Monetary Policy Shocks: We got News![*]

Sandra Gomes[†]
Bank of Portugal
and ISEG/TULisbon

Nikolay Iskrev[‡]
Bank of Portugal

Caterina Mendicino[§]
Bank of Portugal

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Abstract

We augment a medium-scale DSGE model with monetary policy news shocks and fit it to US data. Monetary policy news shocks improve the performance of the model both in terms of marginal data density and in terms of its ability to match the empirical moments of the variables used as observables. We estimate several versions of the model and find that the one with news shocks over a two-quarter horizon dominates in terms of overall goodness of fit. We show that, in the estimated model: (1) adding monetary policy news shocks to the model does not lead to identification problems; (2) monetary policy news shocks account for a larger fraction of the unconditional variance of the observables than the standard unanticipated monetary policy shock; (3) these news shocks also help to achieve a better matching of the covariances of consumption growth and the interest rate.

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[†]Address: Bank of Portugal, Economic Research Department, Av. Almirante Reis 71, 1150-012 Lisbon, Portugal; e-mail: sandra.cristina.gomes@bportugal.pt

[‡]Address: Bank of Portugal, Economic Research Department, Av. Almirante Reis 71, 1150-012 Lisbon, Portugal; e-mail: nikolay.iskrev@bportugal.pt

[§]Address: Bank of Portugal, Economic Research Department, Av. Almirante Reis 71, 1150-012 Lisbon, Portugal; e-mail: cmendicino@bportugal.pt

1 Introduction

The role of changes in expectations as drivers of macroeconomic fluctuations has long been discussed in macroeconomics. Notable earlier work that emphasise the importance of expectation-driven cycles include Pigou (1927) and Keynes (1936). In recent years, there has been a considerable effort to understand and quantify the macroeconomic effects of changes in expectations that anticipate future shifts in fundamentals as captured by news shocks. Using a vector autoregression (VAR) model and data on total factor productivity and stock prices, Beaudry and Portier (2006) show that stock price fluctuations reflect future permanent improvements in TFP. They argue that "*...business cycles may be driven to a large extent by TFP growth that is heavily anticipated by economic agents thereby leading to what might be called expectation-driven booms. Hence, our empirical results suggest that an important fraction of business cycle fluctuations may be driven by changes in expectations—as is often suggested in the macro literature—but these changes in expectations may well be based on fundamentals since they anticipate future changes in productivity.*" Since Beaudry and Portier (2006), several authors have investigated how news about future productivity may drive current production in real and monetary models of the business cycle (Beaudry et al., 2007; Floden, 2007; Christiano, Ilut, Motto, and Rostagno, 2008; Jaimovich and Rebelo, 2009; Den Haan and Kaltenbrunner, 2009; Auray, Gomme and Guo, 2012). More recently, an increasing number of papers quantify the importance of news on a variety of shocks for business cycle fluctuations (Fujiwara, Hirose, and Shintani, 2011; Milani and Treadwell, 2012; Schmitt-Grohé and Uribe, 2012; Khan and Tsoukalas, 2012; Gomes and Mendicino, 2011; Christiano, Motto, and Rostagno, 2013). The main concern of this literature is to understand whether news shocks are important drivers macroeconomic fluctuations. We contribute to the news-shocks literature by assessing quantitatively evaluating the role of news on monetary policy shocks in an estimated medium-sized dynamic stochastic general equilibrium (DSGE) model. Further, we assess news on which type of shocks are important to fit the data well.

Unanticipated monetary policy shocks have played a central role in the understanding of the transmission mechanism of monetary policy.[1] A very large number of papers investigate the effects of unanticipated shocks to a given interest rate rule in DSGE models.[2] As highlighted by Lassen and Svensson (2011) "Such policy simulations correspond to a situation when the central bank would non-transparently and secretly plan to surprise the private sector by deviations from an announced instrument rule or alternatively, a situation when the central bank announces and follows a future path but the path is not believed by, and each period surprises, the private sector." Thus, as argued by Lassen and Svensson (2011), unanticipated monetary policy shocks correspond to "policy that is either non-transparent or lacks credibility".

Monetary policy news shocks, i.e. anticipated components of the monetary policy shock, capture instead deviations from a given policy interest rate rule describing the usual behaviour of the monetary policy

[1] See Sims (1980), Sims and Zha (), etc...

[2] Leeper and Zha, 2003; Christiano, Eichembaum and Evans, 2005;

authority that are anticipated by the agents. Thus, news shocks may reflect credible central bank announcements about the plan to implement particular interest-rate paths that deviate from their usual behaviour as captured by the systematic part of the monetary policy rule.[3] Alternatively, they might capture the private sector's own beliefs about future unanticipated deviations from the standard conduct of monetary policy.

While the literature has investigated extensively the impact of unanticipated monetary policy shocks, evidence on the macroeconomic effects of anticipated monetary policy shocks is still limited. This paper investigates the effects of monetary policy news shocks in a DSGE model and quantifies the importance of such news shocks with respect to both unanticipated monetary policy shocks and other anticipated sources of macroeconomic fluctuations. To this purpose, we introduce monetary policy news shocks, into a standard New Keynesian model that features a rich set of shocks and frictions as in Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2003, 2007).[4]

We argue that monetary policy news shocks are important to improving the empirical performance of the model. We develop this argument by comparing in several dimensions the quantitative performance of nested models: a model that only features standard unanticipated shocks and various versions of the same model that also allow for anticipated monetary policy shocks over various alternative horizon specifications.

We estimate different versions of the model using Bayesian methods and quarterly US data from 1960:1 to 2010:4. Following the DSGE literature, we conduct Bayesian inference and use posterior probabilities to assess the adequacy of the alternative modelling frameworks. We address the question of how many quarters in advance monetary policy shocks are anticipated and find that, among all alternative horizon specifications, the data strongly favor the inclusion of news shocks two quarters in advance. The version of the model featuring two-quarter ahead monetary policy news shocks also outperforms the model without news shocks in terms of overall goodness of fit. These results hold for different specifications of the priors used for the standard deviations of the shocks.

On the basis of identification analysis, we also argue that introducing monetary policy news shocks does not lead to identification problems. The effects of the standard deviation of this shock on the likelihood are non-negligible and distinct from the effects of the other parameters of the model, including the standard deviation of the unanticipated component of the same shock and of other shocks. In particular, we find that the effects of monetary policy news shocks on the likelihood function is mostly via their impact on the first and second order moments of the nominal interest rate, GDP growth and consumption growth.

Further differences between the unanticipated and anticipated components of the monetary policy shock

[3] Policy announcements regarding anticipated policy rates paths are part of the regular conduct of monetary policy by central banks that follow a transparent flexible inflation targeting, such as the Reserve Bank of New Zealand, the Norges Bank, the Riksbank, and the Czech National Bank. Forward guidance, i.e. information that comes from the Federal Open Market Commitee (FOMC) about the future path for policy instruments, have also been extensively used by the Federal Reserve since December 2008. FOMC's statements anticipating the maintainance of policy accommodation were also present in the minutes of the second half of 2003.

[4] Apart from the monetary policy shock, the model features six other sources of business cycle fluctuations: a neutral technology shock, a risk-premium shock, an investment specific shock, government spending shock, a wage-markup shock and a price-markup shock.

are found in the propagation mechanism and, in particular, in the role of structural parameters for the impulse responses to these shocks. In terms of the sensitivity to parameters, the most sizeable differences are detected in the response of consumption and investment growth that display much larger sensitivity to changes in the interest-rate smoothing and wage stickiness parameters.

According to our estimates, the overall contribution of monetary policy shocks to the unconditional variance of consumption growth, hours worked and GDP growth is substantial. The anticipated component of this shock is generally more important than the unanticipated component in accounting for macroeconomic fluctuations. In particular, monetary policy news shocks explain around 15 per cent of fluctuations in hours worked and also account for a larger percentage of fluctuations in consumption growth than most of the other shocks. Further, news shocks account for about the same percentage of fluctuations in GDP growth as the investment-specific shocks. Despite the larger implied variance share of the unanticipated shocks, we find that neglecting monetary policy news substantially reduces the ability of the model to match the moments of the observables. In particular, the model without monetary policy news shocks displays substantially larger gaps between the theoretical and empirical covariances of consumption growth and the interest rate.

Last, we test if monetary policy news shocks capture the impact of other types of news shocks. Using the same set of observables, we re-estimate the model allowing for news on a variety of other shocks. We find that, in the specification with news on all shocks, the estimated standard deviation of monetary policy news shock is significanlty different from zero and similar to the one of the model with only news on monetary policy shocks. In contrast, the 95 per cent probability interval of the standard deviation of the all other news shocks includes the value of zero. This suggests that news on shocks other than monetary policy, are not important in the model. Indeed, adding news on all shocks reduces the ability of the model to match the moments of most variables. The largest discrepancies are found in terms of the moments of hours worked, investment growth and the nominal interest rate. The specification with only monetary policy news shocks outperforms all other specifications in terms of overall goodness of fit.

Related Literature.

Fujiwara, et al. (2011) argue that the contribution of news on TFP shocks is often larger than that of the unanticipated TFP shocks based on the results of an estimated DSGE model with only news on TFP shocks. Schmitt-Grohé and Uribe (2012) document that news on future neutral productivity shocks, investment-specific shocks, and government spending shocks account for a sizable fraction of aggregate fluctuations in post-war United States. Khan and Tsoukalas (2012) show that, in the presence of wage and price rigidities and a variety of news shocks, non-technology sources of news dominate technology news, with wage-markup news shocks in particular accounting for about sixty per cent of the variance share of both hours and inflation. None of these papers considers monetary policy news shocks.

More recently, Christiano et al. (2013) argue that news on risk shocks, i.e. anticipated shocks to the idiosyncratic risk in actual business ventures, are a key driver of business cycles. Interestingly, Christiano et al. (2013) also estimate alternative versions of their model with news on different aggregate shocks and find that the specification with monetary policy news fits the data better than the specifications with news on other aggregate shocks, such as equity shocks, technology shocks and government consumption shocks.

Lassen and Svensson (2011) propose the use of anticipated shocks to introduce forward guidance in DSGE models. Indeed, selected sequences of anticipated shocks can be used to deliver any desired anticipated policy interest rate path. They investigate the implications of policy simulations for alternative policy rate paths based on anticipated and unanticipated shocks.[5] The work of Milani and Treadwell (2012) is more closely related to our the paper. They augment a stylized three-equation New Keynesian model with news on monetary policy shocks and find that it outperforms the model without news shocks. They also find that anticipated policy shocks play a larger role in the business cycle than unanticipated ones. We complement their work in two important ways. First, we rely on a model with a much richer stochastic structure and a larger set of frictions that has been shown to explain US data quite well (Smets and Wouters, 2005 and 2007; Justiniano, Primiceri and Tambalotti, 2010 and 2011; Altig, Christiano, Eichenbaum and Linde, 2011). Thus, we can draw quantitatively relevant implications about the importance of monetary policy news shocks. Second, we formally address the issue of the identification of news shocksin a more comprehensive way than is usually done in the related literature. Differently from previous papers, we also document the main differences between the anticipated component of monetary policy shocks and all other parameters in terms of the likelihood and of the moments of the observables. Last, we compare the model with monetary policy news shocks against the estivated version of the same model with news on a variety of other shocks, such as risk-premium shocks, price- and wage-markup shocks and investment-specific shocks.

The rest of the paper is organised as follows. Section 2 describes the model and Section 3 describes the estimation methodology. Section 4 tests for identification. Section 5 comments on the quantitative implications of the model and Section 6 reports robustness analysis. Section 7 concludes.

2 The Model

The basic structure of the model follows the standard News Keynesian framework as developed by Christiano, Eichembaum and Evans (2005) and Smets and Wouters (2007). The model economy consists of households, final and intermediate goods firms, employment agencies and a government. The model can be summarised by the following log-linearised system of equations, where $\widehat{\ }$ denotes variables in log-deviation from the steady-state balanced growth path and the variables without time subscripts are steady-state values.[6]

[5] Verona et al. (2012) show that anticipations of too low for too long interest rates generate a larger and quicker boom in economic activity and asset prices than similar unanticipated policies.

[6] See Appendix A for futher details about the non-linear version of the model.

The dynamics of aggregate consumption follows the consumption Euler equation:

$$\widehat{c}_t = \frac{h/\gamma}{1+h/\gamma}\widehat{c}_{t-1} + \left(1 - \frac{1}{1+h/\gamma}\right) E_t\widehat{c}_{t+1} + \frac{(\sigma_c - 1)\left(w^h l/c\right)}{\sigma_c\,(1+h/\gamma)}\left(\widehat{l}_t - E\widehat{l}_{t+1}\right) - \frac{1-h/\gamma}{\sigma_C\,(1+h/\gamma)}\left(\widehat{R}_t + \widehat{\varepsilon}_{b,t}\right), \quad (1)$$

where w^h denotes steady-state wages, σ_c is the inverse of the intertemporal elasticity of substitution, h is the parameter governing the degree of external habits in consumption and γ is the steady-state growth rate. Current consumption, $\widehat{c}_t$, depends on the ex-ante real interest rate, $\widehat{R}_t = \widehat{r}_t - E\widehat{\pi}_{t+1}$, and on a weighted average of past and expected future consumption as implied by the assumption of external habit formation in consumption. Notice that in the absence of external habits, i.e. $h = 0$, and with log-utility in consumption, i.e. $\sigma_c = 1$, it is possible to obtain the standard forward-looking consumption equation. Due to the assumption of non-separability of the utility function between consumption and hours worked, current consumption also depends on the expected growth in hours worked, $\left(\widehat{l}_t - E\widehat{l}_{t+1}\right)$. Equation (1) also features an exogenous premium in the return to bonds, $\widehat{\varepsilon}_{b,t}$, i.e. a wedge between the interest rate controlled by the central bank and the return on bonds. The risk-premium shock follows a standard $AR(1)$ process, $\widehat{\varepsilon}_{b,t} = \rho^b\widehat{\varepsilon}_{b,t-1} + u_{b,t}$, where ρ^b is the persistence parameter and $u_{b,t}$ is a white noise process with mean zero and standard deviation σ_b. The dynamics of investment follows the investment Euler equation:

$$\widehat{i}_t = \frac{1}{1+\beta\gamma^{(1-\sigma_c)}}\widehat{i}_{t-1} + \left(1 - \frac{1}{1+\beta\gamma^{(1-\sigma_c)}}\right) E_t\widehat{i}_{t+1} + \frac{1}{1+\beta\gamma^{(1-\sigma_c)}}\frac{1}{\gamma^2\varphi}\widehat{q}_t + \widehat{\varepsilon}_{q,t}, \quad (2)$$

where $\widehat{q}_t$ is the real value of existing capital stock, φ is the steady state elasticity of the capital adjustment cost function and β denotes the households discount factor. $\widehat{\varepsilon}_{q,t}$ is a disturbance to the investment-specific technology process, i.e. a source of exogenous variation in the efficiency with which the final good can be transformed into physical capital and thus, into tomorrow's capital input. The investment-specific shock follows a standard $AR(1)$ process, $\widehat{\varepsilon}_{q,t} = \rho^q\widehat{\varepsilon}_{q,t-1} + u_{q,t}$, where ρ^q is the persistence parameter and $u_{q,t}$ is a white noise process with mean zero and standard deviation σ_q. The arbitrage condition for the price of capital follows the capital Euler equation:

$$\widehat{q}_t = \beta\gamma^{-\sigma_c}(1-\delta)\,E\widehat{q}_{t+1} + \left(1 - \beta\gamma^{-\sigma_c}(1-\delta)\right)E\widehat{r}^k_{t+1} - \widehat{R}_t - \widehat{\varepsilon}_{b,t}, \quad (3)$$

where δ is the depreciation rate and $\widehat{\varepsilon}_{b,t}$ is the risk-premium disturbance.[7] Installed capital, $\widehat{k}_t$, evolves according to the standard accumulation equation:

$$\widehat{k}_t = \left((1-\delta)/\gamma\right)\widehat{k}_{t-1} + \left(1 - (1-\delta)/\gamma\right)\widehat{i}_t + \left[\left(1-(1-\delta)/\gamma\right)\left(1+\beta\gamma^{(1-\sigma_c)}\right)\gamma^2\varphi\right]\widehat{\varepsilon}_{i,t}. \quad (4)$$

[7] Similarly to a net-worth shock (see, among others, Bernanke, Gertler and Ghilchrist, 1999; and Christiano, Motto and Rostagno, 2003), a positive risk-premium shock reduces current consumption through an increase in the required return on assets, and simultaneously it reduces the value of capital and, thus, investment.

