Karnizova, Lilia

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News versus Sunspot Shocks in a New Keynesian Model

Lilia Karnizova
University of Ottawa

Abstract Separately, news and sunspot shocks have been shown empirically to be determinants of changes in expectations. This paper considers both of them together in a simple New Keynesian monetary business cycle model. A full set of rational expectations solutions is derived analytically. The analytical characterization allows an explicit comparison of news about future monetary policy and sunspots. The key distinction between the shocks lies in their relation to the realized policy shock. If monetary policy is "passive", both types of shocks affect model dynamics through forecast errors. The effect of the news on forecast errors is not unique, and the dynamics induced by news and sunspot shocks can be observationally equivalent. If monetary policy is "active", the sunspots are irrelevant, and the model responses to the news shocks are unique. In both cases, news shocks strengthen the endogenous propagation of the model, since anticipation of future changes prolongs agents' reaction.

JEL E32, E47, E52

Keywords News shocks; sunspots; expectations; monetary policy; indeterminacy

Correspondence Lilia Karnizova, Department of Economics, University of Ottawa, 55 Laurier Avenue East, room 10121, Ottawa, Ontario, Canada, K1N 6N5; e-mail address: lilia.karnizova@uottawa.ca

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Introduction

Changes in expectations, induced by either sunspots or news about future fundamentals, are potentially important in explaining aggregate fluctuations. While there is some empirical support for both sunspots and news shocks, effects of these shocks have been analyzed separately. This paper makes the first step towards understanding the similarities and differences between these two types of shocks.

A New Keynesian monetary business cycle model is used for analysis. The model exhibits indeterminacy and permits sunspot shocks if a central bank, following an interest rate rule, is not aggressive enough on inflation. Lubik and Schorfheide (2004) argue that indeterminacy and possibly the existence of sunspot shocks may be relevant for understanding the dynamics of U.S. output, inflation and interest rates in a pre-Volcker period. In this paper, the sunspots are compared with news shocks about future monetary policy. These news shocks are partly motivated by the results of Cochrane (1998). He finds that decomposition of monetary policy shocks into unanticipated and anticipated components can influence significantly the measured output responses to changes in monetary policy.

To compare the news and sunspot shocks, a full set of rational expectations solutions is derived analytically following a method of Lubik and Schorfheide (2003). The properties of the news shock are characterized analytically. This is a contribution to the existing literature on news shocks that investigates the role of these shocks only by numerical exercises. The dynamic behaviour of the model in the presence of the news shocks is also studied numerically by conducting impulse response analysis.

The paper is organized as follows. Section 2 describes the model. Sections 3 and 4 characterize analytical solutions under determinacy and indeterminacy. The analytical solutions and impulse response functions are used to study the effects of news and sunspot shocks. Section 5 concludes.

1 Model

News shocks about future monetary policy are introduced into a model studied by Lubik and Schorfheide (2003). The model is summarized by the following four

equations:

$$\begin{aligned} &\text{IS equation} && x_t = E_t x_{t+1} - \sigma\left(R_t - E_t \pi_{t+1}\right), \\ &\text{Phillips curve} && \pi_t = \beta E_t \pi_{t+1} + \kappa x_t, \\ &\text{Monetary policy rule} && R_t = \psi \pi_t + \varepsilon_t, \\ &\text{Monetary policy shock} && \varepsilon_t = \upsilon_t + \mu_{t-n},\ n \geq 1. \end{aligned} \tag{1}$$

Output x_t, inflation π_t and the nominal interest rate R_t are expressed as log-deviations from the unique non-stochastic steady state. The parameter β, $0 < \beta < 1$, is the discount factor, $\sigma > 0$ is the intertemporal elasticity of substitution, $\kappa > 0$ is related to the speed of price adjustment and $\psi \geq 0$ measures the elasticity of the interest rate response to inflation.

