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

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Keywords: News-driven business cycles; nominal rigidities; sticky-price; monetary policy

JEL Classification: E22, E32, E37, E52

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Abstract

A news-driven business cycle is a business cycle in which positive news about the future causes a current boom defined as simultaneous increases in consumption, labor, investment, and output. Standard real business cycle models do not generate it. In this paper, we find that a fairly popular market friction, sticky prices, can be a source of a news-driven business cycle and that it can be generated due to news about future technology growth, technology level, and expansionary monetary policy shock. The key mechanism is that markups vary through nominal rigidities when the news arrives.

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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 effects of “news shock” might be one of important sources of business cycle fluctuations. A news-driven business cycle (hereafter NDBC) is a business cycle in which positive news about the future causes a current boom defined as simultaneous increases in consumption, labor, investment, and output.¹

There are two major reasons why NDBC is highlighted in modern macroeconomics. One comes from empirical episodes. The Internet bubble of the U.S. economy during the late-1990s and the Japanese bubble era during the late-1980s might be accounted for by NDBCs; positive news about the future might cause such booms.² The other comes from the theoretical side. 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 (see Beaudry and Portier, 2004). For instance, if the news of an increase in future productivity arrives and raises the present discounted value of 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 the important challenges in macroeconomic theory is investigating what kinds of features should be introduced in a standard model in order to generate NDBCs.

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

²Christiano and Fujiwara (2006) apply their model of NDBCs to account for the Japanese boom-bust cycles.

In this paper, we find that a fairly popular market friction, nominal rigidity, can be a source of NDBC's and that they can be generated by changes in markups in response to news about the future. Our model is a simple New-Keynesian sticky price model with adjustment costs of investment. It generates NDBC's due to news about technology growth, technology level, and monetary policy. When the news about technology growth (or monetary policy) arrives, people expect future inflation, which implies that the current optimal price level increases. However, price-setting firms cannot fully increase their prices because of nominal rigidities and it leads to a decrease in their markups. This decrease in markups induces an increase of aggregate demand, and output and labor input increase. Finally, household's income becomes so high that both consumption and investment increase. If the news turns out to be false, a recession, which is defined as simultaneous decreases in consumption, investment, and labor below the levels of steady-state, occurs since markup increases. In the case of news about technology level, the model without adjustment costs of investment cannot generate NDBC's since future wealth effect is small and future price does not increase. However, the model with adjustment costs of investment can generate NDBC's through a different mechanism. News provide households' incentives to increase both current consumption and investment through current wealth effect and adjustment costs of investment. In the standard RBC models, these two incentives are not compatible: consumption and investment move in opposite directions. In our model, however, these increases in demand for consumption and investment are satisfied by an increase in the aggregate supply caused by a decrease in markups. In this case, recession does not occur even if the news turns out to be false. However, the responses to news are delayed and persistent. Our model also generates procyclical movements of Tobin's q (i.e., stock prices). In our model, countercyclical movements in markups are the key feature to generate NDBC's. This countercyclicality of markups is consistent with

U.S. facts, as in Rotemberg and Woodford (1999).

Related literature is as follows. The main strand of the literature looks into the conditions for generating NDBC in the economy without market failures. Beaudry and Portier (2004, 2007) introduce the notion of NDBC inspired by Pigou (1927) into modern business cycle research. They show that a certain type of complementarity between production technologies in a multi-sector model can generate NDBC. Jaimovich and Rebelo (2006, 2007) show that NDBC are generated in a model where they assume preferences without income effect on labor supply, adjustment costs of investment, and variable capital utilization. Christiano, Ilut, Motto, and Rostagno (2007) (hereafter CIMR) show that a model with habit persistence and adjustment costs of investment generates NDBC. There is another strand of the literature that explains NDBC by market failures. 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 is one of the models that explain NDBC by market frictions. The contribution of this paper is to show that a very simple mechanism due to the most popular and standard market frictions, nominal rigidities, can generate NDBC.

We need to mention that CIMR is related to this paper since they also introduce nominal rigidities. In CIMR, NDBC are generated by news even without nominal rigidities, but Tobin's q moves countercyclically in this case. They find that the introduction of sticky prices and wages makes the model generate procyclical movements of Tobin's q . Therefore, the key mechanism that generates NDBC is habit persistence and adjustment costs of investment in CIMR, while, in our model, it is movements of markup through price stickiness. In our model, NDBC are generated without habit persistence in preference and even without

adjustment costs of investment.³

The organization of this paper is as follows. Section 2 introduces our model, a simple New Keynesian sticky-price model with adjustment costs of investments. In Section 3, we set parameter values, and show that our model generates NDBC's by numerical experiments. Positive news about technology growth, technology level, and expansionary monetary policy generate current booms in our model. Section 4 draws 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 monetary authority. Price staggeredness occurs in the intermediate-goods sector.

2.1 Households

Households consume c_t , invest i_t , own capital stock k_{t-1} at the beginning of period, supply labor n_t and capital service k_{t-1} to competitive firms, and earn wage $w_t n_t$ and rent of capital $r_t k_{t-1}$. Households also own one-period bonds and money as assets. The budget constraint of households is

$$c_t + i_t + \frac{M_t}{P_t} + \frac{B_t}{P_t} \leq w_t n_t + r_t k_{t-1} + F_t + T_t + \frac{M_{t-1}}{P_t} + \frac{R_t B_{t-1}}{P_t}, \quad (1)$$

where P_t is the nominal price, M_t is the money supply, B_t is the one-period bonds, R_t is the nominal interest rate, F_t is a lump-sum transfer from the monopolistic intermediate-goods firms, T_t is a lump-sum transfer from the central bank. The

³Fujiwara (2007) find that it is difficult to generate NDBC's as responses to *growth* shock in CIMR model while our model can generate them.

evolution of capital stock follows

$$k_t = (1 - \delta)k_{t-1} + \Phi\left(\frac{i_t}{k_{t-1}}\right)k_{t-1}, \quad (2)$$

where $\Phi(\cdot)$ is the reduced form of the adjustment cost of investment. We assume that $\Phi'(\cdot) > 0$, $\Phi''(\cdot) < 0$ as in Bernanke, Gertler, and Gilchrist (1999). Note that adjustment costs of investment are not necessary to generate NDBC in the case of news about technology growth and monetary policy.⁴ The main purpose for the introduction adjustment costs of investment is to generate procyclical movements of Tobin's q (stock price). The utility function of households is

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{[c_t^{1-\gamma}(1-n_t)\gamma]^{1-\theta}}{1-\theta} + \xi \frac{(M_t/P_t)^{1-\theta'}}{1-\theta'} \right\}. \quad (3)$$

We restrict $(1-\theta)(1-\gamma) = 1-\theta'$ to guarantee the existence of the balanced growth path. Finally, the household's problem maximizes (3) subject to (1) and (2). The first order necessary conditions are as follows.

$$(1-\gamma)c_t^{(1-\gamma)(1-\theta)-1}(1-n_t)^{\gamma(1-\theta)} = \lambda_{c,t}, \quad (4)$$

$$\frac{\gamma}{1-\gamma} \cdot \frac{c_t}{1-n_t} = w_t, \quad (5)$$

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

$$1 = \beta E_t \left[\frac{1}{\pi_{t+1}} \cdot \frac{\lambda_{c,t+1}}{\lambda_{c,t}} R_{t+1} \right], \quad (7)$$

$$q_t = \left[\Phi'\left(\frac{i_t}{k_{t-1}}\right) \right]^{-1}, \quad (8)$$

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 (2), the evolution of capital. (5) is the intra-temporal consumption-leisure-choice optimization condition. (6) is the Euler equa-

⁴The details of this are in Section 3.3.

tion for capital holding, and (7) is that for government debt holding. (8) is the first-order condition for investment, and determines Tobin's q .⁵

2.2 Final-goods firms

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

$$y_t = \left(\int_0^1 Y_t(z)^{\frac{\varepsilon-1}{\varepsilon}} dz \right)^{\frac{\varepsilon}{\varepsilon-1}} \quad (9)$$

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

$$Y_t(z) = \left(\frac{P_t(z)}{P_t} \right)^{-\varepsilon} y_t, \quad (10)$$

where P_t denotes the aggregate price level and $P_t(z)$ denotes the price level of intermediate good indexed by z . Combining (9) and (10) yields the following price index for intermediate goods:

$$P_t = \left(\int_0^1 P_t(z)^{1-\varepsilon} dz \right)^{\frac{1}{1-\varepsilon}}. \quad (11)$$

2.3 Intermediate-goods firms

The intermediate-goods firms are monopolistic 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 is⁶

$$Y_t(z) = A_t \left[K_t(z) \right]^\alpha \left[\zeta_t N_t(z) \right]^{1-\alpha}, \quad (12)$$

⁵We ignore the first-order condition of money since it does not matter in the equilibrium system.

