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Ichiro Fukunaga

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Research and Statistics Department
Bank of Japan

C.P.O BOX 203 TOKYO
100-8630 JAPAN

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Ichiro Fukunaga†

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Abstract

How do financial factors due to credit-market imperfections affect economic fluctuations? This paper calibrates a dynamic general equilibrium model incorporating credit-market imperfections using Japanese data. The model exhibits financial accelerator effects, the mechanism whereby credit-market imperfections help to propagate or amplify initial shocks to the economy. Our main result is that the large volatility of Japan's corporate investment can be explained by taking account of this mechanism. We examine the robustness of the results and consider some variations of the model including the adoption of alternative monetary policy rules and the introduction of an asset price bubble.

Keywords: financial accelerator, dynamic general equilibrium model, monetary policy rule, asset price bubble, Japan's economy.

JEL classification: E30, E44, E50

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†Human Resources Management Department, Bank of Japan. He can be reached at fukunaga@gf7.so-net.ne.jp (office e-mail address ichirou.fukunaga@boj.or.jp is currently closed.)

1 Introduction

Japan's economy has experienced large fluctuations especially since the late 1980s. After strong expansion from 1986 to 1991, long-lasting severe recessions have alternated with short-lived moderate expansions. Among several components of real activity to have undergone fluctuations during this period, the key factor has been corporate fixed investment. A large number of studies have investigated the cause of this volatile investment. While the standard neoclassical framework implies that investment is determined by expected future business profitability and the cost of capital, many empirical studies have suggested that financial factors such as balance sheet conditions also influence investment expenditures to some extent, especially those of small and medium sized firms, due to agency costs arising from asymmetric information between firms and financial intermediaries.[1] According to this view, credit market imperfections help to propagate or amplify initial shocks including monetary policy shocks to the economy.[2] Changes in credit market conditions such as asset prices, corporate debt burdens, and banking capital adequacies are not simply passive reflections of the real economy, but are also in turn major factors that affect real economic activity. These feedback mechanisms, which we will specify later as "financial accelerator" effects, might have become active when asset prices underwent large swings in the late 1980s and early 1990s and when the banking system suffered from broad-scale malfunction in the late 1990s.

The purpose of this paper is to examine how financial factors due to credit-market imperfections affect economic fluctuations, especially the volatility of corporate fixed investment[3], in a stochastic dynamic general equilibrium[4] setting. Although many academic researchers and practitioners share the view that financial factors may be important, standard macroeconomic frameworks such as real business cycle or Keynesian models usually ignore credit-market imperfections.[5] While a large number of previous studies consider

[1] See, for example, Ogawa and Kitasaka (1998), Motonishi and Yoshikawa (1999), and Nagahata and Sekine (2002) for empirical studies which suggest the effects of financial factors on investment in Japan. On the other hand, Kiyotaki and West (1996) estimate on investment function within the standard neoclassical framework.

[2] The transmission mechanism of monetary policy that works through changes in firms' balance sheet is referred to as the balance sheet channel; see Bernanke and Gertler (1995).

[3] Household consumption and investment may also be affected by credit-market imperfections. However, we consider only the effects on corporate investment in this paper.

[4] Often abbreviated to SDGE, DSGE, or simply DGE. The real business cycle model which considers only real shocks as sources of economic fluctuation is nested by the DGE model as a special case.

[5] In other words, both real business cycle models and Keynesian models inherently

financial factors by estimating a single investment function with corresponding explanatory variables, we calibrate a dynamic general equilibrium model incorporating credit-market imperfections using Japanese data.[6]

We follow the standard approach for calibrating a dynamic general equilibrium model and begin by identifying the facts underlying Japan's business cycles. Here our interest is focused on the cyclical behavior of variables around their balanced growth paths, as captured by the widely-used Hodrick-Prescott(HP) filter. Chart 1 shows standard deviations and cross correlations with output (real GDP) of several detrended series over the period from 1980/Q1 to 2001/Q1. We deal here with GDP, corporate fixed investment, household consumption, total working hours, the inflation rate, the monetary aggregate, and the nominal interest rate.[7] We can see that corporate fixed investment during our sample period is nearly five times more volatile than output, and that this ratio is much larger than that of the U.S. (about three).[8] In previous studies based on real business cycle (RBC) models, the ratio ranges from two to three.[9] The gap between the actual volatility and RBC simulated volatility suggests the existence of some other types of shocks in addition to standard RBC shocks and/or some mechanism that amplifies shocks to the economy. We try to make up for this gap by introducing both nominal shocks (monetary policy shocks) and credit-market imperfections. We first introduce price stickiness into the RBC model, thus setting up a so-called dynamic new Keynesian (DNK) model or new neoclassical synthesis model,[10] and then introduce credit-market imperfections into this DNK model.

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subscribe to the Modigliani-Miller theorem (see footnote 18).

[6]See, for example, Cooley (1995) and Kim and Pagan (1995) for general exposition and various examples of calibration approach. In Japan, the calibration approach within a dynamic general equilibrium setting is not yet popular. A few examples are Ohkusa (1991) and Soejima (1997).

[7]GDP, investment, consumption, and working hours are real and per-capita base. Inflation is measured by changes in the GDP deflator. The monetary aggregate is M2+CD (Japan) or M2 (U.S.). The nominal interest rate is the call rate (Japan) or the federal funds rate (U.S.). All variables except inflation and interest rates are in logarithms and seasonally adjusted.

[8]We can also see that the relative volatility in Japan exceeds four in both subsample periods of 1980s and 1990s.

[9]The relative volatility of investment to output is two in Ohkusa (1991) which calibrated a basic RBC model using Japanese data, and is three in King and Rebelo (1999) which calibrated one using U.S. data.

[10]See Goodfriend and King (1997) for an exposition of the new neoclassical synthesis model.

The model is based on Bernanke, Gertler and Gilchrist (1999)[11] (BGG hereafter). They embedded a micro financial contracting problem between firms (borrowers) and financial intermediaries (lenders) into a macroeconomic DNK framework in a manner that is both rigorous and yet straightforward.[12] The model contains households and entrepreneurs (and financial intermediaries) distinctively in order to explicitly motivate lending and borrowing. In addition, there are retailers who set the final (retail) price of output goods, capital producers who transform output goods into capital goods, and a government sector which conducts fiscal and monetary policy.[13] The economy is described as a decentralized rational expectation equilibrium. The only source of economic fluctuation comes from unanticipated shocks: technology shocks, demand shocks, and monetary policy shocks. The model incorporates credit-market imperfections through the assumption that external funds and internal funds are not perfect substitutes: in particular, the difference in the cost of these funds (the external finance premium) depends inversely on the value of entrepreneurs' own wealth (net worth[14]). Procyclical movements in entrepreneurs' net worth caused by unanticipated shocks then lead to countercyclical movements in the external finance premium, and thus enlarge the volatility of investment and amplify economic fluctuations. BGG named this mechanism the "financial accelerator".

We adopt this model to explain the above facts underlying Japan's business cycles. We set parameter values based on actual Japanese data and calculate second moment properties such as standard deviations and cross correlations for both of the price stickiness models: the one with, the other without credit-market imperfections. Our main result, which we demonstrate fully in Section 4.3, is that introducing credit-market imperfections significantly enlarges the volatility of investment and brings it close to the actual volatility, without loosing the model's fit in other dimensions such as consumption and inflation. This is one piece of evidence supporting the existence of financial accelerator effects in Japan's business cycles: credit-market imperfections help to propagate unanticipated shocks, especially monetary

[11] We slightly change their original model: we introduce a monetary policy rule which reacts to both output and price level rather than inflation, and simplify their setting of entrepreneurs' net worth accumulation (omit entrepreneurs' consumption and labor supply).

[12] Other important examples which embed credit-market imperfections into a macroeconomic dynamic general equilibrium framework are Calmstrom and Fuerst (1997) and Kiyotaki and Moore (1997). However, unlike BGG, they do not introduce a nominal rigidity.

[13] We sketch an overview of the whole model in Chart 2.

[14] The net worth is defined as liquid assets plus the collateral value of illiquid assets less outstanding obligations.

policy shocks, and do indeed amplify economic fluctuations. Our result supports the view emphasizing the importance of financial factors.[15]

We then examine the robustness of the result and consider some variations of the model. First we vary the composition of the exogenous shocks and some underlying parameter values. We report the outcomes of varying the values assigned to key parameters governing entrepreneurs' balance sheet conditions, price stickiness, and labor market elasticity. These experiments illustrate various properties of the model and may also be of potential simulative interest in considering possible future states of the economy. Moreover, we adopt alternative monetary policy rules and introduce an asset price bubble to the model. In this model, the monetary policy rule has a particularly important role in either stabilizing or destabilizing the economy, and these stabilizing effects are stronger in the case with the financial accelerator than in the case without it. An asset price bubble can be another important source of economic fluctuation in the case with financial accelerator effects, and we find that we can better explain the large volatility of investment by introducing such a bubble as a supplement to the model.

The remainder of this paper is organized as follows. In Section 2, we explain the functioning of the financial accelerator within a minimal setting in which we focus on corporate investment. The rest of the full macroeconomic model is then described in Section 3. We calibrate the model using Japanese data and calculate the second moment properties in Section 4. We examine how well these properties correspond to those observed in the actual Japanese data, and demonstrate the results in detail. In Section 5, we examine the robustness of the results and consider some variations of the model including the adoption of alternative monetary policy rules and the introduction of an asset price bubble as mentioned above. Section 6 presents our concluding remarks.

[15]Based on an orthodox growth account approach, Hayashi and Prescott (2002) argue that the problem in 1990s Japan was not a breakdown of the financial system but a low productivity growth rate. Unlike them, however, we focus on cyclical behaviors, so that our argument is not necessarily contradictory to theirs.

2 Financial Accelerator Effects on Corporate Investment

In this section, we explain the mechanism whereby credit-market imperfections help to propagate or amplify initial shocks to the economy, the so-called financial accelerator effects, in a minimal setting in which we focus on corporate investment.[16] The core model described below will be one part of the full macroeconomic dynamic general equilibrium model we calibrate in this paper.

2.1 The Core Model

We here model the capital-purchasing decisions of "entrepreneurs". There are also external capital producing firms and financial intermediaries providing external funds in this model. Entrepreneurs purchase capital from the capital producers and then produce their output good. In order for the entrepreneurs to purchase capital, they have access to external funds in addition to their own wealth (net worth). Capital producers, on the other hand, purchase the entrepreneurs' output good and transform it into the capital good to sell to entrepreneurs. Although the entrepreneurs' output good is all sold out and finally consumed by some other agents (households), here we do not describe the behavior of consumers.

2.1.1 Entrepreneurs

Entrepreneurs purchase capital in each period for use in the subsequent period.[17] Capital is used in combination with hired labor to produce the output good as follows

$$Y_t = A_t \left(K_{t-1}\right)^{\alpha} \bar{H}^{1-\alpha}, \tag{1}$$

[16] Other models that explain the financial accelerator more simply in a partial equilibrium setting are given in Bernanke, Gertler, and Gilchrist (1996) and Kasuya and Fukunaga (2002). Here we extract the minimal setting straightforwardly from the dynamic general equilibrium model of BGG.

[17] We here assume that the economy contains a large number of identical entrepreneurs and describe the model below as the representative entrepreneur's problem. (This assumption also holds for the capital producers, households, and retailers we will describe later.) To consider the credit-market imperfections explicitly, we should start from the individual firm subject to idiosyncratic risk on its return to capital, as BGG does. However, some assumptions, such as the independent and identical distributions of the idiosyncratic disturbances and the constant returns to scale in production, allow us to derive aggregate relationships straightforwardly.

where Y_t, K_t, $\bar{H}$ are output, capital, and the labor input, respectively. A_t is an exogenous technology parameter (total factor productivity). Here the labor input and the payments for it, corresponding to its marginal product, are assumed to be fixed.

