mestre (2005).

Figure 1 plots the first release and the first annual revision of real GDP growth, GDP deflator inflation and the unemployment rate (left panel), as well as the difference between the first release and the first annual revision (right panel). The standard deviation of the annual revision in real GDP growth lies between 0.1 and 0.2 and is quite persistent. In the most recent recession, the downward revision was particularly large. The variability of the annual revision in inflation is of the same size but much less persistent. Finally, revisions in unemployment are the most persistent.

One source of revision in the euro area data set is the increasing number of EU countries being a member of the euro area. Over the estimation sample the euro area developed from 12 to 16 members: Updates 4, 5, and 6 of the AWM database cover the euro area 12 data and are taken from 2003, 2004, and 2006, respectively. The euro area 13 composition is available in update 7 from 2007, while the euro area 15 composition is available in update 8, dated 2008. The last two updates that we make use of, 9 and 10, both cover the euro area 16 composition and were frozen in 2009 and 2010. The available files prior to update 7 are dated in September

---

[6] See, e.g., Garcia (2003) and Bowles, Friz, Genre, Kenny, Meyler, and Rautanen (2007) for information on the ECB's SPF. For a recent study using SPF data, see Genre, Kenny, Meyler, and Timmermann (2013).

[7] Relative to the vintage date, employment and wages are actually backcasted, while the remaining variables are nowcasted.

although the time they were frozen is unknown; as of update 7 the AWM data is frozen at the beginning of August.

Table 1 also shows that the SPF forecasts for HICP inflation, real GDP growth and unemployment typically become available in the first month of the quarter.[8] We associate this forecast with the quarter. The SPF data set contains average one-year and two-year ahead forecasts covering the period 1999Q1–2010Q4. Due to the different frequency and lags in the release of HICP inflation, real GDP and unemployment, the end date of the one-year and two-year ahead forecasts differs across the variables. For HICP inflation, the Q1-released one-year ahead forecasts refers to annual inflation in December in the same year, the Q2-release refers to March in the following year, etc. For real GDP growth, the "one-year ahead forecast" in the Q1-release refers to annual growth in the third quarter of the same year, etc. Finally, for the unemployment rate the "one-year ahead" in the Q1-release refers to the unemployment rate in November the same year, the Q2-release to the rate in February next year, etc. If we take the release-quarters as the current date for these forecasts, then for HICP inflation and unemployement we may think of this as having three and seven-quarters ahead forecasts and for real GDP growth two and six-quarters ahead forecasts.

The information set available to the professional forecasters is smaller than the RTDB available in the last month of the quarter, as last quarter's national account data are not available early in the quarter. On the other hand, it is clear that the professional forecasters have a lot more information available to nowcast the last quarter than the data we use from the RTDB. As a result, it is not clear whether the net information advantage is positive or negative.

4. Full-Sample Estimation Results

In this section we first discuss the estimation results using the latest-vintage full sample data set and make some comparisons with those reported for the United States in GSW (2011). We estimate the model over the period 1985Q1–2010Q4 using Bayesian full-system estimation techniques as in SW (2003) and (2007). The period from 1980Q1 till 1984Q4 is used as training period.

Table 2 reports the parameter estimates. A few striking differences with the US results are worth mentioning.

First, the average unemployment rate over the 1985–2010 period is quite a bit higher in the euro area (about nine percent) than in the United States (five percent). In steady state, the unemployment rate is proportional to the wage markup and the labor supply elasticity. For the euro area, the wage markup is estimated to be quite a bit higher (around 50 percent) and the labor supply elasticity somewhat lower. In other words, labor supply responds less to changes in real wages in the euro area.

---

[8] The inflation forecasts in the SPF only covers HICP inflation and not the GDP deflator. We therefore use the HICP inflation forecasts. In the estimation under the noise interpretation, the difference is picked up by the measurement error term. The model under the news interpretation is estimated from the RTDB data only, and SPF forecasts are only used as conditioning information when forecasting.

Second, the parameter, ν, governing the short-run wealth effects on labor supply, is quite small (0.08) as in the United States. Roughly speaking this amounts to a preference specification closer to that in Greenwood, Hercowitz, and Huffman (1988), in which the wealth effects are close to zero in the short run. As discussed at length in GSW, this helps ensure that not only employment, but also the labor force moves procyclically in response to most shocks.

Third, turning to some of the other parameters that enter the price and wage Phillips curve, the euro area economy appears to be much more sticky than the US economy. The estimated degree of price and wage indexation is relatively small (around 0.25) in both areas, but the estimated Calvo probability of unchanged wages and prices are quite a bit higher. The average wage contract duration is a bit higher than 3 quarters, whereas the average duration of unchanged prices is higher than six quarters. This is consistent with some of the micro evidence on price and wage adjustment.[9]

Fourth, it is worth pointing out that the monetary policy reaction coefficient to the output gap (defined as the deviation relative to the constant markup output) is quite high (0.19), whereas the coefficient on inflation is quite a bit lower (though higher than one).

Finally, focusing on the volatility and persistence of the eight structural shocks, the striking difference is that the risk premium shock is much more persistent in the euro area, whereas the investment-specific technology shock is much less persistent.