Output, $\widehat{y}_t$, is produced using capital services, $\widehat{k}_t^s$, and hours worked, $\widehat{l}_t$, such that:

$$\widehat{y}_t = \phi_p \left[\alpha \widehat{k}_t^s + (1-\alpha)\, \widehat{l}_t + \widehat{\varepsilon}_{a,t} \right], \tag{5}$$

where α denotes the share of capital in production and ϕ_p is a fixed cost of production such that profits are zero in steady state. $\widehat{\varepsilon}_{a,t}$ is a neutral technology shock that follows a standard $AR(1)$ process, $\widehat{\varepsilon}_{a,t} = \rho^a \widehat{\varepsilon}_{a,t-1} + u_{a,t}$, where ρ^a is the persistence parameter and $u_{a,t}$ is a white noise process with mean zero and standard deviation σ_a. Physical capital is transformed into current capital services to be used in production:

$$\widehat{k}_t^s = \widehat{k}_{t-1} + \widehat{z}_t, \tag{6}$$

where $\widehat{z}_t$ is the degree of capital utilization that is optimally chosen by households as a function of the rate at which effective capital is rented to firms, $\widehat{r}_t^k$. Accordingly,

$$\widehat{z}_t = \frac{1-\psi}{\psi} \widehat{r}_t^k, \tag{7}$$

where ψ is a positive function of the elasticity of capital utilization adjustment cost function and it is normalised to be between zero and one. Firm cost minimization implies the typical relationship between factor payments

$$\widehat{r}_t^k = -\left(\widehat{k}_t - \widehat{l}_t \right) + \widehat{w}_t. \tag{8}$$

The aggregate resource constraint is given by:

$$\widehat{y}_t = c_y \widehat{c}_t + i_y \widehat{i}_t + z_y \widehat{z}_t + \widehat{\varepsilon}_{g,t} \tag{9}$$

where c_y, i_y and z_y are, respectively, the steady state ratios of consumption, investment and capital utilization as a fraction of total output.[8] Government spending $\widehat{\varepsilon}_{g,t}$ is assumed to be exogenously determined and to follow an $AR(1)$ process, $\widehat{\varepsilon}_{g,t} = \rho^g \widehat{\varepsilon}_{g,t-1} + u_{g,t} + \rho^{ga} u_{a,t}$, where ρ^g is the persistence parameter and $u_{g,t}$ is a white noise process with mean zero and standard deviation σ_g. As in Smets and Wouters (2007), we also allow government spending to depend on changes in aggregate productivity, with a coefficient ρ^{ga}.

Price rigidities *à la* Calvo (1983), in combination with partial indexation to lagged inflation of non-

[8] In steady state $i_y = (\gamma - 1 + \delta) k_y$ and $z_y = r^k k_y$ and $c_y = \frac{h/\gamma}{1+h/\gamma}$.

optimised prices, imply the following equation for inflation dynamics

$$\begin{aligned}\widehat{\pi}_t &= \frac{\iota^P}{1+\beta\gamma^{(1-\sigma_c)}\iota^P}\widehat{\pi}_{t-1} + \frac{\beta\gamma^{(1-\sigma_c)}}{1+\beta\gamma^{(1-\sigma_c)}\iota^P}E\widehat{\pi}_{t+1} \\ &\quad - \frac{1}{1+\beta\gamma^{(1-\sigma_c)}\iota^P}\left[\left(1-\beta\gamma^{(1-\sigma_c)}\xi^P\right)\frac{1-\xi^P}{\xi^P\left(\left(\phi_p-1\right)\zeta^p+1\right)}\right]\widehat{\mu}_t^P + \widehat{\varepsilon}_{p,t},\end{aligned} \tag{10}$$

where $\left(1-\xi^P\right)$ denotes the fraction of firms that optimise their price every period, ι^P is the degree of indexation to past inflation and ζ^p is the curvature of the Kimball (1995) good market aggregator. $\widehat{\varepsilon}_{p,t}$ represents the price mark-up shock that follows a standard $AR(1)$ process, $\widehat{\varepsilon}_{p,t} = \rho^p\widehat{\varepsilon}_{p,t-1} + u_{p,t}$, where ρ^p is the persistence parameter and $u_{p,t}$ is a white noise process with mean zero and standard deviation σ_p. Monopolistic competition in the goods market implies a price markup, $\widehat{\mu}_t^P$, equal to the difference between the marginal productivity of labor, $\alpha\left(\widehat{k}_t^s - \widehat{l}_t\right)$, and the real wages, $\widehat{w}_t$, such that:

$$\widehat{\mu}_t^P = \alpha\left(\widehat{k}_t^s - \widehat{l}_t\right) - \widehat{w}_t + \widehat{\varepsilon}_{a,t}. \tag{11}$$

Similar to prices, wage dynamics follow

$$\begin{aligned}\widehat{w}_t &= \frac{1}{1+\beta\gamma^{(1-\sigma_c)}}\widehat{w}_{t-1} + \frac{\beta\gamma^{(1-\sigma_C)}}{1+\beta\gamma^{(1-\sigma_C)}}\left(E\widehat{w}_{t+1} + E\widehat{\pi}_{t+1}\right) - \frac{1+\beta\gamma^{(1-\sigma_c)}\iota^W}{1+\beta\gamma^{(1-\sigma_c)}}\widehat{\pi}_t \\ &\quad + \frac{\iota^W}{1+\beta\gamma^{(1-\sigma_c)}}\widehat{\pi}_{t-1} - \left[\frac{1-\beta\gamma^{(1-\sigma_c)}\xi^W}{1+\beta\gamma^{(1-\sigma_c)}}\frac{1-\xi^W}{\xi^W\left(\left(\phi_W-1\right)\zeta^W+1\right)}\right]\widehat{\mu}_t^W + \widehat{\varepsilon}_{w,t},\end{aligned} \tag{12}$$

where $\left(1-\xi^W\right)$ is the probability of the representative household optimizing its wage every period, ι^W is the degree of indexation to past wage inflation and ζ^W is the curvature of the labor market aggregator. $\widehat{\varepsilon}_{w,t}$ is a wage mark-up disturbance that follows a standard $AR(1)$ process, $\widehat{\varepsilon}_{w,t} = \rho^w\widehat{\varepsilon}_{w,t-1} + u_{w,t}$, where ρ^w is the persistence parameter and $u_{w,t}$ is a white noise process with mean zero and standard deviation σ_w.[9] In the monopolistic competitive labor market, the wage mark-up is given by:

$$\widehat{\mu}_t^W = \widehat{w}_t - \sigma_l\widehat{l}_t + \frac{1}{1-h/\gamma}\left(\widehat{c}_t - (h/\gamma)\,\widehat{c}_{t-1}\right), \tag{13}$$

where σ_l is the elasticity of labor supply with respect to the real wage.

Finally, we assume that the monetary authority sets the interest rate following a generalised Taylor rule

$$\widehat{r}_t = \rho\widehat{r}_{t-1} + (1-\rho)\left[r_\pi\widehat{\pi}_t + r_y\left(\widehat{y}_t - \widehat{y}_t^P\right)\right] + r_{\Delta y}\left[\left(\widehat{y}_t - \widehat{y}_t^P\right) - \left(\widehat{y}_{t-1} - \widehat{y}_{t-1}^{fP}\right)\right] + \widehat{\varepsilon}_{r,t}$$

[9] Smets and Wouters (2007) adopt an ARMA process for the wage- and price-markup shocks. In this paper, we assume a more standard AR(1) process.

where ρ is the interest rate smoothing parameter, $\widehat{\varepsilon}_{r,t}$ is a monetary policy shock and $\left(\widehat{y}_t - \widehat{y}_t^P\right)$ is the output gap is defined as the difference between the actual and the flexible prices and wages equilibrium output. We also allow for "speed limit policies" through the first difference term in the output gap (see Walsh, 2003, and Smets and Wouters, 2007). We assume that the monetary policy shock follows a standard $AR(1)$ process, such that:

$$\widehat{\varepsilon}_{r,t} = \rho^r \widehat{\varepsilon}_{r,t-1} + u_{r,t},$$

where ρ^r is the persistence parameter. Thus, we allow the error term of this shock to include an unanticipated component, $\eta^0_{x,t}$, and anticipated changes n quarters in advance, $\eta^n_{x,t-n}$,

$$u_{r,t} = \eta^0_{r,t} + \eta^n_{r,t-n},$$

where $\eta^0_{r,t}$ and $\eta^n_{r,t-n}$ are a white noise processes with mean zero and standard deviations σ^0_r and σ^2_r, respectively. Thus, at time $t-n$, agents receive a signal about the occurrence of future shocks at time t. This specification for the news shocks follows Schmitt-Grohé and Uribe (2012), Fujiwara et al. (2011), Milani and Treadwell (2012) and Khan and Tsoukalas (2012). Regarding the horizon at which news shocks enter the model, there is no specific reason to select any particular horizon, n, a priori or to prefer news at a single horizon rather than at multiple horizons. Thus, in Section 3.1, we consider various specifications and, using Bayesian criteria, we select the best one in terms of overall goodness of fit.

3 Estimation

The model is estimated over 1960:Q1 to 2010:Q4 using seven time series for the US with quarterly frequency. The vector of observables is given by the log difference of real GDP, $\Delta\ln(GDP_t)$, real consumption, $\Delta\ln(c_t)$, real investment, $\Delta\ln(I_t)$, real wages, $\Delta\ln(w_t)$, and of the GDP deflator, $\Delta\ln(p_t)$, the log of hours worked, $\ln(h_t)$, and the federal fund rate, r_t. See Appendix B for details on the data used.

As in Smets and Wouters (2007), we calibrate five parameters prior to estimation. We fix the curvature of the labor and good market aggregator at 10, i.e. ζ^W and ζ^P.[10] We also follow Smets and Wouters (2007) in setting the depreciation rate, δ, at 0.025, the exogenous government spending to GDP ratio, g_y, at 18 per cent and the steady-state labor market mark-up, λ_w, at 1.5.

The remaining 35 parameters are gathered in the vector $\boldsymbol{\theta}$ given by

$$\boldsymbol{\theta} = [\sigma^c, h, \sigma^l, \xi^w, \xi^p, \iota^w, \iota^p, \varphi, \psi, \alpha, \phi, \rho, r_\pi, r_y, r_{\Delta y}, l_{ss}, \pi_{ss}, \bar{\beta}, \bar{\gamma}, \rho^a, \rho^b, \rho^g, \rho^q, \rho^r, \rho^p, \rho^w, \rho^{ga}, \sigma^r_2, \sigma^x],$$

where σ^r_2 is the standard deviation of the monetary policy news shock and σ^x denotes the standard deviations

[10] As shown by Iskrev (2010a), fixing the curvature of the labor and goods market aggregator is needed to overcome identification problems in the model.

of all other innovations, with $x = \{a, b, q, g, r, w, p, g\}$.[11] We estimate $\boldsymbol{\theta}$ using standard Bayesian techniques. First, we define the priors on the set of parameters to estimate. Then, we use numerical optimization to find the mode of the posterior distribution and approximate the inverse of the Hessian matrix evaluated at the mode. Subsequently, we use the random walk Metropolis-Hastings algorithm to simulate the posterior, where the covariance matrix of the proposal distribution is proportional to the inverse Hessian at the posterior mode computed in the first step. We run 1.000.000 draws from the posterior distribution and discard the first 10 per cent of draws to proceed with statistical inference on the parameters and functions of the parameters, such as second moments at the posterior means of the parameters.

The priors on the structural parameters are as in Smets and Wouters (2007). Regarding the stochastic process of the shocks, we use a beta distribution with mean equal to 0.5 and standard deviation equal to 0.2 for the serial correlations of the shocks, as in Smets and Wouters (2007). Following Schmitt-Grohé and Uribe (2012), we assume a Gamma distribution for the standard deviations of the innovations since it allows for a positive density at zero. In particular, we specify a Gamma distribution strongly skewed towards zero. Prior distributions are summarised in the first block of columns of Tables 3 and 4. Sensitivity to alternative priors is reported in Section 6.

Prior to estimating the model, we check whether the parameters can be identified from the data. Lack of identification would suggest either problems in the structure of the model or that the set of observables does not provide sufficient information about certain parameters. For example, if a parameter does not affect the policy functions of the model or if several parameters play an identical role in the equilibrium conditions of the model, there may be identification failures. Alternatively, a parameter that does not affect the moments of the observables chosen in estimation would also be unidentified. The model as originally estimated in Smets and Wouters (2007) is identified (See Iskrev, 2010a). Here, we ask whether introducing news shocks leads to identification problems. As suggested by Iskrev (2010a), we proceed by drawing 100.000 sets of parameter values from the prior distribution and evaluating the Jacobian matrix of the mapping from $\boldsymbol{\theta}$ to a vector of moments consisting of the mean, the covariance and the first order autocovariance matrix of the observed variables.[12] We find that the Jacobian matrix has full rank everywhere in the prior distribution, and conclude that all parameters can be identified. Further identification analysis is reported in Section 4.

3.1 Horizon Length Selection: Overall Goodness of Fit

In order to select the best horizon length for the news shocks, we estimate the model using several horizon specifications and rank them in terms of overall goodness of fit. First, we consider news at each single horizon n from 1 to 6. Then, we consider news at multiple time horizons between 0 and 8. As in Schmitt-Grohé and Uribe (2012) and Khan and Tsoukalas (2012), we allow for anticipated changes four and eight quarters ahead,

[11] For recent surveys of Bayesian methods, see An and Schorfheide (2007) and Fernandéz-Villaverde (2010).
[12] This gives us 84 moments for 44 parameters to estimate.