⁶Our production function is the same as in Aguiar and Gopinath (2007). They find that the growth shocks can account for the business cycles of the emerging economies.

where A_t and ζ_t denote technologies, and they evolve according to the first order autoregressive processes:

$$\ln(A_{t+1}) = \rho_A \ln(A_t) + (1 - \rho_A) \ln(A) + \varepsilon_{t+1}^A, \quad (13)$$

$$g_{t+1} = \rho_g g_t + (1 - \rho_g)g + \varepsilon_{t+1}^g, \quad (14)$$

where $g_t \equiv \ln(\zeta_t/\zeta_{t-1})$, and then, ζ_t is integrated of order one: I(1). A and g denote the steady-state values of A_t and g_t , respectively. ε_{t+1}^g and ε_{t+1}^A are i.i.d. shocks with zero means and interpreted as technology growth and level shocks, respectively. As we will show, NDBC's are generated due to news on both technology growth and level in our model. The cost minimization problem implies

$$w_t = mc_t \cdot (1 - \alpha) \cdot \frac{Y_t(z)}{N_t(z)}, \quad (15)$$

$$r_t = mc_t \cdot \alpha \cdot \frac{Y_t(z)}{K_t(z)}, \quad (16)$$

where mc_t is the real marginal cost. We introduce markup, $X_t \equiv 1/mc_t$, which is the inverse of the real marginal cost. Therefore, (17) and (18) become

$$w_t = \frac{1 - \alpha}{X_t} \cdot \frac{Y_t(z)}{N_t(z)}, \quad (17)$$

$$r_t = \frac{\alpha}{X_t} \cdot \frac{Y_t(z)}{K_t(z)}. \quad (18)$$

The intermediate goods firms set their prices subject to Calvo-type price staggeredness. Therefore, the price can be changed at t only with probability $1 - \kappa$. Denote with $P_t^*(z)$ the reset price and with $Y_{t+k}^*(z) \equiv (P_t^*(z)/P_{t+k})^{-\varepsilon} y_{t+k}$ the corresponding demand.

The problem of retailers who can change their price levels at period t is

$$\max_{P_t^*(z)} \sum_{k=0}^{\infty} \kappa^k \beta^k E_t \left\{ \frac{\lambda_{c,t+k}}{\lambda_{c,t}} \left(\frac{P_t^*(z)}{P_{t+k}} - mc_{t+k} \right) Y_{t+k}^*(z) \right\}. \quad (19)$$

By the first-order condition and the definition of markup, optimal $P_t^*(z)$ solves

$$\sum_{k=0}^{\infty} \kappa^k \beta^k E_t \left\{ \frac{\lambda_{c,t+k}}{\lambda_{c,t}} \left(\frac{P_t^*(z)}{P_{t+k}} \right)^{-\varepsilon} \left(\frac{P_t^*(z)}{P_{t+k}} - \frac{X}{X_{t+k}} \right) y_{t+k} \right\} = 0. \quad (20)$$

where $X \equiv \varepsilon/(\varepsilon - 1)$. The lump-sum transfer is $F_t = (1 - 1/X_t)y_t$.

The aggregate price level evolution is

$$P_t = \left[\kappa P_{t-1}^{1-\varepsilon} + (1 - \kappa)(P_t^*)^{1-\varepsilon} \right]^{1/(1-\varepsilon)}. \quad (21)$$

By the log-linearized equations of (20) and (21) around the steady-state with zero inflation, we obtain the New Keynesian Phillips Curve,

$$\hat{\pi}_t = \beta E_t \left[\hat{\pi}_{t+1} \right] - \frac{(1 - \kappa)(1 - \kappa\beta)}{\kappa} \hat{x}_t, \quad (22)$$

where $\hat{\pi}_t \equiv \ln(P_t/P_{t-1})$ and $\hat{x}_t \equiv \ln(X_t/X)$.

2.4 Market clearing conditions

The market clearing conditions of capital and labor are

$$k_{t-1} = \int_0^1 K_t(z) dz, \quad (23)$$

$$n_t = \int_0^1 N_t(z) dz. \quad (24)$$

The resource constraint is

$$c_t + i_t = y_t, \quad (25)$$

and the aggregate production function⁷ is

$$y_t = A_t k_{t-1}^\alpha \left[\zeta_t n_t \right]^{1-\alpha}. \quad (26)$$

⁷Following Iacoviello (2005) and Bernanke, Gertler, and Gilchrist (1999), we approximate $y_t = \int_0^1 (P_t(z)/P_t)^\varepsilon Y_t(z) dz \approx \int_0^1 Y_t(z) dz$. This is justified around the steady-state with zero inflation.

2.5 Monetary policy

The monetary authority follows, as in Dittmar, Gavin, and Kydland (2005), the backward-looking Taylor rule,

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1 - \rho_R) \left[\rho_\pi \hat{\pi}_{t-1} + \rho_y \hat{y}_{t-1} \right] + \varepsilon_t^R, \quad (27)$$

where \hat{y}_t is output gap, \hat{R}_t is deviation of nominal interest rate from the steady-state, and ε_t^R is i.i.d. monetary policy shock with zero mean.⁸

2.6 Equilibrium

Here, we define a competitive equilibrium of this economy as follows.

Definition 1 (Recursive competitive equilibrium) *A recursive competitive equilibrium consists of (I) price functions $\{\pi(\mathbf{s}), X(\mathbf{s}), w(\mathbf{s}), r(\mathbf{s}), R(\mathbf{s})\}$, (II) aggregate decision rules $\{c(\mathbf{s}), n(\mathbf{s}), i(\mathbf{s}), k(\mathbf{s}), y(\mathbf{s})\}$, and (III) evolutions of states $\mathbf{s}' = \Psi(\mathbf{s}, \boldsymbol{\varepsilon}')$, where $\mathbf{s}_t \equiv [k_{t-1}, y_{t-1}, \pi_{t-1}, R_{t-1}, g_t, A_t, \varepsilon_t^R]'$ and $\boldsymbol{\varepsilon}_{t+1} \equiv [\varepsilon_{t+1}^A, \varepsilon_{t+1}^g]'$, that satisfy (i) household's optimization conditions and first-order conditions of intermediate-goods and final-goods firms; (5), (6), (7), (8), (17), (18), and (22), (ii) market clearing conditions; (23), (24), (25), and (26), and (iii) monetary policy rule; (27), given evolutions of exogenous technologies; (13) and (14).*

2.7 News-driven business cycles

In the next section, we investigate whether our model generates NDBC's or not. To do this, we define NDBC's as follows.

⁸Our results are robust to other specifications of Taylor rule. For example, if the monetary authority follows the forward-looking Taylor rule as in CIMR is

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1 - \rho_R) \left[\rho_\pi E_t \left\{ \hat{\pi}_{t+1} \right\} + \rho_y \hat{y}_t \right] + \varepsilon_t^R, \quad (28)$$

NDBC's are generated.

Definition 2 (News-driven business cycles) *News-driven business cycles (NDBC) are simultaneous increases in consumption c_t , labor n_t , investment i_t , and output y_t in response to positive news about T -period-ahead future technology growth ($\varepsilon_{t+T}^g > 0$) or level ($\varepsilon_{t+T}^A > 0$) or monetary policy ($\varepsilon_{t+T}^R < 0$) arrives at period t .*

Then, we focus only on directions of responses of consumption, labor, investment, and output when the news arrives to judge whether NDBC are generated or not in our model.

3 News-Shock Experiments

3.1 Parameter values

The values of parameters are in Table 1.

[Insert Table 1]

The model is specified to be a quarterly one. Most parameter values are standard. The discount factor of household β is .99, implying that the annual real interest rate is 4 %. The curvature of the utility function θ is 1, or we assume the log-utility function. The weight of leisure γ is set such that the steady-state labor supply n equals to 1/3. The share of capital in the production α is .36, and the depreciation rate of capital δ is .02.

