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# Can News Be a Major Source of Aggregate Fluctuations? A Bayesian DSGE Approach

**Ippei Fujiwara*, Yasuo Hirose**, and Mototsugu Shintani*****

**Abstract**

We examine whether the news shocks, as explored in Beaudry and Portier (2004), can be a major source of aggregate fluctuations. For this purpose, we extend a dynamic stochastic general equilibrium model, à la Christiano, Eichenbaum, and Evans (2005), by allowing news shocks on the total factor productivity and estimate the model using Bayesian methods. Estimation results on the Japanese and U.S. economies show that (1) the news shocks play an important role in business cycles; (2) a news shock with a longer forecast horizon has larger effects on nominal variables; and (3) the overall effect of the total factor productivity on hours worked becomes ambiguous in the presence of news shocks.

**Keywords:** Bayesian Estimation; Business Cycles; News; Total Factor Productivity (TFP)

**JEL classification:** E30, E40, E50

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# 1 Introduction

Macroeconomists have long realized that changes in the expectation about the future can be a major source of economic fluctuations. This tradition can be traced back to Pigou (1926), who emphasized the possibility that capital accumulation, caused by optimistic expectations of future demand increase, may result in recessions when the expectations are not met.[1] This idea of the expectation-driven cycles, sometimes referred to as "Pigou cycles," has recently been reformulated in the framework of modern equilibrium business cycle models.[2] Theoretical works that successfully yielded procyclical labor, investment, and consumption in the presence of news shocks include Beaudry and Portier (2004), Beaudry, Collard, and Portier (2006), Jaimovich and Rebelo (2006), Denhaan and Kaltenbrunner (2007), Fujiwara (2007), Kobayashi, Nakajima, and Inaba (2007) and Christiano, Ilut, Motto, and Rostagno (2008). In contrast to the growing interest in the theoretical analysis, the empirical evidence on the importance of news shocks in business cycles is quite limited. To the best of our knowledge, exceptions are Beaudry and Portier (2005) for Japan and Beaudry and Portier (2006) for the United States. They identified the news shocks by estimating a structural vector autoregression (VAR) model with an assumption that the news shock has an impact on both the stock price and total factor productivity (TFP) in the long run but not on the latter in the short run.

In this paper, we empirically examine the role of the news shocks in explaining the business cycles based on a dynamic stochastic general equilibrium (DSGE) model. In particular, we introduce both expected and unexpected shock components in the TFP and evaluate the relative contribution of the two components to aggregate fluctuations by estimating the Christiano, Eichenbaum and Evans' (2005) type New Keynesian DSGE model using Bayesian methods applied to the Japanese and U.S. economies.[3] Although, our

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[1] Pigou (1926) stated that "while recognizing that the varying expectations of business men may themselves be in part a psychological reflex of good and bad harvests - while not, indeed, for the present inquiring how these varying expectations themselves come about - we conclude definitely that they, and not anything else, constitute the immediate cause and direct causes or antecedents of industrial fluctuations."

[2] For example, the terminology of "Pigou cycles" has been used by Beaudry and Portier (2004).

[3] Christiano and Fujiwara (2006) show the news shock can be a potential candidate for the explanation of the bubble in Japan with a similar model, but they use the calibrated model.

analysis is similar to Beaudry and Portier (2005, 2006) in spirit, it has several advantages over their VAR approach. First, we directly estimate a fully specified DSGE model, and thus interpretation of our results, such as estimated parameters and impulse responses, is straightforward.[4] Second, the contribution of news shocks in business cycles relative to that of other structural shocks can be directly investigated. Third, since our model allows the presence of multiple news shocks with different forecast horizons, the role of horizons in news shocks can be systematically examined.

As pointed out by Barro and King (1984), generating the expectation-driven cycles in the equilibrium models has been a difficult task, since "with a simple one-capital-good technology, no combination of income effects and shifts to the perceived profitability of investment will yield positive comovements of output, employment, investment, and consumption." Only recently have the Pigou cycles been successfully described by balancing the tension between the wealth effect and the substitution effect stemming from the expectation of changes in future productivity.[5] The pioneering work by Beaudry and Portier (2004) showed that the introduction of the multi-sectoral adjustment cost intensifies the complementarity between consumption and investment, which leads to the comovement of consumption, labor, and investment.

Among the many works that followed, Christiano, Ilut, Motto, and Rostagno (2008) is particularly of great interest to us, because they showed that the Pigou cycles could also be produced in the *de facto* standard macroeconomic model of Christiano, Eichenbaum, and Evans (2005), namely, a DSGE model that incorporates the investment growth adjustment cost, habit formation in consumption, sticky prices and wages, and the inflation-targeting monetary policy. The model has been widely used among practitioners, because it can account for many important characteristics of macroeconomic data, such as the inflation inertia and output persistence, even in the case of moderate degrees of nominal rigidities.[6]

[4] Recent works by Christiano, Ilut, Motto, and Rostagno (2008) and Schmitt-Grohé and Uribe (2008) also employed a method similar to ours.

[5] With a positive news shock in TFP, for example, the wealth effect reduces labor and investment, while the substitution effect reduces consumption. A Dynare toolkit created by Fujiwara and Kang (2006) can be used to compute the impulse responses to news shocks under many different scenarios.

[6] In fact, many models developed by central banks can be viewed as variations of Christiano, Eichenbaum,

To examine the role of news shocks, we employ the procedure of Smets and Wouters (2003, 2007) in estimating a DSGE model, largely based on Christiano, Eichenbaum, and Evans (2005). We let the TFP innovations in these models consist of news shocks and remaining unexpected components, namely, contemporaneous shocks. Our estimation results from Japanese and U.S. quarterly data show that, while the unexpected shocks in the TFP are one of the dominant drivers of the aggregate fluctuations, the news shocks also play a non-negligible role. When the forecast horizon of the news shock becomes longer, effects of the news shocks on nominal variables become larger. Furthermore, the overall effect of the TFP innovations on hours worked, which has been one of the key issues in the recent business cycle literature, becomes ambiguous when both news and contemporaneous shocks occur simultaneously.

The remainder of this paper is structured as follows. In Section 2, the concepts of news shocks are first introduced, followed by the description of the log-linearized model. In Section 3, the estimation strategy is explained. In Section 4, estimation results are demonstrated. Finally, in Section 5, a conclusion and discussion of some possible future extensions are provided.

## 2 The Model

We examine the plausibility of the expectation-driven cycles by introducing news shocks in the model used in Smets and Wouters (2003, 2007). We choose this model for various reasons. First, this model includes almost all features of the frictions typically introduced in the New Keynesian or New Neoclassical Synthesis models. Second, indeed, the model is largely based on Christiano, Eichenbaum, and Evans (2005) and contains all essential features, according to Christiano, Ilut, Motto, and Rostagno (2008), in producing Pigou cycles. Third, Smets and Wouters (2003, 2007) have already established that this class of DSGE model estimated by Bayesian methods fits well with the data in the United States and the Euro area and has out-of-sample forecasting performance comparable to that of

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and Evans (2005). For example, see Smets and Wouters (2003, 2007), Laxton and Pesenti (2003), Erceg, Guerrieri, and Gust (2006), Adolfson, Laseen, Linde, and Villani (2007), and Sugo and Ueda (2008).

standard Bayesian VAR models. Sugo and Ueda (2008) estimated a similar model for the Japanese economy. We can take advantage of their findings in setting our priors without risk of relying on an arbitrary model.

We first define news shocks in the TFP in the model. The remaining part of the model is described later in the next subsection. In what follows, all the variables are expressed in terms of log deviation from the steady-state values.