$n = \{4, 8\}$. Other specifications we consider are $n = \{1, 2\}$, $n = \{2, 4\}$, $n = \{1, 2, 3, 4\}$ and $n = \{2, 4, 6, 8\}$.[13] All specifications are compared against the model without news shocks. In order to avoid over-weighting a priori the anticipated component of the monetary policy shock, in the estimation of the model with multiple horizon specification of the news component we follow, among others, Fujiwara et al. (2011) and assume that the variance of the unanticipated innovation is equal to the sum of the variances of the anticipated components.[14]

We compare the alternative specifications in terms of the overall goodness of fit of the model as measured by the log marginal data density.[15] Table 1 reports the log marginal data density of each specification of the model and the difference with respect to the log marginal data density of the model without news shocks. The best fit is obtained by the model with monetary policy news shocks at a single horizon length equal to 2. The Bayes factors indicate decisive evidence in favor of the model allowing for two quarters in advance news shocks (see Jeffreys,1961; and Kass and Raftery,1995) and, comparing with the model without news shocks, it implies a posterior odds ratio of $e^{7.05} = 1152.83 : 1$ in favour of the model allowing for two quarters in advance news shocks.[16]

Notice that the specifications with $n = \{1, 2\}$, $n = \{2, 4\}$ and $n = \{1, 2, 3, 4\}$ also performs substantially better than the no news specification. In contrast, news shocks specifications that include longer horizon signals turn out to perform poorly compared with both two-quarter ahead and the no news specifications.

In the benchmark estimations, we use Gamma priors for the standard deviations of the shocks that assign high probability to values close to zero. In order to assess the effects of priors on the model selection, we re-estimate the model using two alternative specifications of the priors. First, we use an Inverse Gamma distribution with prior mean of 0.1 and standard deviation of 2. This prior assigns a large probability to positive values of the standard deviations and is the same specification as in Smets and Wouters (2007). Second, we adopt a non-informative Uniform distribution bounded between 0 and 1. The results in terms of the overall goodness of fit are presented in Table 1, panel (B) and (C). They show that the selection of the best specification is not sensitive to the prior used. Indeed, comparing the specification that features monetary policy news shocks two quarters in advance with the no news version of the model, we find evidence in favour of the model with two quarters in advance news shocks. Table 2 also shows the log marginal likelihood at the posterior mean for the best-fitting specification and the specification without monetary policy news.

[13] The assumption of multiple time horizons allows for revisions in expectations, e.g. in the case of $n = \{4, 8\}$, $\varepsilon^8_{x,t-8}$ can be revised at time $t - 4$ and $\varepsilon^4_{x,t-4} + \varepsilon^8_{x,t-8}$ can be revised at time 0.

[14] For instance, in the case of $n = \{4, 8\}$, the variance of the unanticipated innovation is equal to the sum of the variances of the anticipated components

$$\left(\sigma^0_r\right)^2 = \left(\sigma^4_r\right)^2 + \left(\sigma^8_r\right)^2 .$$

[15] See also Fujiwara et al. (2011) and Milani and Treadwell (2012).

[16] In order for the model without news to be preferred, we would need a priori probability over this model $e^{7.05} = 1152.83$ larger than the prior belief about the model with two-quarter ahead news on monetary policy shock. See Jeffreys' (1961) scale of evidence and the discussion in Kass and Raftery (1995).

Irrespectively of the priors used to estimate the model, the version of the model featuring two-quarter ahead monetary policy news always outperforms the model without news shocks in terms of the marginal likelihood.

3.2 Posterior Estimates

The estimates of the best-fitting specification, i.e. $n = 2$ are reported in Tables 3 and 4. The last block of columns report the standard deviations and the 95 per cent probability interval.[17] Overall, the posterior estimates of most of the model's parameters are in line with results presented in previous papers that estimated similar models, such as Smets and Wouters (2007), Justiniano et al. (2010), Fujiwara el al. (2011) and Khan and Tsoukalas (2012). We find no significant differences in terms of parameter estimates relative to the results of the model without news shocks.[18]

Regarding the stochastic processes of the shocks, we find little persistence in the monetary policy, price- and wage-markup shocks. The estimated standard deviation of the anticipated component of the monetary policy shock is similar to that of the unanticipated component. Compared to the estimated model without monetary policy news, we find a lower standard deviation of the risk premium shock and of the unanticipated component of the monetary policy shock.

Tables 13 and 14 report the posterior mean estimates for the best fit specifications under the three alternative priors of the standard deviations of the shocks. The results are not significanlty affected by the use of alternative priors. The posterior means for the monetary policy shock parameters fall close to each other. The same holds for the estimates of the standard deviations of the other shocks. This result provides evidence that the estimations are not driven by the priors and that the data are indeed informative regarding the parameters of all shocks processes.

4 Monetary Policy News Shocks: Identification

In Section 3, we test for the identifiability of the parameters of the best-fitting specification, i.e. $n = 2$, by evaluating the Jacobian matrix of the mapping from the model's parameters to the theoretical unconditional first and second order moments of the model using sets of parameters values drawn from the prior distribution. However, this does not guarantee that $\boldsymbol{\theta}$ is identified everywhere in the parameter space or that there are no weak identification issues. By checking that the Jacobian matrix has full rank at the posterior mean, we conclude that all estimated parameters are identified. Next, we examine the strength of identification of the estimated parameters at the mean of the posterior distribution.

We start with the observation that for a parameter to be well identified, its effect on the likelihood must be both strong and distinct from the effects of the other parameters. A violation of either one of these

[17] See Appendix B for the convergence of the MCMC and other details on the estimation.

[18] Estimating a reduced version of this model with data up to 2009:Q4, Milani and Treadwell (2012) find a high degree of price rigidities and indexation.

conditions results in a flat likelihood and lack of identification. See Iskrev (2010b). A useful way to quantify the two conditions is to measure them as sensitivity of the log likelihood $l_T(\boldsymbol{\theta})$ to a parameter θ_i :

$$\Delta_i \equiv \sqrt{E\left(\frac{\partial l_T(\boldsymbol{\theta})}{\partial \theta_i}\right)^2},$$

and collinearity between the effects of different parameters on the likelihood:

$$\varrho_i \equiv corr\left(\frac{\partial l_T(\boldsymbol{\theta})}{\partial \theta_i}, \frac{\partial l_T(\boldsymbol{\theta})}{\partial \theta_{-i}}\right).$$

If the likelihood is flat, one or more parameters are not identified and therefore cannot be consistently estimated. Problems may also arise if the likelihood exhibits low curvature with respect to some parameters, i.e. $\Delta_i(\theta_i) \approx 0$ or $\varrho_i(\theta_i) \approx 1$. In this case, the value of parameter θ_i would be difficult to pin down. Thus, Δ_i and ϱ_i can be used as measures of the strength of identification.[19]

Table 5 reports the elasticity of the likelihood with respect to the estimated standard deviations of the innovations evaluated at the posterior mean, i.e. $\Delta_i\theta_i$.[20] Among the shocks' parameters, the largest likelihood sensitivity is displayed by the persistence parameter of the productivity and government spending shocks. Overall, we do not find substantial differences in terms of sensitivity across the standard deviations of the unanticipated shocks. The standard deviation of the news component of the monetary policy shock diplays somewhat lower likelihood sensitivity compared to the unanticipated shocks but the elasticity is well above zero. See Appendix C for the sensitivity in the likelihood of all estimated parameters.

Monetary policy news shocks also appear to be distinguishable from the other parameters in the determination of the likelihood. Table 6 reports the collinearity with respect to the likelihood, i.e ϱ_i, between the standard deviation of the monetary policy news shock, σ_2^r, and all other estimated model's parameters. The highest collinearity is displayed with the unanticipated component of the monetary policy shock. However, given a correlation in the likelihood of below 0.5, we can conclude that the effect of the news component of the monetary policy shock in the likelihood cannot be approximated by the unanticipated component of the same shock.

To sum up, the results in Tables 5 and 6 indicate that at the posterior mean the monetary policy news parameters are well identified from the likelihood function.

[19] It is possible to show that the asymptotic MLE standard error of a parameter can be expressed as $s.e.(\theta_i) = 1/\sqrt{\Delta_i(1-\varrho_i^2)}$. Lack of identification, due to either $\Delta_i(\theta_i)$=0 or $\varrho_i(\theta_i) = 1$, manifests itself as $s.e.$ going to ∞.

[20] This measure is, then, comparable across parameters. Note that $\Delta_i\theta_i = \sqrt{E\left(\frac{\partial l_T(\boldsymbol{\theta})}{\partial \theta_i}\theta_i\right)^2}$.

4.1 Sensitivity in the Unconditional Moments

Note that the model's parameters affect the likelihood function through their effects on the first and second order moments of the observed variables. It is interesting to know the moments of which variables are most strongly affected by the standard devation of monetary policy news shocks, σ_r^2. We measure the sensitivity of the unconditional first and second order moments of the observables as the norm of the vector of elasticities of the moments to that parameter. Table 7 reports the moments sensitivity to σ_r^2 and compares it to the sensitivities to the other unanticipated shocks, $\sigma_x = \left\{\sigma_a, \sigma_b, \sigma_q, \sigma_g, \sigma_w, \sigma_\pi, \sigma_r^0\right\}$.

Table 7 reports the sensitivity of moments of individual variables, which are computed taking into account own and cross moments of each single variable. Monetary policy news have a larger effect on the determination of the moments of the nominal interest rate, followed by GDP and consumption growth. In particular, monetary policy news shocks are more important than unanticipated monetary policy shocks, government spending shocks and price-markup shocks when determining the moments of the interest rate and the growth rate of consumption, investment and GDP. As for the moments of GDP growth, they also display larger sensitivity to monetary policy news shocks than to wage-markup shocks. The moments of wages and inflation display larger sensitivity to monetary policy news than to the either the unanticipated monetary policy shocks or to the risk-premium and government spending shocks.

5 Monetary Policy News Shocks: Quantitative Implications

In this section, we investigate the differences in the propagation of the anticipated and unanticipated components of the monetary policy shock and study the role of structural parameters in the model responses to both shocks. Further, we explore the importance of monetary policy news in explaining the volatility of the observables.

5.1 Transmission Mechanism

Figure 1 displays the impulse-responses to a two-quarter ahead news on a one-per cent contractionary monetary policy shock (solid line). For comparison, we also report the responses to a contractionary, unanticipated shock (dashed-line). News shocks have a more persistent effect on wages, inflation and especially hours worked which display a peak response after five quarters instead of three as in the case of the unanticipated shock. Larger persistence is also displayed in the responses of the other aggregate variables. The main difference in the model response to the two shocks is the behaviour of the policy interest rate. In fact, in response to a contractionary unanticipated shock, the policy rate increases on impact whereas, in response to news shocks, it first declines and only rises at the time in which the shock occurs (t=2). Contractionary monetary policy news shocks generate expectations of higher future interest rates. Agents anticipate the future contractionary effect by reducing current consumption and investment. The drop in demand reduces inflationary pressures. For the decline in investment to be coupled with a decline in labor input, wages decrease as well. Thus, the current decline in both inflation and output gap leads to an initial decline in the policy rate.

5.1.1 Sensitivity in the Impulse-Responses

Now we investigate which structural parameters play the most important role in the transmission of monetary policy shocks in the model. We also highlight the main differences between the anticipated and unanticipated components of the shock. To this end we construct a measure of the sensitivity of the impulse response functions (IRF) to each parameter θ_i, evaluated at the posterior mean. IRF sensitivity to a parameter θ_i is measured as the norm of the vector of elasticities of the impulse responses with respect to that parameter. In Panel (A) of Table 8, we show the overall sensitivity of the IRF of all seven observables to each component of the monetary policy shock over the first twenty periods. The impulse-responses to news and unanticipated monetary policy shocks are most sensitive to the degree of wage stickiness, ξ^w, followed by the smoothing parameter in the interest-rate rule, ρ. In contrast, the weakest effect on the response of the observables is with respect to the price indexation parameter, ι^p. Panel (A) of Table 9 reports the absolute difference in the overall sensitivity of the impulse-responses with respect to the model's parameters. Overall, the parameters indicating the degree of wage stickiness and the response to the lagged interest rate in the Taylor rule have a larger effect on the response to news shocks than to unanticipated shocks. The habit persistence parameter, h, the intertemporal rate of substitution, σ^c, and the price stickiness parameter, ξ^p, also have a substantially stronger effect on the response to monetary policy news shocks than on the response to the unanticipated shock.

In Panels (B) and (C) of Table 8, we report the sensitivities of the IRF of the individual observed variables to the anticipated and unanticipated monetary policy shocks. For both shocks, the large overall sensitivity to the wage stickiness parameter and to the smoothing parameter in the interest-rate rule reflects the high sensitivity of the response of wages and inflation. However, in the case of news shocks, the largest sensitivity to the wage stickiness parameter is displayed in the response of investment growth. Regarding the other parameters, the most sizable differences in the sensitivity of news and unanticipated monetary policy shocks are detected in the response of consumption and investment growth. Indeed, the response of investment and consumption growth to news shocks displays high sensitivity to most parameters. Unlike the response to unanticipated shocks, the investment growth response to news shocks displays the largest sensitivity to several parameters. The absolute difference in the sensitivity with respect to the model's parameters of the impulse-response of each single variable is reported in Panel (B) of Table 9.

5.2 Monetary Policy News Shocks as Sources of Business Cycle Fluctuations

Table 10 shows the contribution of shocks to the unconditional variance of the observable variables. The analysis is based on the best-fitting specification, i.e. $n = 2$. We report both the sum of the contributions of the two components of the monetary policy shock, u_r, and the single contributions of the unanticipated and news component, η_r^0 and η_r^2, respectively.

Productivity and government spending shocks are mainly related to GDP growth. Investment specific shocks are the main contributors to the standard deviations of investment growth and account for about 20 per cent of the variability of hours worked.[21] Risk premium shocks are very important in explaining the volatility of GDP growth as well as hours worked, and are the main sources of fluctuations in the federal fund rate and consumption growth.[22] Price and wage markup shocks are mainly related to inflation and wage growth.

Monetary policy shocks account for about the same percentage of variation in GDP growth as the productivity and government spending shocks. Further, monetary policy shocks explain around 25 per cent of the variation in consumption growth and hours worked, 18 per cent of the variation in GDP growth and 13 per cent of the standard deviation of the nominal interest rate. Interestingly, news shocks account for half or more of the variations in most of the observables explained by the monetary policy shock.

The largest contribution of monetary policy news shocks to the business cycle is in terms of fluctuations in hours worked followed by consumption growth and GDP growth. Monetary policy news shocks explain around 15 per cent of the fluctuations in hours worked and account for a larger percentage of fluctuations in consumption growth than most of the other shocks, including the productivity shock. Further, this shock accounts for about the same percentage of fluctuations in GDP growth as the investment-specific shock.

5.3 Matching Moments

In this section, we describe the performance of the model in matching moments and compare it with the model without news shocks. We also study how monetary policy news shocks affect the unconditional moments of the observables.