Entrepreneurs are risk-neutral. Their demand for capital is determined by comparing the expected marginal return to holding capital with its expected marginal financial cost. Given the production technology (1), the expected gross return to holding a unit of capital from t to $t+1$, $\mathrm{E}_t F_{t+1}$, is defined as

$$\mathrm{E}_t F_{t+1} = \mathrm{E}_t \left[\frac{\frac{\alpha Y_{t+1}}{K_t} + Q_{t+1}(1-\delta)}{Q_t} \right], \tag{2}$$

where Q_t is the relative price (in terms of the output good) of a unit of capital which varies depending on the capital production technology (described below) and which entrepreneurs take as given. δ is the depreciation rate of capital. The first term of the numerator, $\frac{\alpha Y_{t+1}}{K_t}$, is the income gain, corresponding to the rent paid to a unit of capital that is assumed to be subject to diminishing returns. The second term is the capital gain, which is all enjoyed by entrepreneurs rather than capital producers who must earn zero profits in competitive equilibrium.

The financial cost condition for the capital-purchasing decision is the main feature of this model. In the standard framework, the expected rate of return is always taken to be equal to the marginal opportunity cost of funds, such as the riskless interest rate, R_{t+1}, which is given independently of entrepreneurs' decision making.

$$\mathrm{E}_t F_{t+1} = R_{t+1}.$$

On the other hand, here we are assuming that there exist credit-market imperfections whereby additional costs (the premium) are imposed on borrowers if they demand external funds (uncollateralized loans) to purchase more of the capital good than they are able to purchase using only internal funds (collateral value).[18] Following BGG, we consider the situation where lenders (financial intermediaries) must pay a cost if they wish to observe borrowers' (entrepreneurs') realized returns. In this situation, the optimal contract between lenders and borrowers looks very much like a standard debt contract under which lenders only observe the realized return of the borrowers who could not earn enough to repay at the predetermined rate; lenders then withdraw all of that observed return from the bankrupt borrowers.[19] In such a

[18] Under perfect credit markets, there are no additional costs of external funds and no distinction between external and internal funds (the Modigliani-Miller theorem).

[19] This type of setting is referred to as "costly state verification (CSV)," a problem analyzed first by Townsend (1979).

situation we may interpret the auditing cost lenders must pay as the cost of default. Since competitive lenders must receive an expected return to lending (less the auditing cost) equal to the opportunity cost of their funds, the borrowers' expected rate of return ($\mathrm{E}_t\, F_{t+1}$) must exceed the riskless interest rate (R_{t+1}) to compensate for the default cost. The default risk itself is determined by the extent to which entrepreneurs depend on external funds, and this leads to a relationship between two crucial ratios: the ratio of $\mathrm{E}_t\, F_{t+1}$ to R_{t+1}, which we call the external finance premium, and the ratio of internal (or alternatively external) funds to the total value of purchased capital, as follows[20]

$$\mathrm{E}_t\, F_{t+1} = R_{t+1}\ S\left(\frac{N_t}{Q_t K_t}\right) \quad \text{with } N_t \le Q_t K_t,\ S(1) = 1,\ S'(\cdot) < 0, \qquad (3)$$

where N_t is entrepreneurs' own wealth (net worth). When the ratio of internal funds is low, the default risk is high, and in this case the external finance premium should be large.[21] Note that entrepreneurs borrow only if they cannot afford their optimal capital stock; their internal funds are always used fully (thus $N_t \le Q_t K_t$) since the cost of internal funds is always lower than that of external funds for them.[22]

Chart 4 illustrates two curves corresponding to the expected gross return to holding a unit of capital, (2), and the expected marginal cost of funds, (3). While the former is downward sloping due to the diminishing return (depicted linearly for simplicity), the latter varies in shape depending on the cases considered below. The upper panel depicts the case where there are no credit-market imperfections so that the curve of the marginal cost of funds is flat at the level of the riskless rate, R_{t+1}. In the lower panel where there are credit-market imperfections, on the other hand, the curve of the marginal cost is upward sloping if entrepreneurs demand capital in excess of their net worth and so require external funds; otherwise it is flat as long as their net worth suffices. The amount of capital purchased by entrepreneurs is determined at the intersection of these two curves. Under credit-market imperfections (lower panel), there could be an external finance premium in equilibrium.

[20] Here we do not describe the optimal contracting problem precisely. That is fully described in BGG (Appendix A), and we sketch its essence in Chart 3. The lower panel of the chart shows the situation described here, while the upper panel shows the situation where lenders can observe each borrower's realized return without any cost and can thus require the repayment corresponding to the ratio of borrowing to each borrower ensuring that there is no default.

[21] Note that all entrepreneurs choose the same ratio of internal funds. $S(\cdot)$ is not entrepreneur-specific.

[22] This is referred to as the "pecking order" assumption.

In Section 2.2 below, we demonstrate financial accelerator effects in a static setting using this chart.

Turning to the dynamics of this model, we see that the evolution of entrepreneurs' net worth plays an critical role. It may be written as

$$N_t = \gamma \ \{ \, F_t \, Q_{t-1} K_{t-1} - R_t \ S \left(\frac{N_{t-1}}{Q_{t-1} K_{t-1}} \right) (Q_{t-1} K_{t-1} - N_{t-1}) \, \}, \tag{4}$$

where we assume that each entrepreneur has a constant probability γ of surviving to the next period (i.e. there is a probability $1 - \gamma$ that he dies in between periods).[23] The terms in the braces describe the operational firm's value (equity): the first term is gross return; the second is a repayment term which includes compensation for the potential cost of default (the auditing cost) reflecting the external finance premium. Note that F_t is the ex-post return and $R_t \ S \left(\frac{N_{t-1}}{Q_{t-1} K_{t-1}} \right)$ is the ex-post cost of borrowing. (This differs from equation (3) which describes the ex-ante relationship.) If an unanticipated movement in returns such as an unpredictable variation in the capital (asset) price, Q_t, occurs within period t, the ex-post return diverges from costs and net worth is directly affected. Under credit-market imperfections, net worth responds endogenously to such unanticipated shocks, and this in turn affects economic fluctuations via its interaction with the external finance premium.

2.1.2 Capital Producers

Capital producers purchase the entrepreneurs' output good as a material input, I_t, and combine it with rented capital, K_{t-1}, to produce new capital, $\hat{K}_t$, as follows[24]

$$\hat{K}_t = \Phi \left(\frac{I_t}{K_{t-1}} \right) K_{t-1} \quad \text{with } \Phi(0) = 0, \ \Phi'(\cdot) > 0, \ \Phi''(\cdot) < 0.$$

[23] This assumption preclude the probability either that the net worth diverges or entrepreneurs accumulate enough wealth to be fully self-financed so that credit markets disappear. This is essentially the same situation as that described by Carlstrom and Fuerst (1997) where infinitely lived entrepreneurs discount the future more heavily than do households (in the core model here, their discount rate is higher than the riskless interest rate, R_t). On the other hand, the birth rate is set to keep the total number of entrepreneurs constant. We do not consider an inheritance problem by assuming implicitly that the bequest which would be left by the dead entrepreneurs perishes immediately on his death, while the new generation of entrepreneurs (and those losing their net worth by default) are given some wealth to begin operations. BGG deal with this problem more explicitly by introducing entrepreneurs' inelastic labor supply and consumption. However, this does not change the essential dynamic properties of the model.

[24] The concavity of the following capital production function ($\Phi''(\cdot) < 0$) implies increasing marginal adjustment costs.

To capture the empirical fact that corporate investment slightly lags output as shown in Chart 1, we assume that the capital producers' purchasing decision has to be made one period in advance. They choose next period expenditure, I_{t+1}, to maximize their expected profits, $\mathrm{E}_t\,[\,Q_{t+1}\,\hat{K}_{t+1} - I_{t+1}\,]$, taking the expected relative price of capital, $\mathrm{E}_t\,Q_{t+1}$, as given. The first-order condition is

$$\mathrm{E}_t\,Q_{t+1} = \mathrm{E}_t\,\left[\Phi'\left(\frac{I_{t+1}}{K_t}\right)\right]^{-1}. \tag{5}$$

Here we normalize the capital production function so that the relative price of capital is unity in the steady state, i.e. $\Phi'(I/K) = 1$ where I and K without time subscripts are the steady-state values. We interpret the capital producers' expenditure, I_t, as "investment" for capital. Their decision is linked with the entrepreneurs' capital-purchasing decision described above via the variation in the price of capital.

The aggregate capital stock evolves according to

$$K_t = \Phi\left(\frac{I_t}{K_{t-1}}\right)K_{t-1} + (1-\delta)\,K_{t-1}, \tag{6}$$

where δ is the depreciation rate. Note that capital is homogeneous, so there is no difference between newly-produced and old capital. Old capital used by entrepreneurs is rented out for the production of new capital, and then returned at the same price as the newly-produced capital.[25]

2.1.3 Equilibrium

A rational expectations equilibrium is defined as a set of endogenous variables $\{\,Y_t,\,K_t,\,N_t,\,I_t,\,F_t,\,Q_t\,\}$ which satisfies entrepreneurs' decision rules (2) and (3) (the latter implicitly includes financial intermediaries' decisions), capital producers' decision rule (5), and resource constraints (1), (4), and (6), given that the exogenous variables $\{\,R_t,\,A_t\,\}$ follow the stochastic processes defined below:

$$r_t = \rho_r\,r_{t-1} + {e^r}_t \tag{7}$$

$$a_t = \rho_a\,a_{t-1} + {e^a}_t, \tag{8}$$

where r_t and a_t are percentage deviations from the steady states of R_t and A_t, respectively. ${e^r}_t$ and ${e^a}_t$ are random variables distributed normally and

[25]The rental rate is determined by the zero profit condition for competitive capital producers using constant returns to scale technology. It must be zero in the steady-state.

uncorrelated either serially or contemporaneously. These are assumed to be stationary autoregressive processes (i.e. they do not contain trend growth).

We can analyze the dynamics of the model by restricting our attention to stationary fluctuations around the steady state. We log-linearize the system as follows.

$$
\begin{aligned}
y_t &= a_t + \alpha\, k_{t-1} && (9)\\
f_{t+1} &= (1-\upsilon)\,(y_{t+1} - k_t) + \upsilon\, q_{t+1} - q_t && (10)\\
f_{t+1} &= r_{t+1} - \psi\,[\; n_t - (q_t + k_t)\;] && (11)\\
n_t &= \gamma\, F\,[\;\chi\, f_t - (\chi - 1)\, r_t \\
&\quad + \psi\,(\chi-1)\,(q_{t-1} + k_{t-1}) + \{\,1 - \psi\,(\chi - 1)\,\}\, n_{t-1}\,] && (12)\\
q_{t+1} &= \phi\,(i_{t+1} - k_t) && (13)\\
k_t &= \delta\; i_t + (1-\delta)\, k_{t-1}. && (14)
\end{aligned}
$$

Equations (9) to (14) correspond to equations (1) to (6), respectively. Following the convention, all lowercase variables denote percentage deviations from steady state.[26] We here omit the conditional expectations operator on the assumption of certainty equivalence. We demonstrate the financial accelerator effects in the following subsection by examining the responses of endogenous variables to exogenous shocks.