## 2.1 News Shocks in Productivity

As in Beaudry and Portier (2004), we consider the case where agents can observe signals that contain information on the future technological innovations. Other than allowing for such an information structure, both our production function and innovation process are fairly standard. Let $y_t$, $k_t^s$, $l_t$, and $z_t$ be the output, the current capital services in production, the hours worked, and the TFP around the deterministic linear trend, respectively. Our (log-linearized) aggregate production function is given by

$$y_t = \phi_p \left[\alpha k_t^s + (1-\alpha) l_t + z_t\right],$$

where $\phi_p$ denotes one plus the share of the fixed costs in production and $\alpha$ represents the capital share. The detrended TFP $z_t$ is assumed to follow an AR (1) process:

$$z_t = \rho_z z_{t-1} + \varepsilon_t^z, \quad \varepsilon_t^z \sim \text{i.i.d. } N(0, \sigma_z^2),$$

where $\varepsilon_t^z$ is a technological innovation in productivity. To introduce the information structure, it is convenient to rewrite $\varepsilon_t^z$ as a summation of the unexpected component, $\nu_{0,t}$, and the expected component, $\nu_t^*$. At the beginning of period $t$, $\nu_{0,t}$ is not known but $\nu_t^*$ is known to agents. To allow for the variation in the timing of the arrival of the news, we further decompose the latter component $\nu_t^*$ into a summation of news shocks, or $\sum_{j=1}^{n} \nu_{j,t-j}$, where $\nu_{j,t-j}$ is news of the $j$-periods ahead technological innovation learned at period $t-j$, where $0 < j \leq n$. For identification, we assume

$$\nu_{j,t} \sim \text{i.i.d. } N(0, \sigma_{zj}^2), \quad \text{for } j = 0, 1, ..., n.$$

This assumption implies zero correlation between the news and contemporaneous shocks as well as zero cross-correlation among news shocks. The variance of $\varepsilon_t^z$ can be simply computed as $\sum_{j=1}^{n}\sigma_{zj}^{2}$.

In this paper, we assume that the agents can obtain news about future technology up to four periods ahead and set $n = 4$. Under such circumstances, the technology process can be written as

$$\begin{aligned} z_t &= \rho_z z_{t-1} + \nu_{0,t} + \nu_t^* \\ &= \rho_z z_{t-1} + \nu_{0,t} + \nu_{1,t-1} + \nu_{2,t-2} + \nu_{3,t-3} + \nu_{4,t-4}. \end{aligned}$$

In the model, at the period $t$, agents form rational expectations on the future productivity $z_{t+j}$, $j > 0$, using the information set $\{z_t, \nu_{1,t}, ..., \nu_{4,t}, \nu_{1,t-1}, ..., \nu_{4,t-1}, ...\}$. To understand this information updating structure, it is convenient to rewrite the above equation in the canonical form as

$$\begin{pmatrix} z_t \\ \nu_{1,t} \\ \nu_{2,t} \\ \nu_{2,t-1} \\ \nu_{3,t} \\ \nu_{3,t-1} \\ \nu_{3,t-2} \\ \nu_{4,t} \\ \nu_{4,t-1} \\ \nu_{4,t-2} \\ \nu_{4,t-3} \end{pmatrix} = \begin{pmatrix} \rho_z & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} z_{t-1} \\ \nu_{1,t-1} \\ \nu_{2,t-1} \\ \nu_{2,t-2} \\ \nu_{3,t-1} \\ \nu_{3,t-2} \\ \nu_{3,t-3} \\ \nu_{4,t-1} \\ \nu_{4,t-2} \\ \nu_{4,t-3} \\ \nu_{4,t-4} \end{pmatrix} + \begin{pmatrix} \nu_{0,t} \\ \nu_{1,t} \\ \nu_{2,t} \\ 0 \\ \nu_{3,t} \\ 0 \\ 0 \\ \nu_{4,t} \\ 0 \\ 0 \\ 0 \end{pmatrix} \tag{1}$$

or $\mathbf{s}_t = A\mathbf{s}_{t-1} + \boldsymbol{\varepsilon}_t$, where $\mathbf{s}_t = (z_t, \nu_{1,t}, \nu_{2,t}, \nu_{2,t-1}, ..., \nu_{4,t-3})'$ and $\boldsymbol{\varepsilon}_t = (\nu_{0,t}, \nu_{1,t}, \nu_{2,t}, 0, \nu_{3,t}, ..., 0)'$. Note that the expected value of $z_{t+j}$ at period $t$ can be easily obtained from $\mathrm{E}_t\mathbf{s}_{t+j}$ using $\mathbf{s}_{t+j} = A^j\mathbf{s}_{t+j-1} + ... + \boldsymbol{\varepsilon}_{t+j}$. Let us examine the propagation mechanism of the news shocks using a simple example. In our system, a news shock on 4-period ahead technological progress expected at period $t$, $\nu_{4,t}$, will have no effect on $z_t$, $\mathrm{E}_t z_{t+1}$, $\mathrm{E}_t z_{t+2}$, and $\mathrm{E}_t z_{t+3}$. However, it will have an effect on $\mathrm{E}_t z_{t+4}$ and expectation of $z_t$ for a longer horizon, since computation of $\mathrm{E}_t\mathbf{s}_{t+4}$ yields

$$\begin{aligned} E_t z_{t+4} &= \rho_z^4 z_{t-1} + \rho_z^3 (\nu_{1,t} + \nu_{2,t-1} + \nu_{3,t-2} + \nu_{4,t-3}) \\ &\quad + \rho_z^2 (\nu_{2,t} + \nu_{3,t-1} + \nu_{4,t-2}) + \rho_z (\nu_{3,t} + \nu_{4,t-1}) + \nu_{4,t}. \end{aligned}$$

## 2.2 Other Shocks in the Linearized System

The remaining part of the model is a slightly simplified version of the model used in Smets and Wouters (2003, 2007). Here we only show the log-linearized system of equations around steady states, which are denoted without time subscript. Let $c_t$, $i_t$, $r_t^k$, and $k_t$ be the consumption, the investment, the rental rate of capital, and the physical capital. The current capital services in production $k_t^s$ are defined as

$$k_t^s = k_{t-1} + u_t,$$

where $u_t$ is the capacity utilization rate, which is given by

$$u_t = \frac{1-\psi}{\psi} r_t^k,$$

where $\psi$ is a positive function of the elasticity of capacity utilization adjustment cost function normalized to be between zero to unity. The aggregate resource constraint is

$$y_t = \frac{c}{y} c_t + \frac{i}{y} i_t + \frac{r^k k}{y} u_t + g_t,$$

where $g_t$ is the government expenditure shock. The consumption Euler equation is expressed as

$$\begin{aligned} c_t \quad = \quad & \frac{\lambda}{\gamma\left(1+\frac{\lambda}{\gamma}\right)} c_{t-1} + \left[1 - \frac{\lambda}{\gamma\left(1+\frac{\lambda}{\gamma}\right)}\right] \mathrm{E}_t c_{t+1} \\ & + \frac{(\sigma_c - 1)\left(\frac{wl}{C}\right)}{\sigma_c\left(1+\frac{\lambda}{\gamma}\right)} \left(l_t - \mathrm{E}_t l_{t+1}\right) \\ & - \frac{1-\frac{\lambda}{\gamma}}{\sigma_c\left(1+\frac{\lambda}{\gamma}\right)} \left(r_t - \mathrm{E}_t \pi_{t+1}\right), \end{aligned}$$

where $r_t$ denotes the nominal interest rate, $w_t$ is the nominal wage, and $\pi_t$ represents the inflation rate while $\lambda$ is the parameter on the external habit, $\gamma$ is the steady-state growth rate, and $\sigma_c$ represents the inverse of the intertemporal elasticity of substitution. The investment Euler equation is given by

$$i_t = \frac{1}{1+\beta\gamma^{1-\sigma_c}} i_{t-1} + \left(1 - \frac{1}{1+\beta\gamma^{1-\sigma_c}}\right) \mathrm{E}_t i_{t+1} + \frac{1}{\left(1+\beta\gamma^{1-\sigma_c}\right)\gamma^2\varphi} q_t + v_t,$$

where $q_t$ is the real value of existing capital and $v_t$ is the investment-specific technology process, while $\beta$ denotes the subjective discount factor and $\varphi$ represents the steady-state elasticity of the investment adjustment cost function. The capital Euler equations is now expressed as

$$\begin{aligned} q_t &= \beta\gamma^{-\sigma_c}(1-\delta)\mathrm{E}_t q_{t+1} + \left[1-\beta\gamma^{-\sigma_c}(1-\delta)\right]\mathrm{E}_t r^k_{t+1} \\ &\quad -(r_t - \mathrm{E}_t\pi_{t+1}), \end{aligned}$$

where $\delta$ is the capital depreciation rate. The capital accumulation is given by

$$k_t = \frac{1-\delta}{\gamma}k_{t-1} + \left(1-\frac{1-\delta}{\gamma}\right)i_t + \left(1-\frac{1-\delta}{\gamma}\right)\left(1+\beta\gamma^{1-\sigma_c}\right)\gamma^2\varphi v_t.$$