Overall, the estimation results for the euro area point to a less flexible economy with more persistence in the effects of various shocks on economic activity, prices and unemployment. This is also clear from Figures 2 to 4, which show the estimated impulse responses of output, inflation, the real wage, the interest rate, employment, the labor force, the unemployment rate, and the output gap to the eight structural shocks.

Before turning to the real-time forecasting results, it is also worth discussing briefly the forecast error variance decomposition at the 10 and 40 quarter horizon (Table 3). At the business cycle frequency about half of the fluctuations in output are driven by demand shocks and particularly the risk premium shock. The risk premium shock explains almost two thirds of the movement in unemployment at the 2.5 year horizon. The monetary policy shock another 12 percent. The most important shock driving output is the productivity shock. Price inflation is mostly driven by the price markup shock (61 percent) and the wage markup shock (17 percent).

In the longer run (after ten years), the role of wage markup shocks becomes more important in driving both unemployment and inflation. This is, however, much less so than in the United States where those shocks account for between 60 and 80 percent of the movements. The role of demand shocks in explaining real output and unemployment falls somewhat in the longer run, but remains much more important than in the US. Productivity shocks become relatively more important. In the longer run, inflation is mostly driven by price and wage markup shocks.

---

[9] See, for instance, Altissimo, Ehrmann, and Smets (2006) and WDN (2009).

These full-sample estimation results are very similar when we re-estimate the model using the SPF forecasts as noisy indicators of the model-consistent expectations (see Section 5). We find that the estimates of the standard deviation of the iid normal measurement error are relatively large: 0.76 for expected annual real GDP growth, 0.32 for expected GDP deflator inflation and 0.60 for the expected unemployment rate.

5. Real-Time Forecasting Performance

In this section we evaluate the real-time forecasting performance of the GSW model over the EMU period and compare it with five alternative models. Each of these models is re-estimated on an annual basis from the first RTDB vintage in 2001Q1 onwards. The forecasts are conditional on the data observed in the last historical period, where the available information in that period is used to backcast the variables that are missing in that period (typically employment and wage compensation). For example, the RTDB vintage 2001Q1 forecasts are computed for 2000Q4–2001Q4 with conditioning assumptions for 2000Q4 based on the historical data available for that quarter.

One question in real-time forecast evaluation exercises is which actual data to use to evaluate the forecast against and to calculate the forecast errors. As is common in the literature, we use the first annual revision of the data (as in Figure 1). We have checked the robustness of our findings against two possible alternatives for the actual data: (1) the first release data and (2) latest vintage data. Overall, the results are very similar.

We compare the GSW model with five alternative models. The two competing non-structural models are the random-walk model and a BVAR model using the same eight variables. The BVAR estimation follows Villani (2009). It is estimated using a prior on the steady-state mean and standard deviation of the variables which is the same as the prior steady-state mean and standard deviation used in estimating the DSGE model (with the exception of the standard deviation of unemployment). In addition, a fairly standard Minnesota-type prior with a diffuse prior on the covariance matrix is used.

The benchmark GSW model is also compared with three alternative estimated GSW models in which the mean forecasts of real GDP growth, HICP inflation, and unemployment from the SPF are used as additional information. We consider two interpretations of those professional forecasts. Under the "noise" interpretation, the mean professional forecasts are assumed to be noisy indicators of the rational expectations forecasts implied by the DSGE model. Specifically, mean SPF forecasts of annual inflation is added to the set of measurement equations in (10):

$$\pi^{\mathrm{a}}_{t+3|t} = 4\bar{\pi} + E_t\big[\widehat{\pi}_{t+3} + \widehat{\pi}_{t+2} + \widehat{\pi}_{t+1} + \widehat{\pi}_t\big] + \eta_{\pi,t},$$

where $\pi^{\mathrm{a}}_{t+3|t}$ is the mean SPF forecast of annual inflation between $t+3$ and $t-1$ in period t, and $E_t[\widehat{\pi}_{t+i}]$ is the rationally expected quarterly inflation rate (in deviation from steady-state) in period $t+i$ using information available until period t in the GSW model. The sum of the first and second term (in brackets) on the right hand side is therefore equal to the rational expectations

forecast of annual inflation three quarters ahead, while $\eta_{\pi,t}$ is an iid normal measurement error with mean zero and standard deviation σ_π. Measurement equations are similarly added to (10) for the mean SPF forecast of unemployment three quarters ahead and for the mean SPF forecast of annual real GDP growth two quarters ahead, both with individual measurement errors. The additional randomness makes it possible to estimate the parameters of the GSW model extended with the SPF data.[10] As discussed in Section 4, the standard deviations of the errors in the measurement equations are quite large. Conditional forecasts are computed using the Waggoner and Zha (1999) approach with hard conditions; see Warne (2013) for details on the implementation in linear state-space models.

Under the "news" interpretation, it is assumed that the forecasts reveal the presence of expected future structural shocks in line with those estimated over the past. This exercise is similar to the one performed by Del Negro and Schorfheide (2012) for the United States. In this case, the corresponding DSGE model forecast of annual real GDP growth two quarters ahead, annual GDP deflator inflation three quarters ahead, and the unemployment rate three quarters ahead will be identical to the mean SPF forecast. The Waggoner and Zha methodology is again used to compute the conditional forecasts, and we report results for two cases: one in which we only use the one-year ahead forecasts and another one in which we use in addition the two-year ahead SPF forecasts.