We specify the functional form of adjustment costs of investment as

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

where q is the steady-state of Tobin's q , and $\Phi(0) = 0$ and $\Phi(\delta + g) = \delta + g$.⁹ If we employ this specification, the first order condition (8) is

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

Detrending and log-linearizing (30) yields

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

where variables with the notation $\hat{\cdot}$ denote the log-deviation from the steady-state. Then, the parameter σ is the price elasticity of investment (elasticity of investment with respect to Tobin's q) and we set $\sigma = 1.01$.¹⁰ The values of \bar{a} and \bar{b} is determined as a solution of $\Phi(0) = 0$ and $\Phi(\delta + g) = \delta + g$ given σ and q . Note that even if there is no adjustment cost of investment, our model generates NDBC's as responses to news about technology growth and monetary policy shock.¹¹ However, to generate the procyclical movement of Tobin's q , we introduce adjustment costs of investment. Our model can generate NDBC's if we employ other specifications of adjustment costs of investment. Even if we employ the "level specification" of adjustment costs of investment as in CIMR:

$$\Phi(\omega) \equiv \omega - \frac{\delta}{2\sigma}(\omega - \bar{\omega})^2, \quad (32)$$

where $\bar{\omega}$ is the steady-state value of ω , NDBC's are generated under suitable parameter values. Our result is also robust to the "flow specification" of adjustment

⁹This specification is slightly different from that of Bernanke, Gertler, and Gilchrist (1999). They assume that $\Phi(0) = 0$ and the steady-state value of Tobin's q equals one while the steady-state value of Tobin's q is greater than one in our specification. However, this difference does not matter; even if we employ the same specification as in Bernanke, Gertler, and Gilchrist (1999), NDBC's are generated.

¹⁰To guarantee a positive value of \bar{a} , the value of σ should be greater than one. This is shown by the steady-state equilibrium conditions.

¹¹As we will show, the adjustment cost of investment is important to generate NDBC's in response to news about technology level.

costs of investment as in CIMR:

$$k_t = (1 - \delta)k_{t-1} + \Psi \left(\frac{i_t}{i_{t-1}} \right) i_t, \quad (33)$$

$$\Psi(\omega) \equiv \omega - \sigma_\Psi(\omega - \bar{\omega})^2. \quad (34)$$

However, the model with the flow specification might not generate the procyclical movements of Tobin's q under some parameter values. On the contrary, models with the level specification or our specification generate them as long as NDBC's are generated. This is easily verified by (31).

The persistence of exogenous technologies ρ_g and ρ_A are .95. However, these parameters does not change results and NDBC's are generated even if $\rho_g = 0$ and $\rho_A = 0$. The steady-state technology growth g is set to be zero in order to see effects of news shocks without worrying about scaling and this does not change results at all. The steady-state technology level A is normalized to one.

The probability of price change $1 - \kappa$ is .25. The steady-state gross inflation π is 1, and the steady-state markup X is 1.05. The persistence of nominal interest rate ρ_R is .73. These are taken from Iacoviello (2005). It is hard to decide the values of the weights of inflation and output gaps, ρ_π and ρ_y , in the Taylor rule since these estimates vary in the literature. We set $\rho_\pi = 1.5$ and $\rho_y = .2$ as a benchmark case and we will check the sensitivity of these values in Section 3.3.¹²

3.2 News-shock experiments

To calculate policy functions of our economy, we detrend the equilibrium system by growing technology ζ_t since the economy is growing, and ζ_t is integrated of order one, or I(1).¹³ We approximate this detrended economy by the log-linearization

¹²One of strategies to decide parameter values is to estimate our model directly by employing Bayesian methods. However, we don't take this strategy since it is difficult to identify current growth and level technology shocks and to identify news shocks about both growth and level.

¹³The equilibrium system and the detrended system are in Appendix A.

technique, and calculate policy functions without news shocks following the method of Uhlig (1999). The method to calculate policy functions under news shocks is in Appendix B.

Our numerical experiment is as follows. For $t \leq -1$, the economy is at the deterministic steady-state, where all agents believe that there will be no shocks at all in the future: $\varepsilon_t^j = 0$ for all t and $j = g, A, R$. In period $t = 0$, the agents receive news that there will be a productivity or policy shock at $t = 4$ (one year after): $\varepsilon_4^j = \bar{\varepsilon} \neq 0$. The agents have complete confidence in the news, so that, for $t = 0, \dots, 3$, they believe that $\varepsilon_4^j = \bar{\varepsilon}$ with probability one. However, at $t = 4$, the news turns out to be false.

News about technology growth ε_t^g : Figure 1 shows that NDBC's are generated as responses to news about technology growth $\varepsilon_4^g = .01$.

[Insert Figure 1]

Note that variables are defined as detrended.

When good news arrives, people expect that inflation rate will increase in the future, which is verified by the impulse response functions of inflation to technology growth shock as in Figure 2.

[Insert Figure 2]

The New Keynesian Phillips Curve (22) 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 demands and output and labor input increase. Finally, household income becomes so high that both consumption and investment increase.

Note that, when the news turns out to be false, the economy falls into recession defined as simultaneous decreases at $t = 4$ (or year 1) in consumption, labor, investment, and output to lower levels than those of the steady-state. 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. Models with collateral constraints as in Koabayashi, 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 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). In our model, countercyclical movement of markups is key feature in generating NDBC's and this countercyclicality of markups is consistent with U.S. facts as in Rotemberg and Woodford (1999).¹⁴

News about technology level ε_t^A : Figure 3 shows that NDBC's are generated as responses to news about technology level $\varepsilon_4^A = .01$.

[Insert Figure 3]

There are three differences from the case of news about technology growth: (i) responses to news are delayed and persistence, (ii) deflation occurs when the news

¹⁴The U.S. and the Japanese experiences show that 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.

arrives, and (iii) recession does not occur even if the news turns out to be false. These features imply that the mechanism of NDBC is different between two news, since in the case of growth news a boom occurs due to a decrease in markups, which is caused by the future and current inflations. In this economy, inflation does not occur as responses to current technology level shock as in Figure 2, which is a standard property of sticky-price model. In case of news about technology level, the adjustment costs of investment is the key friction that generates NDBC. This friction works together with the nominal rigidities. To smooth the investment intertemporally in response to the future increase in technology level, households increase current investment when the news arrives. 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 satisfied by an increase in the aggregate supply caused by decrease in the markups and increase of labor input. Then, output increases. This is easily verified by the intratemporal optimization condition:

$$\frac{\gamma}{1-\gamma} \cdot \frac{c_t}{1-n_t} = \frac{1-\alpha}{X_t} \left[\frac{k_{t-1}}{n_t} \right]^\alpha A_t \zeta_t^{1-\alpha}. \quad (35)$$

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

News about monetary policy ε_t^R : Figure 4 shows that NDBC are generated in response to news about expansionary monetary policy shock, $\varepsilon_4^R = -.01$.

[Insert Figure 4]

When the news arrives, a boom occurs. If the news turns out to be false subsequently, 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. The U-shaped responses between period 1–3 are due to the adjustment costs of investment.

3.3 Monetary policy and news-driven business cycles

Parameters in Taylor rule: In Section 3.2, we chose parameters in the Taylor rule, ρ_π and ρ_y , arbitrarily. Here, we investigate the region in which NDBC are generated. We try various sets of parameters $(\rho_\pi, \rho_y) \in [1, 3] \times [0, 3]$, and check whether model predictions are consistent with Definition 2 or not.¹⁵ In the dark blue regions in Figure 5 are ones in which NDBC are generated.

[Insert Figure 5]

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

Note that in the case without adjustment costs NDBC are generated even if the news is about technology level under suitable sets of parameter values. Figure 6 is the enlarged (2,2) panel of Figure 5.

[Insert Figure 6]

This implies that NDBC are generated if ρ_π is in the range 1.1–1.7 and if reaction to output gap is small, or ρ_y is small enough; under such a policy, the news increases

¹⁵Note that the parameter ρ_π should be greater than one to satisfy the Blanchard-Kahn condition.

future inflation and decrease of current markups.

We also find that adjustment costs of investment expand regions in which NDBC are generated. If there are adjustment costs of investment, NDBC are generated in the broad range of parameters to news about monetary policy. The region of NDBC due to 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 costs of investment is key to generate NDBC. In the cases of news about technology growth and monetary policy, the news decreases markups through nominal rigidities, and households' income become high enough to increase both consumption and investment. However, households increase only consumption by decreasing investment if increase of income is not so high. The adjustment costs of investment make households have incentive to invest and help our model to generate NDBC. The panels in the lower row imply that NDBC are not generated due to news about technology growth and monetary policy if ρ_π is high. This is because high ρ_π prevents the news from generating future inflations and from decreasing markups.

In the case with adjustment costs of investment, news about technology level causes NDBC 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. The weight on output ρ_y in the Taylor rule generates negative correlation between output gap and inflation as pointed out in Dittmar, Gavin, and Kydland (2005). When a positive news on the future technology level comes, a high ρ_y causes deflationary pressure which prevents a current boom from occur-

ring. Therefore, ρ_y should be small in order to generate NDBC's due to news about technology level.

