Nominal Rigidities, News-Driven Business Cycles, and Monetary Policy*

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Abstract

A news-driven business cycle is a positive comovement in consumption, labor, investment, and output caused by positive news about the future. Standard real business cycle models do not generate it. In this paper, we find that a model with widely used market friction – i.e., sticky prices – can generate news-driven business cycles as responses to news about future technology growth, technology level, and expansionary monetary policy shocks. The key mechanism is the countercyclical movements of markups through nominal rigidities.

Keywords : News-driven business cycles; nominal rigidities; sticky prices
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1 Introduction

According to Pigou (1927), when agents receive positive news (or have optimistic expectations) about the future, they decide to build up capital since future aggregate demand increases. If the news turns out to be false, there will be a period of retrenched investment, which is likely to cause a recession. Such an effect of "news shock" might be an important source of business cycle fluctuations. A news-driven business cycle (hereafter NDBC) is a positive comovement in consumption, labor, investment, and output caused by positive news about the future.[1]

There are two major reasons why NDBCs are interesting in modern macroeconomics. The first comes from empirical episodes. The Subprime housing bubble of the U.S. economy in the mid-2000s, the Internet bubble of the U.S. economy during the late 1990s, and the Japanese real estate bubble era during the late 1980s might be accounted for by NDBCs. The other reason is theoretical. It is well known that standard real business cycle (hereafter RBC) models do not generate NDBCs. News about the future moves consumption and labor in opposite directions due to the wealth effect in a standard RBC model. Since the news of an increase in future productivity raises wealth, the consumer increases both consumption and leisure, and hence reduces labor supply. It follows that output and investment decline as well. Therefore, one of challenges in macroeconomic theory is investigating what kinds of features should be introduced in a standard model in order to generate NDBCs.

In this paper, we find that a model with standard market friction – i.e., sticky prices – can generate NDBCs. Our model is a simple New-Keynesian sticky-price model with adjustment costs of investment. It generates NDBCs from news shocks about technology growth, technology level, and expansionary monetary policy. The countercyclical movement in markups is the key feature to generate NDBCs and it is consistent with U.S. facts, as found by Rotemberg and Woodford (1999). In our model, if the news turns out to be false, the economy falls into a recession in the cases of news about technology

[1] There are various names to describe this phenomenon: Pigou cycles, boom-bust cycles, expectations-driven business cycles, and so on.

growth and monetary policy while there is no recession in the case of news about technology level. Our model also generates procyclical movements of Tobin's q (i.e., stock prices). It is well known that stock prices move procyclically and our theory is consistent with such movements of stock prices.

There are two strands of the literature of models for NDBCs. Papers in the first strand explain NDBCs in Pareto optimal economies. Beaudry and Portier (2004, 2007) introduce the notion of NDBCs into modern business cycle research. They show that a certain type of complementarity between production technologies in a multi-sector model can generate NDBCs. Jaimovich and Rebelo (2006, 2007) show that NDBCs are generated in a model with preferences exhibiting no income effect on labor supply, adjustment costs of investment, and variable capital utilization. Papers in another strand of the literature explain NDBCs in Pareto suboptimal economies. Den Haan and Kaltenbrunner (2007) construct a model with matching frictions in the labor market. Kobayashi, Nakajima, and Inaba (2007) and Kobayashi and Nutahara (2007) consider models with collateral constraints on working capital. The present paper belongs to the second strand since nominal price rigidity is a source of NDBCs in our model.

Christiano, Ilut, Motto, and Rostagno (2007) (hereafter CIMR) covers both strands of the literature. CIMR find that a Pareto optimal economy with habit persistence and adjustment costs of investment can generate NDBCs. However, they obtain the procyclicality of Tobin's q only after they introduce sticky prices, sticky wages and a forward-looking Taylor rule. In this paper, we show that NDBCs are generated without habit persistence if the nominal price is sticky and also show that NDBCs by sticky prices in our model naturally generate procyclical movements of Tobin's q. Our model can also generate both NDBCs and procyclical movements of Tobin's q with news shock about technology growth while CIMR model cannot, as shown by Fujiwara (2008).

The organization of this paper is as follows. Section 2 introduces our model, a simple New Keynesian sticky-price model with adjustment costs of investment. In Section 3, we set parameter values, and show that our model generates NDBCs by numerical simulations. Positive news about technology growth, technology level, and expansionary monetary policy generate current booms in our model. We also provide some sensitivity analyses and comparisons with the paper by CIMR. Section 4 draws main conclusions.

2 The Model

The model is a simple New Keynesian sticky-price model with capital accumulation and adjustment costs of investment. There are identical households, competitive final-goods firms, monopolistically competitive intermediate-goods firms, and the monetary authority. Price staggeredness occurs in the intermediate-goods sector.

2.1 Households

The utility function of households is

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \log(c_t) - \gamma \frac{n_t^{1+\sigma_n}}{1+\sigma_n} + \xi \log\left(\frac{M_t}{P_t}\right) \right\}. \tag{1}$$

where c_t denotes consumption; n_t, labor supply; M_t, money holding at the end of period t; P_t, aggregate price level; and $\sigma_n > 0$, the Frisch elasticity. The budget constraint of households is

$$c_t + i_t + \frac{M_t}{P_t} + \frac{B_t}{P_t} \leq w_t n_t + r_t k_{t-1} + F_t + T_t + \frac{M_{t-1}}{P_t} + \frac{R_{t-1} B_{t-1}}{P_t}, \tag{2}$$

where i_t denotes investment; P_t, the nominal price; M_t, the money supply; B_t, the one-period bonds; w_t, real wage rate; r_t, real rental rate of capital; k_{t-1}, capital stock at the end of period; R_{t-1}, the risk-free gross nominal interest rate; F_t, a lump-sum transfer from the monopolistic intermediate-goods firms; and T_t, a lump-sum transfer from the central bank.

The evolution of capital stock is

$$k_t = (1-\delta) k_{t-1} + \Phi\left(\frac{i_t}{k_{t-1}}\right) k_{t-1}, \tag{3}$$

where $\Phi(\cdot)$ is the reduced form of the adjustment cost of investment. We assume that $\Phi'(\cdot) > 0$, $\Phi''(\cdot) < 0$ as in the paper by Bernanke, Gertler, and Gilchrist (1999).

The households' problem is to choose consumption, labor, investment, capital stock, nominal bond and money holdings so as to maximize (1) subject to (2) and (3).

The first-order necessary conditions are as follows.

$$(1-\gamma)\frac{1}{c_t} = \lambda_{c,t}, \tag{4}$$

$$\frac{\gamma}{1-\gamma} \cdot c_t n_t^{\sigma_n} = w_t, \tag{5}$$

$$q_t = \beta E_t \left[\frac{\lambda_{c,t+1}}{\lambda_{c,t}} \left\{ (1-\delta) q_{t+1} + r_{t+1} + q_{t+1} \left[\Phi\left(\frac{i_{t+1}}{k_t}\right) - \Phi'\left(\frac{i_{t+1}}{k_t}\right) \frac{i_{t+1}}{k_t} \right] \right\} \right], \tag{6}$$

$$1 = \beta E_t \left[\frac{1}{\pi_{t+1}} \cdot \frac{\lambda_{c,t+1}}{\lambda_{c,t}} R_t \right], \tag{7}$$

$$\lambda_t = \xi \left[\frac{M_t}{P_t} \right]^{-\theta'} + \beta E_t \left[\frac{1}{\pi_{t+1}} \cdot \lambda_{t+1} \right], \tag{8}$$

$$q_t = \left[\Phi'\left(\frac{i_t}{k_{t-1}} \right) \right]^{-1}, \tag{9}$$

where $\lambda_{c,t}$ is the Lagrange multiplier with respect to the household's budget constraint, $q_t \equiv \lambda_{k,t}/\lambda_{c,t}$ is the shadow price of capital (Tobin's q), and $\lambda_{k,t}$ is the Lagrange multiplier with respect to (3), the evolution of capital. (5) is the intratemporal optimization condition. (6), (7), and (8) are the Euler equations of capital, nominal debt, and money holdings, respectively. (9) is the first-order condition for investment, and determines Tobin's q.