Figures 5 and 6 summarise the results. Figure 5 report the mean squared forecast errors for the *annual* growth rate of real GDP, consumption, investment, employment, the GDP deflator and real wages, as well as the unemployment rate and the short-term interest rate at each of the four horizons across the six competing models. Figure 6 plots two summary statistics, the log-determinant and the trace statistic of the MSE, as a function of the forecast horizon.

A few findings are worth highlighting. First, from the summary statistics it is clear that overall there is no model that dominates. It appears that the random walk model performs the worst at all horizons, but the differences are relatively small. According to the trace statistic, the DSGE model performs similarly to the BVAR model. Second, turning to the individual variables, all models perform equally in predicting annual real GDP growth. However, the DSGE model clearly underperforms in predicting consumption growth and real wage growth. An inspection of the forecast errors reveals that the GSW model systematically overpredicts real wage growth, while it underpredicts consumption. A similar result was found in Christoffel, Coenen, and Warne (2011) which evaluated the forecast performance of the NAWM for the euro area; see also Warne, Coenen, and Christoffel (2013). The New Keynesian model, which assumes a constant steady-state labor share and consumption to output ratio, has a difficult time explaining the falling labor share and the rising consumption to GDP ratio over this period. The non-structural models do much better in this respect. Finally, adding the additional information from the SPF forecasts has only a limited effect on the forecasting performance of the DSGE

---

[10] For inflation expectations, our approach is similar to Del Negro and Eusepi (2011), where we add measurement noise instead of modifying the policy rule.

model. Adding the SPF HICP inflation forecasts helps reducing the mean squared forecast error of GDP deflator inflation at the 3 to 4 quarter horizon, as it corrects somewhat for the downward bias of the benchmark DSGE model. This improvement is independent of whether the noise or the news interpretation is used. However, the noise versus news interpretation does matter for the predictive performance regarding wage growth. In the news model the higher inflation HICP forecasts are rationalised by higher expected markup shocks, which at the same time tend to reduce expected wage growth and thereby alleviate part of the upward bias of the benchmark DSGE model. In the noise model, the overprediction of real wage growth is instead magnified.

Examining the real-time estimates of the parameters of the DSGE model, we find that most of the estimated structural parameters are quite stable, but there is some variation over time. In particular, on occasion those parameters that are weakly identified such as, for example, the degree of habit formation and the persistence of the risk premium shock may covary.

6. Conclusion

In this paper we evaluated the real-time forcasting performance of the New Keynesian model of Galí, Smets, and Wouters (2012) estimated on euro area data. Overall, we find that the GSW model outperforms the random-walk model and has similar performance as the non-structural BVAR model. Adding one to two-year-ahead professional forecasts of real GDP growth, inflation, and the unemployment rate does not significantly improve the overall performance of the GSW model, although it does help to reduce some of the bias in the forecasts of wage growth in the news models.

TABLE 1: Time flow of data releases available for the RTDB and the SPF over a quarter.

	Month 1		Month 2	Month 3
	⇑	⇑	⇑	⇑
	RTDB M1	SPF	RTDB M2	RTDB M3
Monthly series	u_{m-2}	u_{m-2}	u_{m-2}	u_{m-2}
	π_{m-2}	$\boldsymbol{\pi_{m-1}}$	π_{m-2}	π_{m-2}
	r_{m-1}	r_{m-1}	r_{m-1}	r_{m-1}
Quarterly series	y_{q-2}	y_{q-2}	y_{q-2}	y_{q-1}
	c_{q-2}	c_{q-2}	c_{q-2}	c_{q-1}
	i_{q-2}	i_{q-2}	i_{q-2}	i_{q-1}
	$p_{y,q-2}$	$p_{y,q-2}$	$p_{y,q-2}$	$p_{y,q-1}$
	e_{q-2}	e_{q-2}	e_{q-2}	e_{q-2}
	w_{q-2}	w_{q-2}	w_{q-2}	w_{q-2}
	u_{q-2}	u_{q-2}	u_{q-1}	u_{q-1}
	r_{q-1}	r_{q-1}	r_{q-1}	r_{q-1}

The columns Month 1, Month 2, and Month 3 span the "Quarter".

NOTE: Unemployment is denoted by u, HICP by π, the average quarterly 3-month nominal interest rate by r, real GDP by y, real private consumption by c, the GDP deflator by p_y, total employment by e, and wages by w.