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

$$M_t = (1 + \mu_t)M_{t-1}, \quad (36)$$

$$\mu_t = \rho_\mu \mu_{t-1} + (1 - \rho_\mu)\mu + \varepsilon_t^\mu, \quad (37)$$

where μ is the steady-state money growth rate, and ε_t^μ is an i.i.d. money supply shock. In this case, the real money balance M_t/P_t becomes an endogenous state variable of the model, and we have to consider the first-order condition of money explicitly:

$$\lambda_t = \xi \left[\frac{M_t}{P_t} \right]^{-\theta'} + \beta E_t \left[\frac{1}{\pi_{t+1}} \cdot \lambda_{t+1} \right], \quad (38)$$

which implies that the marginal utility of consumption in the left-hand side equals the marginal utility of money holding in the right-hand side. 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 NDBC's are as in Figure 7.

[Insert Figure 7]

We check whether or not NDBC's 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 blue regions, NDBC's are generated due to news about growth and money supply shock even if we employ the money supply rule. Note that NDBC's are generated in the broad range of M/y . The intuitive mechanism of NDBC's is similar to the case of the Taylor rule since inflation occurs due to current technology growth shocks and

deflation occurs due to current technology level shocks as shown in the right-hand side panel of Figure 2. We set $M/y = .5$ in Figure 2. Then, we find that even if we employ the money supply rule as monetary policy, our sticky-price model can generate NDBC.

4 Conclusion

A news-driven business cycle (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 NDBC. In this paper, we found that a New Keynesian sticky-price model with adjustment costs of investment can generate NDBC. NDBC are generated by news about technology growth, technology level, and expansionary monetary policy shock. Our model also generate procyclical movements of Tobin's q . 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 the news arrives. 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 A: Equilibrium System

The equilibrium system is as follows.

$$(1 - \gamma)c_t^{(1-\gamma)(1-\theta)-1}(1 - n_t)^{\gamma(1-\theta)} = \lambda_{c,t}, \quad (39)$$

$$\frac{\gamma}{1 - \gamma} \cdot \frac{c_t}{1 - n_t} = w_t, \quad (40)$$

$$q_t = \beta E_t \left[\frac{\lambda_{c,t+1}}{\lambda_{c,t}} \left\{ (1 - \delta)q_{t+1} + r_{t+1} + q_{t+1} \left[\Phi \left(\frac{i_{t+1}}{k_t} \right) - \Phi' \left(\frac{i_{t+1}}{k_t} \right) \frac{i_{t+1}}{k_t} \right] \right\} \right], \quad (41)$$

$$1 = \beta E_t \left[\frac{1}{\pi_{t+1}} \cdot \frac{\lambda_{c,t+1}}{\lambda_{c,t}} R_{t+1} \right], \quad (42)$$

$$y_t = A_t \cdot k_{t-1}^\alpha \cdot \left[\zeta_t n_t \right]^{1-\alpha}, \quad (43)$$

$$w_t = \frac{1 - \alpha}{X_t} \cdot \frac{y_t}{n_t}, \quad (44)$$

$$r_t = \frac{\alpha}{X_t} \cdot \frac{y_t}{k_{t-1}}, \quad (45)$$

$$q_t = \left[\Phi' \left(\frac{i_t}{k_{t-1}} \right) \right]^{-1}, \quad (46)$$

$$k_t = (1 - \delta)k_{t-1} + \Phi \left(\frac{i_t}{k_{t-1}} \right) k_{t-1}, \quad (47)$$

$$\hat{\pi}_t = \beta E_t \left[\hat{\pi}_{t+1} \right] - \frac{(1 - \kappa)(1 - \kappa\beta)}{\kappa} \hat{x}_t, \quad (48)$$

$$c_t + i_t = y_t, \quad (49)$$

$$\ln(A_{t+1}) = \rho_A \ln(A_t) + (1 - \rho_A) \ln(\bar{A}) + \varepsilon_{t+1}^A, \quad (50)$$

$$g_{t+1} = \rho_g g_t + (1 - \rho_t) \bar{g} + \varepsilon_{t+1}^g, \quad (51)$$

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1 - \rho_R) \left[\rho_\pi \hat{\pi}_{t-1} + \rho_y \hat{y}_{t-1} \right] + \varepsilon_t^R. \quad (52)$$

For detrending, we introduce the detrended variables

$$\tilde{G}_t \equiv \frac{G_t}{\zeta_t}, \quad (53)$$

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

$$\tilde{\lambda}_{c,t} \equiv \frac{\lambda_{c,t}}{\zeta_t^{(1-\gamma)(1-\theta)-1}}. \quad (54)$$

The detrended equilibrium system is as follows.

$$(1 - \gamma)\tilde{c}_t^{(1-\gamma)(1-\theta)-1}(1 - n_t)^{\gamma(1-\theta)} = \tilde{\lambda}_{c,t}, \quad (55)$$

$$\frac{\gamma}{1 - \gamma} \cdot \frac{\tilde{c}_t}{1 - n_t} = \tilde{w}_t, \quad (56)$$

$$q_t = \beta E_t \left[\frac{\tilde{\lambda}_{c,t+1}}{\tilde{\lambda}_{c,t}} (1 + g_{t+1})^{(1-\gamma)(1-\theta)-1} \left\{ (1 - \delta)q_{t+1} + r_{t+1} + q_{t+1} \left[\Phi \left(\frac{\tilde{i}_{t+1}}{\tilde{k}_t} (1 + g_{t+1}) \right) - \Phi' \left(\frac{\tilde{i}_{t+1}}{\tilde{k}_t} (1 + g_{t+1}) \right) \frac{\tilde{i}_{t+1}}{\tilde{k}_t} (1 + g_{t+1}) \right] \right\} \right], \quad (57)$$

$$1 = \beta E_t \left[\frac{1}{\pi_{t+1}} \cdot \frac{\tilde{\lambda}_{c,t+1}}{\tilde{\lambda}_{c,t}} (1 + g_{t+1})^{(1-\gamma)(1-\theta)-1} R_{t+1} \right], \quad (58)$$

$$\tilde{y}_t = A_t \left[\frac{\tilde{k}_{t-1}}{1 + g_t} \right]^\alpha n_t^{1-\alpha}, \quad (59)$$

$$\tilde{w}_t = \frac{1 - \alpha}{X_t} \cdot \frac{\tilde{y}_t}{n_t}, \quad (60)$$

$$r_t = \frac{\alpha}{X_t} \cdot \frac{\tilde{y}_t}{\tilde{k}_{t-1}} (1 + g_t), \quad (61)$$

$$q_t = \left[\Phi' \left(\frac{\tilde{i}_t}{\tilde{k}_{t-1}} (1 + g_t) \right) \right]^{-1}, \quad (62)$$

$$\tilde{k}_t = \frac{1 - \delta}{1 + g_t} \tilde{k}_{t-1} + \Phi \left(\frac{\tilde{i}_t}{\tilde{k}_{t-1}} (1 + g_t) \right) \frac{\tilde{k}_{t-1}}{1 + g_t}, \quad (63)$$

$$\hat{\pi}_t = \beta E_t \left[\hat{\pi}_{t+1} \right] - \frac{(1 - \kappa)(1 - \kappa\beta)}{\kappa} \hat{x}_t, \quad (64)$$

$$\tilde{c}_t + \tilde{i}_t = \tilde{y}_t, \quad (65)$$

$$\ln(A_{t+1}) = \rho_A \ln(A_t) + (1 - \rho_A) \ln(\bar{A}) + \varepsilon_{t+1}^A, \quad (66)$$

$$g_{t+1} = \rho_g g_t + (1 - \rho_g) \bar{g} + \varepsilon_{t+1}^g, \quad (67)$$

$$\hat{R}_t = \rho_R \hat{R}_{t-1} + (1 - \rho_R) \left[\rho_\pi \hat{\pi}_{t-1} + \rho_y \hat{y}_{t-1} \right] + \varepsilon_t^R. \quad (68)$$