2.2 Final-goods firms

Final-goods, y_t, are produced by combining a continuum of intermediate goods, $Y_t(z)$, using technology:

$$y_t = \left(\int_0^1 Y_t(z)^{\frac{\theta-1}{\theta}} dz \right)^{\frac{\theta}{\theta-1}} \tag{10}$$

with no cost. The final-goods sector is competitive. The demand curve for $Y_t(z)$ is

$$Y_t(z) = \left(\frac{P_t(z)}{P_t} \right)^{-\theta} y_t, \tag{11}$$

where P_t denotes the aggregate price level and $P_t(z)$ denotes the price level of intermediate-goods indexed by z. Combining (10) and (11) yields the following price index for intermediate goods:

$$P_t = \left(\int_0^1 P_t(z)^{1-\theta} dz \right)^{\frac{1}{1-\theta}}. \tag{12}$$

2.3 Intermediate-goods firms

The intermediate-goods firms are monopolistically competitive, and they produce intermediate-goods $Y_t(z)$ employing capital service $K_t(z)$ and labor $N_t(z)$ from households. The production function is

$$Y_t(z) = \Gamma_t \Big[K_t(z) \Big]^{\alpha} N_t(z)^{1-\alpha}, \tag{13}$$

where Γ_t denotes technology.

Defining markup as the inverse of the real marginal costs, $X_t \equiv 1/mc_t$, the cost minimization problem implies

$$w_t = \frac{1-\alpha}{X_t} \cdot \frac{Y_t(z)}{N_t(z)}, \tag{14}$$

$$r_t = \frac{\alpha}{X_t} \cdot \frac{Y_t(z)}{K_t(z)}. \tag{15}$$

The intermediate-goods firms set their prices subject to Calvo-type price staggeredness with price indexation. The price can be re-optimized at period t only with probability $1-\kappa$. Among κ firms who cannot re-optimize their prices, a fraction η firms index their prices to the past inflation π_{t-1}. Under this setting, we obtain the hybrid New Keynesian Phillips Curve,

$$\hat{\pi}_t = \frac{\beta}{1+\eta\beta} E_t \Big[\hat{\pi}_{t+1} \Big] + \frac{\eta}{1+\eta\beta} \hat{\pi}_{t-1} - \frac{(1-\kappa)(1-\kappa\beta)}{\kappa(1+\eta\beta)} \hat{x}_t, \tag{16}$$

where $\hat{\pi}_t$ denotes $\ln(P_t/P_{t-1})$ and $\hat{x}_t$ denotes $\ln(X_t/X)$. We introduce the price indexation only to be consistent with empirical findings that the New Keynesian Phillips Curve has the past inflation term. Even without price indexation ($\eta = 0$), our model can generate NDBCs.

2.4 Monetary authority

The monetary authority follows a forward-looking Taylor rule,

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1-\rho_R)\Bigg\{\rho_\pi E_t\Bigg[\hat{\pi}_{t+1}\Bigg] + \rho_y \hat{y}_t\Bigg\} - u_t^R, \tag{17}$$

where $\hat{y}_t$ denotes output gap; $\hat{R}_t$, deviation of nominal interest rate from the steady state; and u_t^R, expansionary monetary policy shock.[2]

2.5 Technology

Technology Γ_t of intermediate-goods firms consists of two components:

$$\Gamma_t = A_t \zeta_t^\alpha. \tag{19}$$

A_t and ζ_t evolve according to the first order autoregressive processes:

$$\ln(A_t) = \rho_A \ln(A_{t-1}) + (1-\rho_A)\ln(A) + u_t^A, \tag{20}$$

$$g_t = \rho_g g_{t-1} + (1-\rho_g)g + u_t^g. \tag{21}$$

where $g_t \equiv \ln(\zeta_t/\zeta_{t-1})$, and then, ζ_t is integrated of order one. A and g denote the steady-state values of A_t and g_t, respectively. u_t^g and u_t^A are technology growth and level shocks, respectively. As we will show, NDBCs are generated from news shocks on both technology growth and level in our model.

2.6 Market clearing conditions

The market clearing conditions of capital and labor are

$$k_{t-1} = \int_0^1 K_t(z)dz, \tag{22}$$

$$n_t = \int_0^1 N_t(z)dz. \tag{23}$$

[2] Our results are robust to other specifications of Taylor rule. For example, if the monetary authority follows a backward-looking Taylor rule, which is employed by Bernanke, Gertler, and Gilchrist (1999):

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1-\rho_R)\Bigg[\rho_\pi \hat{\pi}_{t-1} + \rho_y \hat{y}_{t-1}\Bigg] - u_t^R, \tag{18}$$

NDBCs are also generated.

The resource constraint is

$$c_t + i_t = y_t, \tag{24}$$

and the aggregate production function is

$$y_t = \frac{1}{\Delta_t} A_t k_{t-1}^{\alpha} \left[\zeta_t n_t \right]^{1-\alpha}. \tag{25}$$

where Δ_t is a measure of resource cost of price dispersion:

$$\Delta_t \equiv \int_0^1 \left(\frac{P_t(z)}{P_t} \right)^{-\theta} dz. \tag{26}$$

2.7 News shock structure

Technology shocks, u_t^g and u_t^A, and monetary policy shock, u_t^R, are divided into two parts as follows.

$$u_t^j = \varepsilon_t^j + \nu_{t-p}^j, \tag{27}$$

where ε_t^j is i.i.d. with zero mean observed at period t and ν_{t-p}^j is i.i.d. with zero mean observed at period $t-p$, for $j = A$, g, and R. We call ν_{t-p}^j the news shock.

In order to write the model recursively, we employ the following canonical form of news shock:

$$\begin{bmatrix} \nu_t^j \\ \nu_{t-1}^j \\ \vdots \\ \nu_{t-p+1}^j \end{bmatrix} = \begin{bmatrix} 0 & \cdots & 0 \\ & & \vdots \\ & \boldsymbol{I}_{p-1} & \\ & & 0 \end{bmatrix} \begin{bmatrix} \nu_{t-1}^j \\ \nu_{t-2}^j \\ \vdots \\ \nu_{t-p}^j \end{bmatrix} + \begin{bmatrix} \nu_t^j \\ 0 \\ \vdots \\ 0 \end{bmatrix}, \tag{28}$$

where $\boldsymbol{I}_{p-1}$ denotes a $(p-1) \times (p-1)$ identity matrix for $j = A$, g, and R.

2.8 Equilibrium

Define $\boldsymbol{s}_t$ as

$$\boldsymbol{s}_t \equiv [k_{t-1}, \pi_{t-1}, R_{t-1}, g_{t-1}, A_{t-1}, \nu_{t-1}^A, \cdots, \nu_{t-p}^A, \nu_{t-1}^g, \cdots, \nu_{t-p}^g, \nu_{t-1}^R, \cdots, \nu_{t-p}^R]',$$

and $\boldsymbol{\varepsilon}_t \equiv [\varepsilon_t^A, \varepsilon_t^g, \varepsilon_t^R, \nu_t^A, \nu_t^g, \nu_t^R]'$. In this economy, $\boldsymbol{s}_t$ and $\boldsymbol{\varepsilon}_t$ are vectors of endogenous and exogenous state variables, respectively.

Finally, a competitive equilibrium of this economy is defined as follows.