TABLE 2: Prior distributions and posterior estimates for the US and euro area models.

| | | Prior | | Posterior | | | | | | | |
| | | | | United States (1966:1–2007:4) | | | | Euro area (1985:1–2009:4) | | | |
parameter	type	mean	st.dev	mode	mean	5%	95%	mode	mean	5%	95%
structural parameters											
φ	N	4.0	1.0	4.09	3.96	2.34	5.58	4.65	4.77	3.34	6.31
h	B	0.7	0.1	0.78	0.75	0.65	0.85	0.65	0.64	0.54	0.72
ω	N	2.0	1.0	3.99	4.35	3.37	5.32	5.66	5.56	4.49	6.63
υ	B	0.5	0.2	0.02	0.02	0.01	0.04	0.06	0.12	0.03	0.34
θ_p	B	0.5	0.15	0.58	0.62	0.53	0.71	0.85	0.85	0.79	0.90
θ_w	B	0.5	0.15	0.47	0.55	0.44	0.66	0.74	0.72	0.60	0.89
γ_p	B	0.5	0.15	0.26	0.49	0.20	0.78	0.22	0.27	0.11	0.49
γ_w	B	0.5	0.15	0.16	0.18	0.07	0.29	0.22	0.25	0.12	0.42
ψ	B	0.5	0.15	0.57	0.56	0.36	0.75	0.46	0.48	0.29	0.69
ϕ_p	N	1.25	0.12	1.74	1.74	1.61	1.88	1.48	1.48	1.31	1.65
ϕ_w	N	1.25	0.12	1.18	1.22	1.15	1.29	1.53	1.51	1.41	1.62
α	N	0.3	0.05	0.17	0.17	0.14	0.20	0.22	0.22	0.19	0.26
θ_e	B	0.5	0.15	–	–	–	–	0.71	0.71	0.65	0.76
ρ_R	B	0.75	0.1	0.85	0.86	0.82	0.89	0.86	0.86	0.81	0.89
r_π	N	1.5	0.25	1.91	1.89	1.62	2.16	1.25	1.27	1.02	1.57
r_y	N	0.12	0.05	0.15	0.16	0.11	0.22	0.19	0.19	0.14	0.25
$r_{\Delta y}$	N	0.12	0.05	0.24	0.25	0.20	0.30	0.02	0.02	−0.00	0.06
$\bar{\pi}$	G	0.62	0.1	0.62	0.66	0.49	0.83	0.55	0.56	0.44	0.70
$\bar{\beta}$	G	0.25	0.1	0.31	0.31	0.17	0.43	0.24	0.27	0.13	0.43
$\bar{l}$	N	0.0	2.0	−1.65	−1.52	−3.83	0.77	–	–	–	–
$\bar{e}$	N	0.2	0.5	–	–	–	–	0.22	0.22	0.20	0.25
τ	N	0.4	0.1	0.34	0.34	0.30	0.37	0.14	0.14	0.08	0.20
τ_{wE}	N	0.2	0.1	0.07	0.08	0.03	0.12	–	–	–	–

NOTE: The prior distribution types are normal (N), standardized beta (B), gamma (G), and uniform (U). The parameter $\bar{\beta} = 100(\beta^{-1}-1)$. The parameter ϕ_w has prior mean 1.5 and standard deviation 0.25 for the euro area, while the parameter τ has prior mean 0.3 and standard deviation 0.1 for the vintages prior to 2008 and standard deviation 0.05 thereafter. The US results are taken from Galí, Smets, and Wouters (2012).

TABLE 2: Continued.

parameter	type	Prior mean	st.dev	Posterior United States (1966:1–2007:4) mode	mean	5%	95%	Euro area (1985:1–2009:4) mode	mean	5%	95%
st.dev. of the innovations											
σ_a	U	2.5	1.44	0.41	0.42	0.37	0.46	0.58	0.60	0.46	0.78
σ_b	U	2.5	1.44	1.73	1.60	0.56	2.50	0.24	0.28	0.16	0.44
σ_g	U	2.5	1.44	0.47	0.48	0.43	0.52	0.30	0.31	0.28	0.35
σ_q	U	2.5	1.44	0.42	0.42	0.34	0.49	0.49	0.49	0.39	0.60
σ_r	U	2.5	1.44	0.21	0.22	0.19	0.24	0.11	0.11	0.10	0.13
σ_p	U	2.5	1.44	0.05	0.11	0.03	0.18	0.35	0.49	0.21	1.02
σ_w	U	2.5	1.44	0.04	0.06	0.01	0.13	0.30	0.76	0.16	3.66
σ_s	U	2.5	1.44	1.07	1.17	0.89	1.45	1.02	1.07	0.85	1.33
persistence of the exogenous processes: $\rho = $ AR(1), $\mu = $ MA(1)											
ρ_a	B	0.5	0.2	0.98	0.98	0.97	0.99	0.98	0.98	0.97	0.99
ρ_b	B	0.5	0.2	0.36	0.42	0.19	0.67	0.91	0.91	0.84	0.96
ρ_g	B	0.5	0.2	0.97	0.97	0.96	0.99	0.99	0.99	0.98	1.00
ρ_{ga}	N	0.5	0.25	0.69	0.69	0.55	0.83	0.18	0.19	0.09	0.30
ρ_q	B	0.5	0.2	0.72	0.75	0.62	0.88	0.36	0.35	0.18	0.53
ρ_r	B	0.5	0.2	0.09	0.10	0.02	0.17	0.30	0.30	0.16	0.44
ρ_p	B	0.5	0.2	0.76	0.43	0.07	0.79	0.56	0.53	0.27	0.76
μ_p	B	0.5	0.2	0.59	0.57	0.24	0.96	0.44	0.47	0.25	0.71
ρ_w	B	0.5	0.2	0.99	0.98	0.97	1.00	0.91	0.89	0.81	0.95
μ_w	B	0.5	0.2	0.67	0.63	0.35	0.91	0.85	0.80	0.65	0.90

NOTE: The uniform priors all have lower bound 0 and upper bound 5. The parameter ρ_{ga} measures the effect of TFP innovations on exogenous spending. The persistence parameter for the labor supply process $\widehat{\varepsilon}_t^s$ is calibrated and given by $\rho_s = 0.999$.