5.3.1 Model with Monetary Policy News Shocks

Now, we present the model predictions regarding the moments of the seven time series included as observables in the estimation. Table 11 compares the theoretical and empirical first and second moments of the seven observables included as observables in the estimation. Overall, the model performs well in matching key empirical unconditional moments. In particular, it predicts well the standard deviations of consumption

[21] Among others, Justiniano et al. (2010) and Justiniano et al. (2011) document the importance of investment-specific shocks for business cycle fluctuations.

[22] For the importance of this shock see, among others, Smets and Wouters (2007) and Galí, Smets and Wouters (2012)

growth, investment growth and hours worked relative to GDP. The contemporaneous correlation of GDP growth with all other observables are in line with the data. The correlation with the short term interest rate is an exception. The model also predicts quite well the serial correlation of order 1 of most observables.

For a more exhaustive analysis, we investigate the ability of the model to match higher order autocovariances. We measure the gaps between the moments in the model and in the data by:

$$Gap(q) = \left| \frac{m_T(\theta, q) - \hat{m}_T}{\hat{m}_T} \right|, \tag{14}$$

where $\hat{m}_T$ is the estimate of the vector $m_T(\theta, q)$ that collects the first and second order moments up to lag q of the observed data of sample size $T = 180$. In particular, we consider all covariances and autocovariances of order up to 10 (see Figure 2). In darker color, we highlight the worse matched (auto)covariances. Overall, the estimated model matches well the empirical moments. The worst performance is in terms of the covariance of order two of the interest rate with consumption growth, i.e. $cov(c_t, r_{t+2})$. Large discrepancies are also found in the covariance of order one of inflation with investment growth, $cov(i_t, \pi_{t+1})$, and investment growth with hours worked, $cov(l_t, i_{t+1})$. Among the most notable discrepancies between the model and data, the figure also highlights $cov(l_t, c_{t+2})$, and the convariances of order higher than one of inflation with wages, i.e. $cov(w_t, \pi_{t+q})$ with $2 < q < 10$. In contrast, the model matches particularly well the covariances of hours worked with all other observables.

5.3.2 Monetary Policy News vs No News

We also compare the best-fitting specification, i.e. $n = 2$, with the benchmark model without monetary policy news shock. The gaps are defined as in (14). Table 12 (Panel A) summarises the gaps by variables as measured by the norm of the differences between model and data moments of each variable. Covariances up to order 10 are considered. The model without news shocks performs slightly better in terms of the moments of hours worked and of investment growth. In contrast, neglecting news on monetary policy shocks results in a substantially worse performance in matching the covariances of consumption growth and of the interest rate. It is important to highlight that in the model with news shocks, the moment gaps of these two variables are the largest among all gaps (see Figure 2). Nevertheless, the model featuring monetary policy news shocks substantially improves upon the no news model in terms of matching the moments of both variables. Indeed, the moments gaps of these two variables are reduced by more than half. No substantial differences are found in terms of inflation and wages.

Table 12 (Panel B) reports the gaps by type of moments, i.e. means and autocovariances of different lags. The gaps are measured as the norm of the differences between model and data moments of all observables for each type of moment. The model with monetary policy news performs better in terms of covariances of order two. Covariances of order two are particularly difficult to match, i.e. display the largest gap in the models. However, in the absence of news shocks, the performance of the model is sizeably worse. Other order covariances display less substantial differences.

The overall measure, which accounts for the gaps of all moments and all observables, indicates that the model with news on monetary policy shocks performs substantially better than the no news version of the same model. This result confirms the ranking in terms of overall goodness of fit based on the log data density.[23] It is important to point out that this measure weights all moments equally and, in this respect, differs from other likelihood based measures.

6 News on Other Shocks

Are monetary policy news shocks capturing the impact of other types of anticipated disturbances that are not included in the model? In order to address this question, we re-estimate the model allowing for a variety of other news shocks. Apart from the monetary policy shock, the model features six other sources of business cycle fluctuations: a neutral technology shock, $\widehat{\varepsilon}_a$, a risk-premium shock, $\widehat{\varepsilon}_b$, an investment specific shock, $\widehat{\varepsilon}_q$, government spending shock, $\widehat{\varepsilon}_g$, a wage-markup shock, $\widehat{\varepsilon}_w$, and a price-markup shock, $\widehat{\varepsilon}_p$. Now, we assume that the error term of each of these shocks consists of an unanticipated component, $\eta^0_{x,t}$, and anticipated changes n quarters in advance, $\eta^n_{x,t-n}$, i.e. $u_{x,t} = \eta^0_{x,t} + \eta^n_{x,t-n}$,where $\eta_{x,t}$ is i.i.d. and $x = \{a, b, q, g, r, w, p\}$. We consider several specifications regarding the horizon length of the anticipated component of the shocks. See Table 15.

Allowing for news on all shocks, we again find that the best specification features two quarters in advance anticipation length, i.e. $n = 2$. However, the specification with only monetary policy news shocks outperforms all news specifications in terms of overall goodness of fit. The specification without news shocks is also better than the specification with news on all shocks. In fact, the log data density of the specification of the model with two-quarter ahead news on all shocks implies posterior odds ratios of $e^{13.64} : 1$ in favour of the no news model, and of $e^{20.68} : 1$ in favour of the model with only news on monetary policy shocks.

In terms of parameters estimates, we do not find substantial differences in comparison with the other estimated versions of the model.[24] Panel A of TABLE 16 reports the estimates of the standard deviations of the news components of the shocks at the mode and mean of the posterior distribution and the 95 per cent confidence interval. At the mode, the standard deviations of news on shocks other than monetary policy equal zero. News on government spending shocks offer an exception, however their standard deviation is only slightly above zero. Due to the use of a prior Gamma distribution that is defined over the $[0, +\infty)$ interval the estimated mean of the standard deviations of news is positive for all shocks. Still, with the exception of the standard deviation of news on monetary policy shocks, the 95 per cent probability interval includes

[23] The ranking of models in terms of this overall measure is robust to the inclusion of autocovariances of orders higher than 10.

[24] For the estimation results of the model's parameters see Appendix D.

the value of 0. These results suggest that news on shocks, other than monetary policy, are not important in improving the quantitative performance of the model. In contrast, the estimated standard deviation of monetary policy news shock is significantly different from zero and similar to the one of the model with only news on monetary policy shocks.

Table 15 also reports the horizon selection under the assumption of the Inverse Gamma distribution. The specification featuring two-quarter in advance news shocks is always the best-fitting one. Contrary to the results with the Gamma prior, assigning a higher probability to a positive value for the standard deviation of news shocks results in a higher log data density for the model with news on all shocks than the no news version of the model. However, the model with only monetary policy news shocks is still preferred in terms of overall goodness of fit.[25] [26] The use of an Inverse Gamma does not alter the ranking between the specification with only monetary policy news shocks and news on all shocks. However, since the support of the Inverse Gamma includes only positive values, both the mode and the mean of the posterior of the standard deviation of the news shocks are now positive. Panel B TABLE 16 reports the estimates of the standard deviations of news shocks obtained with the use of Inverse Gamma.

We now compare the specifications that feature only monetary policy news shocks against the versions that allow for news on all shocks in terms of matching the data moments. In particular, we consider the best-fitting horizon length specifications, i.e. $n = 2$. The gaps reported in Table 12 are computed at the posterior mean that implies positive values for the standard deviations of news shocks. Adding news on all shocks performs poorly in terms of matching the moments of hours worked and investment. It also reduces the ability of the model to match the moments of all other variables in comparison with the model with only monetary policy news shocks. However, having news on all shocks improves upon the model without news shocks in matching the moments of consumption and the interest rate. In particular, the model performs better than the no news specification in terms of covariances of order two. Nevertheless, the ranking of the three models according to the overall measure of the gaps is in line with the results in terms of the posterior odd ratios presented in Tables 1 and 15.[27]

We re-estimate the model with two-quarter ahead news on shocks other than monetary policy. The mean estimates of news on productivity, risk premium and government spending shocks are larger. See Table ??. However, we find that the log data density is substantially lower than all other estimated versions of the model, i.e. -1093.81. Further, the overall measure of the moments gaps confirms the ranking among the different specifications. Last, we also estimate the model with two-quarter ahead news on each shock

[25] Under the Inverse Gamma prior for the standard deviations of the shocks, the model displays a posterior odds ratio of $e^{5.80} = 331.26 : 1$ in favour of the model with only news on monetary policy shocks.

[26] Notice that using a Uniform prior, the model with two-quarter ahead news on all shocks has a log data density of -1103.5030. Then, in comparison with the versions of the model with no news and only monetary policy news shocks, reported in Panel (C) of Table 1, the model with news on all shocks has a worse performance in terms of overall goodness of fit .

[27] We re-estimate the model with two-quarter ahead news on all shocks other than monetary policy and find that: (1) the log data density is substantially lower than all other estimated versions of the model, i.e. -1093.81; (2) the overall measure of the moments gaps confirms the same ranking.

other then monetary policy, separately. None of these alternative specifications outperforms the model with monetary policy news in terms of overall goodness of fit. See Table 18.

The results presented in this section suggest that in a standard New-Keynesian DSGE model, news on shocks other than monetary policy do not improve the model fit. This could be due to the fact that the observables used in the estimation do not contain information regarding these other news shocks. Alternatively, the model could be mis-specified in some dimensions.[28]

7 Conclusion

In this paper, we assess the role of anticipated monetary policy shocks in the context of a medium scale DSGE model estimated on US data. We consider versions of the model with different anticipation horizons and find that two-quarter in advance news on monetary policy shocks provide the best fit to the data. In particular, it improves upon the no news version of the model in matching the first and second order moments of consumption growth and the nominal interest rate. The ranking of the different specifications of the model is robust to alternative prior specifications as well as to the introduction of news on other shocks.

We contribute to the literature by carefully investigating the identification of news on monetary policy shocks. We show that news shocks are identified and have an effect on the likelihood that is both non-negligible and distinct from that of other parameters. We find that monetary policy shocks are relevant sources of fluctuations in aggregate variables. News on monetary policy shocks are generally more important than unanticipated monetary policy shocks in explaining business cycles.

[28] Looking at direct indicators of fiscal foresight rather than relying on the estimation of DSGE models, few authors found that fiscal news are important business cycle drivers (see e.g. Leeper, Richter and Walker, 2012; Mertensen and Ravn, 2012). Model comparison based on the use of particular indicators of news would only test the performance of the model in one particular dimension. In order to understand which news shocks are important for business cycle fluctuations, we follow most of the DSGE literature and base our analysis on the full-information approach. See, among others, Lubik and Schorfheide (2004), Rabanal and Rubio-Ramirez (2005). Using survey expectations as observables could result in a larger role of news shocks that help matching the moments of the expectations variables. However, in the specific case of anticipated fiscal changes, we acknowledge that the model we use is not well suited to address the importance of anticipated fiscal policies.

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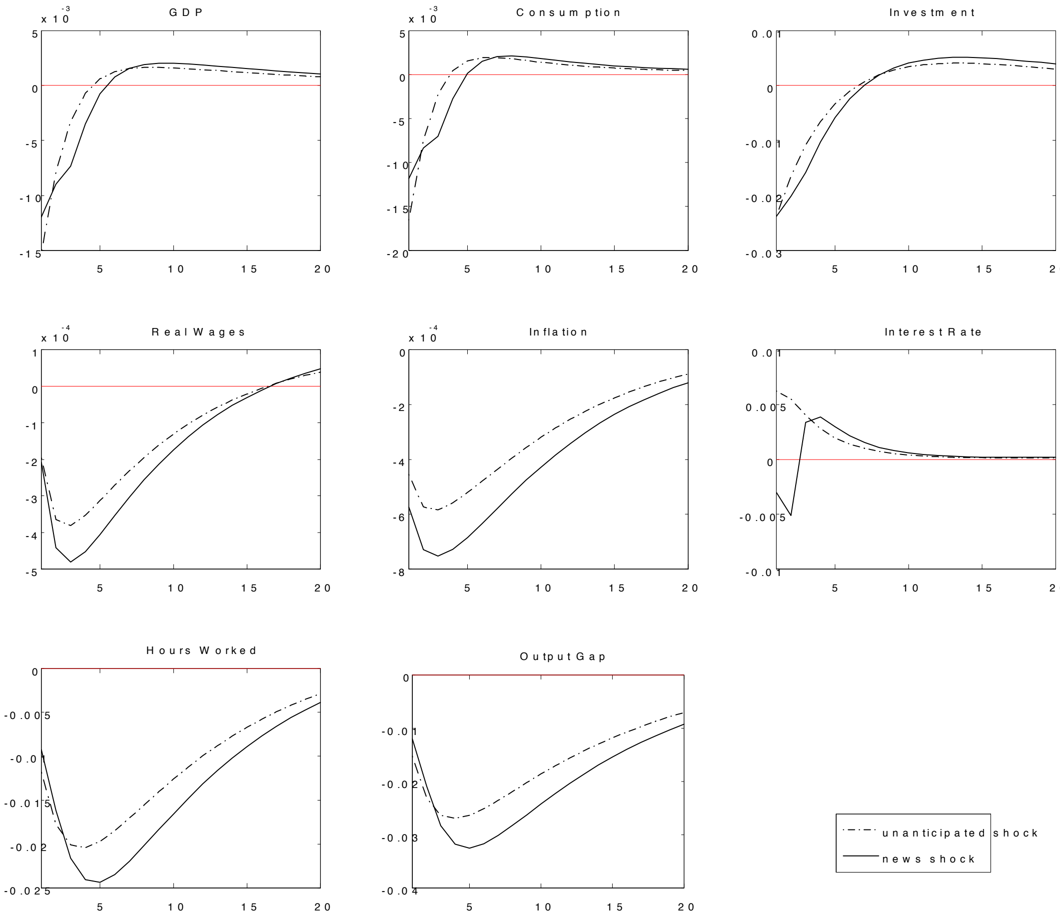