Definition 1 (Recursive competitive equilibrium) *A recursive competitive equilibrium consists of (I) price functions* $\{\pi(\boldsymbol{s}_t, \boldsymbol{\varepsilon}_t), X(\boldsymbol{s}_t, \boldsymbol{\varepsilon}_t), w(\boldsymbol{s}_t, \boldsymbol{\varepsilon}_t), r(\boldsymbol{s}_t, \boldsymbol{\varepsilon}_t), R(\boldsymbol{s}_t, \boldsymbol{\varepsilon}_t)\}$*, (II) aggregate decision rules* $\{c(\boldsymbol{s}_t, \boldsymbol{\varepsilon}_t), n(\boldsymbol{s}_t, \boldsymbol{\varepsilon}_t), i(\boldsymbol{s}_t, \boldsymbol{\varepsilon}_t), k(\boldsymbol{s}_t, \boldsymbol{\varepsilon}_t), y(\boldsymbol{s}_t, \boldsymbol{\varepsilon}_t)\}$*, and (III) evolutions of states* $\boldsymbol{s}_t = \boldsymbol{\Psi}(\boldsymbol{s}_{t-1}, \boldsymbol{\varepsilon}_t)$*, that satisfy (i) household's optimization conditions and first-order conditions of intermediate-goods and final-goods firms (5), (6), (7), (9), (14), (15), and (16), (ii) market clearing conditions (22), (23), (24), and (25), and (iii) monetary policy rule (17), given evolutions of exogenous technologies (20) and (21) and the canonical form of news shocks (28).*

2.9 News-driven business cycles

In Section 3, we investigate whether our model generates NDBCs or not. To do this, we define NDBCs as follows.

Definition 2 (News-driven business cycles) *News-driven business cycles (NDBCs) are simultaneous increases in consumption* c_t*, labor* n_t*, investment* i_t*, and output* y_t *as the responses to positive news shocks about technology growth and level,* ν_t^g *and* ν_t^A*, and expansionary monetary policy,* ν_t^R*.*

We focus on the directions of the responses of consumption, labor, investment, and output to news shocks to judge whether NDBCs are generated or not in our model. In addition, we are also interested in the movements of Tobin's q since the procyclicality of Tobin's q is widely known.

3 News-Shock Experiments

3.1 Functional form and parameter values

We specify the functional form of adjustment costs of investment as

$$\Phi(\omega) \equiv \frac{\sigma_\Phi(\delta+g)}{q}\ln(\omega+\bar{a})+\bar{b}, \tag{29}$$

where q is the steady-state value of Tobin's q, and $\Phi(0)=0$ and $\Phi(\delta+g)=\delta+g$. Under this specification, the first order condition (9) is

$$\frac{\sigma_\Phi(\delta+g)}{q}q_t = \frac{i_t}{k_{t-1}}+\bar{a}. \tag{30}$$

Detrending and log-linearizing (30) yields

$$\hat{i}_t = \sigma_\Phi \hat{q}_t + \hat{k}_{t-1} + (g_t - g), \tag{31}$$

where variables with the notation ˆ denote the log-deviation from the steady state. The parameter σ_Φ is the price elasticity of investment (elasticity of investment with respect to Tobin's q).

The values of parameters are summarized in Table 1.

[Insert Table 1]

The model period is one quarter. All parameter values except the price elasticity of investment, σ_Φ, and persistence of technology growth, ρ_g, are the same as those employed by CIMR. The discount factor of household, β, is $1.01358^{-.25}$. The weight of leisure, γ, is set to be 109.82 and the Frisch elasticity, σ_n, is 1. The share of capital in the production, α, is .4, and the depreciation rate of capital, δ, is .025. The probability of price change, $1-\kappa$, is .36 and the fraction of backward-pricing firms, η, is .84. The steady-state gross inflation, π, is 1, and the steady-state markup, $X \equiv \theta/(\theta-1)$, is 1.2. The persistence of nominal interest rate, ρ_R, is .81. The weights of inflation and output gaps, ρ_π and ρ_y, in the Taylor rule are 1.95 and .18, respectively. The persistence of exogenous technologies, ρ_g and ρ_A, is .83. However, NDBCs are generated even if $\rho_g=0$ and $\rho_A=0$. The steady-state technology growth, g, is set to zero in order to see the effects of news shocks to abstract from the scaling effect, which does not change the properties of our model on NDBCs. The steady-state technology level, A, is normalized to one. The price elasticity of investment σ_Φ, is 1.01.[3] The values of $\bar{a}$ and $\bar{b}$ are determined as a solution of $\Phi(0) = 0$ and $\Phi(\delta + g) = \delta + g$ given σ_Φ and q. The lags of news shocks are four quarters, $p = 4$, which means that news is about one year later. We do not set the value of the weight of money balance in the utility function, ξ, since, if monetary authority follows a Taylor rule, we can calculate the aggregate decision rules without the Euler equation of money holdings (8).

3.2 News-shock experiments

To calculate policy functions of our economy, we detrend the equilibrium system by growing technology ζ_t.[4] We approximate this detrended economy by the log-linearization technique, and calculate aggregate decision rules by the method of Uhlig (1999).

Following CIMR, we consider the following impulse. Up until period $t = 0$, the economy is at the steady state. At period $t = 0$, a news shock hits the economy, which suggests productivity (or nominal interest rates) will be high (or low) in period $t = 4 (= p)$. However, when period $t = p$, the expected rise in technology (or drop in nominal interest rates) in fact does not happen: $\varepsilon_4^j + \nu_0^j = 0$ for $j = A$, g, and R. This is interpreted as the news turning out to be false.[5]

News shock about technology growth ν_t^g: Figure 1 shows that NDBCs are generated as responses to news about technology growth, $\nu_0^g = .01$, and $\varepsilon_4^g = -.01$.

[Insert Figure 1]

Variables are shown as deviations from the steady state.

[3] To guarantee a positive value of $\bar{a}$, the value of σ_Φ should be greater than one. This is shown by the steady-state equilibrium conditions. Our result is robust to the value of σ_Φ. If σ_Φ is very close to one or if σ_Φ is large, like 1.5, NDBCs are generated.

[4] The equilibrium system and the detrended system are described in the Appendix.

[5] This impulse is different from standard impulse response functions in macroeconomics since two shocks, ν_{t-4}^j and ε_t^j, hit the economy.

The intuition is as follows. When a news shock occurs, people expect that the inflation rate will increase in the future, which is verified in the impulse response functions of inflation to a current technology growth shock, ε_t^g, as in Figure 2.

[Insert Figure 2]

Future technology growth increases future consumption by the future wealth effect. If the wage rate is unchanged, households have an incentive to reduce their future labor supply by the optimization condition of consumption-leisure choice. Since the wealth effect is very strong in the case of a technology growth shock, the increase of future aggregate demand is larger than the technology improvement, and in order to increase future output, future labor input increases and future wage rate increases. This increase in the wage rate implies the increase of competitiveness among firms and the decrease of markups. The future inflation occurs through the New Keynesian Phillips Curve.

The New Keynesian Phillips Curve (16) implies that future inflation results in the current inflation. While the current optimal price level also increases, price-setting firms cannot fully increase their prices because of nominal rigidities and it leads to the decrease of their markups. The decrease of markups induces the increase of aggregate demand and output and labor input increase. Finally, household income becomes so high that both consumption and investment increase. [6]

When the news turns out to be false, the economy falls into recession defined as simultaneous decreases at $t = 4$ in consumption, labor, investment, and output to lower levels than those of the steady state. The reason is that, if the news turns out to be false, the optimal current price level decreases, but price-setters cannot fully decrease their prices because of nominal rigidities. This means an increase in markup, and the economy falls into recession.

[6] The U.S. and Japanese experiences show that a stock market boom or real estate bubble can occur under low inflation. Our simulation result in the case of news about technology growth may not be consistent with these observations. However, in the case of news about technology level, predictions of our model are consistent with these facts.

Models with collateral constraints of Kobayashi, Nakajima, and Inaba (2007) and Kobayashi and Nutahara (2007) also generate recessions if the news turns out to be false, but the mechanism is totally different. In their models, the key is heterogeneity of agents: households and entrepreneurs. Entrepreneurs sell their collateralized assets to households when the news arrives, and if the news turns out to be false, holding assets of entrepreneurs are too short and collateral constraints are too tight, and this causes recessions in their models. One of the contributions of this paper is that recessions occur when the news turns out to be false even in a representative agent model.