TABLE 3: Variance decompositions in percent for the US and the euro area models.

variance decomposition	output			inflation			employment			unemployment		
10 quarter horizon												
demand shocks												
risk premium	6	/	32	2	/	12	16	/	67	20	/	64
exogenous spending	3	/	0	1	/	0	7	/	1	8	/	0
investment-specific	9	/	2	3	/	0	12	/	2	10	/	1
monetary policy	5	/	6	8	/	0	11	/	11	11	/	11
supply shocks												
productivity	59	/	54	6	/	8	5	/	1	4	/	2
price markup	2	/	0	27	/	61	3	/	0	0	/	0
labor market shocks												
wage markup	6	/	0	53	/	17	18	/	2	41	/	15
labor supply	11	/	3	0	/	0	29	/	12	5	/	4
40 quarter horizon												
demand shocks												
risk premium	2	/	14	1	/	12	6	/	43	7	/	54
exogenous spending	1	/	0	1	/	0	3	/	4	3	/	0
investment specific	5	/	1	2	/	0	4	/	1	3	/	1
monetary policy	2	/	2	5	/	0	4	/	7	4	/	9
supply shocks												
productivity	56	/	75	4	/	12	3	/	0	1	/	0
price markup	1	/	0	18	/	53	1	/	2	0	/	0
labor market shocks												
wage markup	17	/	0	67	/	19	39	/	4	80	/	27
labor supply	17	/	5	0	/	0	40	/	0	2	/	3

NOTE: The first entry gives the variance decompositions for the US (1966:1–2007:4) from Galí, Smets, and Wouters (2012); the second entry for the euro area (1985:1–2009:4).