The definition of the price markup $\mu^p_t$ is

$$\mu^p_t = \alpha(k^s_t - l_t) + z_t - w_t.$$

The new Keynesian Phillips curve is given by

$$\pi_t = \frac{\iota_p}{1+\beta\gamma^{1-\sigma_c}\iota_p}\pi_{t-1} + \frac{\beta\gamma^{1-\sigma_c}}{1+\beta\gamma^{1-\sigma_c}\iota_p}\mathrm{E}_t\pi_{t+1} - \frac{\left(1-\beta\gamma^{1-\sigma_c}\xi_p\right)\left(1-\xi_p\right)}{\left(1+\beta\gamma^{1-\sigma_c}\iota_p\right)\xi_p\left[(\phi_p-1)\epsilon_p+1\right]}\mu^p_t + a_t,$$

where $a_t$ is the cost-push shock, while $\iota_p$ denotes the degree of indexation to past inflation, $\xi_p$ is the degree of price stickiness, and $\epsilon_p$ is the curvature of the Kimball (1995) goods market aggregator. The rental rate of capital can be computed from

$$r^k_t = -(k^s_t - l_t) + w_t.$$

The definition of the wage markup $\mu^w_t$ is given by

$$\mu^w_t = w_t - \left[\sigma_l l_t + \frac{1}{1-\frac{\lambda}{\gamma}}\left(c_t - \frac{\lambda}{\gamma}c_{t-1}\right)\right],$$

where $\sigma_l$ denotes the elasticity of labor supply to the real wage. The wage Phillips curve is given by:

$$\begin{aligned} w_t &= \frac{1}{1+\beta\gamma^{1-\sigma_c}}w_{t-1} + \left(1-\frac{1}{1+\beta\gamma^{1-\sigma_c}}\right)(\mathrm{E}_t w_{t+1} + \mathrm{E}_t\pi_{t+1}) \\ &\quad -\frac{1+\beta\gamma^{1-\sigma_c}\iota_w}{1+\beta\gamma^{1-\sigma_c}}\pi_t + \frac{\iota_w}{1+\beta\gamma^{1-\sigma_c}}\pi_{t-1} \\ &\quad -\frac{\left(1-\beta\gamma^{1-\sigma_c}\xi_w\right)(1-\xi_w)}{(1+\beta\gamma^{1-\sigma_c})\xi_w\left[(\phi_w-1)\epsilon_w+1\right]}\mu^w_t + b_t, \end{aligned}$$

where $b_t$ is the wage markup disturbance, while $\iota_w$ denotes the degree of indexation to past wage inflation, $\xi_w$ is the degree of nominal wage stickiness, and $\epsilon_w$ is the curvature of the

Kimball (1995) labor market aggregator. Finally, we use the Taylor (1993)-type monetary policy rule as

$$r_t = \rho r_{t-1} + (1-\rho)\left(r_\pi \pi_t + r_y \Delta y_t\right) + m_t,$$

where $m_t$ is the monetary policy shock, while $\rho$, $r_\pi$ and $r_y$ are positive policy parameters. There are five exogenous disturbances in addition to the TFP shock in the system. These five additional driving forces are assumed to follow the following AR (1) processes:

$$\begin{aligned}
g_t &= \rho_g g_{t-1} + \varepsilon_t^g, \quad \varepsilon_t^g \sim \text{i.i.d. } N(0,\sigma_g^2), \\
v_t &= \rho_v v_{t-1} + \varepsilon_t^v, \quad \varepsilon_t^v \sim \text{i.i.d. } N(0,\sigma_v^2), \\
m_t &= \rho_m m_{t-1} + \varepsilon_t^m, \quad \varepsilon_t^m \sim \text{i.i.d. } N(0,\sigma_m^2), \\
a_t &= \rho_a a_{t-1} + \varepsilon_t^a, \quad \varepsilon_t^a \sim \text{i.i.d. } N(0,\sigma_a^2), \text{ and} \\
b_t &= \rho_b b_{t-1} + \varepsilon_t^b, \quad \varepsilon_t^b \sim \text{i.i.d. } N(0,\sigma_b^2).
\end{aligned}$$

Note that unlike the TFP shocks, each innovation term is given as a single component, implying that all the shocks are unexpected.

# 3 Estimation Strategy

We use Bayesian techniques to estimate the model parameters and to evaluate the importance of the news shocks. Bayesian estimation strategies help to estimate DSGE models with cross-equation restrictions, coping well with misspecification and identification problems, and provide a coherent model evaluation procedure. In this section, we begin with a brief explanation of the Bayesian methods. Next, we describe the data used for estimation and explain the prior distributions of the parameters.

## 3.1 Bayesian Estimation Methodology

In solving a rational expectations system, we follow the approach of Sims (2002).[7] In his approach, the log-linearized system can be written in the following canonical form:

$$\Gamma_0(\theta)\,\mathbf{s}_t = \Gamma_1(\theta)\,\mathbf{s}_{t-1} + \Psi_0(\theta)\,\boldsymbol{\varepsilon}_t + \Pi_0(\theta)\,\boldsymbol{\eta}_t, \tag{2}$$

[7] Sims' solution method generalizes the technique in Blanchard and Kahn (1980).

where $\Gamma_0$, $\Gamma_1$, $\Psi_0$, and $\Pi_0$ are the conformable matrices of coefficients that depend on the structural parameters $\theta$, $\mathbf{s}_t$ is a stacked vector of endogenous variables including expectations at $t$, and $\boldsymbol{\varepsilon}_t$ is a vector of fundamental shocks. $\boldsymbol{\eta}_t$ is a vector of endogenous forecast errors, defined as

$$\boldsymbol{\eta}_t = \widehat{\mathbf{s}}_t - E_{t-1}\widehat{\mathbf{s}}_t,$$

where $\widehat{\mathbf{s}}_t$ is a subvector of $\mathbf{s}_t$ that contains expectational variables. In the present model, $\widehat{\mathbf{s}}_t$ consists of $i_t$, $r_t^k$, $q_t$, $c_t$, $l_t$, $\pi_t$, and $w_t$. Note that the canonical representation of news shocks in (1) has been incorporated into the form (2). Then, the solution is given by[8]

$$\mathbf{s}_t = \Gamma(\theta)\,\mathbf{s}_{t-1} + \Psi(\theta)\,\boldsymbol{\varepsilon}_t. \tag{3}$$

Let $Y^T$ be a set of observable data. Since the rational expectations solution (3) and a set of measurement equations that relates data to the model variables $\mathbf{s}_t$ provide a state-space representation, the likelihood function $L(\theta|Y^T)$ can be evaluated using the Kalman filter. The Bayesian approach places a prior distribution $p(\theta)$ on parameters and updates the prior through the likelihood function. Bayes' Theorem provides the posterior distribution of $\theta$:

$$p\left(\theta|Y^T\right) = \frac{L\left(\theta|Y^T\right)p(\theta)}{\int L\left(\theta|Y^T\right)p(\theta)\,d\theta}.$$

Markov Chain Monte Carlo methods are used to generate the draws from the posterior distribution. Based on the posterior draws, we can make inference on the parameters.[9] Details of its computational implementation are shown in Schorfheide (2000). The marginal data density, which assesses the overall fit of the model, is given by[10]

$$p\left(Y^T\right) = \int L(\theta|Y^T)p(\theta)d\theta.$$

### 3.2 Data and Priors

The data used for estimation are the same as Sugo and Ueda (2008) for Japan and Smets and Wouters (2007) for the United States. The models are fitted to the log difference of

[8] We only consider the parameter space that leads to equilibrium determinacy.