At the steady-state, the detrended equilibrium system becomes

$$(1 - \gamma)\tilde{c}^{(1-\gamma)(1-\theta)-1}(1 - n)^{\gamma(1-\theta)} = \tilde{\lambda}_c, \quad (69)$$

$$\frac{\gamma}{1 - \gamma} \cdot \frac{\tilde{c}}{1 - n} = \tilde{w}, \quad (70)$$

$$q = \beta \left[(1 + g)^{(1-\gamma)(1-\theta)-1} \left\{ (1 - \delta)q + r + q \left[\Phi \left(\frac{\tilde{i}}{\tilde{k}}(1 + g) \right) - \Phi' \left(\frac{\tilde{i}}{\tilde{k}}(1 + g) \right) \frac{\tilde{i}}{\tilde{k}}(1 + g) \right] \right\} \right], \quad (71)$$

$$1 = \beta \left[\frac{1}{\pi} \cdot (1 + g)^{(1-\gamma)(1-\theta)-1} R \right], \quad (72)$$

$$\tilde{y} = A \left[\frac{\tilde{k}}{1 + g} \right]^\alpha n^{1-\alpha}, \quad (73)$$

$$\tilde{w} = \frac{1 - \alpha}{X} \cdot \frac{\tilde{y}}{n}, \quad (74)$$

$$r = \frac{\alpha}{X} \cdot \frac{\tilde{y}}{\tilde{k}}(1 + g), \quad (75)$$

$$q = \left[\Phi' \left(\frac{\tilde{i}}{\tilde{k}}(1 + g) \right) \right]^{-1}, \quad (76)$$

$$\left[1 - \frac{1 - \delta}{1 + g} \right] = \Phi \left(\frac{\tilde{i}}{\tilde{k}}(1 + g) \right) \frac{1}{1 + g}, \quad (77)$$

$$\tilde{c} + \tilde{i} = \tilde{y}, \quad (78)$$

given the steady-state of exogenous variables.

Appendix B: Policy Function under News Shock

Here, we explain how to compute policy functions under news shock.

B.1 Linearized system and policy functions in an economy without news shock

First, we employ the log-linearization technique to approximate the detrended equilibrium system. Following Uhlig (1999), the matrix representation of the linearized

equilibrium system without news shocks is

$$\mathbf{A}\mathbf{x}_t + \mathbf{B}\mathbf{x}_{t-1} + \mathbf{C}\mathbf{y}_t + \mathbf{D}\mathbf{z}_t = \mathbf{0}, \quad (79)$$

$$E_t \left[\mathbf{F}\mathbf{x}_{t+1} + \mathbf{G}\mathbf{x}_t + \mathbf{H}\mathbf{x}_{t-1} + \mathbf{J}\mathbf{y}_{t+1} + \mathbf{K}\mathbf{y}_t + \mathbf{L}\mathbf{z}_{t+1} + \mathbf{M}\mathbf{z}_t \right] = \mathbf{0}, \quad (80)$$

$$\mathbf{z}_{t+1} = \mathbf{N}\mathbf{z}_t + \boldsymbol{\varepsilon}_{t+1}, \quad E_t \left[\boldsymbol{\varepsilon}_{t+1} \right] = \mathbf{0}, \quad (81)$$

where \mathbf{x}_t , \mathbf{y}_t , and \mathbf{z}_t denote vectors of endogenous state variables, endogenous jump variables, and exogenous variables, respectively. Using the method of Uhlig (1999), we obtain the policy functions;

$$\mathbf{x}_t = \mathbf{P}\mathbf{x}_{t-1} + \mathbf{Q}\mathbf{z}_t, \quad (82)$$

$$\mathbf{y}_t = \mathbf{R}\mathbf{x}_{t-1} + \mathbf{S}\mathbf{z}_t. \quad (83)$$

For our news shock experiments, we introduce a more simple form of the equilibrium system and policy functions. (79) and (80) can be summarized as follows:

$$E_t \left[\tilde{\mathbf{F}}\tilde{\mathbf{x}}_{t+1} + \tilde{\mathbf{G}}\tilde{\mathbf{x}}_t + \tilde{\mathbf{H}}\tilde{\mathbf{x}}_{t-1} + \tilde{\mathbf{L}}\mathbf{z}_{t+1} + \tilde{\mathbf{M}}\mathbf{z}_t \right] = \mathbf{0}, \quad (84)$$

where

$$\begin{aligned} \tilde{\mathbf{x}}_t &= \begin{bmatrix} \mathbf{x}_t \\ \mathbf{y}_t \end{bmatrix}, \quad \tilde{\mathbf{F}} = \begin{bmatrix} \mathbf{0} & \mathbf{0} \\ \mathbf{F} & \mathbf{J} \end{bmatrix}, \quad \tilde{\mathbf{G}} = \begin{bmatrix} \mathbf{A} & \mathbf{C} \\ \mathbf{G} & \mathbf{K} \end{bmatrix}, \\ \tilde{\mathbf{H}} &= \begin{bmatrix} \mathbf{B} & \mathbf{0} \\ \mathbf{H} & \mathbf{0} \end{bmatrix}, \quad \tilde{\mathbf{L}} = \begin{bmatrix} \mathbf{0} \\ \mathbf{L} \end{bmatrix}, \quad \tilde{\mathbf{M}} = \begin{bmatrix} \mathbf{D} \\ \mathbf{M} \end{bmatrix}. \end{aligned}$$

Similar to this, (82) and (83) can be summarized as follows:

$$\tilde{\mathbf{x}}_t = \tilde{\mathbf{P}}\tilde{\mathbf{x}}_{t-1} + \tilde{\mathbf{Q}}\mathbf{z}_t, \quad (85)$$

where

$$\tilde{\mathbf{x}}_t = \begin{bmatrix} \mathbf{x}_t \\ \mathbf{y}_t \end{bmatrix}, \quad \tilde{\mathbf{P}} = \begin{bmatrix} \mathbf{P} & \mathbf{0} \\ \mathbf{R} & \mathbf{0} \end{bmatrix}, \quad \tilde{\mathbf{Q}} = \begin{bmatrix} \mathbf{Q} \\ \mathbf{S} \end{bmatrix}.$$

B.2 Policy functions in an economy with news shock

Our news-shock experiment is as follows;

1. For $t < T_a$, the economy is at the steady-state.
2. At $t = T_a$, news arrives; $\mathbf{z}_{T_b} = \bar{\mathbf{z}} \neq \mathbf{0}$ occurs at T_b .
3. At $t = T_b$, agents know that news is correct or not.

The important point is that the policy functions with news shocks are variant.

For $t = T_b$, since there is no news shock, the policy functions are

$$\tilde{\mathbf{x}}_{T_b} = \tilde{\mathbf{P}}\tilde{\mathbf{x}}_{T_b-1} + \tilde{\mathbf{Q}}\mathbf{z}_{T_b}. \quad (86)$$

We obtain the policy functions in a backward way using (86) and (84). At $t = T_b - 1$, (84) becomes

$$\begin{aligned} E_{T_b-1} \left[\tilde{\mathbf{F}}\tilde{\mathbf{x}}_{T_b} + \tilde{\mathbf{G}}\tilde{\mathbf{x}}_{T_b-1} + \tilde{\mathbf{H}}\tilde{\mathbf{x}}_{T_b-2} + \tilde{\mathbf{L}}\mathbf{z}_{T_b} + \tilde{\mathbf{M}}\mathbf{z}_{T_b-1} \right] &= \mathbf{0}, \\ \iff \tilde{\mathbf{F}} \left[\tilde{\mathbf{P}}\tilde{\mathbf{x}}_{T_b-1} + \tilde{\mathbf{Q}}\bar{\mathbf{z}} \right] + \tilde{\mathbf{G}}\tilde{\mathbf{x}}_{T_b-1} + \tilde{\mathbf{H}}\tilde{\mathbf{x}}_{T_b-2} + \tilde{\mathbf{L}}\bar{\mathbf{z}} &= \mathbf{0}. \end{aligned} \quad (87)$$

Then, the policy functions for $t = T_b - 1$ are

$$\tilde{\mathbf{x}}_{T_b-1} = \mathbf{W}_{T_b-1}\tilde{\mathbf{x}}_{T_b-2} + \mathbf{V}_{T_b-1}\bar{\mathbf{z}}. \quad (88)$$

where

$$\mathbf{W}_{T_b-1} = - \left[\tilde{\mathbf{F}}\tilde{\mathbf{P}} + \tilde{\mathbf{G}} \right]^{-1} \tilde{\mathbf{H}}, \quad (89)$$

$$\mathbf{V}_{T_b-1} = - \left[\tilde{\mathbf{F}}\tilde{\mathbf{P}} + \tilde{\mathbf{G}} \right]^{-1} \left[\tilde{\mathbf{F}}\tilde{\mathbf{Q}} + \tilde{\mathbf{L}} \right]. \quad (90)$$