2.2 Financial Accelerator Effects

2.2.1 Static Financial Accelerator Effects

Before beginning our formal examination of the dynamics of the model, we would like to give a rough illustration of the working of the financial accelerator effects in a static setting, using Chart 4 above.[27]

First, changes in monetary policy controlling the riskless interest rate (here in real terms) are represented by vertical shifts of the marginal cost curve. In the upper panel where there are no credit-market imperfections (hereafter the no financial accelerator, or No-FA case), an upward shift leads to a decline in the demand for capital along the curve of the expected rate of return. The required expected rate of return then rises in parallel to the riskless rate. In contrast, in the lower panel where there are credit-market imperfections (hereafter the FA case), the tightening of monetary

[26] Uppercase variables without time subscripts denote steady-state values. Greek letters without time subscripts are fixed parameters, e.g. χ is the steady-state value of the reciprocal of the self-financing ratio, $\frac{Q_t K_t}{N_t}$.

[27] Kasuya and Fukunaga (2002) describe a static model of firms and banks which backs up Chart 4.

policy shifts the marginal cost curve not only vertically upward but also horizontally to the left, simultaneously steepening its slope through the damage to entrepreneurs' net worth. The external finance premium then widens, and the demand for capital declines more than in the No-FA case. This comparison shows how the monetary policy shock is amplified by credit-market imperfections.[28]

Next, changes in the technology parameter are represented by shifts of the curve depicting the expected rate of return; in the FA case such changes also result in the horizontal shifts and slope-transformations of the marginal cost curve corresponding to variations in the value of entrepreneurs' net worth. Therefore, the technology shock is also amplified in the FA case.

2.2.2 Dynamic Financial Accelerator Effects

In a dynamic setting, endogenous variation in the price of capital affects both the return and cost sides in a complicated fashion. In addition, the endogenous evolution of entrepreneurs' net worth causes persistent effects on investment in the FA case.

We examine here the responses of the six endogenous variables in the core model to one-shot unanticipated shocks to each exogenous variable, consisting of a one percent deviation from the steady state economy.[29] We choose parameter values based on actual data (historical averages), single-equation estimation, or references to preceding studies (shown in Chart 5), as detailed in the fuller discussion in Section 4.1 below.[30] Each variable converges to the steady-state eventually under our parameterization, which means that the system is stable around the steady-state.[31] Responses to the interest-rate shock are shown in Chart 6, and to the technology shock in Chart 7.[32]

[28]When entrepreneurs' net worth deteriorates greatly and the marginal cost curve becomes too steep for the amount of lending to change, monetary policy in the FA case may have less effect on the demand for capital than in the No-FA case. Kasuya and Fukunaga (2002) call such a situation a phase of "excessive external finance premium".

[29]We shift the time subscripts of some endogenous variables when solving the model in order to distinguish the ex-post relationships which are subject to the unanticipated shock from those which are not. In particular, we shift all variables in equation (10) and the riskless interest rate appearing in any equation one period backward.

[30]The first-order autoregressive parameter on the shock process for the riskless interest rate, ρ_r, which is endogenized in the whole model later, is here arbitrarily set to 0.5.

[31]We do not examine the global characteristics of the dynamics. Therefore, the possibility of global instability or indeterminacy may still remain.

[32]The model is solved by the method of undetermined coefficient (the eigen decomposition method). We utilize Harald Uhlig's MATLAB programs which are available at his homepage (http://www.wiwi.hu-berlin.de/wpol/html/toolkit.htm). The detailed method-

First we examine the effects of changes in monetary policy which controls r_t in Chart 6. In the upper panel, ψ is set to zero so that there are no credit-market imperfections (the No-FA case). When the interest rate (always equal to the expected rate of return) rises, investment decreases at first (from the subsequent period to the initial shock), but reverts to the steady-state level as the shock dies away. In the lower panel depicting the FA case, on the other hand, investment remains lower than the steady-state level even after the shock dies away, and capital and output continue to deviate from their steady-states for an accordingly long time. This persistency comes from the damage to entrepreneurs' net worth caused by the unanticipated fall in the price of capital during the initial period. It takes a long time for the damaged net worth to return to its steady-state level. The damage to the net worth causes the external finance premium to widen in the FA case, which in turn further dampens the demand for capital.

Next, we examine the effects of technology shocks, or changes in a_t, in Chart 7. When a positive technology shock boosts output, the demand for capital is stimulated via an upward shift in the marginal product of capital. In the FA case, moreover, the improvement in entrepreneurs' net worth that this causes further stimulates the demand for capital via a reduction in the external finance premium. Therefore, the technology shock is also amplified in the FA case.

We will check the impulse responses again in Section 4.2 within the full macroeconomic framework. However, the essence of the financial accelerator effects have been demonstrated by our core model.

3 The Whole Model

We now develop the core model toward the full macroeconomic dynamic new Keynesian (DNK) framework, including households, retailers, and a government sector, in addition to entrepreneurs, capital producers, and financial intermediaries.

3.1 Households

Here we set up a general equilibrium framework within which entrepreneurs' output goods are finally consumed by households. Households live infinitely, and they consume, work, and save. Their intertemporal optimization prob-

ological exposition is given in Uhlig (1999).

lem is written as follows[33]

$$
\begin{aligned}
\max_{\{C_t\},\{M_t\},\{H_t\}} \qquad & \mathrm{E}_t \sum_{k=0}^{\infty} \beta^k \left[\ \ln(C_{t+k}) + \zeta \ \ln(\frac{M_{t+k}}{P_{t+k}}) + \xi \ \ln(1 - H_{t+k}) \ \right] \\
& s.t. \ C_t + D_{t+1} + \frac{M_t}{P_t} = W_t \, H_t - T_t + V_t + R_t \, D_t + \frac{M_{t-1}}{P_t},
\end{aligned}
$$

where C_t is consumption, $\frac{M_t}{P_t}$ is real money balances, H_t is labor supply, W_t is the real wage, T_t is a lump-sum tax, V_t is dividends received from ownership of retailers (explained below), D_t is deposits held at financial intermediaries, and R_t is the riskless interest rate on these deposits (gross and in real terms). Note that intermediaries lending funds to many entrepreneurs can perfectly diversify the idiosyncratic risk on their return, which enables households to earn the riskless rate on their deposits.

The first order conditions are

$$
\frac{1}{C_t} = \beta \, \frac{1}{\mathrm{E}_t \, C_{t+1}} \, R_{t+1} \tag{15}
$$

$$
\frac{M_t}{P_t} = \zeta \, C_t \, \frac{{R^n}_{t+1}}{{R^n}_{t+1} - 1} \tag{16}
$$

$$
W_t \, \frac{1}{C_t} = \xi \, \frac{1}{1 - H_t}, \tag{17}
$$

where ${R^n}_{t+1}$ is the (gross) nominal interest rate, defined as $R_{t+1} \, \frac{\mathrm{E}_t \, P_{t+1}}{P_t}$. Now both the real interest rate and labor supply are endogenized.

3.2 Retailers

Here we assume that entrepreneurs sell all of their output good to retailers. Retailers then sell final output goods to households, capital producers, and the government sector. While the entrepreneurs' output good is homogeneous, retailers differentiate it slightly at no resource cost and then have the monopolistic power to set the prices of these final output goods.[34] Following Calvo (1983), we assume that the retailers have the opportunity to change their prices in a given period only with probability θ. Then nominal stickiness is introduced in keeping with the conventional dynamic new Keynesian framework.

[33] For simplicity, we assume the instantaneous utility function to be log-linear in the three arguments, which implies that the degree of relative risk aversion is constantly unity.

[34] One can conceive equivalent situations where retailers add their brand name to the goods, or they and households live spaced equidistantly around a circle while producers live in the center of the circle and are thus equidistant from each retailer.

The reason why retailers are incorporated together with entrepreneurs is that the relationship between an individual entrepreneur's demand for capital and his net worth cannot avoid being too complicated to aggregate straightforwardly if entrepreneurs are imperfect competitors. Retailers here are simply a device for introducing price stickiness. Ultimately retailers' monopolistic profits belong to the households who own them, in contrast to entrepreneurs who are independent agents possessing their own wealth.

Retailers who have the opportunity to set their price in a given period t choose their price, P_t^*, that maximizes their expected discounted profits until the period when they are next able to change their price, subject to their individual demand function faced.

$$\max_{P_t^*} \quad \mathrm{E}_t \sum_{k=0}^{\infty} \theta^k \frac{\beta\, C_t}{C_{t+k}} \left(\frac{P_t^* - \frac{P_{t+k}}{X_{t+k}}}{P_{t+k}}\, Y_{t+k}^* \right)$$
$$s.t.\ Y_t^* = \left(\frac{P_t^*}{P_t}\right)^{-\epsilon} Y_t.$$

Note that the discount factor for expected profits consists of two parts: the probability that retailers can change their price in the next period, and the households' intertemporal marginal rate of substitution. X_t is the gross markup rate of retail (final) price over wholesale price. ${Y^*}_t$ is the demand corresponding to the optimally chosen price P^*. Y_t is aggregate demand.[35] P_t is the aggregate price given by

$$P_t = \{\, \theta\, P_{t-1}^{1-\epsilon} + (1-\theta)\, {P_t^*}^{1-\epsilon} \,\}^{\frac{1}{1-\epsilon}}.$$

The optimally chosen price P^* can be expressed explicitly as follows

$$P_t^* = \frac{\epsilon}{\epsilon - 1} \frac{\mathrm{E}_t \sum_{j=0}^{\infty} \theta^j \frac{\beta C_t}{C_{t+j}} \frac{Y_{t+j}^*}{P_{t+j}} \frac{P_{t+j}}{X_{t+j}}}{\mathrm{E}_t \sum_{j=0}^{\infty} \theta^j \frac{\beta C_t}{C_{t+j}} \frac{Y_{t+j}^*}{P_{t+j}}}.$$

[35] This demand function is derived from the definition of aggregate demand as the composite of individual final output (retail) goods and the corresponding price index in the monopolistic competition framework of Dixit and Stiglitz (1977) as follows

$$Y_t = \left(\int_0^1 Y_t(z)^{\frac{\epsilon-1}{\epsilon}}\, dz \right)^{\frac{\epsilon}{\epsilon-1}}$$
$$P_t = \left(\int_0^1 P_t(z)^{1-\epsilon}\, dz \right)^{\frac{1}{1-\epsilon}},$$

where $Y_t(z)$ and $P_t(z)$ are the demand and price faced by each individual retailer $z \in (0,1)$, respectively.

We here approximate percentage deviations from the steady state of P and P^* within their local neighborhood as follows

$$\begin{aligned} p_t &= \theta\, p_{t-1} + (1-\theta)\, p_t^* \\ p_t^* &= (1-\beta\,\theta) \sum_{j=0}^{\infty} (\beta\,\theta)^j \, \mathrm{E}_t\,[\,p_t - x_t\,], \end{aligned}$$

where lowercase variables denote percentage deviations. Then the so-called New Keynesian Phillips curve can be derived as follows[36]

$$\pi_t = -\lambda\, x_t + \beta\ \mathrm{E}_t\, \pi_{t+1}, \tag{18}$$

where $\pi_t = p_t - p_{t-1}$ and $\lambda = \theta^{-1}\,(1-\theta)\,(1-\beta\,\theta)$.

By introducing price stickiness above, we should slightly modify the entrepreneurs' behavior in the core model. Evaluating the rent paid to a unit of capital, $\frac{\alpha Y_{t+1}}{K_t}$, in terms of the retail price of output goods, (2) is rewritten as

$$\mathrm{E}_t\, F_{t+1} = \mathrm{E}_t \left[\frac{\frac{1}{X_{t+1}} \frac{\alpha Y_{t+1}}{K_t} + Q_{t+1}\,(1-\delta)}{Q_t} \right]. \tag{19}$$

In the same way, evaluating the marginal product of labor in terms of the retail price, we should write the entrepreneurs' labor demand condition as follows

$$W_t = \frac{1}{X_t} \frac{(1-\alpha)\, Y_t}{H_t}. \tag{20}$$

This condition and the households' labor supply condition, (17), give the labor market equilibrium.