An exogenous policy shock ε_t is partly anticipated in advance. Impulses υ_t and μ_t are uncorrelated over time and with each other. They are observed by the agents in the model. Since μ_t affects the policy shock with a delay, it is called a *news shock*. The impulse υ_t represents an *unexpected policy shock*. In addition, the agents observe an exogenous sunspot shock ζ_t, unrelated to υ_t and μ_t and satisfying $E_{t-1}\zeta_t = 0$.

The model is solved with the method of Lubik and Schorfheide (2003). The analytical solution is derived for $n = 1$. A numerical method is used to conduct impulse response analysis for $n = 3$. The derivations are provided in the accompanying Technical Appendix.

The analytical solution is derived by analyzing the three-dimensional system of the forecasts of output $\xi_t^x \equiv E_t\left(x_{t+1}\right)$, inflation $\xi_t^\pi \equiv E_t\left(\pi_{t+1}\right)$ and the policy shock $\xi_t^\varepsilon \equiv E_t\left(\varepsilon_{t+1}\right)$

$$\begin{aligned} \xi_t = & \underbrace{\begin{bmatrix} 1+\frac{\kappa\sigma}{\beta} & \sigma\left(\psi-\frac{1}{\beta}\right) & \sigma \\ -\frac{\kappa}{\beta} & \frac{1}{\beta} & 0 \\ 0 & 0 & 0 \end{bmatrix}}_{\Gamma_1^*} \xi_{t-1} + \underbrace{\begin{bmatrix} \sigma & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix}}_{\Psi^*} \begin{bmatrix} \upsilon_t \\ \mu_t \end{bmatrix} \\ & + \underbrace{\begin{bmatrix} 1+\frac{\kappa\sigma}{\beta} & \sigma\left(\psi-\frac{1}{\beta}\right) \\ -\frac{\kappa}{\beta} & \frac{1}{\beta} \\ 0 & 0 \end{bmatrix}}_{\Pi^*} \eta_t \end{aligned} \tag{2}$$

Here $\xi_t = \left[\xi_t^x, \xi_t^\pi, \xi_t^\varepsilon\right]'$ and the vector $\eta_t = [\eta_t^x, \eta_t^\pi]'$ represents the rational expectations forecast errors $\eta_t^x \equiv x_t - \xi_{t-1}^x$ and $\eta_t^\pi \equiv \pi_t - \xi_{t-1}^\pi$. The stability properties of the model are governed by the eigenvalues of the matrix Γ_1^*, defined

by $\lambda_0 = 0$ and $\lambda_{1,2} = \frac{1}{2}\left(1+\frac{\kappa\sigma+1}{\beta}\right) \mp \frac{1}{2}\sqrt{\left(\frac{1+\kappa\sigma}{\beta}-1\right)^2 + \frac{4\kappa\sigma}{\beta}(1-\psi)}$. The eigenvalues λ_1 and λ_2 are identical to the ones in the model without news shocks. Thus, the stability properties of the model are not affected by the presence of news. If $\psi > 1$, the stable solution is unique. If $0 \leq \psi \leq 1$, there are multiple stable solutions.

2 Determinacy

The unique stable solution under determinacy for $n = 1$ is

$$\begin{aligned}\begin{bmatrix} x_t \\ \pi_t \\ R_t \end{bmatrix} &= \frac{1}{1+\kappa\sigma\psi}\begin{bmatrix} -\sigma \\ -\kappa\sigma \\ 1 \end{bmatrix}\underbrace{\left(\upsilon_t + \mu_{t-1}\right)}_{\varepsilon_t} \\ &\quad -\frac{\sigma}{(1+\kappa\sigma\psi)^2}\begin{bmatrix} 1+\kappa\sigma(1-\beta\psi) \\ \kappa(1+\beta+\kappa\sigma) \\ \psi\kappa(1+\beta+\kappa\sigma) \end{bmatrix}\underbrace{\mu_t}_{E_t\varepsilon_{t+1}}. \end{aligned} \tag{3}$$