Figure 1: Monetary Policy Shocks

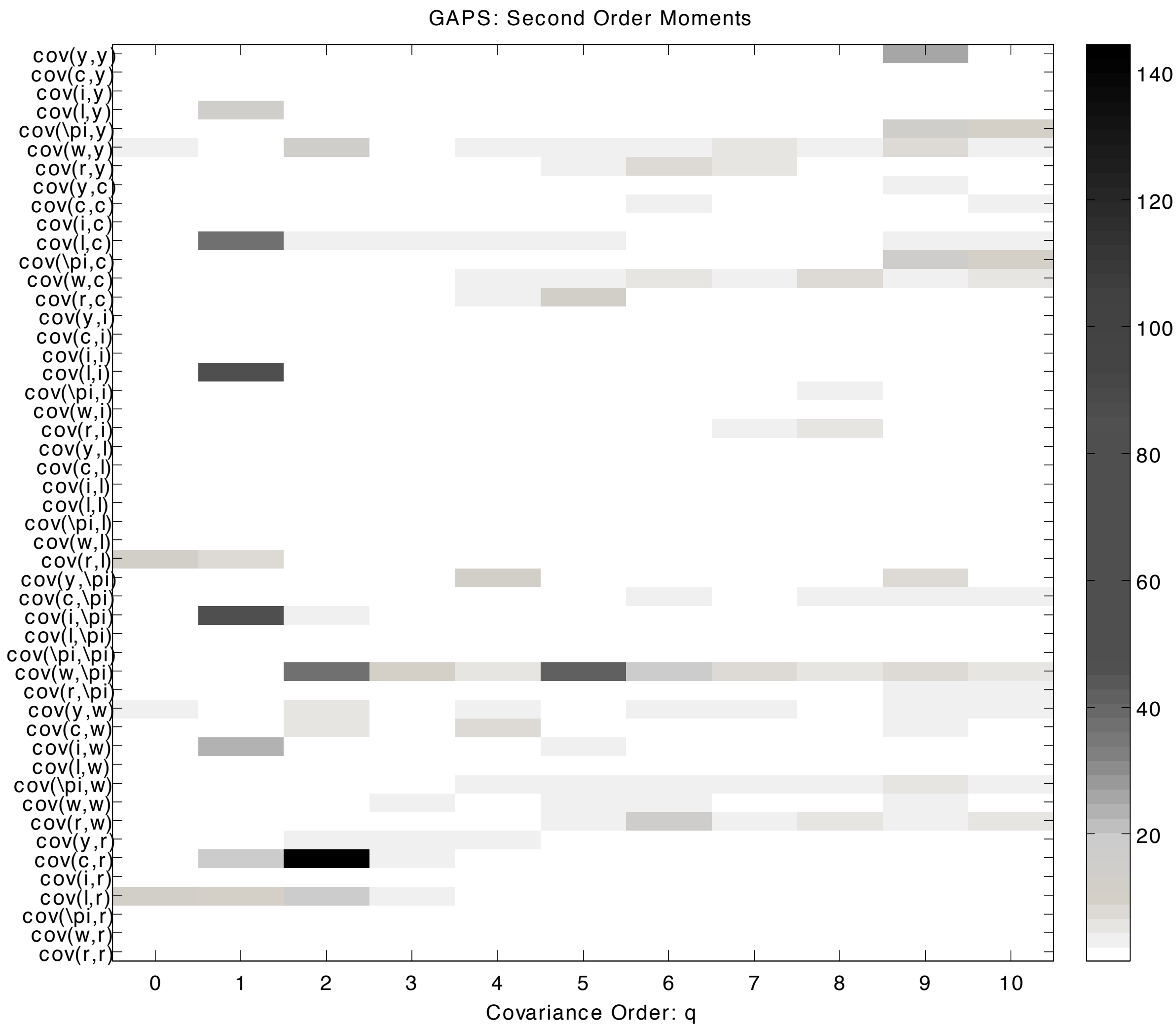

Figure 2: Gaps

Table 1: Model Comparison

	Monetary Policy News Horizon Length (n)											
	No News	1	2	3	4	5	6	1,2	2,4	4,8	1,2,3,4	2,4,6,8
	(A) **GAMMA**											
Log Data Density	-1073.53	-1073.53	-1066.49	-1074.06	-1074.14	-1077.47	-1079.79	-1067.84	-1068.74	-1084.12	-1070.52	-1080.35
Diff. w/no news		0	7.05	-0.53	-0.60	-3.94	-6.25	5.69	4.79	-10.59	3.01	-6.82
	(B) **INV. GAMMA**											
Log Data Density	-1076.41	-1077.29	-1068.99	-1077.04	-1076.59	-1079.92	-1074.22	-1070.92	-1070.64	-1086.18	-1072.88	-1082.10
Diff. w/no news		-0.87	7.43	-0.62	-0.18	-3.50	2.19	5.49	5.78	-9.77	3.53	-5.69
	(C) **UNIFORM**											
Log Data Density	-1069.30	-1075.77	-1067.43	-1075.02	-1075.66	-1079.30	-1083.19	-1071.45	-1071.94	-1087.87	-1081.37	-1089.51
Diff. w/no news		-6.47	1.87	-5.71	-6.36	-10.00	-13.89	-2.15	-2.64	-18.77	-12.07	-20.21

Log Marginal Data Density based on the Modified Harmonic Mean Estimator.

Table 2: Log Likelihood at the Posterior Mean

	GAMMA	INV. GAMMA	UNIFORM
No News	-994.45	-993.14	-1170.87
MP News (2)	-987.06	-987.15	-987.20

Table 3: Estimation results

Parameter			Prior		News MP (2)			No News		
			Mean	**Std**	**Mean**	**5%**	**95%**	**Mean**	**5%**	**95%**
Intert. elast. substitution	σ^c	$\mathcal{N}$	1.5	0.375	1.2273	0.9026	1.5439	1.2368	0.9502	1.5118
Habits	h	$\mathcal{B}$	0.7	0.1	0.5499	0.4547	0.6476	0.6364	0.5469	0.7277
Labor supply elasticity	σ^l	$\mathcal{N}$	2	0.75	2.3659	1.4751	3.2575	2.2151	1.3072	3.116
Calvo prob. - wages	ξ^w	$\mathcal{B}$	0.5	0.1	0.9331	0.9157	0.95	0.9328	0.9146	0.95
Calvo prob. - prices	ξ^p	$\mathcal{B}$	0.5	0.1	0.7939	0.7406	0.8508	0.7825	0.7231	0.8423
Indexation - wages	ι^w	$\mathcal{B}$	0.5	0.15	0.7447	0.6092	0.8826	0.7522	0.6202	0.8877
Indexation - prices	ι^p	$\mathcal{B}$	0.5	0.15	0.2907	0.0552	0.6308	0.2464	0.0418	0.6075
Capital adjust. cost elast.	φ	$\mathcal{N}$	4	1.5	4.009	2.2662	5.5641	4.6853	2.8901	6.413
Capital utiliz. adj. cost	ψ	$\mathcal{B}$	0.5	0.15	0.7082	0.548	0.869	0.7078	0.5548	0.8668
Cobb-Douglas	α	$\mathcal{N}$	0.3	0.05	0.168	0.1393	0.1963	0.1709	0.1424	0.1996
Fixed cost	ϕ	$\mathcal{N}$	1.25	0.125	1.4647	1.344	1.5887	1.4896	1.3566	1.6154
Taylor rule - smoothing	ρ	$\mathcal{B}$	0.75	0.1	0.8504	0.8128	0.8882	0.8311	0.7899	0.872
Taylor rule - inflation	r_π	$\mathcal{N}$	1.5	0.25	1.8232	1.5264	2.1214	1.7588	1.4741	2.0392
Taylor rule - output	r_y	$\mathcal{N}$	0.125	0.05	0.1155	0.0646	0.1672	0.0854	0.0366	0.1328
Taylor rule - output growth	$r_{\Delta y}$	$\mathcal{N}$	0.125	0.05	0.221	0.1778	0.2642	0.242	0.2	0.2851
Log hours worked	l_{ss}	$\mathcal{N}$	0	2	-0.6467	-2.2614	0.9366	-0.5028	-2.1928	1.1723
Steady-state inflation rate	π_{ss}	$\mathcal{G}$	0.625	0.1	0.7801	0.6288	0.9291	0.7933	0.644	0.942
Discount factor	$\bar{\beta}$	$\mathcal{G}$	0.25	0.1	0.1906	0.0822	0.3	0.1799	0.0768	0.279
Steady-state growth rate	$\bar{\gamma}$	$\mathcal{N}$	0.4	0.1	0.3853	0.3472	0.4233	0.3881	0.3513	0.4267

B=Beta, $\mathcal{N}$=Normal, $\mathcal{G}$=Gamma. $\bar{\beta} = \beta^{-1} - 1$; $\bar{\gamma} = \gamma_{ss} - 1$

Table 4: Estimation results - Shocks

Parameter			Prior		News MP (2)			No News		
			Mean	**Std**	**Mean**	**5%**	**95%**	**Mean**	**5%**	**95%**
AR coefficients shocks										
Productivity	ρ^a	$\mathcal{B}$	0.5	0.2	0.9749	0.9567	0.9961	0.9721	0.9519	0.9974
Risk-premium	ρ^b	$\mathcal{B}$	0.5	0.2	0.8346	0.7573	0.9103	0.6884	0.5176	0.852
Government spending	ρ^g	$\mathcal{B}$	0.5	0.2	0.9791	0.9641	0.9947	0.9804	0.9656	0.9959
Investment-specific	ρ^q	$\mathcal{B}$	0.5	0.2	0.8682	0.7981	0.9391	0.8454	0.7695	0.92
Monetary policy	ρ^r	$\mathcal{B}$	0.5	0.2	0.2496	0.1222	0.3756	0.1607	0.0619	0.2599
Price-markup	ρ^p	$\mathcal{B}$	0.5	0.2	0.4694	0.0746	0.719	0.5367	0.1019	0.7743
Wage-markup	ρ^w	$\mathcal{B}$	0.5	0.2	0.2366	0.1169	0.3506	0.2417	0.1201	0.3613
Prod. in gov. spending	ρ^{ga}	$\mathcal{N}$	0.5	0.25	0.5018	0.3791	0.6232	0.5013	0.3755	0.6232
St.deviation shocks										
Productivity	σ^a	$\mathcal{G}$	0.1	0.1	0.4843	0.4368	0.5309	0.4805	0.4351	0.5263
Risk-premium	σ^b	$\mathcal{G}$	0.1	0.1	0.0992	0.0735	0.1241	0.1425	0.1002	0.1856
Government spending	σ^g	$\mathcal{G}$	0.1	0.1	0.4932	0.45	0.5365	0.495	0.4505	0.5374
Investment-specific	σ^q	$\mathcal{G}$	0.1	0.1	0.3811	0.3047	0.4565	0.3822	0.3122	0.4506
Price-markup	σ^p	$\mathcal{G}$	0.1	0.1	0.1238	0.0828	0.1715	0.1134	0.0739	0.1668
Wage-markup	σ^w	$\mathcal{G}$	0.1	0.1	0.249	0.2089	0.2895	0.2484	0.207	0.2895
Monetary policy	σ^r_0	$\mathcal{G}$	0.1	0.1	0.156	0.1165	0.1953	0.2365	0.2137	0.2591
Monetary policy News	σ^r_2	$\mathcal{G}$	0.1	0.1	0.1698	0.1349	0.2066	-	-	-

B=Beta, $\mathcal{N}$=Normal, $\mathcal{G}$=Gamma.

Table 5: Sensitivity in the Likelihood

Std Productivity	σ_a	14.14269
Std Risk-premium	σ_b	11.81208
Std Government spending	σ_g	14.14471
Std Investment-specific	σ_q	14.08771
Std Price-markup	σ_p	14.13895
Std Wage-markup	σ_w	14.14452
Std Monetary policy	σ_r^0	14.14452
Std Monetary policy news	σ_r^2	8.335683

Table 6: Collinearity in the Likelihood

Intert. elast. substitution	σ^c	0.076949	Discount factor	$\bar{\beta}$	0.012122
Habits	h	0.048661	Steady-state growth rate	$\bar{\gamma}$	0
Labor supply elasticity	σ^l	-0.00374	Productivity	ρ^a	-4E-05
Calvo prob. - wages	ξ^w	-0.00503	Risk-premium	ρ^b	0.12801
Calvo prob. - prices	ξ^p	-0.00817	Government spending	ρ^g	-1.1E-05
Indexation - wages	ι^w	-0.00014	Investment-specific	ρ^q	-0.00747
Indexation - prices	ι^p	0.002659	Monetary policy	ρ^r	0.132614
Capital adjust. cost elast.	φ	-0.03065	Price-markup	ρ^p	0.000226
Capital utiliz. adj. cost	ψ	0.061941	Wage-markup	ρ^w	0.00012
Cobb-Douglas	α	0.016277	Prod. in gov. spending	ρ^{ga}	-4.1E-07
Fixed cost	ϕ	-0.10775	Productivity	σ_a	3.26E-07
Taylor rule - smoothing	ρ	0.052945	Risk-premium	σ_b	0.139782
Taylor rule - inflation	r_π	-0.04973	Government spending	σ_g	2.62E-07
Taylor rule - output	r_y	-0.24592	Investment-specific	σ_q	0.002628
Taylor rule - output growth	$r_{\Delta y}$	-0.17185	Price-markup	σ_p	0.000153
Log hours worked	l_{ss}	0	Wage-markup	σ_w	3.85E-05
Steady-state inflation rate	π_{ss}	0	Monetary policy	σ_r^0	0.486098

Collinearity with the standard deviation of the monetary policy news shock σ_r^2

Table 7: Moments Sensitivity to Shocks

Parameters	ΔGDP	ΔC	ΔI	Δw	Hours	π	r
σ_a^0	110.375	101.808	27.265	35.139	34.863	14.765	149.541
σ_b^0	195.231	254.496	21.106	7.969	49.479	2.368	324.193
σ_g^0	13.097	14.600	2.677	1.341	21.879	3.597	28.681
σ_I^0	144.613	86.410	78.509	20.395	53.970	33.109	147.676
σ_p^0	52.347	21.996	14.233	35.507	18.368	17.111	56.268
σ_w^0	53.885	85.813	27.510	78.758	92.835	37.071	119.067
σ_r^0	63.485	32.667	13.711	4.582	19.027	3.862	72.146
σ_r^2	77.886	51.670	19.818	8.627	11.904	7.390	89.016

Sensitivity of the own and cross moments of each variable with respect to the standard deviations of the shocks.