Our model also generates procyclical movements of Tobin's q (i.e., stock prices), which is widely known empirically. The procyclicality of Tobin's q is generated since we employ the level specification of adjustment costs of investment. As in (31), if investment is procyclical, Tobin's q is procyclical.

News shock about technology level ν_t^A: Figure 3 shows that NDBCs are generated as responses to news about technology level $\nu_0^A = .01$ and $\varepsilon_4^A = -.01$.

[Insert Figure 3]

There are two main differences in the case of news about technology growth: (i) responses to news are delayed, and (ii) a recession does not occur even if the news turns out to be false. These features imply that the mechanism of NDBCs is different between news shocks about technology growth and those about level. In the case of growth news, a boom occurs with a decrease in markups, which is caused by future and current inflation, while inflation does not occur as a response to current technology level shock as in Figure 2. This is a standard property of a sticky-price model. In the case of a technology level shock, contrary to that of a technology growth shock, future wealth effect is not so large and the increase of aggregate demand is smaller than the technology improvement. Thus, future labor input and the future wage rate decrease, which implies a future increase of markups and future deflation.

In the case of news about technology level, the adjustment cost of investment is a key friction that generates NDBCs. This friction works together with the nominal rigidities.

To smooth investment intertemporally in response to the future increase in technology level, households increase current investment when the news occurs. Households also increase consumption due to the wealth effect. While the simultaneous increases in consumption and investment do not materialize in the standard RBC models, the nominal rigidities make them happen in our model. The increases in demand for consumption and investment are both met by an increase in the aggregate supply caused by a decrease in the markups and increase of labor input. This leads to the increase of output.

This mechanism is easily verified by the intratemporal optimization condition:

$$\gamma c_t n_t^{\sigma_n} = \frac{1-\alpha}{X_t}\left[\frac{k_{t-1}}{n_t}\right]^{\alpha} A_t \zeta_t^{1-\alpha}. \tag{32}$$

In standard RBC models, an increase of consumption c_t from news about the future implies decreases of labor input n_t since markup X_t is constant over time and current capital stock k_{t-1} and current technologies A_t and ζ_t do not change. Thus, output and investment also decrease. However, in our model, comovements are made possible by the decrease of markup.

There are overshoot responses in $t = 0$ in Figure 3. If we employ $\rho_y = .5$, the smoothed responses are obtained as in Figure 4.

[Insert Figure 4]

The response of output becomes smooth since the central bank is more sensitive to an output gap.

News shock about monetary policy ν_t^R: Figure 5 shows that NDBCs are generated in response to news about an expansionary monetary policy shock, $\nu_0^R = .01$ and $\varepsilon_4^R = -.01$.

[Insert Figure 5]

When the news arrives, a boom occurs. If the news subsequently turns out to be false, a recession occurs. The mechanism of booms and recessions is similar to that in the case of news about technology growth. The news about future expansionary monetary policy increases the current optimal price level, and decreases markup through nominal rigidities.[7]

3.3 Monetary policy and news-driven business cycles

Parameters in Taylor rule: In Section 3.2, we chose parameters of our Taylor rule, ρ_π and ρ_y, following CIMR. Here, we investigate the region in which NDBCs are generated. We try various sets of parameters $(\rho_\pi,\ \rho_y) \in [1,4] \times [0,4]$, and check whether model predictions are consistent with Definition 2 or not.[8] The dark regions of Figure 6 are the ones in which NDBCs are generated.

[Insert Figure 6]

The upper panels are cases with adjustment costs of investment, and the lower ones are cases without adjustment costs. The first column has the cases of technology growth news, the second has technology level news, and the third has expansionary monetary policy news.

Figure 6 show that adjustment costs of investment expand the regions in which NDBCs are generated. If there are adjustment costs of investment, NDBCs are generated in the broad range of parameters to news about monetary policy. The region of NDBC from news about technology level is also expanded if there are adjustment costs of investment while it is very small if there are no adjustment costs of investment. In the case of news about technology level, it is obvious that adjustment cost of investment is key to generating NDBCs. In the cases of news about technology growth and monetary policy, the news decreases markups through nominal rigidities, and households' income becomes high enough to increase both consumption and investment. However, households increase only consumption by decreasing investment if the increase in income is

[7] Ball (1994) and Mankiw and Reis (2002) report a puzzle that future expansionary monetary policy causes current recession in sticky-price models. In their models, money is introduced through the cash-in-advance constraint. The effect of monetary policy on markups is totally different from those in our model, in which money is introduced by the money-in-the-utility setting. Therefore, such a puzzle does not occur in our model.

[8] Note that the parameter ρ_π should be greater than one to satisfy the Blanchard-Kahn condition.

not very high. The adjustment costs of investment make households have an incentive to invest and help our model to generate NDBCs. The panels in the lower row imply that NDBCs are not generated by news shocks about technology growth and monetary policy if ρ_π is high. This is because high ρ_π prevents the news from generating future inflation and from decreasing markups.

In the case with adjustment costs of investment, news about technology level causes NDBCs under the Taylor rule with high ρ_π and low ρ_y. News about future technology level causes deflation and it may cause a current recession by increasing markups. To weaken this mechanism and to generate a boom through smoothing due to adjustment costs of investment, monetary authority should reduce the interest rate drastically in response to deflation. A high ρ_π represents this attitude of monetary authority. A low ρ_y also represents that monetary authority is relatively sensitive to an inflation gap.

Money growth rule: We have employed Taylor rule as a benchmark monetary policy rule. The money growth rule is also a major monetary policy rule, and it is described as

$$M_t = (1+\mu_t)M_{t-1}, \tag{33}$$

$$\mu_t = \rho_\mu \mu_{t-1} + (1-\rho_\mu)\mu + \varepsilon_t^\mu + \nu_{t-p}^\mu, \tag{34}$$

where μ is the steady-state money growth rate, ε_t^μ is an i.i.d. money growth shock, and ν_{t-p}^μ is a news shock about money growth that agents receive at period $t-p$. We set $\mu = g$ to guarantee the existence of the balanced growth path, and we also set $\rho_\mu = .95$. If we employ this monetary policy rule, the regions of NDBCs are as in Figure 7.

[Insert Figure 7]

We check whether or not NDBCs are generated by changing the steady-state ratio of money balance to output, M/y. We set the weight of real money balance in the utility, ξ, such that M/y corresponds to the target value. In the dark regions, NDBCs are generated by news shocks about growth and money supply even if we employ the money growth rule. Note that NDBCs are generated in the broad range of M/y. The intuitive mechanism of NDBCs is similar to the case of the Taylor rule since inflation occurs from current technology growth shocks and deflation occurs from current technology level shocks as shown in the right-hand side panel of Figure 2. We set $M/y = 1$ in Figure 2. Then, we find that even if we employ the money growth rule as monetary policy, our sticky-price model can generate NDBCs.

3.4 Comparison with the model of Christiano et al. (2007)

Here, we compare our model with that of CIMR since they also introduce nominal rigidities. Our model can be interpreted as a simplified version of the model of CIMR. We remove the habit persistence and sticky-wage from their model and change the functional form of the adjustment costs of investment from the flow specification to the level one.

However, the mechanism of NDBCs is different between the two models. CIMR find that a Pareto optimal economy with habit persistence and adjustment costs of investment can generate NDBCs. However, they also find that Tobin's q moves countercyclically unless they introduce sticky prices, sticky wages, and a forward-looking Taylor rule. In this paper, we show that NDBCs are generated without habit persistence if the nominal price is sticky and we also show that NDBCs due to sticky prices in our model naturally generate procyclical movements of Tobin's q. Moreover, CIMR consider only a news shock about technology level while we consider news shocks about technology growth, level, and monetary policy.