News shocks convey the information about future policy changes. Rational agents will update their beliefs about endogenous variables, based on this information. For $n = 1$, the optimal forecasts of output and inflation for one period ahead and their forecast errors are driven by the news shock

$$\begin{bmatrix} E_t x_{t+1} \\ E_t \pi_{t+1} \end{bmatrix} = \frac{-\sigma}{1+\kappa\sigma\psi}\begin{bmatrix} 1 \\ \kappa \end{bmatrix}\mu_t, \tag{4}$$

$$\eta_t = -\frac{\sigma}{1+\kappa\sigma\psi}\begin{bmatrix} 1 & \frac{1+\kappa\sigma(1-\beta\psi)}{1+\kappa\sigma\psi} \\ \kappa & \kappa\frac{1+\beta+\kappa\sigma}{1+\kappa\sigma\psi} \end{bmatrix}\begin{bmatrix} \upsilon_t \\ \mu_t \end{bmatrix} \tag{5}$$

The model's implications are best understood by analyzing three experiments: (i) unexpected monetary expansion ($\varepsilon_t = \upsilon_t < 0$, $\mu_{t-n} = 0$), (ii) realized news about future monetary expansion ($\varepsilon_{t+n} = \mu_t < 0$, $\upsilon_{t+n} = 0$) and (iii) unrealized news about future monetary expansion ($\varepsilon_{t+n} = 0$, $\mu_t < 0$, $\upsilon_{t+n} = -\mu_t$).

An unexpected monetary expansion leads to a one period increase in output and inflation, but to a fall in the nominal and expected real interest rates. The transmission mechanism for this experiment is well known and explained, for example, in Galí (2003). Figure 1 provides a graphical illustration. The solid lines on panels *A* and *B* plot the impulse responses to an unexpected interest rate cut of 25 basis points in period 1 for two values $\psi = 1.05$ and $\psi = 2.19$. The other parameters are $\beta = 0.99$, $\kappa = 0.5$ and $\sigma = 1$, as in Lubik and Schorfheide (2003). A more active policy, associated with higher ψ, influences the magnitude, but not the direction of the responses.

News shocks generate more interesting dynamics, since beliefs about the future trigger the agents' reactions before the actual policy change. Foreseeing a future expansion, firms increase their prices. Positive inflation raises the nominal interest rate through the policy feedback rule. The responses of real variables are due to nominal rigidities. The expected real interest rate increases immediately by $\frac{-\kappa\sigma(1-\psi(1+\beta))}{(1+\kappa\sigma\psi)^2}$, but is predicted to fall by $\frac{1}{1+\kappa\sigma\psi}$ when the policy change takes place. Output depends on the entire path of the expected real interest rates

$$x_t = -\sigma \sum_{j=0}^{\infty} E_t \left[R_{t+j} - \pi_{t+1+j} \right]. \tag{6}$$

When $n = 1$, only two terms in (6) are non-zero. A contemporaneous increase in the expected real rate affects output negatively, while its lower value in the next period has a stimulative effect. If the coefficient ψ in the monetary policy rule is sufficiently high ($\psi > \frac{1+\kappa\sigma}{\beta\kappa\sigma}$), news about a future expansion triggers a temporary contraction.

An expansionary news shock is more likely to decrease output when the number of anticipation periods is larger. As the expected real interest rate remains above its steady state value longer, it becomes easier to overturn the stimulative effect of the future rate decline. Panels *A* and *B* of Figure 1 plot the impulse responses to news shocks for $n = 3$. The responses correspond to a belief, formed in period 1 that in period 4 the interest rate will be cut by 25 basis points. This belief is validated for a realized news shock (R-News), but is followed by no policy change for an unrealized news shock (U-News).

The responses to the realized and unrealized news shocks coincide until period 4, when the actual policy shock ε_4 is observed. Along the transition path, the expected real interest rate rises, stimulating output growth due to consumers' preferences for consumption smoothing. In period 4, the agents adjust their behavior, depending on the actual policy shock.

Overall, there are noticeable differences in responses of output, inflation and interest rates to unexpected policy and news shocks. News shocks strengthen the endogenous propagation of the model, since anticipation of future changes prolongs agents' reaction. Further, news shocks can generate fluctuations in the endogenous variables without any actual policy changes.