FIGURE 1: First release and annual revision data for real GDP growth (Δy_t), GDP deflator inflation ($\pi_{y,t}$), and the unemployment rate (u_t), 2000Q4–2010Q4.
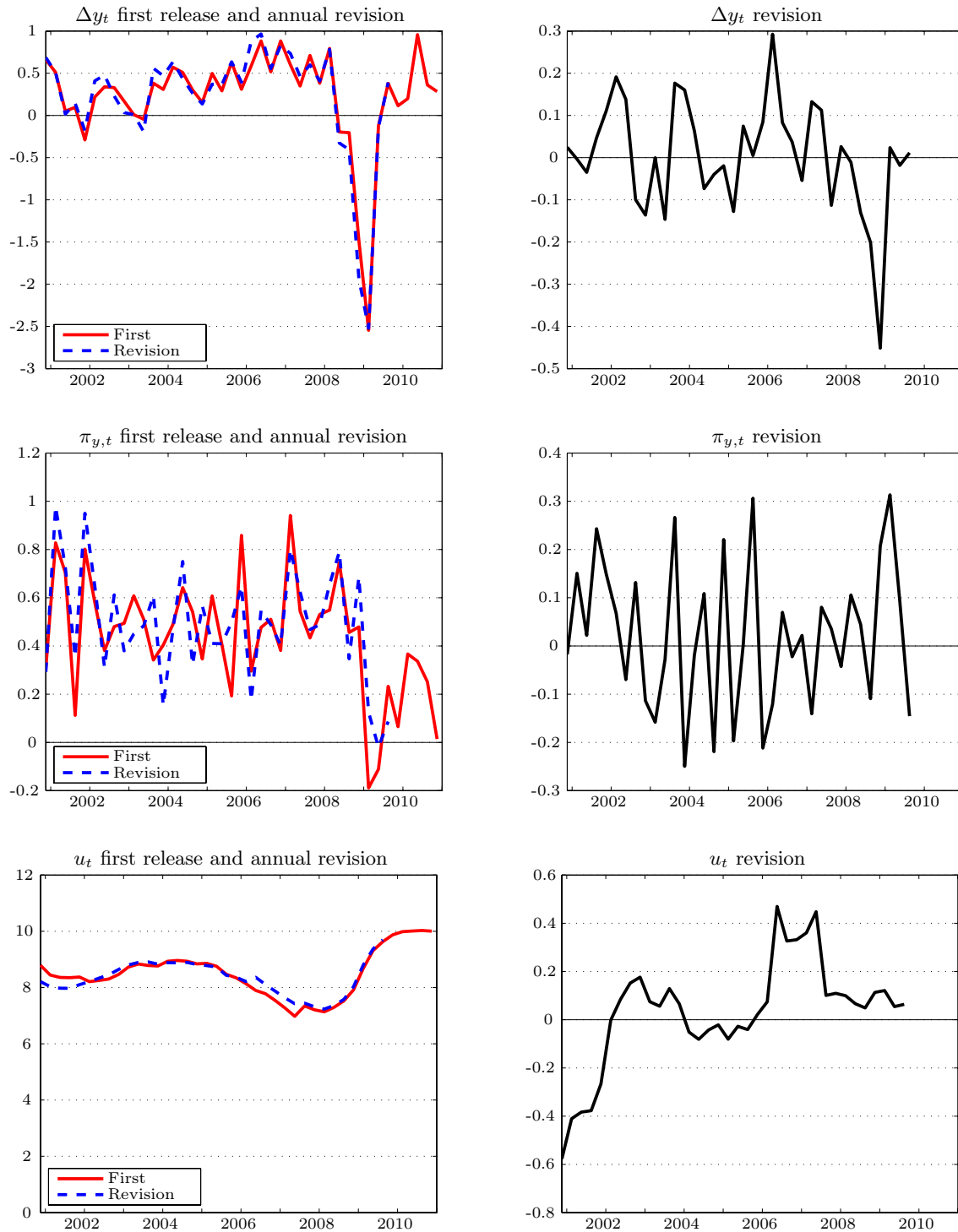
FIGURE 2: Impulse response functions up to 20 quarters for output, inflation, the short-term nominal interest rate, employment growth, unemployment, and the output gap from the four demand shocks in the estimated euro area New Keynesian model.
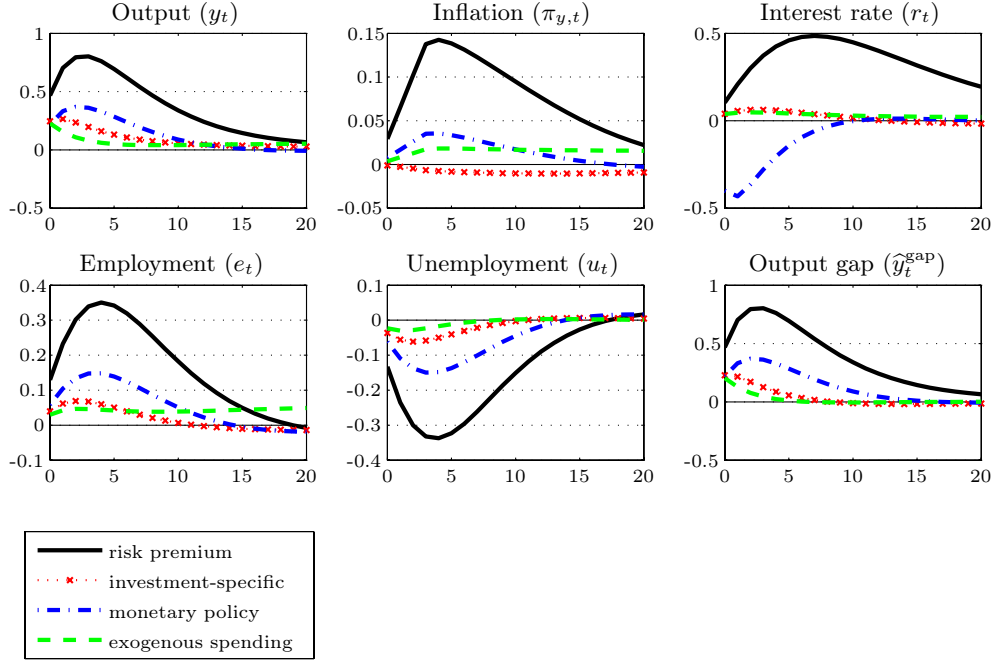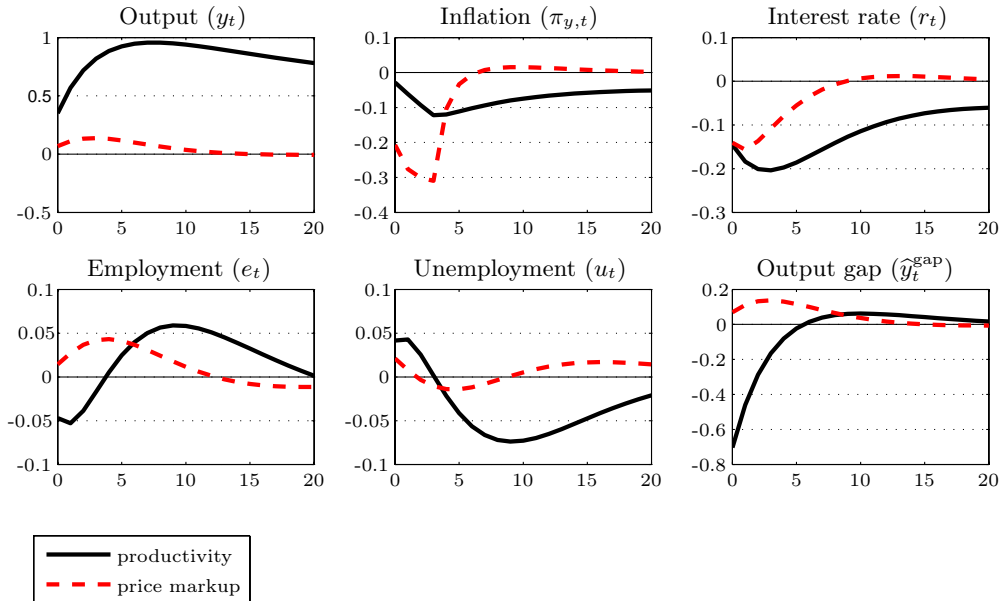

FIGURE 3: Impulse response functions up to 20 quarters for output, inflation, the short-term nominal interest rate, employment growth, unemployment, and the output gap from the two supply shocks in the estimated euro area New Keynesian model.