[9] For our subsequent analysis, 300,000 draws are generated with a random-walk Metropolis Algorithm, and the first 30,000 draws are discarded.

[10] The marginal data densities are approximated using the harmonic mean estimator that is proposed by Geweke (1999).

real GDP, real consumption, real investment, and the real wage, the log of hours worked, the log difference of the CPI (GDP deflator for the United States), and the overnight call rate (the federal funds rate for the United States). For detailed description of the data, see Sugo and Ueda (2008) and Smets and Wouters (2007). The model is estimated over the sample period from 1981:2 to 1998:4 for Japan.[11] For the the United States, it is from 1983:1 to 2004:4.[12]

Prior distributions for the structural parameters of the Japanese economy are summarized in Table 1. Most of the priors are in line with those in Sugo and Ueda (2008), whereas we change the prior means for the steady state values for inflation $\pi$ and hours worked $l$ based on the sample averages of the demeaned data.[13] The standard deviations of the news shocks, $\sigma_{z1}$, $\sigma_{z2}$, $\sigma_{z3}$, and $\sigma_{z4}$, are distributed around 0.25, so that the variance of the total expected component $\nu_t^*$ in productivity is equal to the variance of unexpected component $\nu_{0,t}$ with its standard deviation $\sigma_{z0}$.

## 4 Results

In this section, we describe our estimation results for news shocks in the following order. First, we evaluate the contribution of the news shock in the Japanese and U.S. business cycles. Second, we focus on inflation and examine its relation to the forecast horizon of the news shock. Third, we investigate the implication of the presence of news shocks for the correlation of productivity and hours worked.

[11] The end of the sample period is determined in order not to include the period during which the zero nominal interest rate policy is adopted by the Bank of Japan. This is because there should be the least relationship between the nominal interest rate and the other variables during the period and the zero bound on the nominal interest rate should be dealt with separately due to nonlinearity of the policy rules.

[12] The beginning of the sample is determined to exclude the possibility of equilibrium indeterminacy, based on the finding in Clarida, Galí, and Gertler (2000) and Lubik and Schorfheide (2004).

[13] While not reporeted in the table, priors for the U.S. economy are set in line with Smets and Wouters (2007).

### 4.1 Importance of the News Shock

The last two columns in Table 1 report the posterior distributions of the parameters of the Japanese economy. Basically, the posterior estimates are similar to those in Sugo and Ueda (2008).[14]

In Table 2, relative contributions of the news shocks in both the Japanese and U.S. economies are examined by the variance decomposition. A remarkable finding here is that the total sum of the expected components of the productivity shock has almost the same effects on representative nominal variables as the unexpected part, namely, the standard contemporaneous technology shock.[15] This is the first evidence on the importance of the news shocks that is obtained from the fully specified DSGE model. Our finding reconfirms the result in Beaudry and Portier (2005, 2006), who also estimated the contribution of the news shocks in both the Japanese and U.S. economies using a bivariate VAR model.

The reason behind this important role of the news shocks in aggregate fluctuations can be understood from the impulse responses for the Japanese case in Figure 1. The figure depicts the impulse responses of consumption, investment, output, hours worked, inflation, the real wage, and the interest rate to one-standard-deviation unexpected and news shocks on TFP. In the present model with the habit persistence in consumption, adjustment cost in investment and nominal rigidities, hours worked decrease for a positive unexpected productivity shock, while consumption and investment increase. Thus, in the absence of news shocks, our model cannot generate observed procyclical labor. On the other hand, the impulse responses to the news shocks in Figure 1 imply that the news shock can generate the comovement among consumption, investment, and hours worked. For this reason, to match the observed procyclical labor, news shocks need to make a significant contribution in aggregate fluctuations.

Table 3 reports the robustness check on the above findings for both the Japanese and

[14]For the United States, basic posterior estimates are very close to those obtained by Smets and Wouters (2007).

[15]Even for the real variables, the contributions of the unexpected productivity become much lower than those in Sugo and Ueda (2008). This implies the importance of the news shocks even on the representative real variables.

U.S. economies. In addition to the baseline exercise above, the contributions of the news shock and the marginal likelihood in the alternative cases are provided. These alternative cases are (1) a case with an unexpected shock and a news shock that is expected to occur in the next period only; (2) a case with an unexpected shock and a news shock that is expected to occur 2-periods ahead only; (3) a case with an unexpected shock and a news shock that is expected to occur 3-periods ahead only; (4) a case with an unexpected shock and a news shock that is expected to occur 4-periods ahead only; and (5) a case with all these news shocks but without an unexpected shock. We can point out several intriguing findings from Table 3. The fit of the model is highest when the all news shocks and the unexpected shock altogether are added to the model. In each case, the contributions of the news shocks are non-negligible. These results demonstrate the importance of the news shocks in aggregate fluctuations. We can also observe asymmetric responses of nominal variables to the news shocks with different forecast horizons. We will inquire into this point in the following subsection.

## 4.2 Asymmetric Response of Inflation to the News Shock

Here we consider the role of the forecast horizon in the news shocks on nominal variables in detail. Figure 1 reports a notable finding regarding the sensitivity of the effects of shocks on the nominal variables to forecast horizons. When the forecast horizon of the news shock becomes longer, the effects of the news shock become larger on nominal rather than real variables. This also reflects the discussions above. The hours worked and therefore the marginal cost increase up until the expectation is actually materialized. At the same time, for the longer forecast horizon, the present discounted value of the reduction in the marginal cost becomes smaller. Consequently, the changes in expectation at the longer horizon have more impacts on nominal variables.[16] So far, in the studies on the news shocks, such as Beaudry and Portier (2004), Jaimovich and Rebelo (2006), Denhaan and Kaltenbrunner (2007), Kobayashi, Nakajima, and Inaba (2007), Beaudry, Collard, and Portier (2006), and

[16] Yet this relationship is not monotonic. As the forecast horizon becomes longer, the wealth effects on current consumption and leisure become stronger. As a result, this can result in the further reduction of the marginal cost.

Christiano, Ilut, Motto, and Rostagno (2008), the theoretical responses to the news shocks are analyzed for some arbitrary forecast horizon. To the best of our knowledge, however, the sensitivity of responses to changes in the forecast horizon has never been systematically examined.

### 4.3 Technology Shocks and Hours Worked

Let us now focus on the implication of our estimates for a controversial issue of the response of hours worked to a technology shock. In standard real business cycle models, hours should rise after a positive technology shock. However, Galí (1999) showed empirically that technology shocks identified from a structural VAR model have a negative effect on hours. He pointed out that the negative correlation between a technology shock and hours was consistent with a model with monopolistic competition and sticky prices. His view was later confirmed by Francis and Ramey (2005), who employed a structural VAR model using alternative identifying restrictions, and by Smets and Wouters (2007), who conducted a Bayesian estimation of a DSGE model with nominal price rigidities. In sharp contrast, Christiano, Eichenbaum and Vigfusson (2003, 2004), and Vigfusson (2004) provided empirical evidence of positive correlation between a technology shock and hours and claimed that the previous findings of a positive correlation might have been caused by misspecifications in the estimation. In particular, opposite results could be obtained by estimating a structural VAR model with identifying assumptions very similar to that of Galí (1999) and Francis and Ramey (2005) but allowing for the stationarity of hours worked (Christiano, Eichenbaum, and Vigfusson (2003)), and were robust even if the output in the VAR were replaced by a direct measure of technology (Christiano, Eichenbaum, and Vigfusson (2004)). The correlation between technology shocks and hours worked is also an unsettled question in Japan. For example, while Galí (2005) and Braun and Shioji (2004) showed the correlation to be positive, Watanabe (2006) claimed a near-zero correlation.