3 Indeterminacy

A full set of stable rational expectations solutions under indeterminacy can be written as

$$\begin{aligned}
\begin{bmatrix} E_t x_{t+1} \\ E_t \pi_{t+1} \end{bmatrix} &= \frac{1}{1+\kappa\sigma\psi} \begin{bmatrix} -\sigma \\ -\kappa\sigma \\ 1 \end{bmatrix} \underbrace{\left(\upsilon_t + \mu_{t-1}\right)}_{\varepsilon_t} \\
&- \frac{\sigma}{(1+\kappa\sigma\psi)^2} \begin{bmatrix} 1+\kappa\sigma(1-\beta\psi) \\ \kappa(1+\beta+\kappa\sigma) \\ \psi\kappa(1+\beta+\kappa\sigma) \end{bmatrix} \underbrace{\mu_t}_{E_t\varepsilon_{t+1}} + \frac{1}{d} \begin{bmatrix} \lambda_2 - 1 - \kappa\sigma\psi \\ \kappa\lambda_2 \\ \psi\kappa\lambda_2 \end{bmatrix} M \begin{bmatrix} \upsilon_t \\ \mu_t \end{bmatrix} \\
&+ \frac{1}{d} \begin{bmatrix} \lambda_2 - 1 - \kappa\sigma\psi \\ \kappa\lambda_2 \\ \psi\kappa\lambda_2 \end{bmatrix} \zeta_t + \begin{bmatrix} (\beta(\lambda_2 - 1) - \sigma\kappa)/\kappa \\ 1 \\ \psi \end{bmatrix} \omega_{t-1}, \qquad (7)
\end{aligned}$$

where

$$\begin{aligned}
\omega_t &= \lambda_1 \omega_{t-1} + \frac{\kappa(1+\kappa\sigma\psi)}{\beta d} M \begin{bmatrix} \upsilon_t \\ \mu_t \end{bmatrix} + \frac{\kappa(1+\kappa\sigma\psi)}{\beta d} \zeta_t \qquad (8) \\
M &\equiv \begin{bmatrix} m_1 & m_2 \end{bmatrix}, \; d \equiv \sqrt{(\kappa\lambda_2)^2 + (\lambda_2 - 1 - \kappa\sigma\psi)^2}
\end{aligned}$$

A particular solution is obtained by assigning specific values to the coefficients m_1 and m_2. The representation $(7)-(8)$ is centered around a solution for which the contemporaneous impact of fundamental shocks is continuous on the boundary of determinacy and indeterminacy region. Thus, the form of the solution coincides with the one under determinacy, given by (3), when $m_1 = 0$ and $m_2 = 0$.

Under indeterminacy, both news and sunspot shocks can trigger forecast revisions of the endogenous variables. In particular, the optimal forecasts of output and inflation for one period ahead and their forecast errors are influenced by both the news and sunspot shocks

$$\begin{bmatrix} E_t x_{t+1} \\ E_t \pi_{t+1} \end{bmatrix} = \frac{-\sigma}{1+\kappa\sigma\psi} \begin{bmatrix} 1 \\ \kappa \end{bmatrix} \mu_t + \begin{bmatrix} (\beta(\lambda_2 - 1) - \sigma\kappa)/\kappa \\ 1 \end{bmatrix} \omega_t \qquad (9)$$

$$\begin{aligned}
\eta_t &= -\frac{\sigma}{1+\kappa\sigma\psi} \begin{bmatrix} 1 & \frac{1+\kappa\beta(1-\beta\psi)}{1+\kappa\sigma\psi} \\ \kappa & \frac{\kappa(1+\beta+\kappa\sigma)}{1+\kappa\sigma\psi} \end{bmatrix} \begin{bmatrix} \upsilon_t \\ \mu_t \end{bmatrix} \\
&+ \frac{1}{1+\kappa\sigma\psi} \begin{bmatrix} \lambda_2 - 1 - \kappa\sigma\psi \\ \kappa\lambda_2 \end{bmatrix} \left(M \begin{bmatrix} \upsilon_t \\ \mu_t \end{bmatrix} + \zeta_t \right) \qquad (10)
\end{aligned}$$

with ω_t given by (8).