FIGURE 4: Impulse response functions up to 20 quarters for output, inflation, the short-term nominal interest rate, employment growth, unemployment, and the output gap from the two labor market shocks in the estimated euro area New Keynesian model.
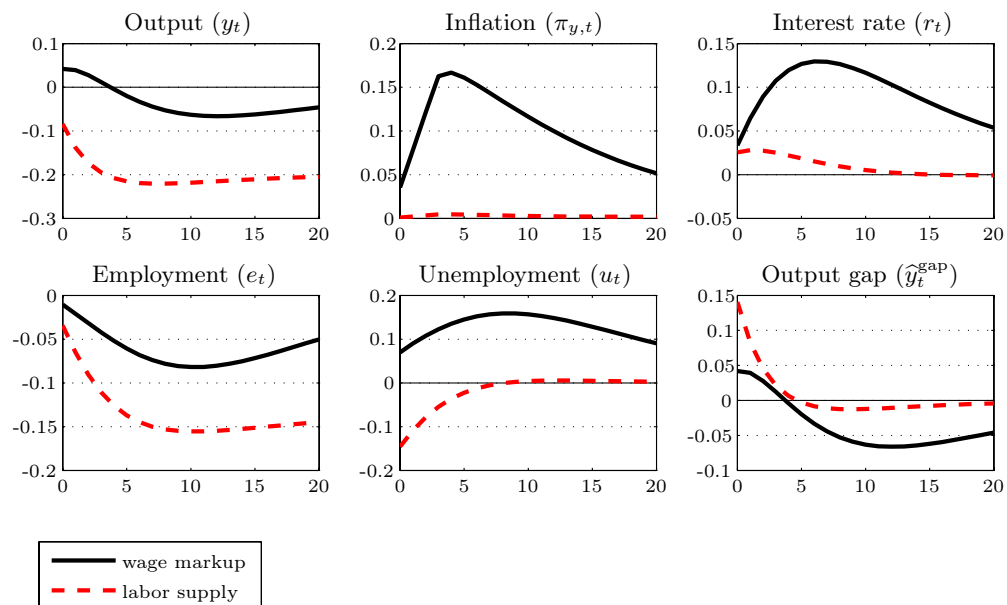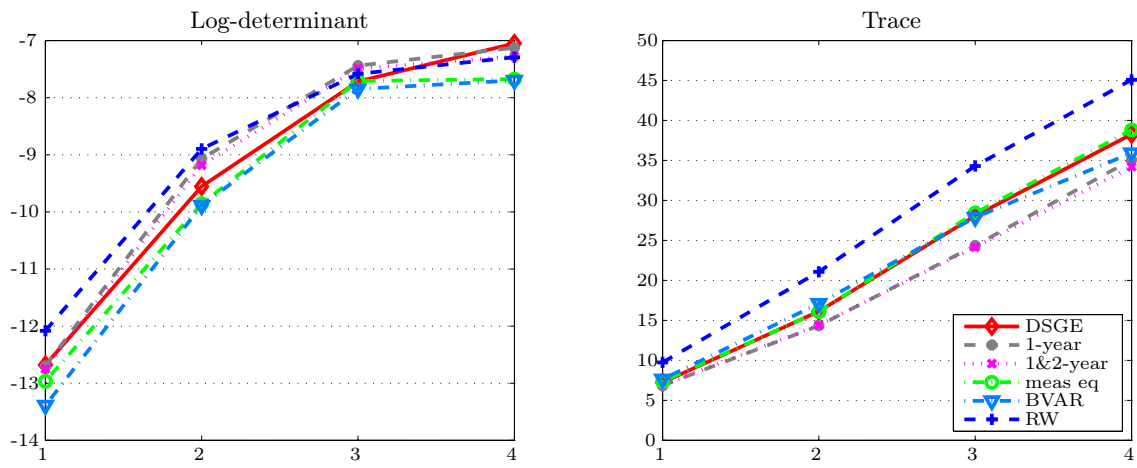
FIGURE 5: Root mean squared forecast errors for RTDB vintages 2001Q1–2010Q4.

FIGURE 6: Multivariate MSE statistics for RTDB vintages 2001Q1–2010Q4.

<center>REFERENCES</center>

Altissimo, F., Ehrmann, M., and Smets, F. (2006), "Inflation Persistence and Price-Setting Behaviour in the Euro Area: A Summary of the IPN Evidence," ECB Occasional Paper Series No. 46.

Bowles, C., Friz, R., Genre, V., Kenny, G., Meyler, A., and Rautanen, T. (2007), "The ECB Survey of Professional Forecasters (SPF): A Review After Eight Years' Experience," ECB Occasional Paper Series No. 59.