In order to make the difference between our model and CIMR's clear, we try news-shock experiments in some modified models of CIMR with various frictions. Table 2 summarizes these results.[9]

[Insert Table 2]

We consider four frictions employed by CIMR: habit persistence in consumption, adjustment cost of investment, sticky prices, and sticky wages. The utility function with habit

[9] We focus on responses of the economy to news about future technology growth and future level here. Figures for each model will be available from authors upon request.

persistence is

$$u(c_t, c_{t-1}, n_t) = \log(c_t - bc_{t-1}) - \gamma \frac{n_t^{1+\sigma_n}}{1+\sigma_n} + \xi \log\left(\frac{M_t}{P_t}\right), \tag{35}$$

where $b > 0$ represents habit persistence. If $b = 0$, this utility function is reduced to that of our model. We consider two types of adjustment costs of investment: flow specification and level specification. The flow specification is the same as that of CIMR:

$$k_t = (1-\delta)k_{t-1} + \Psi\left(\frac{i_t}{i_{t-1}}\right) i_t, \tag{36}$$

$$\Psi(\omega) \equiv \omega - \frac{\sigma_\Psi}{2}(\omega - \bar{\omega})^2. \tag{37}$$

The level specification is the same as ours. Sticky price is the same as that of our model. Sticky wage is introduce as in the CIMR model, monopolistically competitive households have differentiated labor and offer their nominal wage rate à la Calvo with price indexation. Households can re-optimize their nominal wage with probability $1-\kappa_w$. Price indexation means η_w fraction of households who cannot re-optimize their nominal wage rate change their wage rate according to past inflation. We set parameter values following CIMR; $b = .63$, $\sigma_\Psi = 15.1$, $\kappa_w = .19$, $\eta_w = .13$ and the steady-state markup of wage rate is 1.05.

The first three models show the same results as in the paper by CIMR. (I) shows that the model with habit persistence and flow adjustment costs of investment generates NDBCs while (II) shows that the model with level adjustment costs cannot. The Pareto optimal non-monetary economy cannot generate procyclical movements of Tobin's q as in (I). CIMR find that the introduction of sticky prices and wages is one method to generate procyclicality of Tobin's q as shown in (III).[10] (IV)-(XIII) show that (i) models with nominal rigidities generate NDBCs even without habit persistence, and (ii) in the case of flow adjustment costs, it is difficult to generate procyclical movements of Tobin's q. (IX) is our main model. The sticky-price model with our level specification of adjustment

[10] Our results are slightly different from those of Fujiwara (2008), who finds that the CIMR model under realistic parameter values cannot generate NDBCs from a news shock about future technology growth. This seems to be because of the difference of functional form and parameter values of adjustment costs.

cost can generate NDBCs and procyclical movement of Tobin's q. (X)-(XIV) show that our level specification generates procyclical movement of Tobin's q. Note that models with sticky wage can generate NDBCs as in (VI), (VII), (X), and (XIII). As Chari, Kehoe, and McGrattan (2007) show, sticky wages affect labor wedge (or markup) in the intratemporal optimization condition and thus the model with sticky wage generates NDBCs.

4 Conclusion

An NDBC is a business cycle in which positive news about the future causes simultaneous increases in consumption, labor, investment, and output at present. Standard real business cycle models do not generate it. In the recent business cycle literature, many models are proposed to generate NDBCs. In this paper, we found that a New Keynesian sticky-price model with adjustment costs of investment can generate NDBCs and procyclical movements of Tobin's q. NDBCs are generated by news about technology growth, technology level, and expansionary monetary policy shocks. We also found that the economy might fall into recession if the news turns out to be false. The key mechanism is that markups vary through nominal rigidities when news shocks occur. Our findings might imply that nominal rigidities not only generate persistent responses to real shocks, but also drive booms and recessions in response to changes in expectations.

Appendix: Equilibrium System

The equilibrium system is as follows.

$$\frac{1}{c_t} = \lambda_{c,t}, \tag{38}$$

$$\gamma c_t n_t^{\sigma_n} = w_t, \tag{39}$$

$$q_t = \beta E_t \left[\frac{\lambda_{c,t+1}}{\lambda_{c,t}} \left\{ (1-\delta) q_{t+1} + r_{t+1} + q_{t+1} \left[\Phi\left(\frac{i_{t+1}}{k_t} \right) - \Phi'\left(\frac{i_{t+1}}{k_t} \right) \frac{i_{t+1}}{k_t} \right] \right\} \right], \tag{40}$$

$$1 = \beta E_t \left[\frac{1}{\pi_{t+1}} \cdot \frac{\lambda_{c,t+1}}{\lambda_{c,t}} R_{t+1} \right], \tag{41}$$

$$y_t = A_t \cdot k_{t-1}^{\alpha} \cdot \left[\zeta_t n_t \right]^{1-\alpha}, \tag{42}$$

$$w_t = \frac{1-\alpha}{X_t} \cdot \frac{y_t}{n_t}, \tag{43}$$

$$r_t = \frac{\alpha}{X_t} \cdot \frac{y_t}{k_{t-1}}, \tag{44}$$

$$q_t = \left[\Phi'\left(\frac{i_t}{k_{t-1}} \right) \right]^{-1}, \tag{45}$$

$$k_t = (1-\delta) k_{t-1} + \Phi\left(\frac{i_t}{k_{t-1}} \right) k_{t-1}, \tag{46}$$

$$\hat{\pi}_t = \beta E_t \left[\hat{\pi}_{t+1} \right] - \frac{(1-\kappa)(1-\kappa\beta)}{\kappa} \hat{x}_t, \tag{47}$$

$$c_t + i_t = y_t, \tag{48}$$

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1-\rho_R) \left[\rho_\pi E_t \hat{\pi}_{t+1} + \rho_y \hat{y}_t \right] + \varepsilon_t^R + \nu_{t-p}^R, \tag{49}$$

given the evolution of technologies. Note that we ignore the costs of price dispersion Δ_t since it is approximated to one in the neighborhood of the steady state. For detrending, we introduce the detrended variables

$$\tilde{G}_t \equiv \frac{G_t}{\zeta_t}, \tag{50}$$

for $G = c, k, i, y, w$, and

$$\tilde{\lambda}_{c,t} \equiv \frac{\lambda_{c,t}}{\zeta_t^{-1}}. \tag{51}$$

The detrended equilibrium system is as follows.

$$\frac{1}{\tilde{c}_t} = \tilde{\lambda}_{c,t}, \tag{52}$$

$$\gamma \tilde{c}_t n_t^{\sigma_n} = \tilde{w}_t, \tag{53}$$

$$\begin{aligned} q_t = \beta E_t \Bigg[\frac{\tilde{\lambda}_{c,t+1}}{\tilde{\lambda}_{c,t}} (1+g_{t+1})^{-1} \Bigg\{ (1-\delta) q_{t+1} + r_{t+1} \\ + q_{t+1} \Bigg[\Phi\Bigg(\frac{\tilde{i}_{t+1}}{\tilde{k}_t}(1+g_{t+1}) \Bigg) - \Phi'\Bigg(\frac{\tilde{i}_{t+1}}{\tilde{k}_t}(1+g_{t+1}) \Bigg) \frac{\tilde{i}_{t+1}}{\tilde{k}_t}(1+g_{t+1}) \Bigg] \Bigg\} \Bigg], \end{aligned} \tag{54}$$

$$1 = \beta E_t \Bigg[\frac{1}{\pi_{t+1}} \cdot \frac{\tilde{\lambda}_{c,t+1}}{\tilde{\lambda}_{c,t}} (1+g_{t+1})^{-1} R_{t+1} \Bigg], \tag{55}$$

$$\tilde{y}_t = A_t \Bigg[\frac{\tilde{k}_{t-1}}{1+g_t} \Bigg]^{\alpha} n_t^{1-\alpha}, \tag{56}$$

$$\tilde{w}_t = \frac{1-\alpha}{X_t} \cdot \frac{\tilde{y}_t}{n_t}, \tag{57}$$

$$r_t = \frac{\alpha}{X_t} \cdot \frac{\tilde{y}_t}{\tilde{k}_{t-1}} (1+g_t), \tag{58}$$