In the terminology of Lubik and Schorfheide (2003), the variable ζ_t is a reduced form sunspot shock. The impact of this shock on the endogenous variables is determined uniquely. It can be shown that $\lambda_2 > 1 + \kappa\sigma\psi$ and $\lambda_2 > 1 + \sigma\kappa/\beta$ for all values of the parameters in the indeterminacy region. Thus, a positive realization of the reduced form sunspot shock increases inflation and output, as well as their future forecasts. To combat inflation, the central bank raises the nominal interest rate. However, the expected real interest rate declines, stimulating current output. Thus, changes in beliefs, induced by the sunspot shock, become self-fulfilling: forecasts of higher output or inflation are validated by the actual increase in inflation and output. The solid lines on Panel *C* of Figure 1 plot the impulse responses to a sunspot shock of 0.5% for $\psi = 0.95$.

In contrast to the reduced form sunspot shock, the impacts of news and unexpected policy shocks on the endogenous variables are influenced by arbitrary parameters. Panel *C* of Figure 1 shows the impulse responses to a realized news shock for two values of m_2. The news shock corresponds to a belief, formed in period 1 that in period 2 the interest rate will be cut by 25 basis points. This belief is confirmed in period 2. When $m_2 = 0$, the responses resemble the ones under determinacy. When $m_2 < 0$, a news shock about future monetary expansion increases output, inflation and interest rates. These impact responses coincide qualitatively with the responses to the reduced form sunspot shock. With $m_2 = -2$, the impulses responses to a realized news shock and a positive sunspot are closely matched quantitatively. Ambiguity in the model responses to news shocks points to a potential difficulty in empirical evaluation of news and sunspot shocks as sources of changes in expectations.

News shocks capture the idea that policy changes can be anticipated, for example, from the central bank's announcements. One can imagine that agents receive noisy signals about future monetary policy, update their beliefs, based on these signals, and learn whether their previous beliefs were correct by observing the actual realizations of the policy shock.[1] Under the rational expectations hypothesis, the policy shock is a sum of one-period-ahead expectation revisions $\varepsilon_t = \sum_{j=0}^{\infty} \left(E_{t-j}\varepsilon_t - E_{t-j-1}\varepsilon_t\right)$. The decomposition of ε_t in (1) is consistent with the assumption that there is only one signal, n periods before the realization of the policy shock. Thus, beliefs about ε_t are updated only in periods $t-n$ and t. Impulses μ_{t-n} and υ_t represent these updates. Since the correlation between signals and policy shocks need not be perfect, an anticipated policy change may not take place, leading to ex-post mistakes. Modelling these mistakes is one of the motivating factors for studying news shocks, as argued by Beaudry and Portier (2004).

[1] Beaudry and Portier (2004) apply this strategy to study news about future productivity.

Sunspot shocks can trigger changes in agents' beliefs due extrinsic uncertainty. They can be generally treated as uncorrelated with monetary policy shocks. This property differentiates sunspots from news shocks, which are related to future policy shocks by definition.

4 Conclusions

The comparison between news and sunspot shocks in the New Keynesian model leads to the following conclusions. First, both news and sunspot shocks can trigger changes in beliefs. The key distinctions lie in their relation to the realized policy shock and ability to capture ex-post mistakes. Second, non-fundamental expectation revisions caused by sunspots can arise only under indeterminacy. Third, the non-uniqueness of the responses to news shocks under indeterminacy implies a possible observational equivalence between the dynamics induced by news and sunspot shocks. Finally, news shocks enrich dynamic correlation properties of the endogenous variables, as agents generally start acting upon new information about the future immediately.