Table 8: IRF Sensitivity to Parameters

Parameters	(A) Overall		(B) News Shock (η_r^2)							(B) Unanticipated Shock (η_r^0)						
	η_r^2	η_r^0	ΔGDP	ΔC	ΔI	Δw	Hours	π	r	ΔGDP	ΔC	ΔI	Δw	Hours	π	r
σ^c	38.466	16.212	3.79	34.04	14.25	5.60	1.16	2.53	8.02	4.55	11.40	3.32	5.32	1.20	2.62	8.04
h	54.323	20.014	6.46	50.15	18.31	2.23	1.22	2.81	6.70	7.96	16.25	3.26	2.29	1.26	3.13	6.77
σ^l	14.541	13.171	0.31	1.31	3.08	13.69	0.56	2.71	2.24	0.30	0.36	0.56	12.65	0.58	2.77	2.22
ξ^w	554.276	500.403	14.43	62.28	131.94	498.03	27.85	149.96	120.10	13.58	16.90	23.99	458.36	28.92	155.49	119.37
ξ^p	54.747	37.149	4.08	13.73	35.08	35.60	3.52	15.29	6.92	4.06	3.72	6.48	31.79	3.55	15.38	6.91
ι^w	9.942	8.910	0.38	1.72	3.04	6.25	0.86	5.44	4.13	0.35	0.45	0.56	5.55	0.88	5.57	4.01
ι^p	2.539	1.424	0.22	0.71	1.95	1.11	0.18	0.80	0.44	0.19	0.16	0.35	0.99	0.18	0.80	0.43
φ	19.834	5.464	0.89	3.95	19.24	0.89	0.42	0.96	2.23	0.93	1.02	4.51	0.94	0.44	1.08	2.32
ψ	17.286	8.880	0.13	1.14	15.20	1.48	0.79	5.17	6.07	0.17	0.77	2.83	1.46	0.83	5.51	6.08
α	15.553	13.531	1.12	2.54	7.28	11.86	0.89	5.62	2.84	1.27	1.22	2.65	11.24	0.89	6.12	2.88
ϕ	28.477	20.013	1.22	0.51	20.59	5.39	4.55	12.59	13.30	1.31	0.59	3.60	4.53	4.66	12.93	13.27
ρ	264.791	158.455	25.16	86.45	205.61	107.48	32.95	78.11	31.51	30.99	31.37	41.17	107.77	39.70	87.44	25.12
r_π	7.610	4.028	0.75	2.02	6.28	2.84	1.10	2.06	0.52	0.83	0.81	1.24	2.77	1.09	2.06	0.49
r_y	28.410	16.878	2.37	7.13	22.36	12.98	3.91	7.55	3.20	2.65	2.54	4.31	12.79	4.13	7.92	3.08
$r_{\Delta y}$	32.384	22.099	3.36	8.43	22.13	17.44	2.51	8.68	9.54	3.01	2.77	4.67	16.37	2.65	9.34	9.36
ρ^r	10.302	4.988	2.23	8.19	4.63	1.74	1.70	1.84	1.81	2.03	2.05	1.84	1.83	1.79	1.86	1.77

Elasticities of the IRF(h=20) w.r.t the parameters

Table 9: Absolute Difference in IRF Sensitivity to Parameters

Parameters	(A) Overall	(B) Individual Variables						
		ΔGDP	ΔC	ΔI	Δw	Hours	π	r
Intert. elast. substitution σ^c	22.253	0.763	22.643	10.935	0.281	0.040	0.093	0.019
Habits h	34.309	1.497	33.896	15.052	0.061	0.041	0.318	0.072
Labor supply elasticity σ^l	1.370	0.019	0.950	2.526	1.041	0.018	0.062	0.020
Calvo prob. - wages ξ^w	53.873	0.842	45.376	107.957	39.676	1.070	5.537	0.731
Calvo prob. - prices ξ^p	17.598	0.020	10.009	28.597	3.808	0.032	0.087	0.013
Indexation - wages ι^w	1.032	0.033	1.263	2.482	0.703	0.019	0.133	0.118
Indexation - prices ι^p	1.115	0.022	0.554	1.601	0.121	0.002	0.003	0.003
Capital adj. cost elast .φ	14.370	0.043	2.932	14.732	0.055	0.022	0.120	0.088
Capital utiliz. adj. cos tψ	8.406	0.042	0.371	12.372	0.020	0.045	0.347	0.012
Cobb-Douglas α	2.022	0.153	1.313	4.632	0.620	0.005	0.502	0.041
Fixed cost ϕ	8.464	0.091	0.088	16.990	0.855	0.110	0.334	0.030
Taylor rule - smoothing ρ	106.337	5.836	55.085	164.443	0.293	6.756	9.331	6.395
- inflation r_π	3.581	0.083	1.213	5.043	0.072	0.005	0.002	0.031
- output r_y	11.532	0.283	4.589	18.048	0.190	0.219	0.375	0.121
T output growth $r_{\Delta y}$	10.285	0.352	5.662	17.458	1.068	0.147	0.658	0.174
AR Monetary policy ρ^r	5.314	0.195	6.145	2.790	0.088	0.087	0.021	0.034

Elasticities of the IRF(h=20) w.r.t the parameters

Table 10: Variance Decomposition

	u_a	u_b	u_g	u_q	u_p	u_w	u_r		
							tot	η_r^0	η_r^2
ΔGDP	19.76	29.16	17.19	10.92	3.84	1.39	17.74	8.08	9.66
ΔC	10.21	47.95	4.32	6.34	3.94	2.19	25.06	12.6	12.46
ΔI	3.00	10.47	0.16	73.89	2.78	0.90	8.78	3.29	5.49
Hours	4.57	25.06	8.35	21.41	5.04	12.59	22.98	8.39	14.59
π	12.24	0.61	0.71	1.15	51.96	32.52	0.80	0.26	0.54
Δw	1.82	0.15	0.01	0.45	19.38	78.03	0.16	0.05	0.11
r	10.38	46.3	2.25	10.94	3.90	13.24	12.99	6.68	6.31

Table 11: Moments: data versus 2-quarter ahead news model

	Stand. Deviation w.r.t. ΔGDP		**Correlation(0) with ΔGDP**		**Serial Correlation (1)**	
	Data	Model	Data	Model	Data	Model
ΔGDP	1	1	1	1	0.30	0.43
ΔC	0.84	0.83	0.70	0.68	0.28	0.52
ΔI	2.81	2.98	0.69	0.65	0.60	0.74
Hours	3.71	3.15	0.14	0.13	0.95	0.97
π	0.69	0.49	-0.21	-0.22	0.87	0.79
Δw	0.70	0.64	0.03	0.00	0.06	0.18
r	1.00	0.61	-0.10	0.12	0.95	0.92

Model-based unconditional moments are computed at the posterior mean.

Table 12: Moments Gaps

	NONEWS	**MP NEWS**	**ALL NEWS**
Variables			
ΔGDP	42.370	45.768	72.020
ΔC	380.998	153.629	293.810
ΔI	76.378	85.022	276.093
Hours	68.857	80.996	234.710
π	86.013	85.447	250.813
Δw	72.646	75.614	126.260
r	379.559	151.007	230.392
Moments			
mean	0.849	0.783	0.775
Cov(0)	10.430	13.167	17.753
Cov(1)	100.594	95.274	340.912
Cov(2)	376.674	151.419	218.472
Cov(3)	13.696	13.461	21.065
Cov(4)	19.901	18.151	41.363
Cov(5)	44.048	45.948	74.317
Overall	396.683	195.029	421.7967

Table 13: Estimation results – MP News (2)

Parameter		Gamma			Inverse Gamma			Uniform		
		Mean	**5%**	**95%**	**Mean**	**5%**	**95%**	**Mean**	**5%**	**95%**
Intert. elast. substitution	σ^c	1.2273	0.9026	1.5439	1.2503	0.9043	1.5841	1.2611	0.9201	1.5797
Habits	h	0.5499	0.4547	0.6476	0.5444	0.4438	0.6441	0.5375	0.4405	0.6377
Labor supply elasticity	σ^l	2.3659	1.4751	3.2575	2.4001	1.4836	3.3047	2.3746	1.4747	3.2285
Calvo prob. - wages	ξ^w	0.9331	0.9157	0.95	0.9329	0.9152	0.95	0.9328	0.9144	0.95
Calvo prob. - prices	ξ^p	0.7939	0.7406	0.8508	0.7886	0.7322	0.8455	0.7949	0.7391	0.8527
Indexation - wages	ι^w	0.7447	0.6092	0.8826	0.7502	0.6186	0.8873	0.7478	0.6137	0.8833
Indexation - prices	ι^p	0.2907	0.0552	0.6308	0.2562	0.0439	0.6042	0.3247	0.0661	0.6463
Capital adjust. cost elast.	φ	4.009	2.2662	5.5641	3.9598	2.0283	5.474	3.6855	2.0022	5.1512
Capital utiliz. adj. cost	ψ	0.7082	0.548	0.869	0.7129	0.5623	0.8782	0.7198	0.5705	0.8757
Cobb-Douglas	α	0.168	0.1393	0.1963	0.1692	0.1406	0.1985	0.1709	0.1415	0.1997
Fixed cost	ϕ	1.4647	1.344	1.5887	1.4684	1.3463	1.5911	1.4669	1.3419	1.5921
Taylor rule - smoothing	ρ	0.8504	0.8128	0.8882	0.8507	0.8139	0.8881	0.8505	0.8141	0.8901
Taylor rule - inflation	r_π	1.8232	1.5264	2.1214	1.8269	1.5452	2.1228	1.8397	1.5375	2.1319
Taylor rule - output	r_y	0.1155	0.0646	0.1672	0.1143	0.0634	0.1646	0.1176	0.0661	0.1687
Taylor rule - output growth	$r_{\Delta y}$	0.221	0.1778	0.2642	0.2188	0.1756	0.2612	0.2251	0.1809	0.2684
Log hours worked	l_{ss}	-0.6467	-2.2614	0.9366	-0.5521	-2.212	1.0443	-0.6134	-2.2289	1.0068
Steady-state inflation rate	π_{ss}	0.7801	0.6288	0.9291	0.7882	0.6323	0.943	0.7853	0.6326	0.935
Discount factor	$\bar{\beta}$	0.1906	0.0822	0.3000	0.1916	0.0808	0.300	0.1882	0.0783	0.294
Steady-state growth rate	$\bar{\gamma}$	0.3853	0.3472	0.4233	0.3838	0.3431	0.4266	0.3827	0.343	0.4255

Gamma(0.1,0.1); Inverse Gamma(0.1, 2); Uniform [0,1] $\bar{\beta} = \beta^{-1} - 1$; $\bar{\gamma} = \gamma_{ss} - 1$

Table 14: Estimation results – MP News (2)

		Gamma			Inverse Gamma			Uniform		
Parameter		**Mean**	**5%**	**95%**	**Mean**	**5%**	**95%**	**Mean**	**5%**	**95%**
AR coefficients shocks										
Productivity	ρ^a	0.9749	0.9567	0.9961	0.9757	0.9583	0.9971	0.9758	0.9581	0.9963
Risk-premium	ρ^b	0.8346	0.7573	0.9103	0.841	0.7715	0.9126	0.8305	0.7575	0.9094
Government spending	ρ^g	0.9791	0.9641	0.9947	0.9789	0.9638	0.9952	0.9792	0.9647	0.9951
Investment-specific	ρ^q	0.8682	0.7981	0.9391	0.8705	0.7909	0.949	0.8741	0.7973	0.9552
Monetary policy	ρ^r	0.2496	0.1222	0.3756	0.2476	0.1228	0.3697	0.2502	0.1243	0.3747
Price-markup	ρ^p	0.4694	0.0746	0.719	0.5128	0.1044	0.7493	0.4243	0.0563	0.6928
Wage-markup	ρ^w	0.2366	0.1169	0.3506	0.2349	0.1124	0.3512	0.2257	0.1078	0.3403
Prod. in gov. spending	ρ^{ga}	0.5018	0.3791	0.6232	0.501	0.3754	0.6213	0.5036	0.3812	0.6295
St.deviation shocks										
Productivity	σ^a	0.4843	0.4368	0.5309	0.4858	0.4379	0.5337	0.4899	0.4422	0.5392
Risk-premium	σ^b	0.0992	0.0735	0.1241	0.096	0.0714	0.1202	0.1005	0.074	0.1251
Government spending	σ^g	0.4932	0.45	0.5365	0.4955	0.4498	0.5389	0.5001	0.4551	0.5447
Investment-specific	σ^q	0.3811	0.3047	0.4565	0.3919	0.2961	0.4786	0.4063	0.3158	0.4972
Price-markup	σ^p	0.1238	0.0828	0.1715	0.1173	0.0775	0.166	0.1306	0.0867	0.176
Wage-markup	σ^w	0.249	0.2089	0.2895	0.2497	0.2087	0.2917	0.2543	0.2117	0.2951
Monetary policy	σ^r_0	0.156	0.1165	0.1953	0.1528	0.1126	0.1944	0.1596	0.12	0.1993
Monetary policy News	σ^r_2	0.1698	0.1349	0.2066	0.1705	0.1354	0.2068	0.1711	0.136	0.2066

Gamma(0.1,0.1); Inverse Gamma(0.1, 2); Uniform [0,1]

Table 15: Model Comparison

	No News	**MP News(2)**	**News All Shocks Horizon Length (n)**						
			1	2	3	4	5	6	2,4
	(A) **GAMMA**								
Log Data Density	-1073.53	-1066.49	-1092.66	-1087.17	-1090.45	-1095.58	-1102.90	-1110.76	-1133.96
Difff. w/no news		7.05	-19.13	-13.64	-16.91	-22.05	-29.36	-37.22	-60.42
	(B) **INV. GAMMA**								
Log Data Density	-1076.41	-1068.99	-1082.62	-1074.79	-1078.76	-1081.30	-1088.36	-1096.91	-1075.23
Difff. w/no news		7.43	-6.20	1.62	-2.35	-4.88	-11.95	-20.50	1.18

Log Marginal Data Density based on the Modified Harmonic Mean Estimator.

Table 16: Standard deviation of news shocks: alternative priors

		All News (2)			
		Post. Mode	Post. Mean	Conf. interval	
Gamma					
Monetary policy	σ_r^2	0.134	0.1558	0.1196	0.1931
Productivity	σ_a^2	0	0.0386	0	0.0832
Risk premium	σ_b^2	0	0.0376	0	0.0769
Gov. spending	σ_g^2	0.0061	0.0557	0	0.1202
Inv. specific	σ_q^2	0	0.0654	0	0.1455
Price markup	σ_p^2	0	0.0175	0	0.0378
Wage markup	σ_w^2	0	0.0451	0	0.0879
Inv.Gamma					
Monetary policy	σ_r^2	0.1705	0.1754	0.1447	0.208
Productivity	σ_a^2	0.0437	0.0628	0.025	0.1008
Risk premium	σ_b^2	0.0499	0.0705	0.0278	0.1106
Gov. spending	σ_g^2	0.0447	0.0669	0.0251	0.1105
Inv. specific	σ_q^2	0.0447	0.0653	0.0247	0.109
Price markup	σ_p^2	0.0359	0.0459	0.0242	0.0679
Wage markup	σ_w^2	0.0439	0.0561	0.0258	0.0869
Uniform					
Monetary policy	σ_r^2	0.1571	0.1537	0.1168	0.1936
Productivity	σ_a^2	0.0011	0.0465	0	0.0953
Risk premium	σ_b^2	0.0011	0.0526	0	0.0977
Gov. spending	σ_g^2	0.0006	0.0684	0	0.1427
Inv. specific	σ_q^2	0.0059	0.1182	0	0.2481
Price markup	σ_p^2	0	0.0255	0	0.052
Wage markup	σ_w^2	0	0.0463	0	0.0895

Table 17: Alternative model specifications: estimation results (cont.)