$$q_t = \Bigg[\Phi'\Bigg(\frac{\tilde{i}_t}{\tilde{k}_{t-1}}(1+g_t) \Bigg) \Bigg]^{-1}, \tag{59}$$

$$\tilde{k}_t = \frac{1-\delta}{1+g_t} \tilde{k}_{t-1} + \Phi\Bigg(\frac{\tilde{i}_t}{\tilde{k}_{t-1}}(1+g_t) \Bigg) \frac{\tilde{k}_{t-1}}{1+g_t}, \tag{60}$$

$$\hat{\pi}_t = \frac{\beta}{1+\eta\beta} E_t \Big[\hat{\pi}_{t+1} \Big] + \frac{\eta}{1+\eta\beta} \hat{\pi}_{t-1} - \frac{(1-\kappa)(1-\kappa\beta)}{\kappa(1+\eta\beta)} \hat{x}_t, \tag{61}$$

$$\tilde{c}_t + \tilde{i}_t = \tilde{y}_t, \tag{62}$$

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1-\rho_R) \Big[\rho_\pi E_t \hat{\pi}_{t+1} + \rho_y \hat{y}_t \Big] + \varepsilon_t^R + \nu_{t-p}^R, \tag{63}$$

given the evolution of technologies. At the steady state, the detrended equilibrium system becomes

$$\frac{1}{\tilde{c}_t} = \tilde{\lambda}_c, \tag{64}$$

$$\gamma \tilde{c} n^{\sigma_n} = \tilde{w}, \tag{65}$$

$$\begin{aligned} q = \beta\bigg[(1+g)^{-1}\bigg\{&(1-\delta)q + r \\ &+ q\bigg[\Phi\bigg(\frac{\tilde{i}}{\tilde{k}}(1+g)\bigg) - \Phi'\bigg(\frac{\tilde{i}}{\tilde{k}}(1+g)\bigg)\frac{\tilde{i}}{\tilde{k}}(1+g)\bigg]\bigg\}\bigg], \end{aligned} \tag{66}$$

$$1 = \beta\bigg[\frac{1}{\pi} \cdot (1+g)^{-1} R\bigg], \tag{67}$$

$$\tilde{y} = A\bigg[\frac{\tilde{k}}{1+g}\bigg]^{\alpha} n^{1-\alpha}, \tag{68}$$

$$\tilde{w} = \frac{1-\alpha}{X} \cdot \frac{\tilde{y}}{n}, \tag{69}$$

$$r = \frac{\alpha}{X} \cdot \frac{\tilde{y}}{\tilde{k}}(1+g), \tag{70}$$

$$q = \bigg[\Phi'\bigg(\frac{\tilde{i}}{\tilde{k}}(1+g)\bigg)\bigg]^{-1}, \tag{71}$$

$$\bigg[1 - \frac{1-\delta}{1+g}\bigg] = \Phi\bigg(\frac{\tilde{i}}{\tilde{k}}(1+g)\bigg)\frac{1}{1+g}, \tag{72}$$

$$\tilde{c} + \tilde{i} = \tilde{y}, \tag{73}$$

given the steady-state values of exogenous variables.

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Table 1: Parameter values

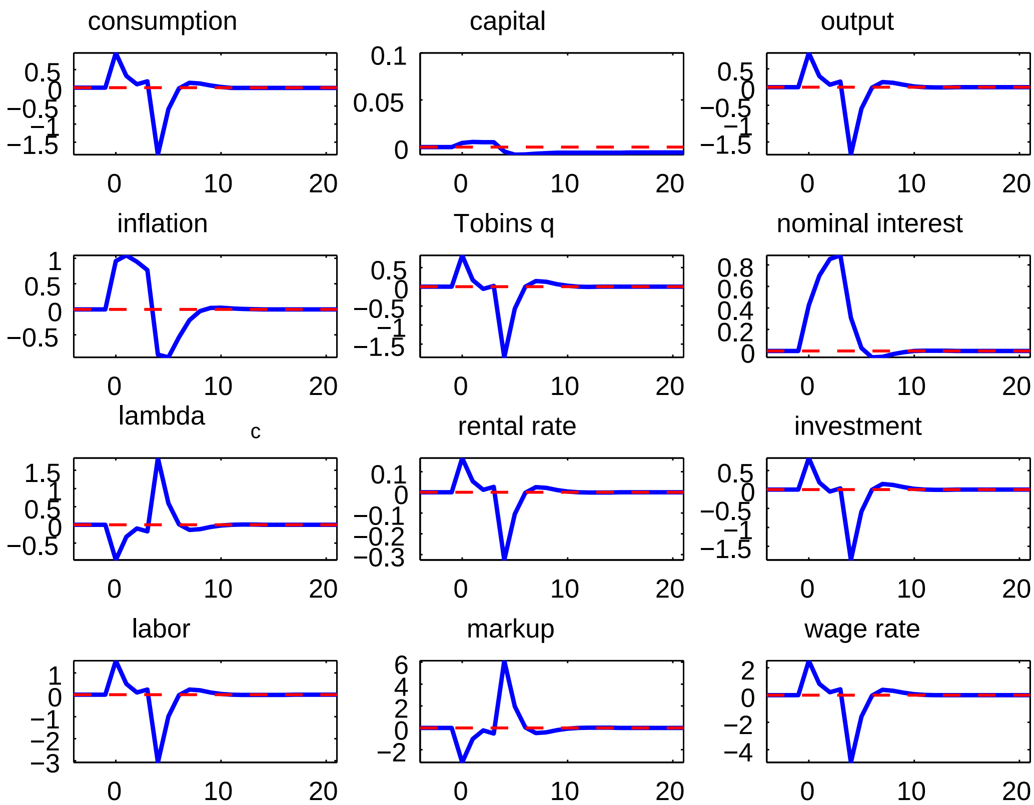
parameter	symbol	value
discount factor of households	β	$1.01358^{-.25}$
weight of disutility of labor	γ	109.82
Frisch elasticity	σ_n	1
share of capital in production	α	.4
price elasticity of investment to Tobin's q	σ_Φ	1.01
depreciation rate of capital	δ	.025
persistence of technology growth	ρ_g	.83
persistence of technology level	ρ_A	.83
steady-state technology growth	g	0
steady-state technology level	A	1
probability of price change	$1-\kappa$	.36
price indexation	η	.84
steady-state gross inflation	π	1
steady-state markup	X	1.2
persistence of nominal interest rate	ρ_R	.81
weight of inflation in Taylor rule	ρ_π	1.95
weight of output in Taylor rule	ρ_y	.18
lag of news shock	p	4

Table 2: Frictions and news-driven business cycles

		Frictions				Results on NDBCs			
		habit	AC	SP	SW	Level	q(L)	Growth	q(G)
CIMR (a)	(I)	√	flow			√			
	(II)	√	level						
CIMR (b)	(III)	√	flow	√	√	√	√	√	
	(IV)	√	flow	√		√		√	
	(V)		flow	√		√		√	
	(VI)	√	flow		√	√	√	√	
	(VII)		flow		√	√	√	√	
	(VIII)		flow	√	√	√	√	√	
Our model	(IX)		level	√		√	√	√	√
	(X)		level		√	√	√	√	√
	(XI)		level	√	√	√	√		
	(XII)	√	level	√		√	√	√	√
	(XIII)	√	level		√	√	√	√	√
	(XIV)	√	level	√	√	√	√		