For $t = T_b - 2$, (84) is

$$\begin{aligned} E_t \left[\tilde{\mathbf{F}}\tilde{\mathbf{x}}_{t+1} + \tilde{\mathbf{G}}\tilde{\mathbf{x}}_t + \tilde{\mathbf{H}}\tilde{\mathbf{x}}_{t-1} + \tilde{\mathbf{L}}\mathbf{z}_{t+1} + \tilde{\mathbf{M}}\mathbf{z}_t \right] &= \mathbf{0}, \\ \iff \tilde{\mathbf{F}} \left[\mathbf{W}_{t+1}\tilde{\mathbf{x}}_t + \mathbf{V}_{t+1}\bar{\mathbf{z}} \right] + \tilde{\mathbf{G}}\tilde{\mathbf{x}}_t + \tilde{\mathbf{H}}\tilde{\mathbf{x}}_{t-1} &= \mathbf{0}. \end{aligned} \quad (91)$$

Thus, the policy functions for $t = T_b - 2$ are computed as follows;

$$\tilde{\mathbf{x}}_t = \mathbf{W}_t \tilde{\mathbf{x}}_{t-1} + \mathbf{V}_t \tilde{\mathbf{z}}, \quad (92)$$

where

$$\mathbf{W}_t = - \left[\tilde{\mathbf{F}} \mathbf{W}_{t+1} + \tilde{\mathbf{G}} \right]^{-1} \tilde{\mathbf{H}}, \quad (93)$$

$$\mathbf{V}_t = - \left[\tilde{\mathbf{F}} \mathbf{W}_{t+1} + \tilde{\mathbf{G}} \right]^{-1} \tilde{\mathbf{F}} \mathbf{V}_{t+1}. \quad (94)$$

In the same logic, the policy functions for $T_a \leq t \leq T_b - 3$ are the same as (92) - (94).

References

- [1] **Aguilar, Mark, and Gita Gopinath.** 2007. “Emerging Market Business Cycles: The Cycle is the Trend.” *Journal of Political Economy*, 115(1): 69–102.
- [2] **Beaudry, Paul, and Franck Portier.** 2004. “An Exploration into Pigou’s Theory of Cycles.” *Journal of Monetary Economics*, 51(6): 1183–1216.
- [3] **Beaudry, Paul, and Franck Portier.** 2007. “When Can Changes in Expectations Cause Business Cycle Fluctuations in Neo-Classical Settings?” *Journal of Economic Theory*, 127(1): 458–477.
- [4] **Bernanke, Ben S., Mark Gertler, and Simon Gilchrist.** 1999. “The Financial Accelerator in A Quantitative Business Cycle Framework.” In *Handbook of Macroeconomics*, ed. John B. Taylor and Michael Woodford, 1341–1393. Amsterdam: North Holland.
- [5] **Christiano, Lawrence J., and Ippei Fujiwara.** 2006. “Bubble, Excess Investment, Shorter Work Hours and the Lost Decade.” Bank of Japan Working Paper Series, No.06–J–08. (In Japanese).

- [6] **Christiano, Lawrence J., Cosmin Ilut, Roberto Motto, and Massimo Rostagno.** 2007. “Monetary Policy and Stock Market Boom-Bust Cycles.” <http://faculty.wcas.northwestern.edu/%7Elchrist/research/ECB/mirage.htm>.
- [7] **Den Haan, Wouter J., and Georg Kaltenbrunner.** 2007. “Anticipated Growth and Business Cycle in Matching Models.” Centre for Economic Policy Research Discussion Paper 6063.
- [8] **Dittmar, Robert D., William T. Gavin, and Finn E. Kydland.** 2005. “Inflation Persistence and Flexible Prices.” *International Economic Review*, 46(1): 245–61.
- [9] **Fujiwara, Ippei.** 2007. “Growth Expectation.” Unpublished.
- [10] **Iacoviello, Matteo.** 2005. “House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle.” *American Economic Review*, 95(2): 739–64.
- [11] **Jaimovich, Nir, and Sergio Rebelo.** 2006. “Can News about the Future Drive the Business Cycle?” National Bureau of Economic Research Working Paper 12537.
- [12] **Jaimovich, Nir, and Sergio Rebelo.** 2007. “News and Business Cycles in Open Economies.” National Bureau of Economic Research Working Paper 13444.
- [13] **Kobayashi, Keiichiro, Tomoyuki Nakajima, and Masaru Inaba.** 2007. “Collateral Constraint and News-Driven Cycles.” Research Institute of Economy, Trade and Industry Discussion Paper 07–E–013.
- [14] **Kobayashi, Keiichiro, and Kengo Nutahara.** 2007. “Collateralized Capital and News-Driven Cycles.” *Economics Bulletin*, 5(17): 1–9.

- [15] **Rotemberg, Julio J., and Michael Woodford.** 1999. “The Cyclical Behavior of Prices and Costs.” In *Handbook of Macroeconomics*, ed. John B. Taylor and Michael Woodford, 1051–1135 Amsterdam: North Holland.
- [16] **Pigou, Arthur C.** 1927. *Industrial Fluctuations*. London: MacMillan.
- [17] **Uhlig, Harald.** 1999. “A Toolkit for Analyzing Nonlinear Dynamic Stochastic Models Easily.” In *Computational Methods for the Study of Dynamic Economies* ed. Ramon Marimon and Andrew Scott, 30–61. Oxford: Oxford University Press.

parameter	symbol	value
discount factor of households	β	.99
curvature of households' utility function	θ	1
steady-state labor supply	n	1/3
share of capital in production	α	.36
price elasticity of investment to Tobin's q	σ	1.01
depreciation rate of capital	δ	.02
persistence of technology growth	ρ_g	.95
persistence of technology level	ρ_A	.95
steady-state technology growth	g	0
steady-state technology level	A	1
probability of price change	$1 - \kappa$.25
steady-state gross inflation	π	1
steady-state markup	X	1.05
persistence of nominal interest rate	ρ_R	.73
weight of inflation in Taylor rule	ρ_π	1.5
weight of output in Taylor rule	ρ_y	.2

Table 1: Parameter values

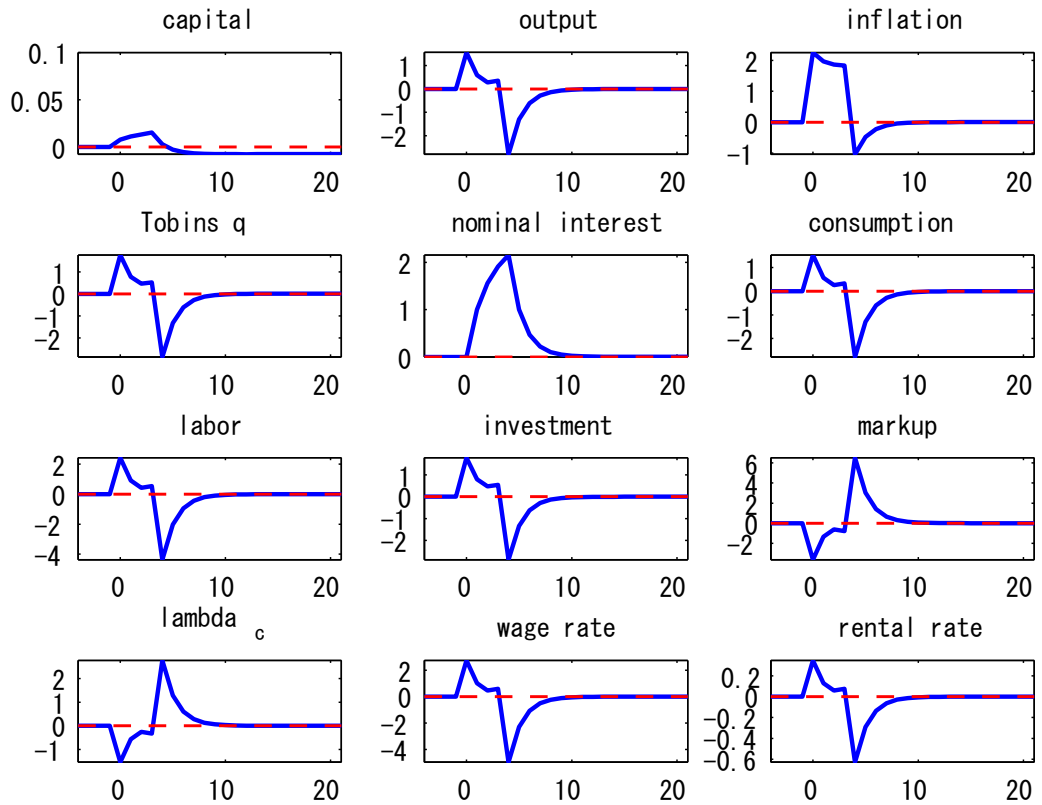


Figure 1: NDBC's to growth news shock: The news arrives at $t = 0$ and turns out to be false at $t = 4$. The vertical axes are percentage deviations from the steady-state (inflation, nominal interest rate, markup and rental rate are level deviations), and the horizontal ones are quarters.