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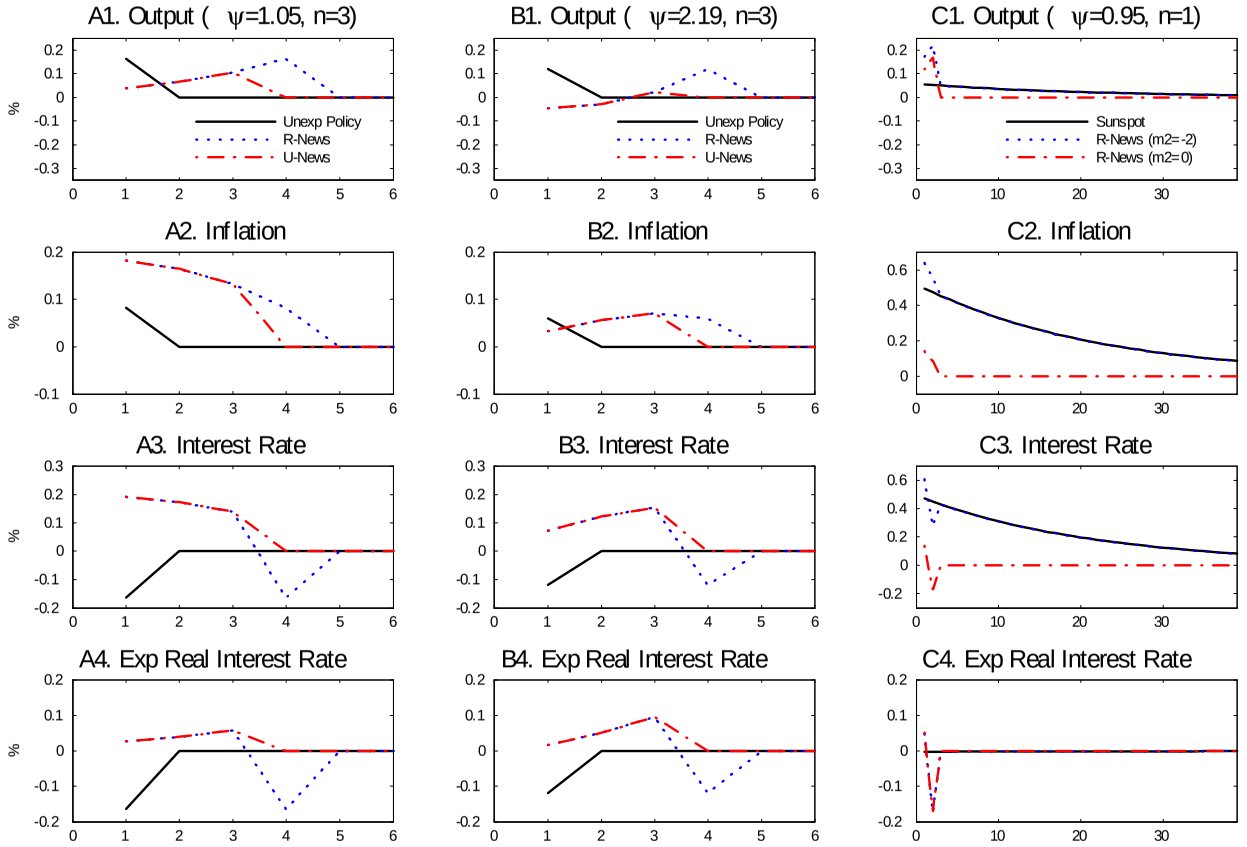
Figure 1: Responses of Output, Inflation and the Interest Rate to Unexpected Policy Changes, News and Sunspot Shocks



Notes: this Figure plots impulse responses to an unexpected 25-basis-point interest rate cut (panels A and B, solid lines), a reduced form sunspot shock of 0.5% (panel C, solid lines) and news shocks about future monetary expansion. News shocks correspond to a belief, formed in period 1 that in period 1+n the interest rate will be cut by 25 basis points. This belief is validated for R-News (dotted and dashed-dotted lines), but followed by no policy change for U-News (dashed lines).