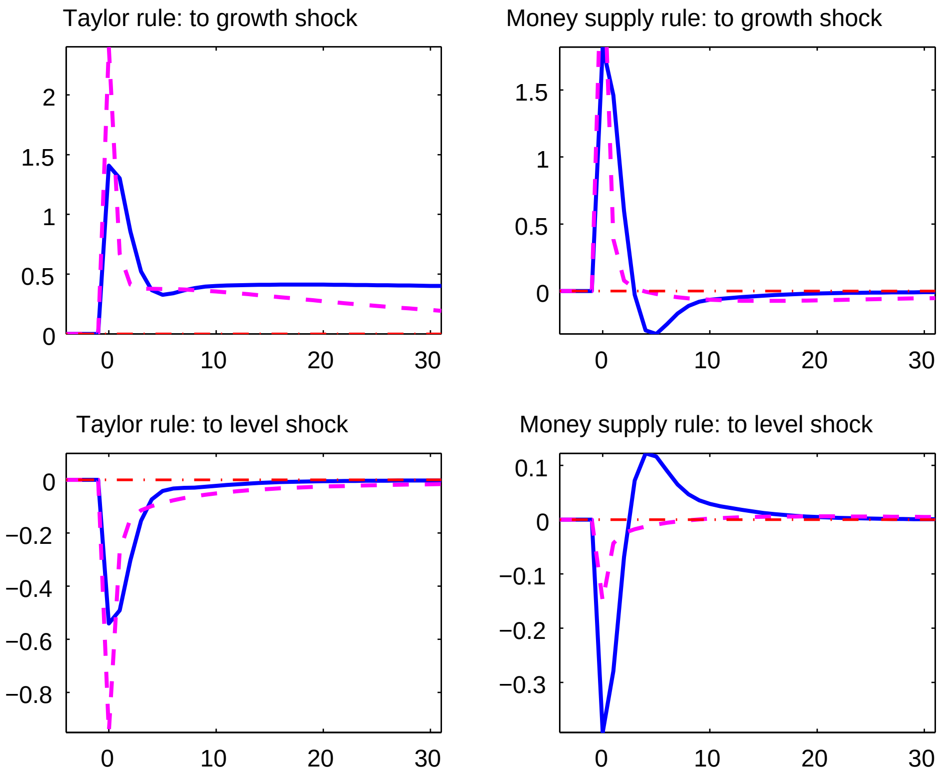
Notes: AC: adjustment costs, SP: sticky prices, SW: sticky wages, Results: NDBC from news about growth and level, q: procyclical Tobin's q from L (Level) or G (Growth) news. Frictions except for level specification of adjustment cost of investment are the same as in CIMR. The level specification is the same as our model (29).

Figure 1: NDBCs to growth news shock



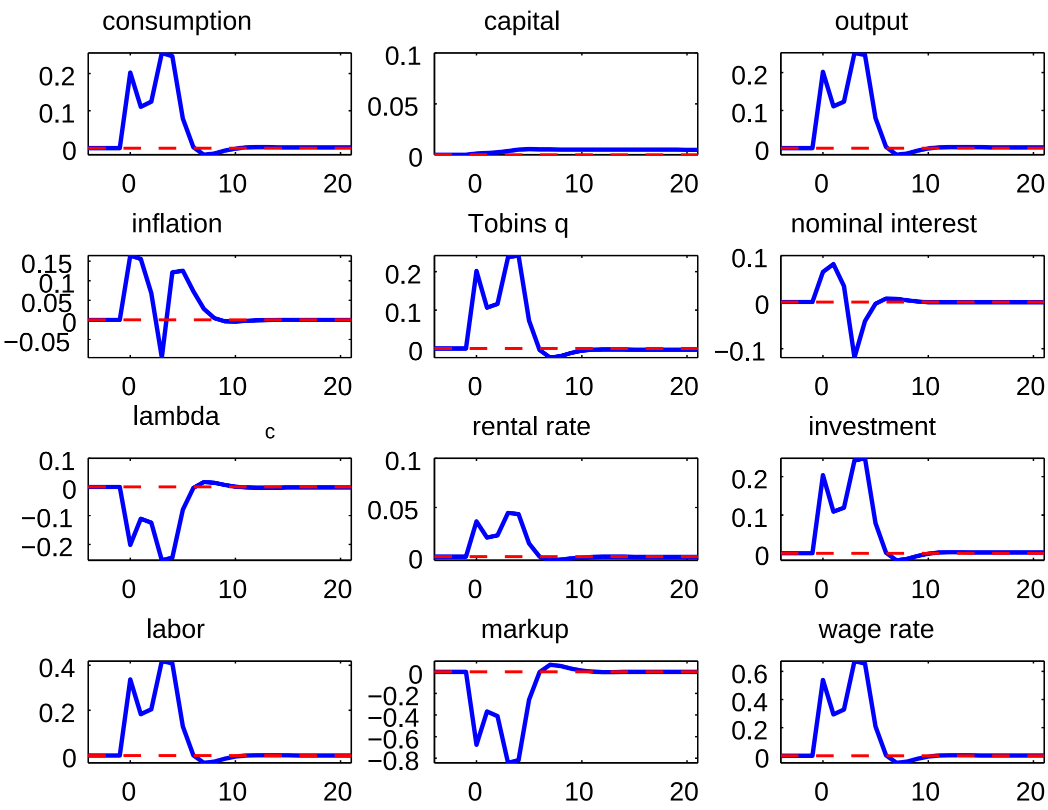
Notes: The news occurs at $t = 0$ and turns out to be false at $t = 4$. The vertical axes are percentage deviations from the steady-state values (inflation, nominal interest rate, markup and rental rate are level deviations), and the horizontal ones are quarters.

Figure 2: Impulse responses of inflation to current technology shocks



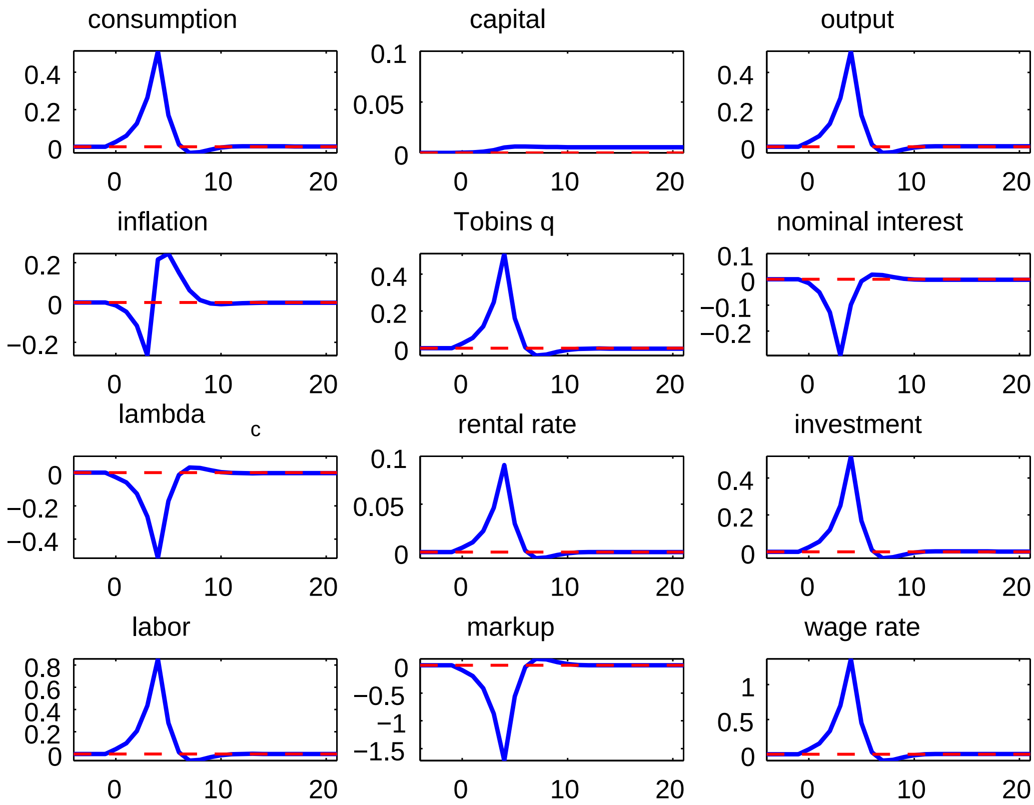
Notes: The solid lines are impulse responses of the model with adjustment costs of investment and the dashed ones are those without adjustment costs. The vertical axes are deviations from the steady-state values, and the horizontal ones are quarters.