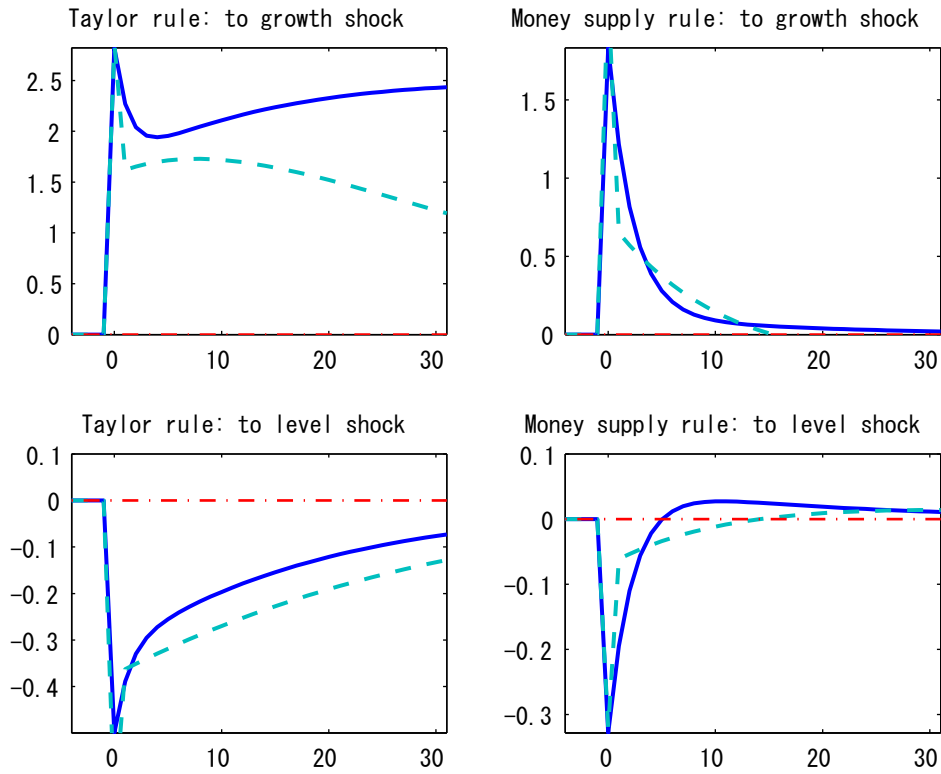


Figure 2: Impulse responses of inflation to current technology growth and level shocks: The real lines are impulse responses of the model with adjustment costs of investment and the dashed ones are those without adjustment costs. The vertical axes are deviations from the steady-state, and the horizontal ones are quarters.

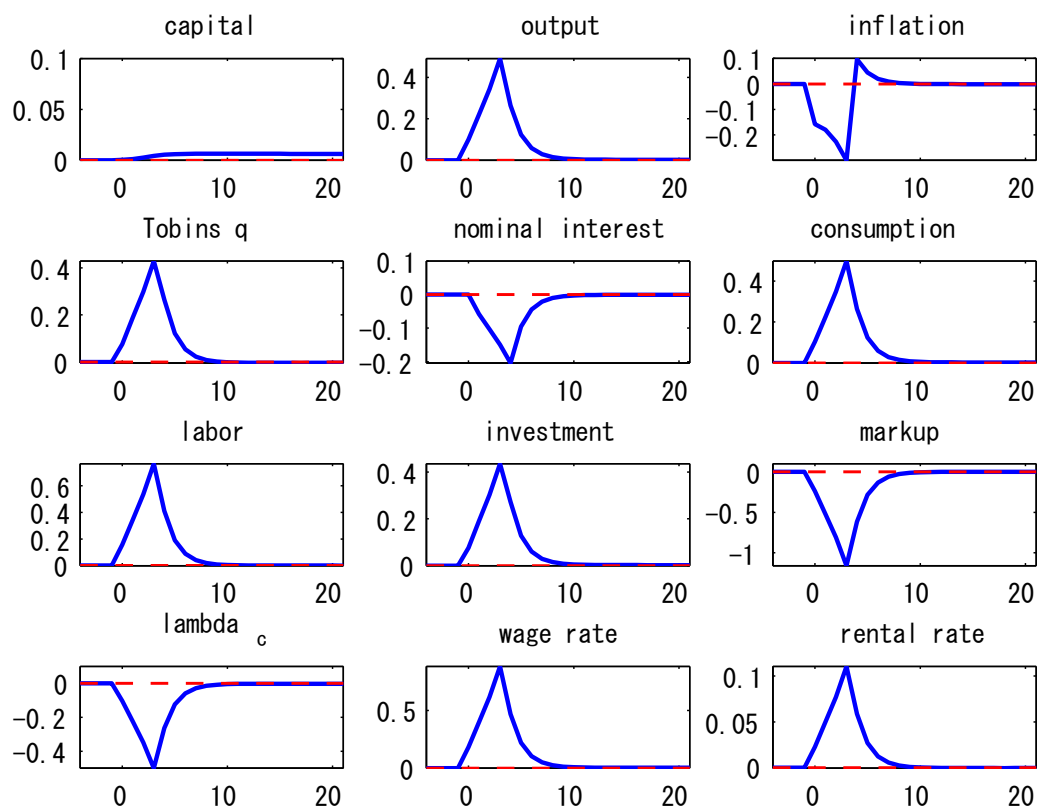


Figure 3: NDBC's to level news shock: The news arrives at $t = 0$ and turns out to be false at $t = 4$. The vertical axes are percentage deviations from the steady-state (inflation, nominal interest rate, markup and rental rate are level deviations), and the horizontal ones are quarters.

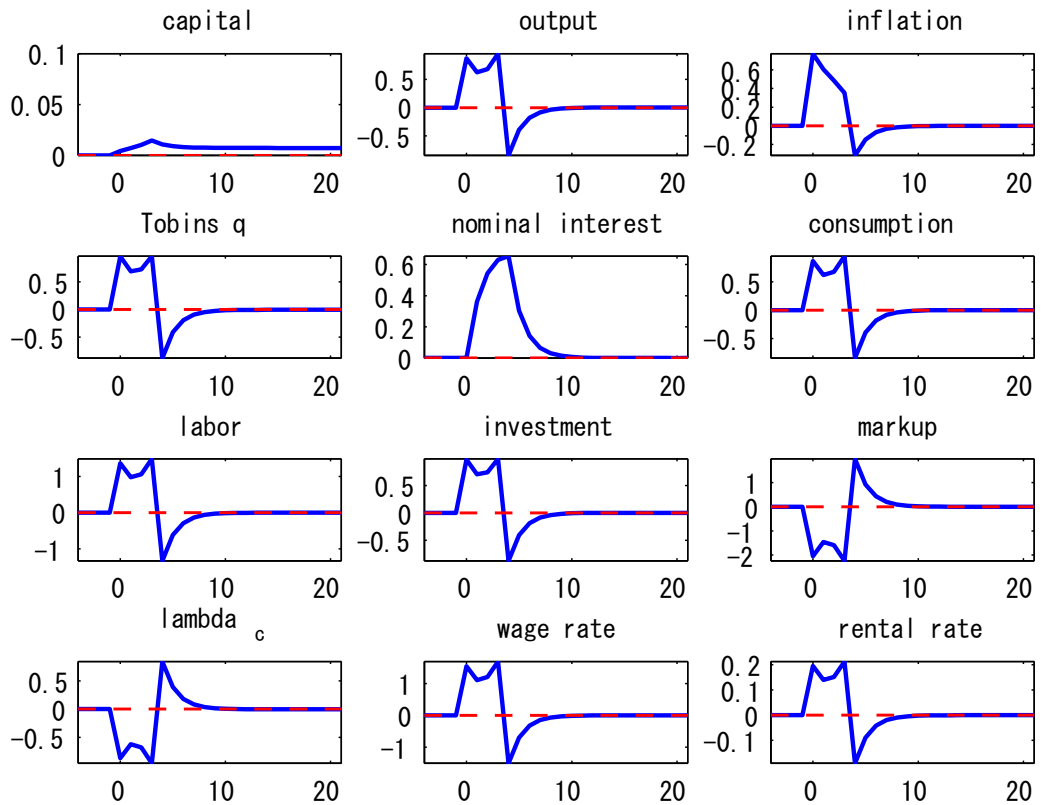


Figure 4: NDBC's to expansionary monetary policy news shock: The news arrives at $t = 0$ and turns out to be false at $t = 4$. The vertical axes are percentage deviations from the steady-state (inflation, nominal interest rate, markup and rental rate are level deviations), and the horizontal ones are quarters.