3.3 Government Sector and Monetary Policy Rule

Finally we set the budget constraint and the policy rule of the government sector to close the whole model. The total expenditure of the economy, which is always equal to the aggregate of final output goods, consists of households' consumption, capital producers' investment, and the expenditure of the government sector, G.

$$Y_t = C_t + I_t + G_t. \tag{21}$$

[36] For details of the derivation of New Keynesian Phillips curve, see, for example, Dotsey et al. (1999), Wolman (1999), King (2000), etc.

Government expenditure is financed by lump-sum taxes and money creation.

$$G_t = \frac{M_t - M_{t-1}}{P_t} + T_t. \tag{22}$$

Here we take the nominal interest rate as the instrument of monetary policy. The monetary aggregate is then endogenized in the money demand function, (16). Following the spirit of the Taylor rule, we specify the policy rule as follows[37]

$$\begin{aligned} {r^n}_t &= \rho_n \, {r^n}_{t-1} + (1-\rho_n)\, {r^{n*}}_t + {e^n}_t, \quad {e^n}_t \sim N(0, {\sigma_n}^2) \\ {r^{n*}}_t &= \nu_y \, y_t + \nu_p \, \mathrm{E}_t \, p_{t+1} \quad \text{with } \nu_y, \ \nu_p > 0, \end{aligned} \tag{23}$$

where ${r^{n*}}_t$ is the target value of the nominal interest rate and e^n is an exogenous random shock to the interest rate which reflects either failure to track the rule or intentional transitory deviations from the rule (pure "policy shocks"). The first equation describes the mechanism of partial adjustment observed in reality, while the second is the policy reaction function which responds to current output and the expected price level in order to stabilize the economy.[38] Note that ${r^n}_t$, y_t, and p_t are all percentage deviations from steady-state and so carry the implication of "gaps". According to this rule, the monetary authority (here included in the government sector) raises the nominal interest rate (sets it above its steady-state level) when current output exceeds its steady-state and/or prices are expected to exceed their steady-state level, and vice versa.[39]

The partial adjustment mechanism and the forward-looking reaction (targeting expected future prices rather than current or past prices) follow Clarida, Gali, and Gertler (1998).[40] Unlike Clarida et al., however, we here adopt a price-level reaction rule[41] rather than an inflation reaction rule which would

[37] We do not model the policy objective function explicitly. Within this type of macroeconomic framework, optimizing behavior should be linked to the underlying structure of economy and would involve imposing a number of additional restrictions throughout the model. Dealing tractably with such restrictions seems beyond the scope of our current treatment.

[38] The above conditions on the coefficients, $\nu_y, \ \nu_p > 0$, are normally imposed to make the policy rule stabilize the economy.

[39] We do not consider the non-negative condition of the nominal interest rate. If the steady-state interest rate is near the zero boundary, the monetary policy shocks may be distributed asymmetrically.

[40] They argue that by specifying a policy rule that reacts to expected future inflation, they effectively nest the specification of the rule that reacts to past inflation, so long as past inflation (or its linear combination with current output) provides a sufficient statistic for future inflation.

[41] Note that this rule does not target a given value of the price level, instead reacts to its deviation from the nonstochastic steady-state equilibrium of the economy.

be more popular and nearer to the original Taylor rule.[42] The reason is that using an inflation reaction rule in our model is liable to cause indeterminacy of the steady state equilibrium, as we discuss in Section 5.3. We estimate this policy rule in our benchmark parameterization in Section 4.1 and try alternative parameterizations in Section 5.3.

For fiscal policy, on the other hand, there is no rule. Like the technology parameter, government expenditure, G_t, follows a stationary autoregressive process as follows.

$$g_t = \rho_g \, g_{t-1} + {e^g}_t, \qquad {e^g}_t \sim N(0, {\sigma_g}^2), \tag{24}$$

where g_t is the percentage deviation from steady-state and ${e^g}_t$ is a serially uncorrelated random shock.

3.4 Equilibrium

We have now described the whole model. As in the core model, we define a rational expectations equilibrium as a set of endogenous variables which satisfies entrepreneurs' decision rules (19), (3), and (20), capital producers' decision rule (5), households' decision rule (15), (16), and (17), retailers' decision rule (18), and resource constraints (1), (4), (6), and (21), given the stochastic processes (23), (8), and (24). Then we log-linearize the system around the steady state as follows.

$$\begin{aligned}
y_t &= \frac{C}{Y} c_t + \frac{I}{Y} i_t + \frac{G}{Y} g_t && (25)\\
c_t &= - r_{t+1} + c_{t+1} && (26)\\
f_{t+1} &= (1-\upsilon)(y_{t+1} - x_{t+1} - k_t) + \upsilon \, q_{t+1} - q_t && (27)\\
f_{t+1} &= r_{t+1} - \psi \, [\, n_t - (q_t + k_t) \,] && (28)\\
q_{t+1} &= \phi \, (i_{t+1} - k_t) && (29)
\end{aligned}$$

$$\begin{aligned}
y_t &= a_t + \alpha \, k_{t-1} + (1-\alpha) \, h_t && (30)\\
h_t &= \frac{\eta_h}{1+\eta_h} (y_t - x_t - c_t) && (31)\\
\pi_t &= -\lambda \, x_t + \beta \, \pi_{t+1} && (32)\\
k_t &= \delta \, i_t + (1-\delta) \, k_{t-1} && (33)\\
n_t &= \gamma F \, [\, \chi f_t - (\chi - 1) \, r_t \\
&\quad + \psi \, (\chi - 1) \, (q_{t-1} + k_{t-1}) + \{ \, 1 - \psi \, (\chi - 1) \, \} \, n_{t-1} \,] && (34)
\end{aligned}$$

[42] BGG specify a rule reacting only to expected inflation and not to output or the price level.

$$
\begin{aligned}
r_{t+1} &= {r^n}_{t+1} - \pi_{t+1} && (35)\\
\pi_t &= p_t - p_{t-1} && (36)\\
m_t - p_t &= c_t - \frac{1}{R}\,{r^n}_{t+1} && (37)\\
{r^n}_t &= \rho_n\, {r^n}_{t-1} + (1-\rho_n)\,(\nu_y\, y_t + \nu_p\, p_{t+1}) \\
&\qquad + {e^n}_t, \quad {e^n}_t \sim N(0,\, {\sigma_n}^2) && (38)
\end{aligned}
$$

$$
\begin{aligned}
a_t &= \rho_a\, a_{t-1} + {e^a}_t, \quad {e^a}_t \sim N(0,\, {\sigma_a}^2) && (39)\\
g_t &= \rho_g\, g_{t-1} + {e^g}_t, \quad {e^g}_t \sim N(0,\, {\sigma_g}^2). && (40)
\end{aligned}
$$

(25) is the log-linearized version of the resource constraint, (21). Household consumption and corporate investment are described by equations (26) to (29). (26) is the Euler equation of households' consumption derived from (15), and corresponds to the IS equation of a Keynsian model. (27) to (29) are almost the same as equations (10), (11), and (13) in the core model.

(30) is the log-linearized version of the production function. (31) is the condition for labor market equilibrium derived from (17) and (20). (32) is the New Keynesian Phillips curve (18). (33) and (34), which describe the evolution of the state variables, are the same as (14) and (12) in the core model.

(35) is the Fischer equation defining the relationship between the nominal and real interest rates, where we omit the conditional expectations operator on the future inflation rate. (36) is the definition of the inflation rate. (37) describes households' money demand derived from (16), and corresponds to the LM equation of a Keynsian model. (38) is the monetary policy rule derived from (23), which also prescribes the shock process governing the nominal interest rate.

(39) and (40) are the shock processes governing the technology parameter (the same as (8) in the core model) and government expenditure (the same as (24) above), respectively. Note that all of the three random variables in the model, ${e^z}_t$, ${e^a}_t$, and ${e^g}_t$, are uncorrelated either serially or contemporaneously.

4 Results

Using the whole log-linearized model above, we conduct some quantitative experiments in this section. As we did for the core model above, we again examine the responses of variables to exogenous shocks. In addition, we calculate the second moment properties of the model such as the standard deviations and cross correlations with output (real GDP), and examine how well these properties correspond to those observed in the actual Japanese data.

4.1 Parameterization

First of all, we set parameter values to calibrate the model to Japan's economy. As a rule, we choose them based on actual data (historical averages), single-equation estimation, or by reference to preceding studies. A list of our chosen values for the benchmark parameterization is shown in Chart 5. Some alternative parameterizations are discussed later in Section 5.2.

Steady-state values of the shares of household consumption, corporate fixed investment, and other exogenous expenditures (the expenditure of the government sector in the model) in the total expenditure of the economy are determined as historical averages of their values in the Japanese National Accounts over the period from 1980/Q1 to 2001/Q1, which we take as our main sample period.[43] The capital share, α, and the depreciation rate of capital, δ, are calculated as averages over our sample period, using the Hayashi and Prescott (2002) data, which is constructed from the National Accounts.

Households' discount factor, β $(= 1/R)$, is set to 0.995 following Ohkusa (1991) and Soejima (1997). As is usual with the standard real business cycle (RBC) model, the parameter on leisure preference is determined by the steady-state fraction of time spent working: 0.268 is the historical average in Japan, which implies a labor supply elasticity of 2.737.

The parameter on price stickiness, θ, is set to 0.75, which implies that price adjustments occur on average once every four periods (a year). This value lies within the range of estimation results for the New Keynesian Phillips curve calculated by Fuchi and Watanabe (2002) using Japanese data. The steady-state elasticity of the price of capital (Q) to the ratio of investment to capital stock (I/K) is set to 0.25 following BGG.

We take the steady-state elasticity of the external finance premium (S) with respect to the ratio of capital to net worth (χ), which determine the

[43]Data before 1980 (partly before 1990) are not available in the new standard (1993 SNA) Japanese National Accounts.

effectiveness of the financial accelerator, as 0.05 following BGG.[44] Among the principal conditions governing BGG's choice of this value are that χ is 2 and that S is annually 200 basis points. These conditions also offer a close fit to historical averages in Japan as well.[45] We also follow BGG in setting the survival rate of entrepreneurs, γ, to 0.9728.

The parameters relating to the monetary policy rule and exogenous shock processes are all given by estimation. We estimate the policy reaction function (38) using the overnight call rate and the National Accounts data detrended by the Hodrick-Prescott (HP) filter over our sample period.[46] We also estimate the first-order autoregressive parameter on the shock processes governing total factor productivity and exogenous expenditures, ρ_a and ρ_g respectively, using data calculated from the National Accounts.[47,48] We apply the standard errors in these estimations to the standard deviations of the innovations in the corresponding shock processes, σ_n, σ_a and σ_g.

4.2 Impulse Responses

We here examine the responses of the whole model to three types of shocks: a monetary policy shock, a technology shock (to total factor productivity) and a demand shock (to exogenous expenditures). Chart 8 to 10 show the results for each type of shock.

First we examine the effects of monetary policy, here those of a policy shock which works through our specified policy rule controlling the nominal

[44] BGG give this value based on a rigorous numerical solution to the optimal contracting problem between entrepreneurs and financial intermediaries which we did not set up precisely in the core model.

[45] According to the previous standard (1968 SNA) National Accounts, the historical average of χ from 1980 to 1998 fiscal year is 1.982. On the other hand, the historical average of the spread between the average contracted lending rate and the official discount rate is annually 241 (long term) or 144 (short term) basis points.