		(A) MP News			(B) News All		
		Post. Mean	Conf. interval		Post. Mean	Conf. interval	
Stand. deviation of shocks							
Unanticipated							
Productivity	σ_a^0	0.4843	0.4368	0.5309	0.4629	0.4173	0.5069
Risk premium	σ_b^0	0.0992	0.0735	0.1241	0.1196	0.0494	0.2033
Gov. spending	σ_g^0	0.4932	0.450	0.5365	0.4987	0.4527	0.5441
Inv. specific	σ_q^0	0.3811	0.3047	0.4565	0.3986	0.3263	0.4683
Monetary policy	σ_r^0	0.1238	0.0828	0.1715	0.1828	0.1488	0.2164
Price markup	σ_p^0	0.249	0.2089	0.2895	0.1121	0.0679	0.1694
Wage markup	σ_w^0	0.156	0.1165	0.1953	0.2508	0.2118	0.2903
Anticipated (2 quarters)							
Monetary policy	σ_r^2	0.1698	0.1349	0.2066	0.1558	0.1196	0.1931
Productivity	σ_a^2				0.0386	0	0.0832
Risk premium	σ_b^2				0.0376	0	0.0769
Gov. spending	σ_g^2				0.0557	0	0.1202
Inv. specific	σ_q^2				0.0654	0	0.1455
Price markup	σ_p^2				0.0175	0	0.0378
Wage markup	σ_w^2				0.0451	0	0.0879

Table 18: Shock by shock: log marginal data sensity at the posterior mean

	News Shocks					
	ε^a	ε^b	ε^g	ε^q	ε^p	ε^w
Log Data Density	-1074.40	-1075.57	-1073.67	-1074.13	-1075.28	-1074.74
Diff. w/mp news	-7.91	-9.09	-7.19	-7.64	-8.79	-8.25
Diff. w/no news	-0.86	-2.04	-0.14	-0.59	-1.75	-1.20

Log Marginal Data Density based on the Modified Harmonic Mean Estimator.

Monetary Policy Shocks: We got News!

Technical Appendix

(NOT FOR PUBLICATION)

A The Model Economy: Households and Firms

The economy is populated by a continuum of households indexed by j, each maximizing the following utility function

$$E_t\Bigg[\sum_{s=0}^{\infty}\beta^s\frac{1}{1-\sigma_C}\Big((C_{t+s}(j)-\lambda C_{t+s-1}(j))^{1-\sigma_C}\Big)\exp\Big(\frac{\sigma_c-1}{1+\sigma_l}L_{t+s}(j)^{1+\sigma_l}\Big)\Bigg], \tag{15}$$

where $C_{t+s}(j)$ is consumption, $L_{t+s}(j)$ is hours worked.

Households supply homogeneous labor services to labor unions indexed by l. Labor services are differentiated by a union, and sold to labor packers. Wage setting is subject to nominal rigidities with a Calvo mechanism whereby each period a union can set the nominal wage to the optimal level with constant probability equal to $1-\xi_w$. Unions that cannot adjust their nominal wage optimally change it according to the following indexation rule

$$W_{t+s}(l)=\gamma W_{t-1}(l)\pi_{t-1}^{\iota_w}\pi_*^{(1-\iota_w)}, \tag{16}$$

where γ is the deterministic growth rate, ι_w measures the degree of wage indexation to past inflation, and π_* is the steady state rate of inflation.

Labor packers buy differentiated labor services $L_t(l)$ from unions, package and sell composite labor L_t, defined implicitly by

$$\int_0^1\mathcal{H}\Big(\frac{L_t(l)}{L_t};\lambda_{w,t}\Big)dl=1, \tag{17}$$

to the intermediate good sector firms. The function $\mathcal{H}$ is increasing, concave, and satisfies $\mathcal{H}(1)=1$; $\lambda_{w,t}$ is a stochastic exogenous process changing the elasticity of demand, and the wage markup over the marginal disutility from work.

In addition to supplying labor, households rent capital to the intermediate goods producers at rate $R_t^K(j)$. Households accumulate physical capital according to the following law of motion:

$$\bar{K}_t(j)=(1-\delta)\bar{K}_{t-1}(j)+\varepsilon_t^i\Big[1-\mathcal{S}\Big(\frac{I_t(j)}{I_{t-1}(j)}\Big)\Big]I_t(j), \tag{18}$$

where δ is the rate of depreciation, I_t is gross investment, and the investment adjustment cost function $\mathcal{S}$ satisfies $\mathcal{S}'>0,\;\;\mathcal{S}''>0$, and in steady state $\mathcal{S}=0,\;\;\mathcal{S}'=0$; ε_t^i represents the current state of technology for producing capital, and is interpreted as investment-specific technological progress.

Households also choose the utilization rate $Z_t(j)$ of the physical capital they own, and pay $P_t a(Z_t(j))\bar{K}_{t-1}(j)$ in terms of consumption good when the capital intensity is $Z_t(j)$. The income from renting capital to firms is $R_t^k K_t(j)$, where $K_t(j)=Z_t(j)\bar{K}_{t-1}(j)$ is the flow of capital services provided by the existing stock of physical capital $\bar{K}_{t-1}(j)$. The utility function (15) is maximised with respect to consumption, hours, investment, and capital utilization, subject to the capital accumulation equation (18), and the following budget constraint:

$$\begin{aligned}&C_{t+s}(j)+I_{t+s}(j)+\frac{B_{t+s}(j)}{\varepsilon_{t+s}^b R_{t+s}P_{t+s}}-T_{t+s}=\frac{W_{t+s}(j)}{P_{t+s}}L_{t+s}(j)\\&+\Big(\frac{R_{t+s}^k Z_{t+s}(j)}{P_{t+s}}-a(Z_{t+s}(j))\Big)\bar{K}_{t+s-1}(j)+\frac{B_{t+s-1}(j)}{P_{t+s}}+\frac{\Pi_{t+s}(j)}{P_{t+s}},\end{aligned} \tag{19}$$

where B_{t+s} is a one-period nominal bond expressed on a discount basis, ε_t^b is an exogenous premium on the bond return, T_{t+s} is lump-sum taxes or subsidies, and Π_{t+s} is profit distributed by the labor union.

There is a perfectly competitive sector producing a single final good used for consumption and investment.

The final good is produced from intermediate inputs $Y_t(i)$ using technology defined implicitly by

$$\int_0^1 \mathcal{G}\left(\frac{Y_t(i)}{Y_t}; \lambda_{p,t}\right) di = 1, \tag{20}$$

where $\mathcal{G}$ is increasing, concave, and $\mathcal{G}(1) = 1$; $\lambda_{p,t}$ is an exogenous stochastic process affecting the elasticity of substitution between different intermediate goods, also corresponding to a markup over marginal cost for intermediate good firms. Firms maximise profits given by

$$P_t Y_t - \int_0^1 P_t(i) Y_t(i) di, \tag{21}$$

where $P_t(i)$ is the price of intermediate good $Y_t(i)$.

Intermediate goods are produced in a monopolistically competitive sector. Each variety i is produced by a single firm using the following production technology:

$$Y_t(i) = \varepsilon_t^a K_t(i)^\alpha (\gamma^t L_t(i))^{1-\alpha} - \Phi \gamma^t, \tag{22}$$

where Φ is a fixed cost of production, and ε_t^a is the total factor productivity. As with wages, every period only a fraction $1 - \xi_P$ of intermediate firms can set optimally the price of the good they produce. The remaining ξ_p firms index their prices to past inflation according to

$$P_t(t) = \gamma P_{t-1}(i) \pi_{t-1}^{\iota_p} \pi_*^{(1-\iota_p)}, \tag{23}$$

where ι_p measures the degree of price indexation to past inflation.

B Data

B.1 Observables

In the following we describe in detail the data used in the estimation:

- Real output growth: quarter-on-quarter log difference of real output, defined as real GDP (Billions U.S. Dollar, 2005 prices) divided by the civilian noninstitutional population (aged 16 and over).
- Real consumption growth: quarter on-quarter log difference of real consumption, defined as nominal personal consumption expenditure (Billions U.S. Dollar) divided by the GDP implicit price deflator and then divided by the civilian noninstitutional population (aged 16 and over).
- Real investment growth: quarter on-quarter log difference of real investment, defined as nominal private fixed investment (Billions U.S. Dollar) divided by the GDP implicit price deflator and then divided by the civilian noninstitutional population (aged 16 and over).
- Hours worked: Average hours worked (non-farm business sector) multiplied by total civilian employment and divided by the civilian noninstitutional population (aged 16 and over); log-transformed; 1950:2010=100.
- Inflation: quarter on-quarter log difference in the GDP implicit price deflator.
- Real wage growth: Log difference in real wage, defined as hourly compensation in the non-farm business sector (1992=100) divided by the GDP implicit price deflator.
- Interest rate: Federal-funds rate.(quarterly).

The data series as described above are shown in Figure B.1.

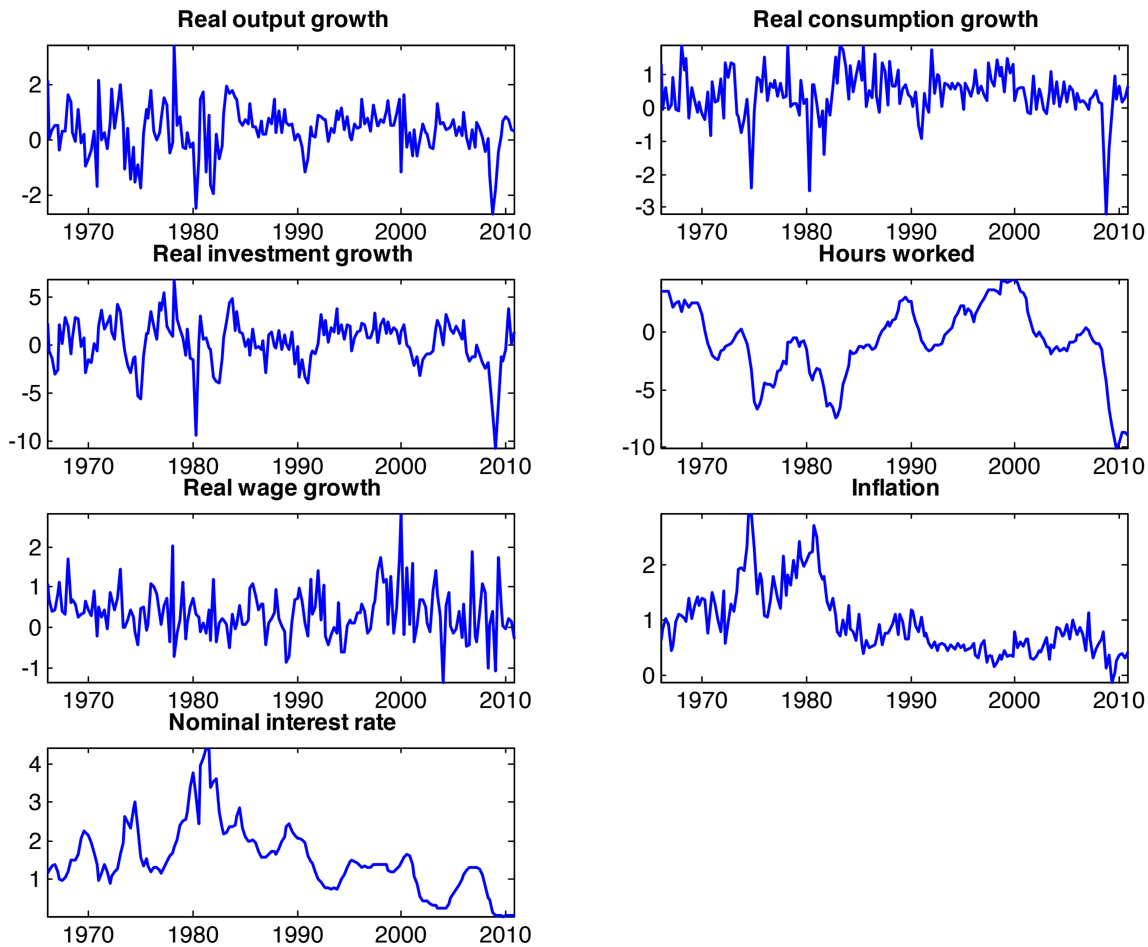

Figure B.1: Observables

C Estimation details

C.1 Convergence of the MCMC algorithm

To assess the convergence of the algorithm we run two independent Markov chains with 250.000 draws and checked both the univariate and the mulivariate statistics of convergence. In Figure C.1 we plot an aggregate measure that is based on the eigenvalues of the variance-covariance matrix of each parameter.[29] The red and blue line represent specific within and between chain measures, namely an interval statistic constructed around parameter mean (Interval), a measure of the variance.(m2) and a measure based on third moments (m3).

We also check convergence by taking the 1 million draws chain and computing the posterior mean at different places in the chain, i.e. the first 250000, 500000, 750000 and 1000000 draws (discaring the first 10 per cent of draws). The results indicate convergence of the MCMC algorithm (see Tables C.1 and C.2).

[29] For details see Brooks, S. and A. Gelman (1998). "Some issues in monitoring convergence of iterative simulations", Computing Science and Statistics.