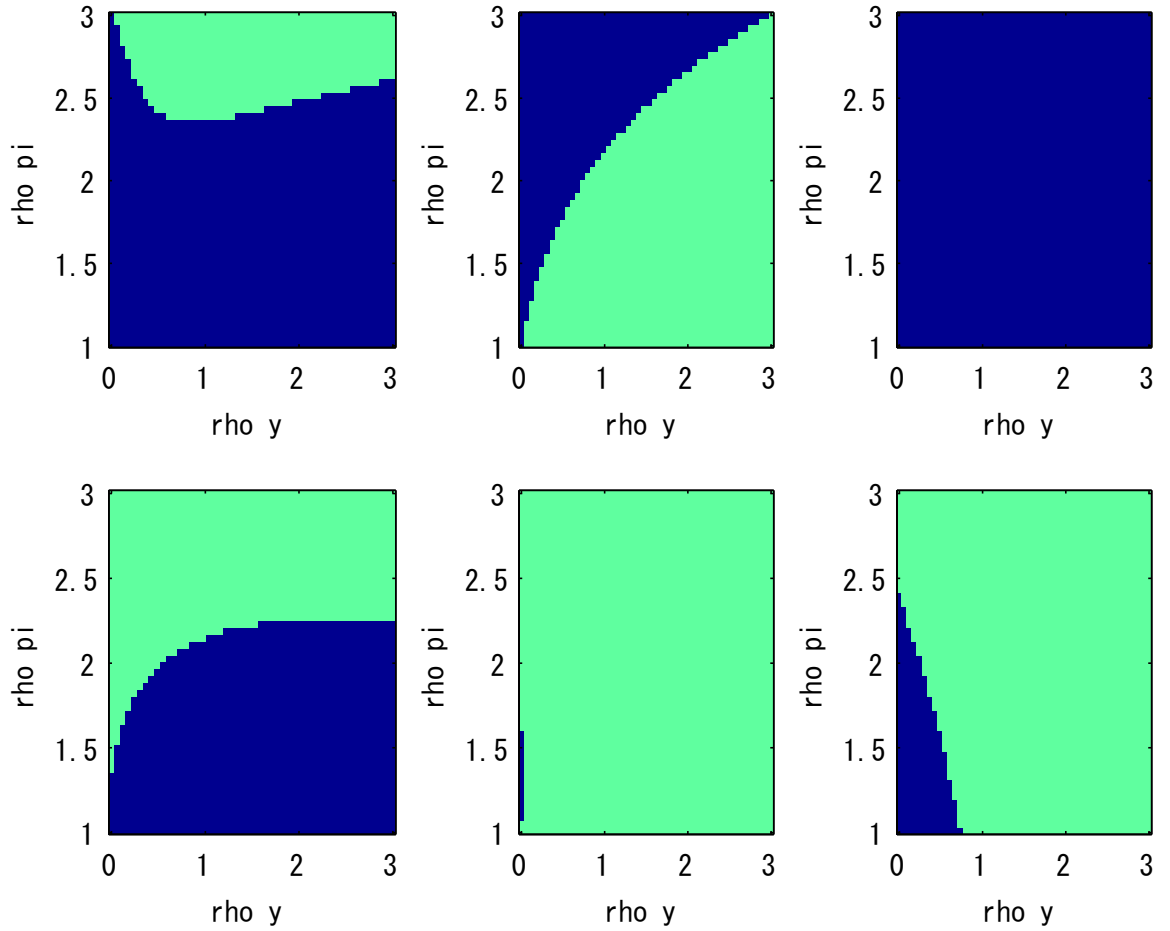


Figure 5: Regions of NDBC (1): NDBC are generated in the dark blue regions. The upper panels are cases with adjustment costs of investment, and lower ones are cases without adjustment costs of investment. The first column is cases of technology growth news, the second is those of technology level news, and the third is those of expansionary monetary policy news.

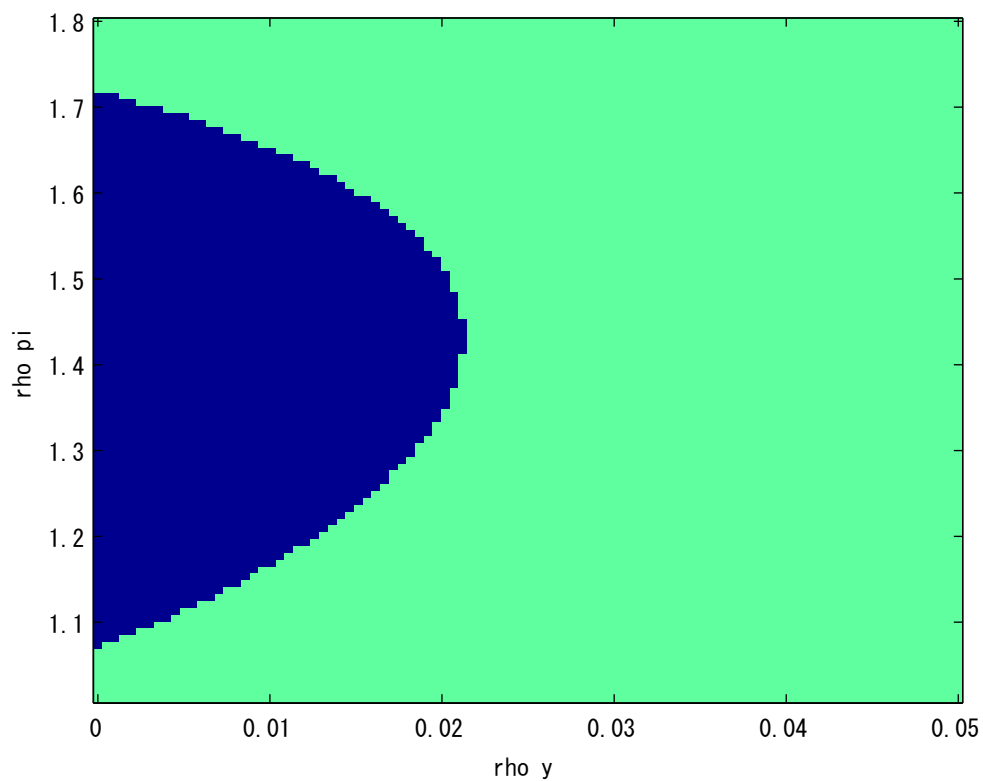


Figure 6: Regions of NDBC (2): NDBC's are generated in the dark blue region. The case in which news about technology level hits a model without adjustment costs of investment. (This is the enlarged illustration of (2,2) component in Figure 5.)

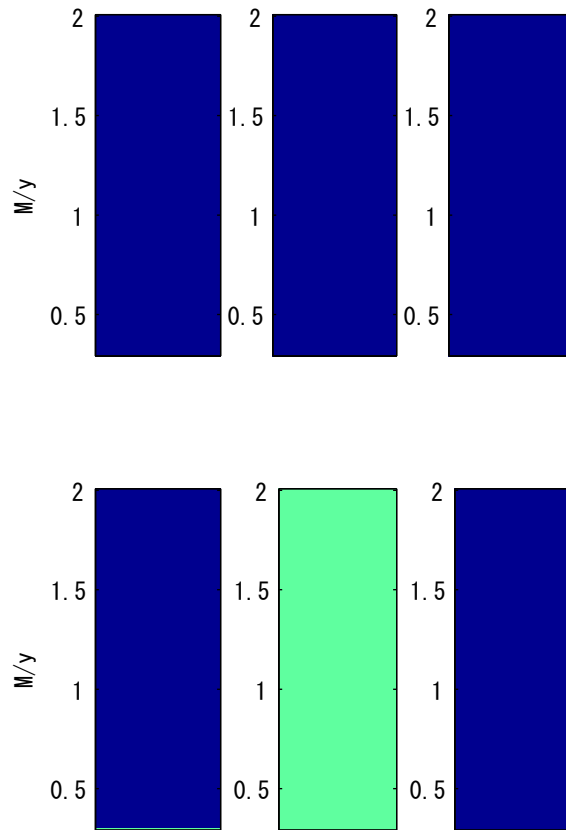


Figure 7: Regions of NDBC under money supply rule: NDBC are generated in the dark blue regions. The upper panels are cases with adjustment costs of investment, and lower ones are cases without adjustment costs of investment. The first column is cases of technology growth news, the second is those of technology level news, and the third is those of money supply news.