Figure 3: NDBCs to level news shock



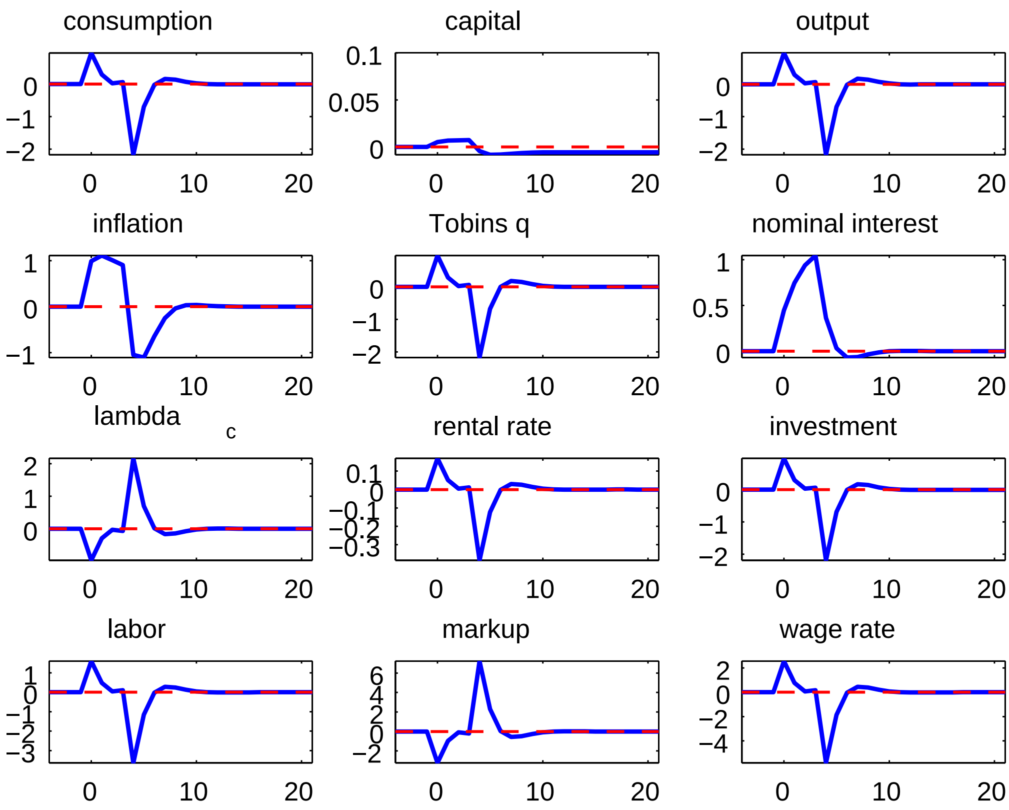
Notes: The news occurs at $t = 0$ and turns out to be false at $t = 4$. The vertical axes are percentage deviations from the steady-state values (inflation, nominal interest rate, markup and rental rate are level deviations), and the horizontal ones are quarters.

Figure 4: NDBCs to level news shock



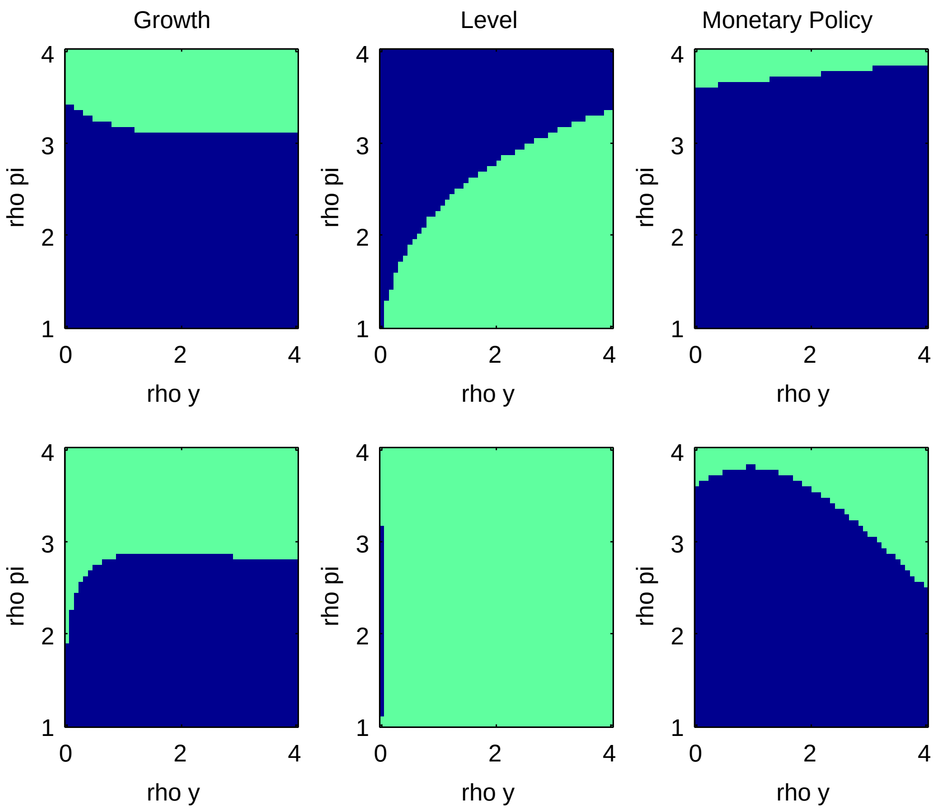
Notes: The news occurs at $t = 0$ and turns out to be false at $t = 4$. We set $\rho_y = .5$. The vertical axes are percentage deviations from the steady-state values (inflation, nominal interest rate, markup and rental rate are level deviations), and the horizontal ones are quarters.

Figure 5: NDBCs to expansionary monetary policy news shock



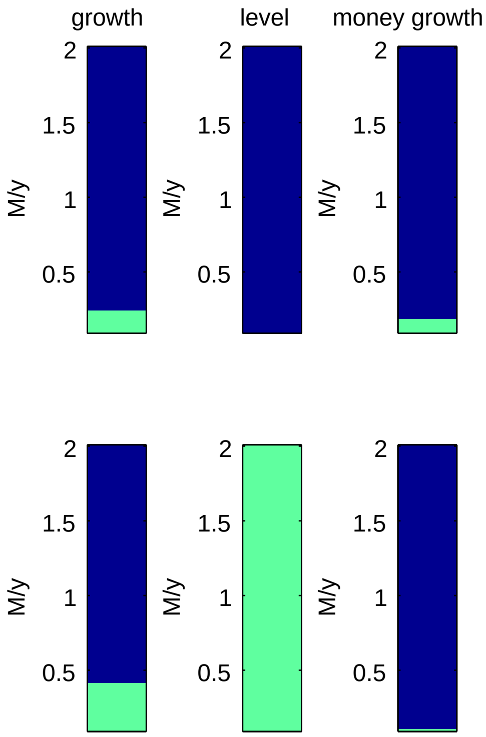
Notes: The news occurs at $t = 0$ and turns out to be false at $t = 4$. The vertical axes are percentage deviations from the steady-state values (inflation, nominal interest rate, markup and rental rate are level deviations), and the horizontal ones are quarters.

Figure 6: Regions of NDBCs



Notes: NDBCs are generated in the dark regions. The upper panels are cases with adjustment costs of investment, and lower ones are cases without adjustment costs of investment. The first column has cases of technology growth news, the second has those of technology level news, and the third has those of expansionary monetary policy news.

Figure 7: Regions of NDBCs under the money growth rule



Notes: NDBCs are generated in the dark regions. The upper panels are cases with adjustment costs of investment, and the lower ones are cases without adjustment costs of investment. The vertical axes are steady-state ratios of real money balance to output. The first column has cases of technology growth news, the second has those of technology level news, and the third has those of money supply news.