Our estimation results offer one possible solution to reconcile the two competing views regarding the sign of the correlation between the technology shock and hours. Recall that there are two components in the technology shock $\varepsilon_t^z$; one is the contemporaneous (unexpected) component $\nu_{0,t}$ and the other is the news component $\sum_{j=1}^{4} \nu_{j,t-j}$. As shown in Figure 1, each of the two components of the technology shock has an instantaneous effect on hours worked in the opposite direction. When all the technology disturbances are unexpected, so that $\varepsilon_t^z = \nu_{0,t}$, the technology shock has an immediate and significant negative impact on the hours worked, thus our results strongly support the findings by Galí (1999), Francis and Ramey (2005), and Smets and Wouters (2007). In contrast, the same figure shows that the impact responses of hours worked to news shocks $\nu_{j,t}$, $j = 1, ..., 4$, are positive and significant. Because of this offsetting role of the news shocks, the overall effect of the broadly defined technology shock can become ambiguous. To confirm this conjecture, let us conduct a simple experiment by generating simultaneous positive shocks on both contemporaneous and news components. The weighted sum of each impulse response, weighted by $\sigma_{zj}$ for $j = 0, 1, ..., 4$, is then interpreted as the total effect. Figure 2 shows the responses of output, hours worked and productivity for both the Japanese and U.S. economies.[17] Unlike the response to the unexpected shock $\nu_{0,t}$ alone, the immediate response of hours has decreased dramatically in size to a value close to zero. The confidence band for the immediate response of hours worked now contains both positive and negative regions. This suggests that the overall effect can be either positive or negative if we employ a broader, but somewhat atypical, definition of a "technology shock."

Finally, the same reasoning can be also used as a possible explanation of the well-known productivity-hours anomaly, namely, the empirical observation of near-zero (or negative) correlation between productivity and hours worked. By comparing the impulse responses of hours worked and productivity in Figure 2, the broadly defined "technology shock" generates a near-zero comovement between the two. The mechanism behind this result is identical to that of Galí (1999), who claimed that (unexpected) technology shocks generate a negative comovement between two variables rather than the positive one predicted in the standard real business cycle models. To offset this effect, however, positive comovement is generated from news shocks in our case, while Galí (1999) relied on nontechnology shocks (such as monetary shocks). In other words, within our framework, the technology shock

[17]Note that the total effect differs from the impulse responses to $\varepsilon_t^z$, since the former is computed as responses to $\nu_{j,t}$ observed at the same time period $t$ and not $\nu_{j,t-j}$.

alone may account for the productivity-hours anomaly.

## 5 Conclusion

In this paper, we have examined the role of the news shocks in the aggregate fluctuations. According to our Bayesian estimates of the canonical DSGE model, the news shocks played an important role in the Japanese and U.S. business cycles. We also found that a news shock with a longer forecast horizon had larger effects on nominal variables, and that the overall effect of the TFP on hours worked became ambiguous in the presence of news shocks.

Possible future extensions of our approach include, introducing news shocks to innovations other than TFP, and allowing for correlation between unexpected shocks and news shocks. It may be possible to derive a different interpretation of wedges stemming from the TFP by allowing multiple forecast horizons in the news shocks introduced in our paper, in the business cycle accounting approach of Chari, Kehoe, and McGrattan (2007). Furthermore, our model may lack some important mechanisms such as the financial accelerator model as in Bernanke, Gertler, and Gilchrist (1999). Especially for the Japanese case, Table 1 shows that the standard error on the investment-specific technology shock is very large. This implies that the Japanese economy was influenced by financial sector developments during the estimated period. It is left for our future research to understand the contributions of the shocks including the expected components in more detailed models like those of Christiano, Ilut, Motto, and Rostagno (2008).

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Table 1: Prior and Posterior Distributions of the Parameters

| | | Prior distributions | | | Posterior distributions | |
|---|---|---|---|---|---|---|
| Parameter | Range | Density | Mean | 90% interval | Mean | 90% interval |
| $\varphi$ | $\Re^+$ | Normal | 4.00 | [ 1.56, 6.45] | 4.56 | [ 2.11, 6.99] |
| $\sigma_c$ | $\Re^+$ | Normal | 1.00 | [ 0.53, 1.61] | 0.87 | [ 0.69, 1.04] |
| $\lambda$ | $[0, 1)$ | Beta | 0.70 | [ 0.46, 0.93] | 0.08 | [ 0.03, 0.12] |
| $\xi_w$ | $[0, 1)$ | Beta | 0.38 | [ 0.21, 0.54] | 0.27 | [ 0.19, 0.34] |
| $\sigma_l$ | $\Re^+$ | Normal | 2.00 | [ 0.81, 3.26] | 3.15 | [ 2.17, 4.11] |
| $\xi_p$ | $[0, 1)$ | Beta | 0.38 | [ 0.21, 0.54] | 0.45 | [ 0.37, 0.52] |
| $\iota_w$ | $[0, 1)$ | Beta | 0.50 | [ 0.11, 0.92] | 0.50 | [ 0.12, 0.89] |
| $\iota_p$ | $[0, 1)$ | Beta | 0.50 | [ 0.11, 0.92] | 0.30 | [ 0.01, 0.56] |
| $\psi$ | $[0, 1)$ | Beta | 0.50 | [ 0.25, 0.74] | 0.74 | [ 0.59, 0.89] |
| $\phi_p$ | $\Re^+$ | Normal | 1.08 | [ 1.05, 1.10] | 1.09 | [ 1.07, 1.11] |
| $r_\pi$ | $\Re^+$ | Normal | 1.50 | [ 1.12, 1.89] | 2.09 | [ 1.81, 2.37] |
| $\rho$ | $[0, 1)$ | Beta | 0.75 | [ 0.59, 0.92] | 0.55 | [ 0.45, 0.64] |
| $r_y$ | $\Re^+$ | Normal | 0.12 | [ 0.04, 0.21] | 0.17 | [ 0.11, 0.24] |
| $\pi$ | $\Re^+$ | Gamma | 0.10 | [-0.06, 0.27] | 0.18 | [ 0.07, 0.30] |
| $100(\beta^{-1} - 1)$ | $\Re^+$ | Gamma | 0.25 | [ 0.09, 0.42] | 0.35 | [ 0.22, 0.47] |
| $l$ | $\Re^+$ | Normal | 0.40 | [ 0.24, 0.57] | 0.40 | [ 0.24, 0.57] |
| $\alpha$ | $\Re^+$ | Normal | 0.37 | [ 0.33, 0.41] | 0.25 | [ 0.22, 0.28] |
| $\rho_z$ | $[0, 1)$ | Beta | 0.85 | [ 0.71, 0.99] | 0.98 | [ 0.97, 1.00] |
| $\rho_g$ | $[0, 1)$ | Beta | 0.85 | [ 0.71, 0.99] | 0.95 | [ 0.92, 0.97] |
| $\rho_v$ | $[0, 1)$ | Beta | 0.85 | [ 0.71, 0.99] | 0.52 | [ 0.41, 0.63] |
| $\rho_m$ | $[0, 1)$ | Beta | 0.85 | [ 0.71, 0.99] | 0.43 | [ 0.33, 0.53] |
| $\rho_a$ | $[0, 1)$ | Beta | 0.85 | [ 0.71, 0.99] | 0.93 | [ 0.86, 0.99] |
| $\rho_b$ | $[0, 1)$ | Beta | 0.85 | [ 0.71, 0.99] | 0.97 | [ 0.94, 1.00] |
| $\sigma_{z0}$ | $\Re^+$ | InvGamma | 0.50 | [ 0.21, 0.79] | 0.81 | [ 0.67, 0.94] |
| $\sigma_{z1}$ | $\Re^+$ | InvGamma | 0.25 | [ 0.11, 0.40] | 0.20 | [ 0.12, 0.27] |
| $\sigma_{z2}$ | $\Re^+$ | InvGamma | 0.25 | [ 0.11, 0.40] | 0.19 | [ 0.11, 0.27] |
| $\sigma_{z3}$ | $\Re^+$ | InvGamma | 0.25 | [ 0.11, 0.40] | 0.25 | [ 0.14, 0.36] |
| $\sigma_{z4}$ | $\Re^+$ | InvGamma | 0.25 | [ 0.11, 0.40] | 0.28 | [ 0.16, 0.40] |
| $\sigma_g$ | $\Re^+$ | InvGamma | 0.50 | [ 0.21, 0.79] | 0.54 | [ 0.46, 0.62] |
| $\sigma_v$ | $\Re^+$ | InvGamma | 0.50 | [ 0.21, 0.79] | 1.22 | [ 1.00, 1.44] |
| $\sigma_m$ | $\Re^+$ | InvGamma | 0.50 | [ 0.21, 0.79] | 0.22 | [ 0.18, 0.26] |
| $\sigma_a$ | $\Re^+$ | InvGamma | 0.50 | [ 0.21, 0.79] | 0.23 | [ 0.17, 0.29] |
| $\sigma_b$ | $\Re^+$ | InvGamma | 0.50 | [ 0.21, 0.79] | 0.49 | [ 0.33, 0.65] |