Calvo, G. A. (1983), "Staggered Prices in a Utility-Maximizing Framework," *Journal of Monetary Economics*, 12, 383–398.

Chari, V. V., Kehoe, P. J., and McGrattan, E. R. (2009), "New Keynesian Models: Not Yet Useful for policy Analysis," *American Economic Journal: Macroeconomics*, 1, 242–266.

Christoffel, K., Coenen, G., and Warne, A. (2011), "Forecasting with DSGE Models," in M. P. Clements and D. F. Hendry (Editors), *The Oxford Handbook of Economic Forecasting*, 89–127, Oxford University Press, New York.

Coenen, G., Levin, A., and Wieland, V. (2005), "Data Uncertainty and the Role of Money as Information Variable for Monetary Policy," *European Economic Review*, 49, 975–1006.

Coenen, G. and Warne, A. (2012), "Risks to Price Stability and the Zero Lower Bound for Nominal Interest Rates," Unpublished manuscript, ECB.

Croushore, D. (2011), "Frontiers of Real-Time Data Analysis," *Journal of Economic Literature*, 49, 72–110.

Croushore, D. and Stark, T. (2001), "A Real-Time Data Set for Macroeconomists," *Journal of Econometrics*, 105, 111–130.

Del Negro, M. and Eusepi, S. (2011), "Fitting Observed Inflation Expectations," *Journal of Economic Dynamics and Control*, 35, 2105–2131.

Del Negro, M. and Schorfheide, F. (2012), "DSGE Model-Based Forecasting," Prepared for *Handbook of Economic Forecasting*, Volume 2.

Diebold, F. X. and Rudebusch, G. D. (1991), "Forecasting Output with the Composite Leading Index: A Real-Time Analysis," *Journal of the American Statistical Association*, 86, 603–610.

Edge, R. M. and Gürkaynak, R. S. (2010), "How Useful Are Estimated DSGE Model Forecasts for Central Bankers?" *Brookings Papers on Economic Activity*, Fall, 209–259.

Erceg, C. J., Henderson, D. W., and Levin, A. T. (2000), "Optimal Monetary Policy with Staggered Wage and Price Contracts," *Journal of Monetary Economics*, 46, 281–314.

Fagan, G., Henry, J., and Mestre, R. (2005), "An Area-Wide Model for the Euro Area," *Economic Modelling*, 22, 39–59.

<center>– **28** –</center>

Galí, J. (2011a), "The Return of the Wage Phillips Curve," *Journal of the European Economic Association*, 9, 436–461.

Galí, J. (2011b), *Unemployment Fluctuations and Stabilization Policies: A New Keynesian Perspective*, MIT Press, Cambridge, MA.

Galí, J., Smets, F., and Wouters, R. (2012), "Unemployment in an Estimated New Keynesian Model," in D. Acemoglu and M. Woodford (Editors), *NBER Macroeconomics Annual 2011*, 329–360, University of Chicago Press.

Garcia, J. A. (2003), "An Introduction to the ECB's Survey of Professional Forecasters," ECB Occasional Paper Series No. 8.

Genre, V., Kenny, G., Meyler, A., and Timmermann, A. (2013), "Combining Expert Forecasts: Can Anything Beat the Simple Average?" *International Journal of Forecasting*, 29, 108–121.

Giannone, D., Henry, J., Lalik, M., and Modugno, M. (2010), "An Area-Wide Real-Time Database for the Euro Area," ECB Working Paper Series No. 1145.

Giannone, D., Henry, J., Lalik, M., and Modugno, M. (2012), "An Area-Wide Real-Time Database for the Euro Area," *Review of Economics and Statistics*, 94, 1000–1013.

Greenwood, J., Hercowitz, Z., and Huffman, G. (1988), "Investment, Capacity Utilization and the Real Business Cycle," *American Economic Review*, 78, 402–417.

Merz, M. (1995), "Search in the Labor Market and th Real Business Cycle," *Journal of Monetary Economics*, 36, 269–300.

Smets, F. and Wouters, R. (2003), "An Estimated Stochastic Dynamic General Equilibrium Model for the Euro Area," *Journal of the European Economic Association*, 1, 1123–1175.

Smets, F. and Wouters, R. (2007), "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, 97, 586–606.

Villani, M. (2009), "Steady-State Priors for Vector Autoregressions," *Journal of Applied Econometrics*, 24, 630–650.

Waggoner, D. F. and Zha, T. (1999), "Conditional Forecasts in Dynamic Multivariate Models," *Review of Economics and Statistics*, 81, 639–651.

Warne, A. (2013), "YADA Manual — Computational Details," Manuscript, European Central Bank. Available with the YADA distribution.

Warne, A., Coenen, G., and Christoffel, K. (2013), "Predictive Likelihood Comparisons with DSGE and DSGE-VAR Models," Manuscript, European Central Bank.

WDN (2009), "Wage Dynamics in Europe: Final Report of the Wage Dynamics Network (WDN)," Mimeo, http://www.ecb.europa.eu/home/pdf/wdn_finalreport_dec2009.pdf.