[46] Following Clarida et al. (1998) and Bernanke and Gertler (2000), we estimate the parameters, ν_y, ν_p, and ρ_n, using the generalized method of moments (GMM). The instrument set includes a constant, plus 1-4 lags of log-differenced real GDP, the log-differenced GDP deflator, and the call rate. For the expected future price level, we take the fourth period (one year) lead of the realized data.

[47] We calculate the total factor productivity, A_t, by subtracting weighted (by α) factor inputs from real GDP in logarithms, and the exogenous expenditures, G_t, by subtracting household consumption and corporate fixed investment from GDP in real terms.

[48] Following much of the RBC literatures, we estimate the first-order autoregressive parameter governing A_t (and G_t) using level data (taking logarithms) together with a constant and a linear trend term. We can alternatively use the HP-filter-detrended data as before, which gives much smaller estimates (around 0.5 and 0.6) than those usually calibrated in the literature.

interest rate, in Chart 8. A tightening policy shock raises the real interest rate as well as the nominal interest rate, which causes the main real variables to respond in almost the same way as those in the core model, where it is the real interest rate that provides the exogenous monetary policy shock. In addition, the responses of variables introduced here such as money and inflation are almost plausible theoretically.

The responses to the technology shock in Chart 9 are different from those of the core model. Under our parameterization, when a positive technology shock hits the economy, entrepreneurs' net worth does not improve but deteriorates. This is partly because the policy reaction function counteracts the positive effects of the shock, and partly because an expansion of the markup due to price stickiness causes the rent paid to a unit of capital in terms of the retail price of output goods to depreciate.[49] The external finance premium thus dampens the demand for capital in the FA case, which counteracts rather than amplifies the positive responses of investment and real GDP. Therefore, the technology shock is less amplified in the FA case, which is the reverse of the outcome in the core model.[50]

A positive demand shock also boosts real GDP and investment, although the rise of the interest rate counteracts this effect, making the increases more modest, as shown in Chart 10. Entrepreneurs' net worth here improves and the external finance premium diminishes, which means that the shock is more amplified in the FA case.

4.3 Second Moment Properties

As our main quantitative experiment, we calculate second moment properties of the model such as standard deviations and cross correlations with output (real GDP), and examine how well these properties correspond to those observed in the actual Japanese data, illustrated in Chart 1. Note that the random variables in our model are the innovations in the three shock process, ${e^n}_t$, ${e^a}_t$, and ${e^g}_t$, and that these innovations are assumed to be distributed normally and uncorrelated either serially or contemporaneously.[51]

[49] On the other hand, households' welfare improves because retailers' monopolistic profits which belong to households increase, accompanied by the expansion of the markup.

[50] Note that this outcome depends on the parameterization, especially that of the policy reaction and price stickiness terms. In BGG, the policy reaction to output is set to zero (omitted) and hence, like the other shocks, the technology shocks are also more amplified in the FA case.

[51] In the actual data, our parameterization implies that the first order sample autocorrelation of ${e^n}_t$ is 0.313, of ${e^a}_t$ is -0.238, and of ${e^g}_t$ is 0.064, and that the sample cross correlation between ${e^n}_t$ and ${e^a}_t$ is 0.079, between ${e^n}_t$ and ${e^g}_t$ is -0.187, and between ${e^a}_t$ and ${e^g}_t$ is 0.302.

For the purpose of comparison with the actual data in Chart 1, we calculate the HP-filtered moments of the model. Chart 11 shows standard deviations and cross correlations with real GDP of the corresponding HP-filtered series in both the No-FA and FA cases of the model, which we calculate analytically. In addition, we also generate stochastically one hundred simulated sets[52] where each set consists of a complete dynamic path over the full 85 periods of our sample. We then calculate sample moments based on these simulations. Chart 12 shows the results of the simulation-based sample moments, together with the sample standard errors for each of them.

Our main result is that the FA case produces more volatile corporate investment (the standard deviation, shown in Chart 11, is 4.36) than the No-FA case (3.36), and corresponds more closely to the actual data (5.32 in Chart 1) though still a little bit short. The sample standard error of the simulation-based moment (0.51 for a simulation-based standard deviation of 4.32 in the FA case, and 0.35 for 3.17 in the No-FA case, in Chart 12) implies that the difference between the results from the two cases seems significant. We can interpret this result as one piece of evidence supporting the existence of financial accelerator effects in Japan's business cycles.

For other variables, on the other hand, the difference between the two cases does not seem to be significant. Moreover, the volatilities of these variables correspond relatively well to the actual data in both cases. A remarkable exception, however, is total working hours. The volatility the model produces for this variable is, in both cases (the standard deviations, shown in Chart 11, are 2.32 in the FA case and 2.17 in the No-FA case) far larger than that of the actual data (0.62 in Chart 1). This point will be discussed later when we vary the parameter value governing the elasticity of the labor supply, η_h, in Section 5.2.

For the most part, the pattern of cross correlations with real GDP roughly corresponds to those of actual business cycles (for example, a high cross correlation of investment is maintained for some lags) and the difference between the two cases does not seem to be significant. We should remark, however, that it is the failure to reproduce the actual pattern of cross correlations that causes higher order autocorrelations of most variables to be too small, although this is a fault shared by many other simple RBC models.

[52]The number of simulated sets, one hundred, follows Soejima (1997).

5 Variations of The Model

We have obtained the result that in the FA case the model produces more volatile corporate investment which corresponds more closely to the actual data than it does in the No-FA case. In this section, we examine the robustness of this result and consider some variations of the model by varying the composition of the exogenous shocks and some underlying parameter values, adopting alternative monetary policy rules, and introducing an asset price bubble into the model. These experiments illustrate various properties of the model and may also be of potential simulative interest in considering possible future states of the economy.

5.1 Variance Decomposition

First we examine the source of economic fluctuation in our benchmark results in Section 4.3 (Chart 11), that is the innovation in the shock processes, ${e^n}_t$, ${e^a}_t$, and ${e^g}_t$. We can decompose the calculated volatilities of the endogenous variables into three parts, each of which represents one of the three exogenous shocks, relying on the assumption that the innovations in these processes are mutually uncorrelated. Chart 13 shows the results of this decomposition in the No-FA and FA cases. In both cases, the variances of real GDP, investment, and consumption as well as of money and the nominal interest rate are mainly caused by the monetary policy shock while those of working hours and inflation are mainly caused by the technology shock. Comparing the No-FA and FA cases, we can see that the proportion of the variance caused by the monetary policy shock is larger in the FA case than in the No-FA case for all variables except consumption. In particular, eighty percent of the variance of investment springs from the monetary policy shock in the FA case while this figure drops to nearly seventy percent in the No-FA case. Together these results suggest that the financial accelerator effects work mostly on investment rather than consumption by amplifying the monetary policy shock.

Next we try varying the composition of the three shocks in order to interpret the decomposition results above. Here it may be sufficient to examine the three extreme compositions where each shock is the only the source of fluctuations. We set the standard deviations of the innovations in those compositions, σ_n, σ_a, and σ_g, so that in each composition the volatility of real GDP in the FA case is the same as that in our benchmark composition set out in the preceding section (1.17) for comparison. Results are presented in the bottom table of the same chart, and show that the composition that includes only the monetary policy shock produces fluctuations that come closest, among all four compositions (including the benchmark composition) to reproducing the fluctuations observed in the actual data, in the sense that investment is more volatile and consumption, working hours, and inflation are less volatile. This implies that the monetary policy shock may be relatively more important in the actual economy than our benchmark composition suggests.

5.2 Varying Parameter Values

Next we try varying the benchmark parameterization set out in Section 4.1. This may be of potential simulative interest in considering possible future states of the economy, as well as providing a robustness check on the sensitivity of the benchmark results. Chart 14 shows some alternative results for the standard deviations in the No-FA and FA cases obtained by varying the values for χ, θ, and η_h, which are the three important and sensitive underlying parameters in the model.

First, if the steady state ratio of internal funds is lower (that is, χ is higher) than the benchmark value (the ratio is 0.5, or equivalently χ is 2), the volatility of corporate investment in the FA case increases and comes closer to the actual volatility, although other parameters remain little changed.[53] This is because the effectiveness of the financial accelerator expands as the share of external financing rises.[54] The result is in contrast to the No-FA case, in which changes in χ leave the volatility unchanged.

Secondly, if retailers can change their prices more frequently, for example as a result of deregulation making a more competitive environment, the volatility of the economy as a whole is reduced although that of inflation itself is increased. The range within which we vary the value for θ in the chart is in line with the estimation results of Fuchi and Watanabe (2002). Since the propagation of the monetary policy shock is sensitive to the degree of price stickiness, the volatility caused by the monetary policy shock is sensitive to variation in θ. In the No-FA case, this sensitivity is less than in the FA case.

Thirdly, if households supply their labor less elastically with respect to wages, the volatilities of working hours, investment, and real GDP are reduced while those of consumption and real money balances are increased.

[53] When χ increases, the elasticity ψ that is fixed here may also increase. Then the volatility of corporate investment may further increase beyond the result shown in Chart 14.

[54] However, if the steady state ratio of internal funds is lower than about 20% (that is, χ exceeds 5), the effectiveness of the financial accelerator and the volatility of investment tend to diminish. This is the phase of an "excessive external finance premium" which Kasuya and Fukunaga (2002) pointed out.

The numerical example in the chart suggests that very small elasticity is required in order to reproduce the actual volatility of working hours. In the No-FA case, the sensitivity is once again less than in the FA case.

5.3 Alternative Monetary Policy Rules

In the whole model above, the monetary policy rule has a particularly important role in either stabilizing or destabilizing the economy. Here we compare the performances of alternative policy rules in both the No-FA and FA cases and examine their properties in the context of this model.

First we try varying our estimated benchmark parameter values for the price-level reaction rule, (23). The standard deviations for each parameterization in both the No-FA and FA cases are shown in Chart 15. Moving from an extreme situation in which monetary policy does not react at all to economic conditions (i.e. both ν_y and ν_p are zero), our benchmark rule stabilizes all variables appearing in the table. As we give larger values to the reaction parameters (for example, $\nu_y = \nu_p = 2$), the economy is further stabilized. We can see that those stabilizing effects are stronger in the FA case than in the No-FA case. Under an active reaction rule such as $\nu_y = \nu_p = 2$, corporate fixed investment in the FA case is strongly stabilized by the policy so that its volatility is smaller than in the No-FA case and our benchmark result in Section 4.3 is overturned.

We can also see that the stabilizing effects of the two terms, ν_y and ν_p, which constitute the policy rule work in different directions. Chart 16 shows the stabilizing effects on output (real GDP) and inflation, generally considered to be the two objectives of monetary policy. As we give a larger value to ν_y, inflation becomes volatile while output is stabilized. This means that we are confronted with a tradeoff between the two objectives. On the other hand, as we increase the value of ν_p above the benchmark value (0.03), both output and inflation are stabilized to some extent. This implies that our benchmark rule leaves room for further stabilization of the economy through more active reaction to the price-level. When ν_p exceeds some threshold, however, although inflation continues to be further stabilized output tends to increasing volatility,[55] and we eventually confront the tradeoff.[56]

[55] The lower limit on the standard deviation of output is around 0.6, which the rule $\nu_y = \nu_p = 2$ of our examples almost achieves. Any active rule cannot stabilize output over this limit.

[56] If we add an exogenous nominal shock process to the price setting rule (18) instead of the monetary policy rule (the policy rule is then always implemented and completely endogenized), following Clarida, Gali, and Gertler (1999), the tradeoff between the variances of output and inflation is presented more clearly.