Table 2-a: Variance Decompositions (Japan)

| Shock | Mean | 90% interval | Shock | Mean | 90% interval |
|---|---|---|---|---|---|
| Consumption | | | Inflation | | |
| Unexpected productivity | 41.01 | [31.61, 51.61] | Unexpected productivity | 16.74 | [ 9.66, 23.20] |
| News 1 period ahead | 1.07 | [ 0.25, 1.84] | News 1 period ahead | 0.74 | [ 0.16, 1.32] |
| News 2 periods ahead | 0.69 | [ 0.18, 1.24] | News 2 periods ahead | 1.92 | [ 0.42, 3.34] |
| News 3 periods ahead | 1.27 | [ 0.27, 2.32] | News 3 periods ahead | 5.23 | [ 1.18, 9.30] |
| News 4 periods ahead | 1.72 | [ 0.36, 3.04] | News 4 periods ahead | 7.49 | [ 1.74, 12.86] |
| Exogenous spending | 8.75 | [ 5.46, 11.68] | Exogenous spending | 2.30 | [ 0.92, 3.63] |
| Investment | 28.05 | [18.25, 37.21] | Investment | 33.89 | [21.34, 45.73] |
| Monetary policy | 3.84 | [ 2.11, 5.59] | Monetary policy | 20.87 | [11.44, 30.10] |
| Price mark-up | 2.81 | [ 1.14, 4.39] | Price mark-up | 7.26 | [ 3.36, 10.52] |
| Wage mark-up | 10.77 | [ 5.41, 15.74] | Wage mark-up | 3.55 | [ 1.03, 5.94] |
| Investment | | | Wage | | |
| Unexpected productivity | 4.06 | [ 1.71, 6.35] | Unexpected productivity | 42.77 | [31.94, 54.43] |
| News 1 period ahead | 0.23 | [ 0.04, 0.42] | News 1 period ahead | 2.57 | [ 0.65, 4.29] |
| News 2 periods ahead | 0.18 | [ 0.04, 0.35] | News 2 periods ahead | 1.54 | [ 0.39, 2.77] |
| News 3 periods ahead | 0.31 | [ 0.04, 0.58] | News 3 periods ahead | 1.89 | [ 0.35, 3.40] |
| News 4 periods ahead | 0.47 | [ 0.07, 0.86] | News 4 periods ahead | 2.36 | [ 0.54, 4.11] |
| Exogenous spending | 0.61 | [ 0.09, 1.09] | Exogenous spending | 0.16 | [ 0.02, 0.35] |
| Investment | 90.62 | [85.71, 95.93] | Investment | 1.46 | [ 0.22, 2.81] |
| Monetary policy | 0.06 | [ 0.01, 0.12] | Monetary policy | 4.40 | [ 1.68, 7.16] |
| Price mark-up | 1.27 | [ 0.20, 2.37] | Price mark-up | 38.90 | [27.85, 48.31] |
| Wage mark-up | 2.18 | [ 0.55, 3.98] | Wage mark-up | 3.96 | [ 1.82, 6.08] |
| Output | | | Interest rate | | |
| Unexpected productivity | 53.93 | [43.38, 67.58] | Unexpected productivity | 10.30 | [ 5.04, 15.84] |
| News 1 period ahead | 1.81 | [ 0.46, 3.06] | News 1 period ahead | 0.49 | [ 0.11, 0.91] |
| News 2 periods ahead | 1.11 | [ 0.30, 2.01] | News 2 periods ahead | 1.44 | [ 0.33, 2.56] |
| News 3 periods ahead | 1.89 | [ 0.43, 3.45] | News 3 periods ahead | 4.76 | [ 1.09, 8.53] |
| News 4 periods ahead | 2.63 | [ 0.57, 4.65] | News 4 periods ahead | 8.01 | [ 1.51, 13.78] |
| Exogenous spending | 4.58 | [ 2.40, 7.00] | Exogenous spending | 3.93 | [ 1.96, 6.05] |
| Investment | 6.22 | [ 2.98, 9.08] | Investment | 61.76 | [49.28, 74.46] |
| Monetary policy | 5.10 | [ 3.10, 7.30] | Monetary policy | 1.20 | [ 0.35, 2.08] |
| Price mark-up | 6.40 | [ 3.44, 9.59] | Price mark-up | 4.78 | [ 2.07, 7.28] |
| Wage mark-up | 16.34 | [10.12, 23.18] | Wage mark-up | 3.33 | [ 0.78, 5.86] |
| Hours | | | | | |
| Unexpected productivity | 3.01 | [ 0.10, 6.57] | | | |
| News 1 period ahead | 0.34 | [ 0.01, 0.69] | | | |
| News 2 periods ahead | 0.31 | [ 0.02, 0.62] | | | |
| News 3 periods ahead | 0.51 | [ 0.02, 1.09] | | | |
| News 4 periods ahead | 0.65 | [ 0.02, 1.41] | | | |
| Exogenous spending | 2.68 | [ 0.27, 5.28] | | | |
| Investment | 4.82 | [ 0.86, 9.00] | | | |
| Monetary policy | 0.55 | [ 0.03, 1.02] | | | |
| Price mark-up | 6.61 | [ 0.23, 13.68] | | | |
| Wage mark-up | 80.51 | [64.06, 97.90] | | | |