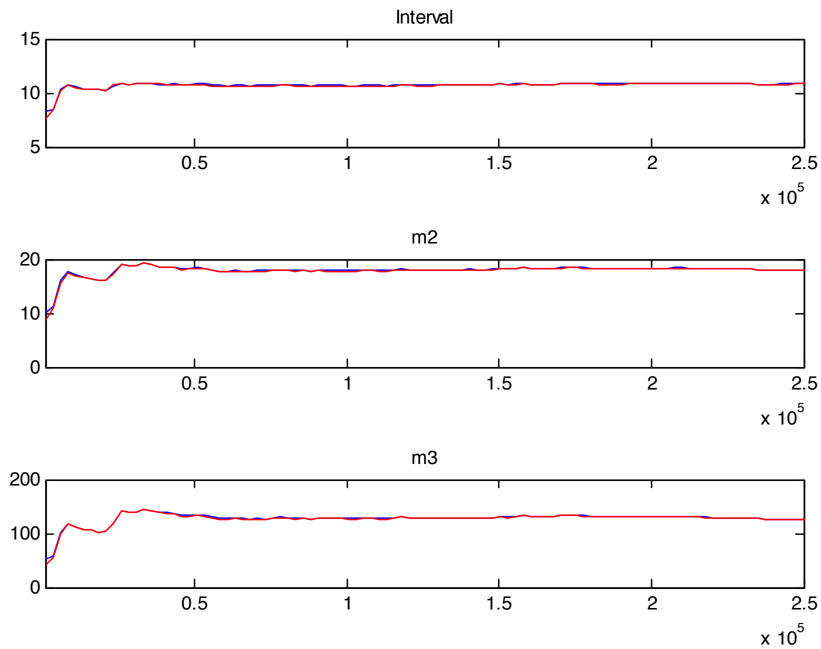

Figure C.1: MCMC convergence

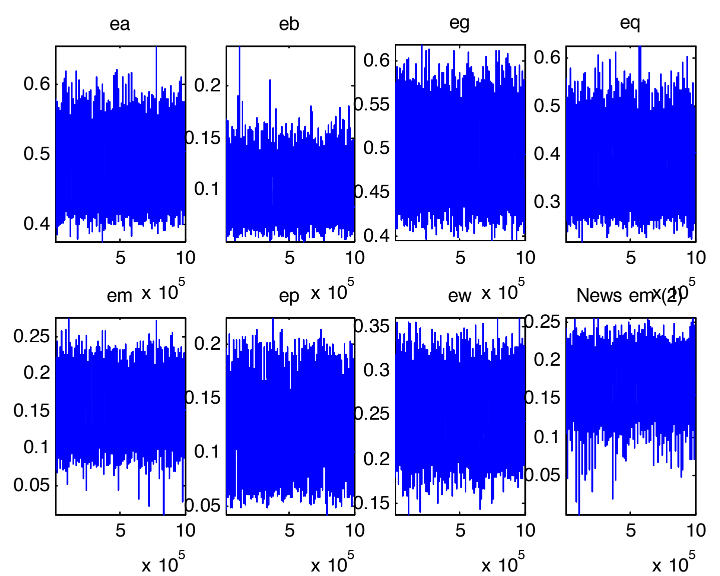

Figure C.2: Draws: standard deviations

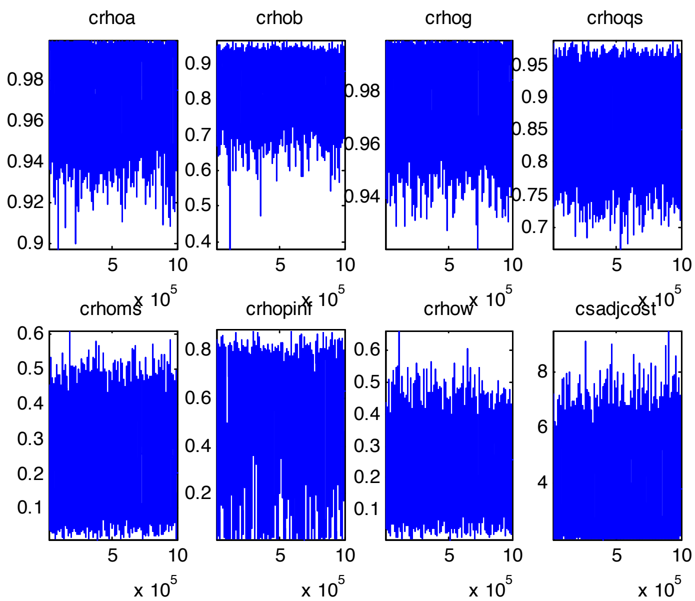

Figure C.3: Draws: other parameters

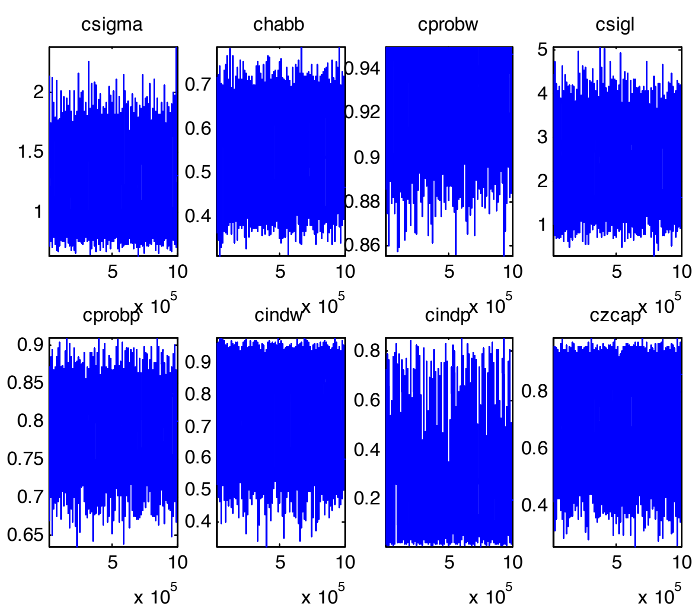

Figure C.4: Draws: other parameters (cont.)

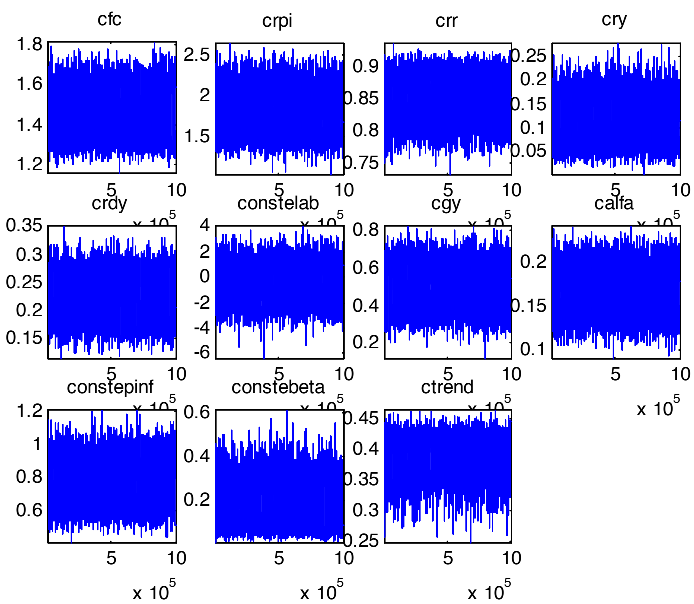

Figure C.5: Draws: other parameters (cont.)

Table C.1: MH convergence: increasing the number of draws

		Mean			
	Draws:	250000	500000	750000	1000000
Parameter					
Intert. elast. substitution	σ^c	1.226	1.227	1.221	1.221
Habits	h	0.556	0.552	0.552	0.552
Labor supply elasticity	σ^l	2.396	2.392	2.396	2.383
Calvo prob. - wages	ξ^w	0.933	0.933	0.933	0.933
Calvo prob. - prices	ξ^p	0.792	0.793	0.794	0.794
Indexation - wages	ι^w	0.748	0.746	0.746	0.746
Indexation - prices	ι^p	0.296	0.282	0.291	0.291
Capital adjust. cost elast.	φ	4.090	4.042	4.030	4.038
Capital utiliz. adj. cost	ψ	0.714	0.712	0.711	0.711
Cobb-Douglas	α	0.169	0.168	0.168	0.168
Fixed cost	ϕ	1.465	1.466	1.465	1.466
Taylor rule - smoothing	ρ	0.851	0.851	0.851	0.851
Taylor rule - inflation	r_π	1.827	1.826	1.826	1.825
Taylor rule - output	r_y	0.115	0.116	0.116	0.116
Taylor rule - output growth	$r_{\Delta y}$	0.220	0.221	0.220	0.221
Log hours worked	l_{ss}	-0.598	-0.642	-0.641	-0.629
Steady-state inflation rate	π_{ss}	0.781	0.781	0.782	0.781
Discount factor	$\bar{\beta}$	0.191	0.190	0.191	0.190
Steady-state growth rate	$\bar{\gamma}$	0.383	0.385	0.385	0.385

Dropping first 10% of draws.

Table C.2: MH convergence: increasing the number of draws

		Mean			
	Draws:	250000	500000	750000	1000000
Parameter					
AR coefficients shocks					
Productivity	ρ^a	0.975	0.975	0.975	0.975
Risk-premium	ρ^b	0.829	0.832	0.834	0.834
Government spending	ρ^g	0.979	0.979	0.979	0.979
Investment-specific	ρ^q	0.868	0.868	0.868	0.868
Monetary policy	ρ^r	0.245	0.248	0.249	0.250
Price-markup	ρ^p	0.465	0.478	0.469	0.469
Wage-markup	ρ^w	0.239	0.238	0.239	0.240
Prod. in gov. spending	ρ^{ga}	0.503	0.503	0.502	0.502
St.deviation shocks					
Productivity	σ^a	0.486	0.485	0.485	0.485
Risk-premium	σ^b	0.101	0.100	0.100	0.100
Government spending	σ^g	0.494	0.493	0.493	0.493
Investment-specific	σ^q	0.379	0.380	0.380	0.379
Price-markup	σ^p	0.125	0.123	0.124	0.124
Wage-markup	σ^w	0.248	0.249	0.249	0.248
Monetary policy	σ_0^r	0.157	0.156	0.156	0.156
Monetary policy News	σ_2^r	0.168	0.169	0.170	0.170

Dropping first 10% of draws.

D Additional Results

Table D.1: Sensitivity in the Likelihood

Intert. elast. substitution	σ^c	12.7979	Discount factor	$\bar{\beta}$	1.201539
Habits	h	16.79054	Steady-state growth rate	$\bar{\gamma}$	3735451
Labor supply elasticity	σ^l	2.79979	AR Productivity	ρ^a	92.24047
Calvo prob. - wages	ξ^w	48.92193	AR Risk-premium	ρ^b	26.27497
Calvo prob. - prices	ξ^p	28.54868	AR Government spending	ρ^g	78.11525
Indexation - wages	ι^w	5.356399	AR Investment-specific	ρ^q	24.29001
Indexation - prices	ι^p	4.273497	AR Monetary policy	ρ^r	3.087784
Capital adjust. cost elast.	φ	6.57961	AR Price-markup	ρ^p	12.43574
Capital utiliz. adj. cost	ψ	5.459381	AR Wage-markup	ρ^w	4.916525
Cobb-Douglas	α	11.56586	AR Prod. in Gov. spending	ρ^{ga}	4.927969
Fixed cost	ϕ	22.26308	Std Productivity	σ_a	14.14269
Taylor rule - smoothing	ρ	37.19313	Std Risk-premium	σ_b	11.81208
Taylor rule - inflation	r_π	7.073737	Std Government spending	σ_g	14.14471
Taylor rule - output	r_y	4.765041	Std Investment-specific	σ_q	14.08771
Taylor rule - output growth	$r_{\Delta y}$	9.118428	Std Price-markup	σ_p	14.13895
Log hours worked	l_{ss}	-0.55129	Std Wage-markup	σ_w	14.14452
Steady-state inflation rate	π_{ss}	4.544092	Std Monetary policy	σ_r^0	14.14452
			Std Monetary policy news	σ_r^2	8.335683

Table D.2: Alternative model specifications: estimation results

Parameters		No news			MP News			News All		
		Post. Mean	Conf. interval		Post. Mean	Conf. interval		Post. Mean	Conf. interval	
Intert. elast. substitution	σ_c	1.2368	0.9502	1.5118	1.2273	0.9026	1.5439	1.4553	1.1369	1.7833
Habits	h	0.6364	0.5469	0.7277	0.5499	0.4547	0.6476	0.5619	0.4252	0.6941
Labor supply elasticity	σ^l	2.2151	1.3072	3.116	2.3659	1.4751	3.2575	2.0275	1.1527	2.9209
Calvo prob. - wages	ξ^w	0.9328	0.9146	0.95	0.9331	0.9157	0.95	0.935	0.9195	0.95
Calvo prob. - prices	ξ^p	0.7825	0.7231	0.8423	0.7939	0.7406	0.8508	0.7585	0.6904	0.83
Indexation - wages	ι^w	0.7522	0.6202	0.8877	0.7447	0.6092	0.8826	0.7522	0.624	0.8828
Indexation - prices	ι^p	0.2464	0.0418	0.6075	0.2907	0.0552	0.6308	0.283	0.0481	0.6815
Capital adjust. cost elast.	φ	4.6853	2.8901	6.413	4.009	2.2662	5.5641			
Capital utiliz. adj. cost	ψ	0.7078	0.5548	0.8668	0.7082	0.548	0.869	0.7697	0.6358	0.9053
Cobb-Douglas	α	0.1709	0.1424	0.1996	0.168	0.1393	0.1963	0.1837	0.1565	0.2111
Fixed cost	ϕ	1.4896	1.3566	1.6154	1.4647	1.344	1.5887	1.607	1.467	1.7434
Taylor rule - smoothing	ρ	0.8311	0.7899	0.872	0.8504	0.8128	0.8882	0.7926	0.7423	0.8446
Taylor rule - inflation	r_π	1.7588	1.4741	2.0392	1.8232	1.5264	2.1214	1.6099	1.3725	1.8551
Taylor rule - output	r_y	0.0854	0.0366	0.1328	0.1155	0.0646	0.1672	0.0335	0.0035	0.0617
Taylor rule - output growth	$r_{\Delta y}$	0.242	0.2	0.2851	0.221	0.1778	0.2642	0.2174	0.1747	0.2589
Log hours worked	l_{ss}	-0.5028	-2.1928	1.1723	-0.6467	-2.2614	0.9366	-1.0418	-3.03	0.9051
Steady-state inflation rate	π_{ss}	0.7933	0.644	0.942	0.7801	0.6288	0.9291	0.7601	0.6087	0.9158
Discount factor	β^{-1}	0.1799	0.0768	0.279	0.1906	0.0822	0.3	0.1568	0.0698	0.2419
Steady-state growth rate	$\gamma_{ss} - 1$	0.3881	0.3513	0.4267	0.3853	0.3472	0.4233	0.3892	0.3605	0.4197

Table D.3: Alternative model specifications: estimation results (cont.)

		No news			**MP News**			**News All**		
		Post. Mean	Conf. interval		Post. Mean	Conf. interval		Post. Mean	Conf. interval	
AR coefficients										
Productivity	ρ^a	0.9721	0.9519	0.9974	0.9749	0.9567	0.9961	0.9655	0.9459	0.9853
Risk premium	ρ^b	0.6884	0.5176	0.852	0.8346	0.7573	0.9103	0.621	0.3739	0.844
Gov. spending	ρ^g	0.9804	0.9656	0.9959	0.9791	0.9641	0.9947	0.9839	0.972	0.9966
Inv. specific	ρ^q	0.8454	0.7695	0.92	0.8682	0.7981	0.9391	0.8312	0.7549	0.9084
Monetary policy	ρ^r	0.1607	0.0619	0.2599	0.2496	0.1222	0.3756	0.3082	0.1742	0.4432
Price markup	ρ^p	0.5367	0.1019	0.7743	0.4694	0.0746	0.719	0.5194	0.0465	0.7875
Wage markup	ρ^w	0.2417	0.1201	0.3613	0.2366	0.1169	0.3506	0.2039	0.0699	0.3304
Prod. in gov. spending	ρ^{ga}	0.5013	0.3755	0.6232	0.5018	0.3791	0.6232	0.5002	0.3722	0.63
Stand. deviation of shocks										
Unanticipated										
Productivity	σ_a^0	0.4805	0.4351	0.5263	0.4843	0.4368	0.5309	0.4629	0.4173	0.5069
Risk premium	σ_b^0	0.1425	0.1002	0.1856	0.0992	0.0735	0.1241	0.1196	0.0494	0.2033
Gov. spending	σ_g^0	0.495	0.4505	0.5374	0.4932	0.450	0.5365	0.4987	0.4527	0.5441
Inv. specific	σ_q^0	0.3822	0.3122	0.4506	0.3811	0.3047	0.4565	0.3986	0.3263	0.4683
Monetary policy	σ_r^0	0.2365	0.2137	0.2591	0.1238	0.0828	0.1715	0.1828	0.1488	0.2164
Price markup	σ_p^0	0.1134	0.0739	0.1668	0.249	0.2089	0.2895	0.1121	0.0679	0.1694
Wage markup	σ_w^0	0.2484	0.207	0.2895	0.156	0.1165	0.1953	0.2508	0.2118	0.2903
Anticipated (2 quarters)										
Monetary policy	σ_r^2				0.1698	0.1349	0.2066	0.1558	0.1196	0.1931
Productivity	σ_a^2							0.0386	0	0.0832
Risk premium	σ_b^2							0.0376	0	0.0769
Gov. spending	σ_g^2							0.0557	0	0.1202
Inv. specific	σ_q^2							0.0654	0	0.1455
Price markup	σ_p^2							0.0175	0	0.0378
Wage markup	σ_w^2							0.0451	0	0.0879