Table 2-b: Variance Decompositions (United States)

| Shock | Mean | 90% interval | Shock | Mean | 90% interval |
|---|---|---|---|---|---|
| Consumption | | | Inflation | | |
| Unexpected productivity | 17.17 | [10.70, 24.42] | Unexpected productivity | 8.48 | [ 4.35, 12.48] |
| News 1 period ahead | 5.07 | [ 0.76, 9.15] | News 1 period ahead | 0.82 | [ 0.11, 1.52] |
| News 2 periods ahead | 4.46 | [ 0.63, 7.82] | News 2 periods ahead | 2.18 | [ 0.24, 4.03] |
| News 3 periods ahead | 3.54 | [ 0.32, 6.42] | News 3 periods ahead | 5.62 | [ 1.17, 9.83] |
| News 4 periods ahead | 2.36 | [ 0.29, 4.29] | News 4 periods ahead | 8.10 | [ 2.00, 13.62] |
| Exogenous spending | 3.41 | [ 1.19, 5.48] | Exogenous spending | 3.60 | [ 1.81, 5.29] |
| Investment | 4.40 | [ 0.85, 7.76] | Investment | 20.39 | [11.65, 27.95] |
| Monetary policy | 6.78 | [ 4.36, 9.25] | Monetary policy | 23.44 | [14.16, 31.59] |
| Price mark-up | 7.32 | [ 3.92, 10.46] | Price mark-up | 13.88 | [ 7.35, 19.50] |
| Wage mark-up | 45.48 | [37.20, 54.80] | Wage mark-up | 13.49 | [ 8.39, 18.42] |
| Investment | | | Wage | | |
| Unexpected productivity | 5.01 | [ 1.66, 7.86] | Unexpected productivity | 8.29 | [ 4.02, 12.58] |
| News 1 period ahead | 0.87 | [ 0.09, 1.68] | News 1 period ahead | 4.07 | [ 0.53, 7.69] |
| News 2 periods ahead | 0.79 | [ 0.06, 1.56] | News 2 periods ahead | 5.75 | [ 1.09, 10.40] |
| News 3 periods ahead | 0.92 | [ 0.10, 1.71] | News 3 periods ahead | 5.68 | [ 0.79, 9.84] |
| News 4 periods ahead | 1.27 | [ 0.14, 2.28] | News 4 periods ahead | 3.93 | [ 0.58, 7.33] |
| Exogenous spending | 2.61 | [ 0.87, 4.43] | Exogenous spending | 1.47 | [ 0.38, 2.62] |
| Investment | 69.00 | [56.40, 80.37] | Investment | 0.86 | [ 0.26, 1.47] |
| Monetary policy | 0.82 | [ 0.16, 1.55] | Monetary policy | 6.45 | [ 3.63, 9.27] |
| Price mark-up | 5.92 | [ 1.85, 9.54] | Price mark-up | 43.87 | [33.09, 54.57] |
| Wage mark-up | 12.77 | [ 6.92, 18.71] | Wage mark-up | 19.63 | [13.01, 26.54] |
| Output | | | Interest rate | | |
| Unexpected productivity | 13.36 | [ 7.32, 19.27] | Unexpected productivity | 8.77 | [ 4.57, 13.05] |
| News 1 period ahead | 3.66 | [ 0.52, 6.56] | News 1 period ahead | 1.31 | [ 0.17, 2.37] |
| News 2 periods ahead | 3.18 | [ 0.54, 5.77] | News 2 periods ahead | 2.13 | [ 0.32, 3.81] |
| News 3 periods ahead | 2.38 | [ 0.30, 4.28] | News 3 periods ahead | 4.86 | [ 0.78, 8.36] |
| News 4 periods ahead | 1.57 | [ 0.25, 2.76] | News 4 periods ahead | 7.50 | [ 1.36, 12.37] |
| Exogenous spending | 21.09 | [14.90, 26.42] | Exogenous spending | 6.64 | [ 3.63, 9.21] |
| Investment | 4.55 | [ 1.99, 7.13] | Investment | 43.13 | [27.39, 55.84] |
| Monetary policy | 5.17 | [ 3.26, 7.04] | Monetary policy | 4.52 | [ 2.10, 6.60] |
| Price mark-up | 9.44 | [ 5.21, 13.27] | Price mark-up | 7.82 | [ 3.94, 11.70] |
| Wage mark-up | 35.60 | [27.85, 43.67] | Wage mark-up | 13.33 | [ 8.04, 18.69] |
| Hours | | | | | |
| Unexpected productivity | 5.39 | [ 1.51, 9.38] | | | |
| News 1 period ahead | 1.23 | [ 0.06, 2.51] | | | |
| News 2 periods ahead | 1.42 | [ 0.22, 2.63] | | | |
| News 3 periods ahead | 1.73 | [ 0.18, 3.26] | | | |
| News 4 periods ahead | 1.62 | [ 0.19, 3.20] | | | |
| Exogenous spending | 3.30 | [ 1.26, 5.37] | | | |
| Investment | 1.78 | [ 0.59, 2.98] | | | |
| Monetary policy | 0.42 | [ 0.19, 0.64] | | | |
| Price mark-up | 4.13 | [ 1.06, 7.18] | | | |
| Wage mark-up | 78.97 | [68.26, 89.85] | | | |

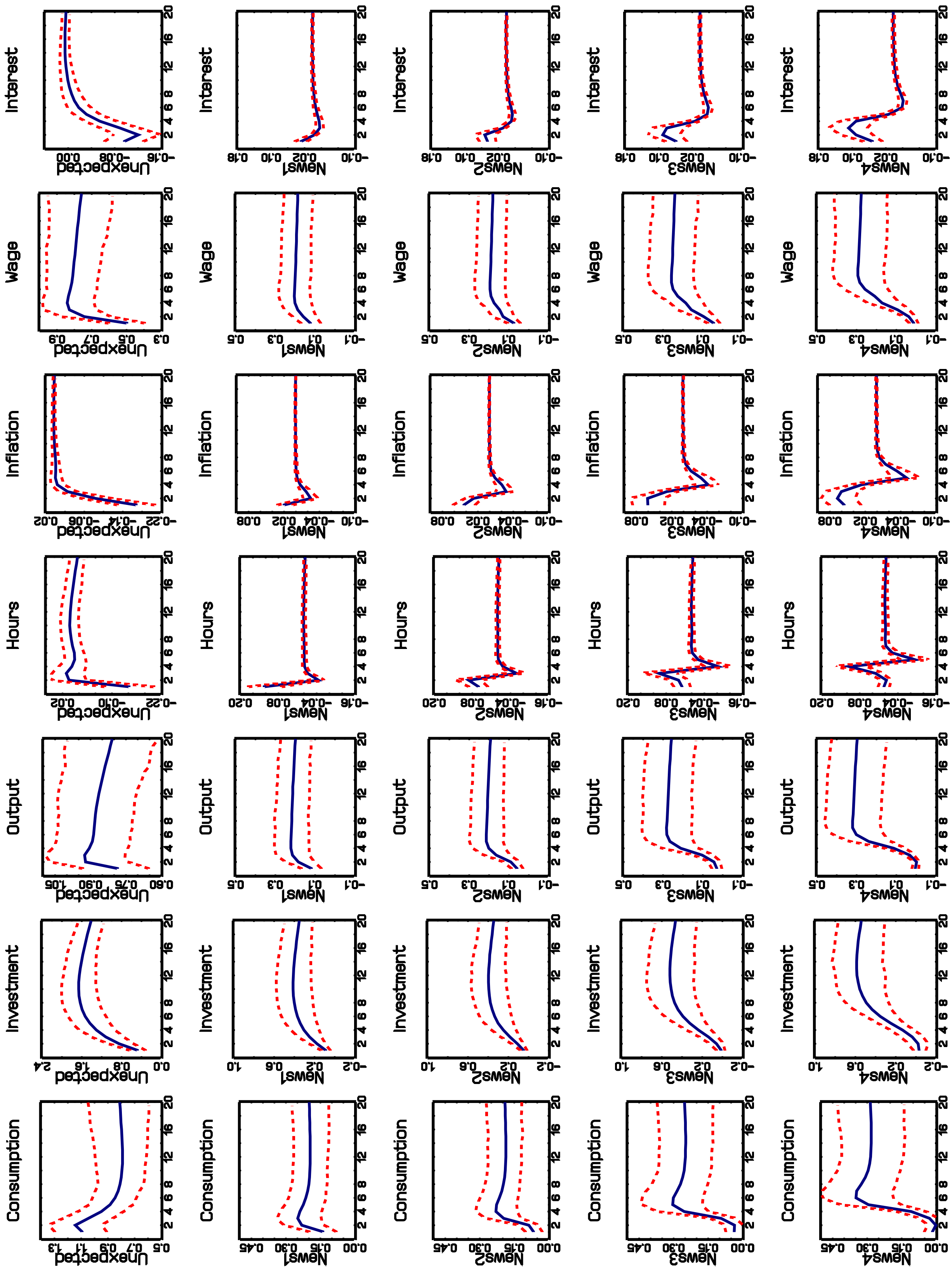
Table 3-a: Marginal Likelihood and Contributions of Unexpected and News Shocks to Output and Inflation in the Alternative Cases (Japan)

| | Baseline | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 |
|---|---|---|---|---|---|---|
| Marginal likelihood: $\ln p(Y^T)$ | -495.00 | -524.59 | -518.60 | -507.69 | -502.54 | -528.00 |
| | | | Output | | | |
| Unexpected shock | 53.93 | 62.72 | 58.91 | 67.77 | 66.47 | - |
| News shocks (in total) | 7.44 | 8.68 | 6.44 | 6.16 | 7.17 | 42.93 |
| News 1 period ahead | 1.81 | 8.68 | - | - | - | 20.99 |
| News 2 periods ahead | 1.11 | - | 6.44 | - | - | 7.99 |
| News 3 periods ahead | 1.89 | - | - | 6.16 | - | 6.81 |
| News 4 periods ahead | 2.63 | - | - | - | 7.17 | 7.14 |
| | | | Inflation | | | |
| Unexpected shock | 16.74 | 32.63 | 20.88 | 19.56 | 17.44 | - |
| News shocks (in total) | 15.38 | 9.11 | 10.34 | 18.72 | 18.52 | 42.06 |
| News 1 period ahead | 0.74 | 9.11 | - | - | - | 11.17 |
| News 2 periods ahead | 1.92 | - | 10.34 | - | - | 7.02 |
| News 3 periods ahead | 5.23 | - | - | 18.72 | - | 10.56 |
| News 4 periods ahead | 7.49 | - | - | - | 18.52 | 13.31 |

Table 3-b: Marginal Likelihood and Contributions of Unexpected and News Shocks to Output and Inflation in the Alternative Cases (United States)

| | Baseline | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 |
|---|---|---|---|---|---|---|
| Marginal likelihood: $\ln p(Y^T)$ | -445.58 | -472.39 | -485.31 | -498.29 | -496.05 | -466.79 |
| | | | Output | | | |
| Unexpected shock | 13.36 | 15.93 | 26.53 | 19.04 | 19.70 | - |
| News shocks (in total) | 10.79 | 24.26 | 12.07 | 7.16 | 6.45 | 23.93 |
| News 1 period ahead | 3.66 | 24.16 | - | - | - | 10.70 |
| News 2 periods ahead | 3.18 | - | 12.07 | - | - | 5.92 |
| News 3 periods ahead | 2.38 | - | - | 7.16 | - | 4.79 |
| News 4 periods ahead | 1.57 | - | - | - | 6.45 | 2.52 |
| | | | Inflation | | | |
| Unexpected shock | 8.48 | 22.83 | 21.98 | 16.50 | 17.12 | - |
| News shocks (in total) | 16.72 | 13.44 | 11.46 | 21.37 | 22.00 | 24.02 |
| News 1 period ahead | 0.82 | 13.44 | - | - | - | 3.91 |
| News 2 periods ahead | 2.81 | - | 11.46 | - | - | 2.88 |
| News 3 periods ahead | 5.62 | - | - | 21.37 | - | 7.47 |
| News 4 periods ahead | 8.10 | - | - | - | 22.00 | 9.76 |

Figure 1: Impulse Responses to Productivity Shocks




Note: The Figure depicts posterior means (solid lines) and pointwise 90% posterior probability intervals (dashed lines) for the impulse responses to one-standard deviation shocks.

Figure 2-a: Impulse Responses of Output, Hours Worked, and Productivity to Simultaneous Shocks on Unexpected and News Components (Japan)

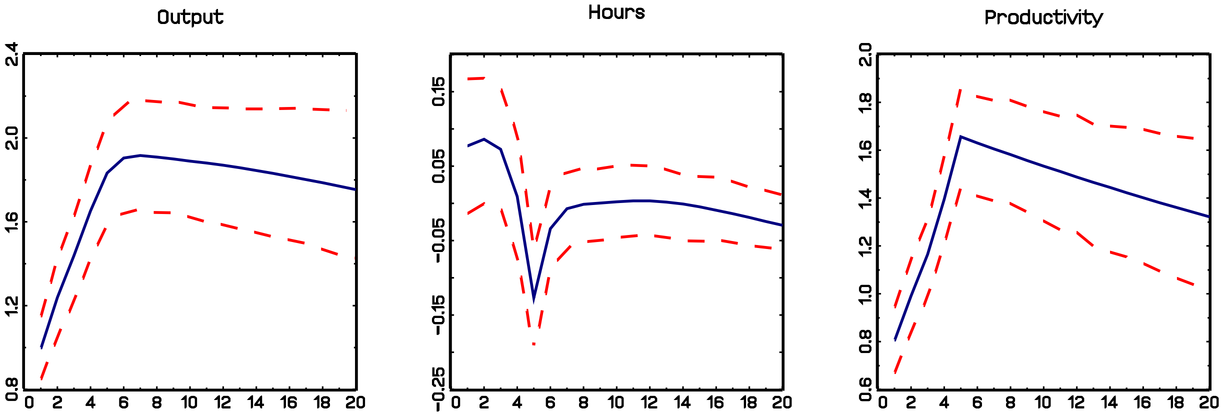
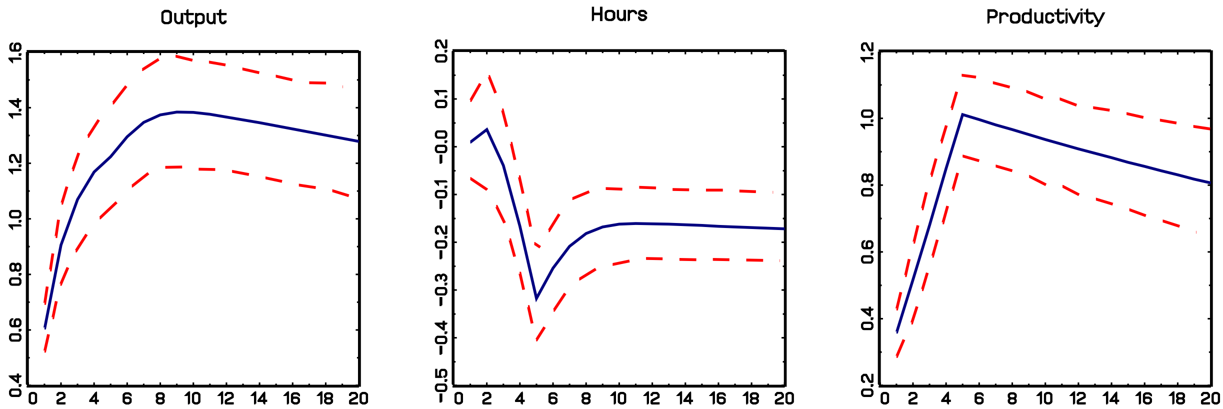



Figure 2-b: Impulse Responses of Output, Hours Worked, and Productivity to Simultaneous Shocks on Unexpected and News Components (United States)




Note: The Figures depict posterior means (solid lines) and pointwise 90% posterior probability intervals (dashed lines) for the impulse responses to one-standard deviation shocks.