Next we consider alternative specifications of the policy rule including the reaction to inflation. We replace the price-level reaction term in our benchmark specification (23) with an inflation reaction term as follows.

$$\begin{aligned} {r^n}_t &= \rho_n \, {r^n}_{t-1} + (1-\rho_n) \, {r^{n*}}_t + {e^n}_t, \quad {e^n}_t \sim N(0, \, {\sigma_n}^2) \\ {r^{n*}}_t &= \nu_y \, y_t + \nu_\pi \, \mathrm{E}_t \, \pi_{t+1} \quad \text{with } \nu_y, \ \nu_\pi > 0. \end{aligned} \tag{41}$$

This specification is nearer to Clarida, Gali and Gertler (1998) and the original Taylor rule.[57] Although this type of specification is popular, it does not work well in our model.[58] When we set ν_π to below unity (say 0.5), both output and inflation are destabilized since the real interest rate moves in the opposite direction to the nominal rate. If we choose a value larger than unity for ν_π, however, prices do not converge to the original level after a shock and the steady state equilibrium becomes indeterminate.[59] To avoid this indeterminacy, we should again add a price-level reaction term to the above specification (41).

5.4 Introducing a Bubble

So far, we regard the asset (capital) price, Q_t, as an endogenous variable which passively reflects the real economy, although in the FA case its unanticipated movements have considerable effects on economic activity through changes in the value of entrepreneurs' net worth. We know, however, from experience in the late 1980s to early 1990s, that if asset markets are influenced by non-fundamental factors, then movements in asset prices may be to some extent considered a further independent source of economic fluctuation, supplementing the three types of shock that we have already considered in the model.

In order to deal with this possibility, we extend the model a little, following Bernanke and Gertler (2000). We introduce a bubble by assuming that the market price of capital, S_t, may differ from capital's fundamental value, Q_t. If a bubble exists at t, it persists and grows with probability p or crashes with probability $1-p$ as follows.

$$\begin{aligned} S_{t+1} - Q_{t+1} &= \frac{a}{p} \, (S_t - Q_t) \, F_{t+1} && \text{with probability } p \\ &= 0 && \text{with probability } 1-p. \end{aligned}$$

[57] Note that this rule does not target inflation at a certain positive value but at zero. Therefore, it also implicitly targets the steady-state price level.

[58] Levin, Wieland and Williams (1999) discuss the robustness of alternative policy rules under model uncertainty.

[59] In Chart 15, we show the standard deviations calculated under this parameterization regardless of the indeterminacy.

where F_{t+1} is here the fundamental return on capital. Therefore,

$$\mathrm{E}_t\,[\,S_{t+1} - Q_{t+1}\,] = a\,(S_t - Q_t)\,\mathrm{E}_t\,F_{t+1}. \tag{42}$$

We assume $0 < p < a < 1$ so that the discount value of the bubble converges to zero over time, while it grows until it bursts. Note that once the bubble crashes it is not expected to re-emerge, which is an assumption for simplicity. While the relationship between the fundamental value and the fundamental return on capital is prescribed by (19), the relationship between the market price and the market return, ${F^S}_{t+1}$, is

$$\mathrm{E}_t\,{F^S}_{t+1} = \mathrm{E}_t\left[\frac{\frac{1}{X_{t+1}}\frac{\alpha Y_{t+1}}{K_t} + S_{t+1}(1-\delta)}{S_t}\right], \tag{43}$$

and the relationship between the fundamental and the market return is

$$\mathrm{E}_t\,{F^S}_{t+1} = \mathrm{E}_t\,F_{t+1}\,[\,a\,(1-\delta) + \{1 - a\,(1-\delta)\}\,\frac{Q_t}{S_t}\,]. \tag{44}$$

This completes the extension. We now log-linearize the above equations (43) and (44) around the steady state as follows.

$$\begin{aligned} {f^s}_{t+1} &= (1-\upsilon)\,(y_{t+1} - x_{t+1} - k_t) + \upsilon\,s_{t+1} - s_t && (45)\\ {f^s}_{t+1} &= f_{t+1} - \{1 - a\,(1-\delta)\}\,(s_t - q_t). && (46)\end{aligned}$$

On condition that the bubble does not burst during $t+1$, the realized value in log-linearized terms is written as

$$s_{t+1} - q_{t+1} = \frac{F}{p\,(1-\delta)}\,(s_t - q_t). \tag{47}$$

We add the above equations (45) to (47) to our log-linearized model in Section 3.4, and replace the fundamental terms, q_t and f_t, by the market terms, s_t and ${f^s}_t$, respectively.[60] We then try generating a bubble that begins with a one percentage point increase in the market price of capital above its fundamental value and bursts four periods (one year) later. Note that agents in the model know only the ex-ante stochastic process governing the bubble. Chart 17 shows responses to this exogenous disturbance in both the No-FA and FA cases. We can see that corporate investment in the FA case undergoes a large-scale decline after the collapse of bubble and it takes a long time for it to revert to its original steady state, while in the No-FA case

[60] We do not replace q_{t+1} in equation (28) following Bernanke and Gertler (2000), assuming that capital producers' investment decision is based on the fundamental value rather than the market price.

it returns to its steady state almost at once. This drop in investment in the FA case is accompanied by a fall in entrepreneurs' net worth, which is greatly damaged by the collapse of bubble. The financial accelerator effects typically amplify shocks that affect entrepreneurs' net worth. Here we set the value determining the bubble's growth in each period, $\frac{F}{p\,(1-\delta)}$ in equation (47), to 2. Then, as shown in Chart 18, the standard deviation of corporate investment in the FA case (5.20) reaches a level that corresponds to the actual data. Thus we see that adding these bubble effects to the benchmark result in Section 4.3 achieves a close match to the observed data, although this result is conditional on our assumption that the bubble occurs independently of the other three shocks.[61]

6 Concluding Remarks

This paper calibrates a dynamic general equilibrium model incorporating credit-market imperfections using Japanese data. The model exhibits financial accelerator effects, the mechanism whereby credit-market imperfections help to propagate or amplify initial shocks to the economy. Our main result is that the large volatility of Japan's corporate investment can be explained by taking account of this mechanism. We examine the robustness of the results and consider some variations of the model by varying the composition of the exogenous shocks and some underlying parameter values, adopting alternative monetary policy rules, and introducing an asset price bubble into the model. These experiments illustrate various properties of the model and may also be of potential simulative interest in considering possible future states of the economy.

By varying parameterization and specification, can this model provide a consistent explanation for a variety of different economic situations? In particular, as shown in Chart 1, the difference in investment volatility between the Japanese and U.S. economies, or between Japan's economy in the 1980s and in the 1990s is remarkably large. There may be some differences in the underlying parameter values governing the effectiveness of the financial accelerator, the performance of monetary policy, or the exogenous shock processes themselves. To investigate the causes of these differences represents another interesting application of this model, and we would like to take this as a subject for future research.[62] Here we can remark that the FA case can

[61] Both the parameterization and the specification of the bubble process here cannot avoid being arbitrary. That is why we did not use this extended model in the benchmark quantitative experiments in Section 4.

[62] Hall (2001) explains the difference of performance between the U.K. economy in the

generally produce a wider range of results than the No-FA case by varying parameterization and specification.

Finally we note that this model is only one of a number of ways of introducing credit-market imperfections into a macroeconomic framework. There are many financial factors we ignore in this model, including banking sector conditions. Therefore other models might give differing quantitative, and possibly qualitative, results. At the same time, the dynamic general equilibrium framework itself still continues to develop, for instance by extension to an open economy setting.[63] We would like to see the results of richer and more diverse studies developing from our approach.

1980s and in the 1990s by varying the parameterization on financial conditions in BGG model.

[63] Gertler, Gilchrist and Natalucci (2000) extend the BGG model to an open economy setting and explore the connection between the exchange rate regime and the financial accelerator.

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Actual Data

(1) Standard deviations

	U.S.A.	Japan		
			1980/Q1-1990/Q4	1991/Q1-2001/Q1
Real GDP	1.32 <1.00>	1.10 <1.00>	0.94 <1.00>	1.27 <1.00>
Corporate fixed investment	3.88 <2.94>	5.32 <4.82>	4.10 <4.38>	6.44 <5.06>
Private consumption	1.03 <0.78>	0.96 <0.87>	0.82 <0.88>	1.10 <0.86>
Total working hours	1.25 <0.94>	0.62 <0.56>	0.56 <0.60>	0.68 <0.54>
Inflation rate	1.14 <0.86>	1.74 <1.58>	2.08 <2.23>	1.30 <1.02>
Monetary aggregate	1.02 <0.77>	1.61 <1.46>	1.79 <1.92>	1.40 <1.10>
Nominal interest rate	1.44 <1.09>	1.02 <0.92>	0.81 <0.86>	0.63 <0.50>

(2) Cross correlations with GDP

1. U.S.A.

	-4	-3	-2	-1	0	1	2	3	4
Real GDP	0.19	0.42	0.63	0.84	1.00	0.84	0.63	0.42	0.19
Corporate fixed investment	-0.15	0.01	0.24	0.48	0.70	0.79	0.77	0.64	0.42
Private consumption	0.44	0.60	0.70	0.80	0.83	0.67	0.50	0.31	0.12
Total working hours	0.06	0.31	0.55	0.78	0.93	0.89	0.75	0.58	0.37
Inflation rate	-0.24	0.00	0.14	0.25	0.33	0.40	0.37	0.43	0.38
Monetary aggregate	0.14	0.11	0.08	0.03	-0.06	-0.14	-0.13	-0.09	-0.07
Nominal interest rate	-0.41	-0.24	-0.05	0.26	0.44	0.46	0.45	0.51	0.39

2. Japan

	-4	-3	-2	-1	0	1	2	3	4
Real GDP	0.35	0.57	0.61	0.73	1.00	0.73	0.61	0.57	0.35
Corporate fixed investment	0.18	0.32	0.49	0.65	0.77	0.79	0.80	0.73	0.59
Private consumption	0.23	0.44	0.29	0.24	0.65	0.25	0.12	0.20	0.07
Total working hours	0.36	0.51	0.59	0.64	0.65	0.65	0.55	0.44	0.25
Inflation rate	0.08	0.14	0.22	0.21	0.11	0.36	0.30	0.26	0.24
Monetary aggregate	0.47	0.55	0.61	0.64	0.62	0.59	0.51	0.42	0.37
Nominal interest rate	0.07	0.20	0.29	0.35	0.43	0.49	0.52	0.50	0.42

< Lead GDP **Lag GDP >**

Notes:

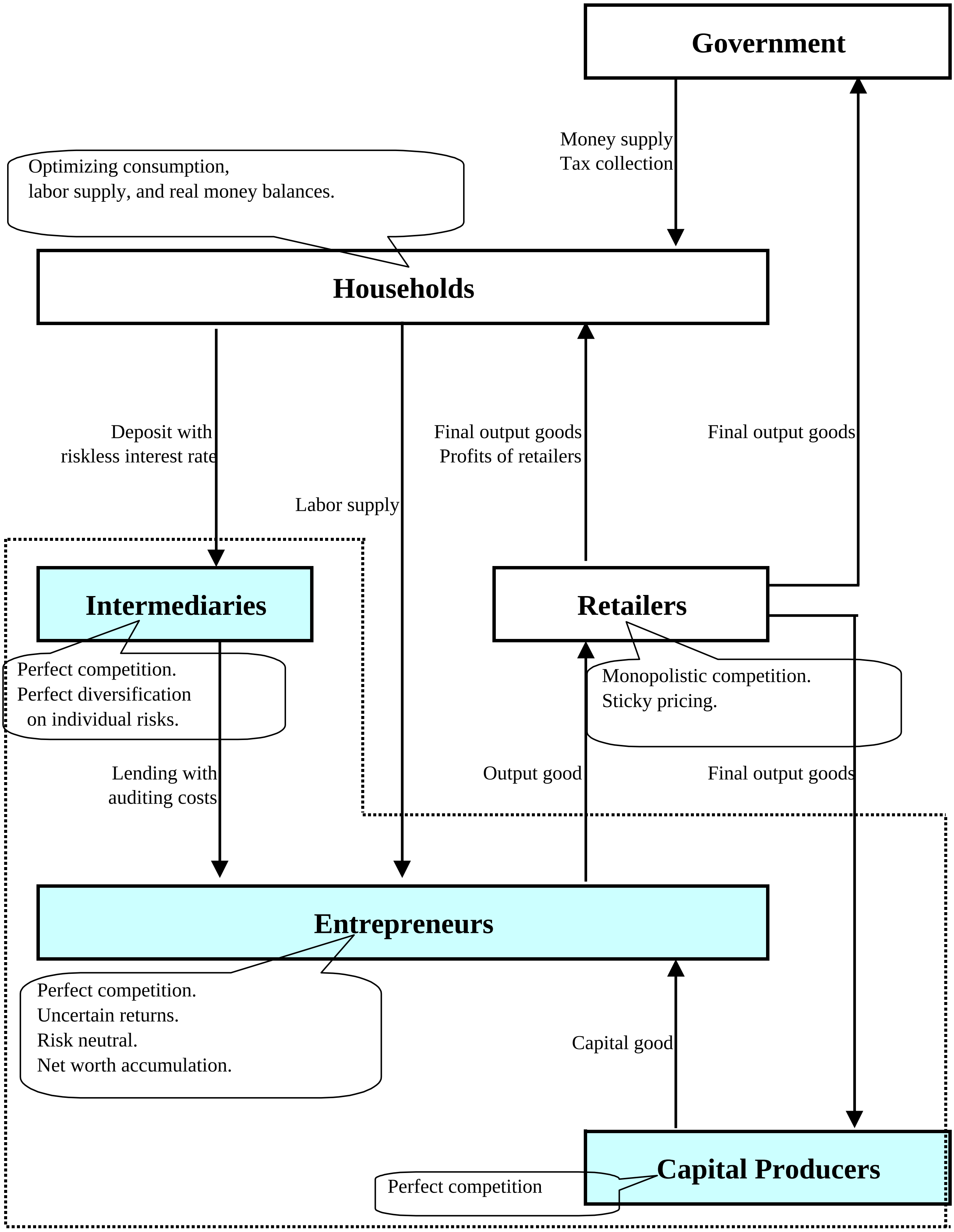
1. Period: 1980/Q1-2001/Q1
2. All variables are in logarithms (except Inflation rate and Nominal interest rate) and have been detrended by the Hodrick-Prescott (HP) filter (λ=1600).
3. GDP, Investment, Consumption, and working hours are real and per-capita base.
4. Inflation rate (rate of change in GDP deflator) and Nominal interest rate (Japan: call rate, US: federal funds rate) are annual rates.
5. Numbers <…> in table (1) represent the relative volatility to GDP.
6. Shaded sells in tables (2) represent the peak.

Sources

Japan: National Accounts, Labor Force Survey, Bank of Japan.

U.S.: National Income and Product Accounts, Monthly Labor Review, Federal Reserve Bank.

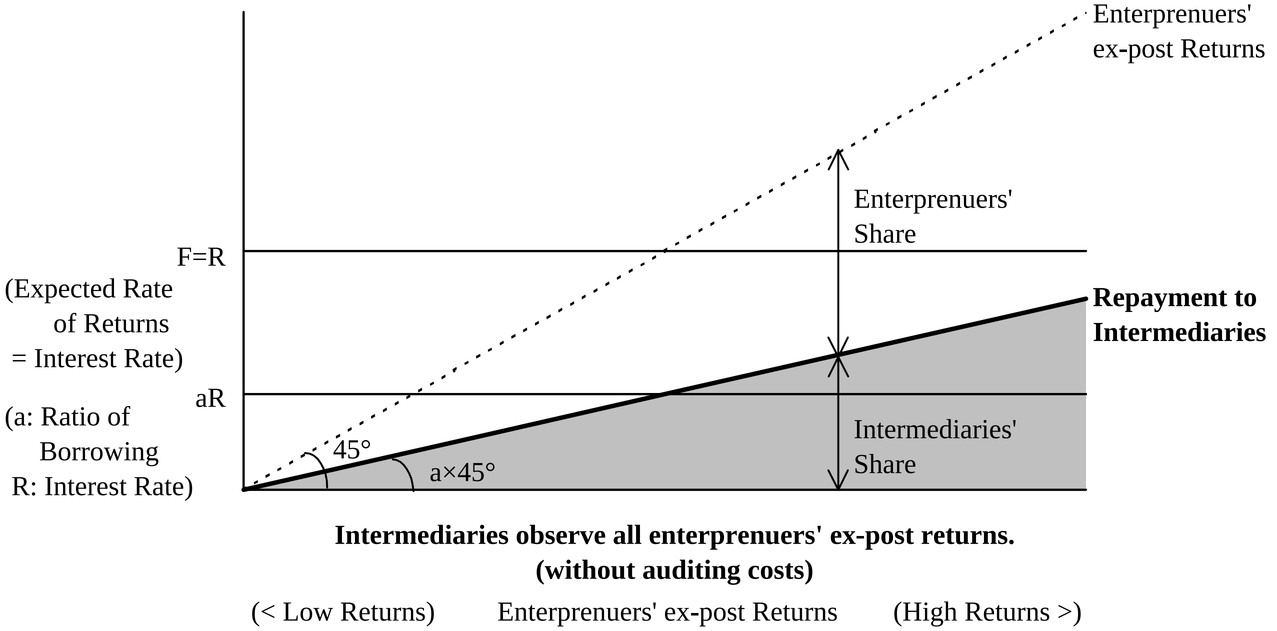
Sketch of the Whole Model



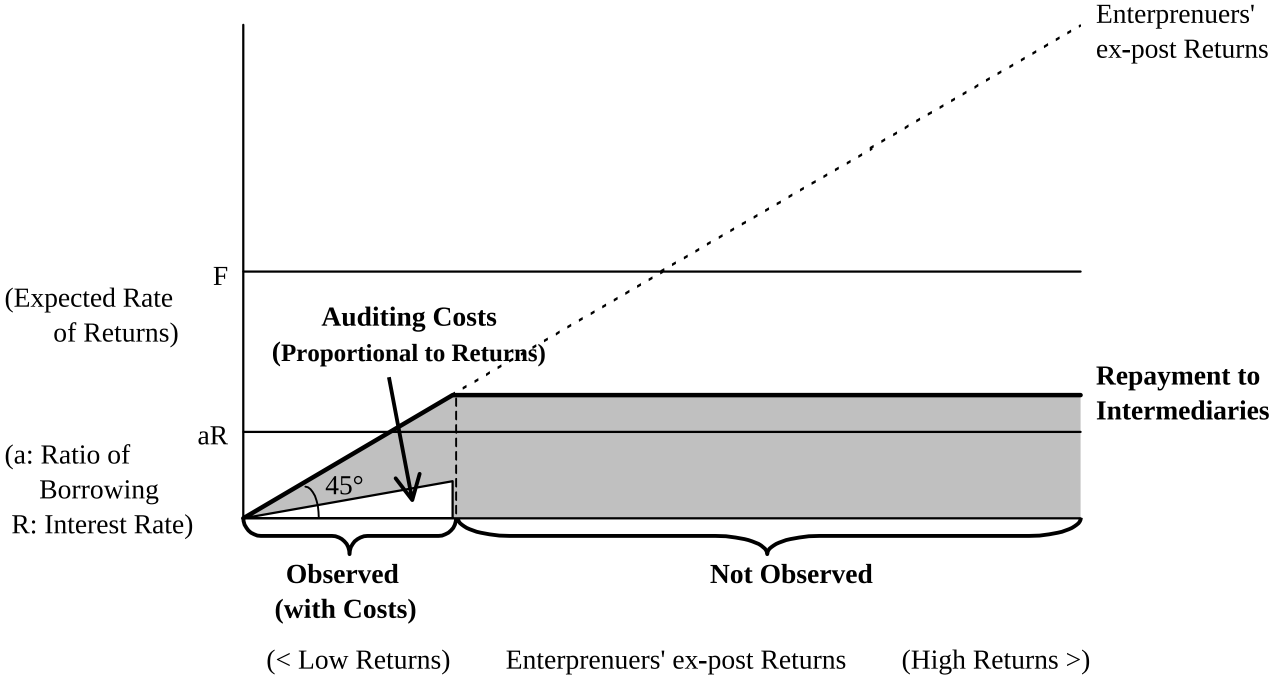
* The part enclosed by the dotted lines (with shaded agents) is the core model.

Sketch of the Optimal Contract

(1) Situation without Auditing Costs (No Financial Accelerator case)



(2) Situation with Auditing Costs (Financial Accelerator case)

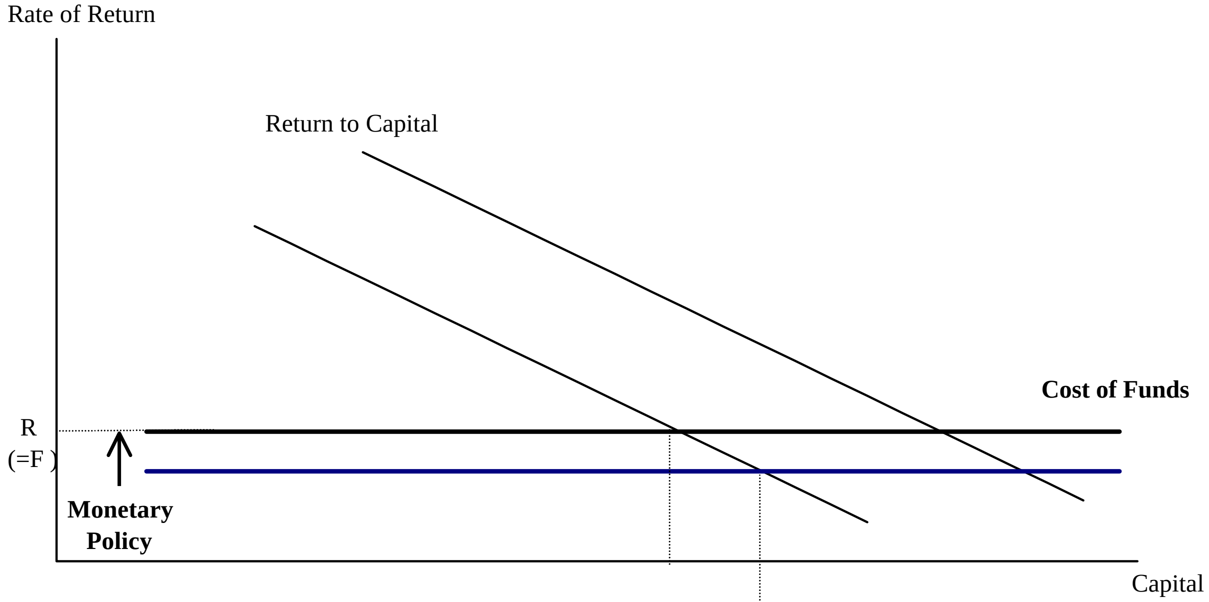


Explanations:

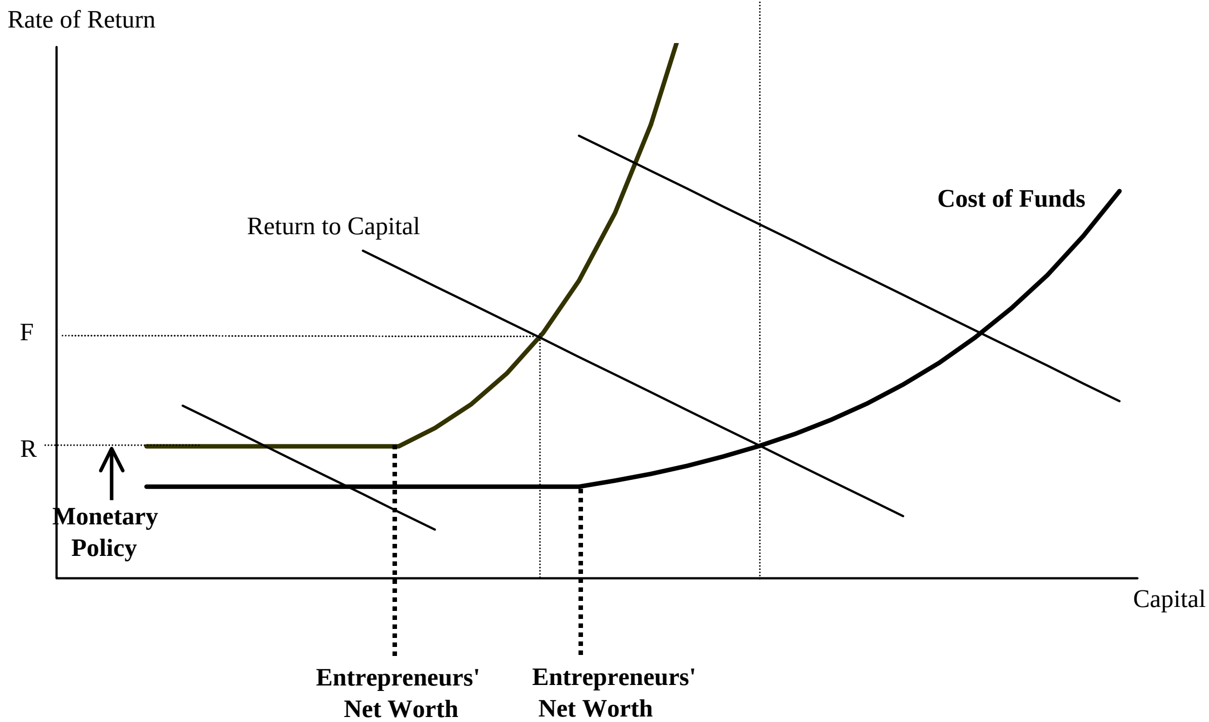
1. Normalizing enterpreneurs' purchasing capital to unity.
2. The ex-post returns are distributed uniformly here.
3. The expected rate of returns, F, and the interest rate, R, are taken as given here.
4. The optimal contracting rule maxmaizes enterpreneurs' share subject to the condition that intermediaries' expected returns of lending less monitoring costs (the average of shaded area) must be equal to the interest rate.
5. Optimally chosen ratio of borrowing (a) is increasing function of F/R.

Static Financial Accelerator Effects

(1) No Financial Accelerator (FA) case



(2) Financial Accelerator (FA) case



The Notation of Variables and Parameter Values

Y_t	Real GDP, Output	X_t	(Gross) Mark-up Rate
C_t	Private Consumption	A_t	Total Factor Productivity
I_t	Corporate Fixed Investment	H_t	Labor Input Hours
G_t	Government Expenditure	W_t	Real Wage per Hour
R_t	(Gross) Real Interest Rate	R^n_t	(Gross) Nominal Interest Rate
F_t	(Gross) Rate of Returns	P_t	Prices Level
Q_t	Price of Capital Good	P^*_t	Optimal Price of Retailers
K_t	Capital	Π_t	(Gross) Inflation Rate
N_t	Net Worth	M_t	Money

C/Y	0.538^+	…… Steady-State Consumption Share in GDP
I/Y	0.155^+	…… Steady-State Investment Share in GDP
G/Y	0.308^+	…… Steady-State Exogenous Expenditures Share in GDP
β	0.995^*	…… Discout factor of Households
R	-----	…… Steady-State Real Gross Interest Rate ($=1/\beta$)
γ	0.9728^*	…… Survival Rate of Enterpreneurs
χ	2^+	…… Steady-State Ratio of Capital to Net Worth (=K/N)
S	1.005^+	…… Steady-State External Finance Premium (=F/R)
ψ	0.05^*	…… Steady-State Elasticity of S to χ ($=S'(\chi)/S(\chi)$)
α	0.358^+	…… Capital Share
δ	0.021^+	…… Depreciation Rate of Capital
υ	0.8^+	…… $= (1-\delta) / \{(1-\delta)+\alpha Y/(XK)\}$
φ	0.25^*	…… Steady-State Elasticity of I/K to Q ($=\Phi''(I/K)/\Phi'(I/K)$)
η_h	2.737^+	…… Elasticity of Labor Supply to Wage
ξ, ζ	-----	…… Parameter on Household Utility
θ	0.75^*	…… Parameter on Price Stickiness
λ	-----	…… $= \theta^{-1}(1-\theta)(1-\theta\beta)$
ε	-----	…… Parameter on Steady-State Markup
ν_y	$0.084^@$	…… Parameter on Monetary Policy Rule for Output Gap
ν_p	$0.004^@$	…… Parameter on Monetary Policy Rule for Price Level
ρ_n	$0.920^@$	…… AR(1) Parameter on Monetary Policy Rule
ρ_a	$0.870^@$	…… AR(1) Parameter on Technology Shock
ρ_g	$0.877^@$	…… AR(1) Parameter on Demand Shock
σ_n	$0.104^@$	…… Standard Deviation of the Monetary Policy Shock
σ_a	$0.890^@$	…… Standard Deviation of the Technology Shock
σ_g	$1.275^@$	…… Standard Deviation of the Demand Shock

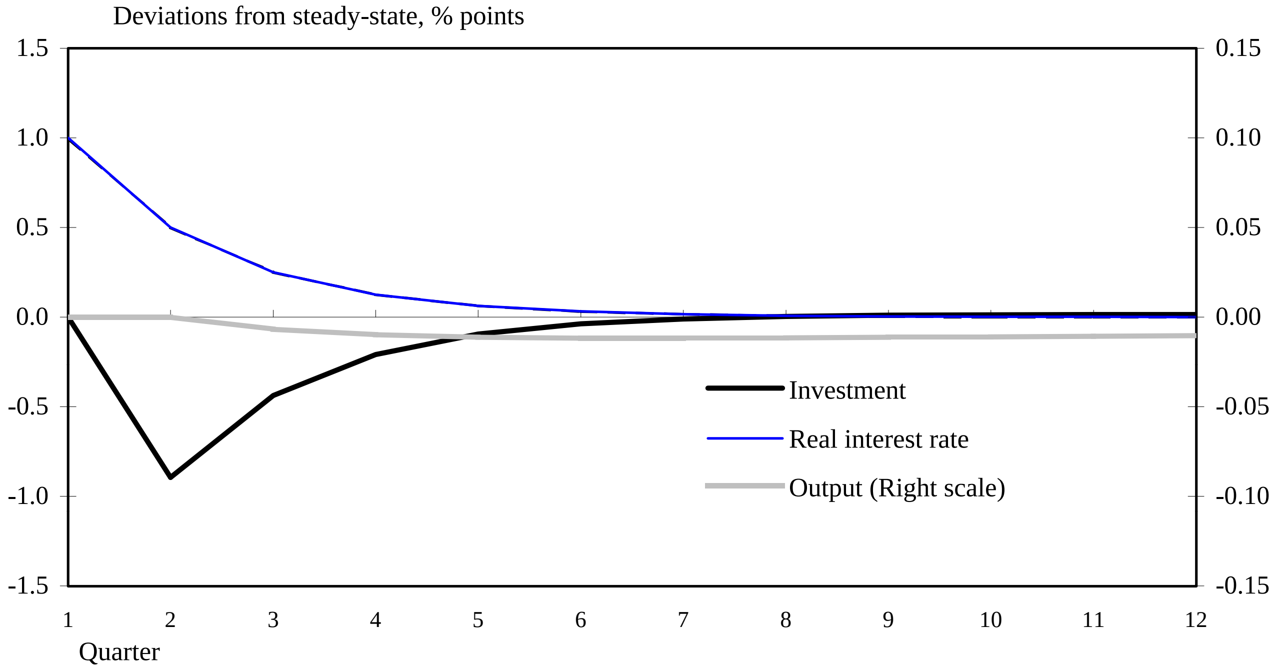
Notes:

1. Uppercase variables denote level, and lowercase variables denote percentage deviations from the stedy-state. Uppercase variables without time subscripts denote the steady-state values.
2. Values with $^+$ are based on actual data (historical averages), with * on references to preceding studies, and with $^@$ on single-equation estimation.

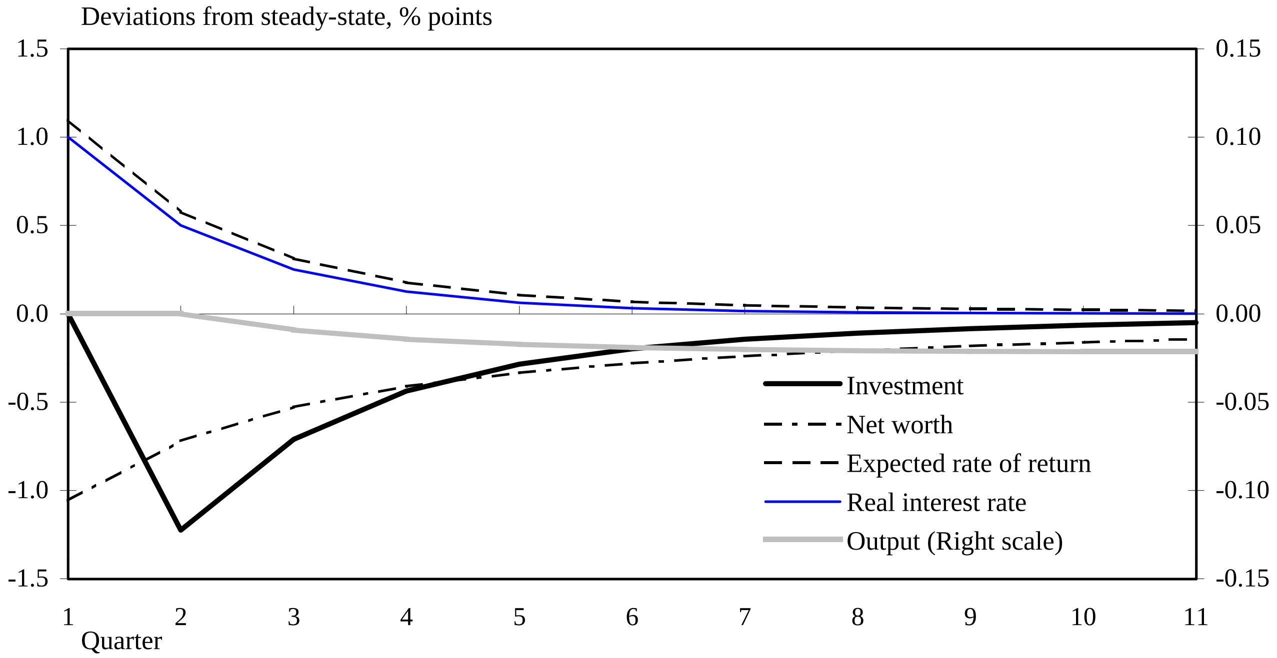
Responses to Monetary Policy Shock (The Core Model)

[Condition] Giving a positive (tightning) monetary policy shock to the real interest rate consisting of annually 1% deviation from the steady-state only in the 1st quarter.

(1) No-FA case



(2) FA case

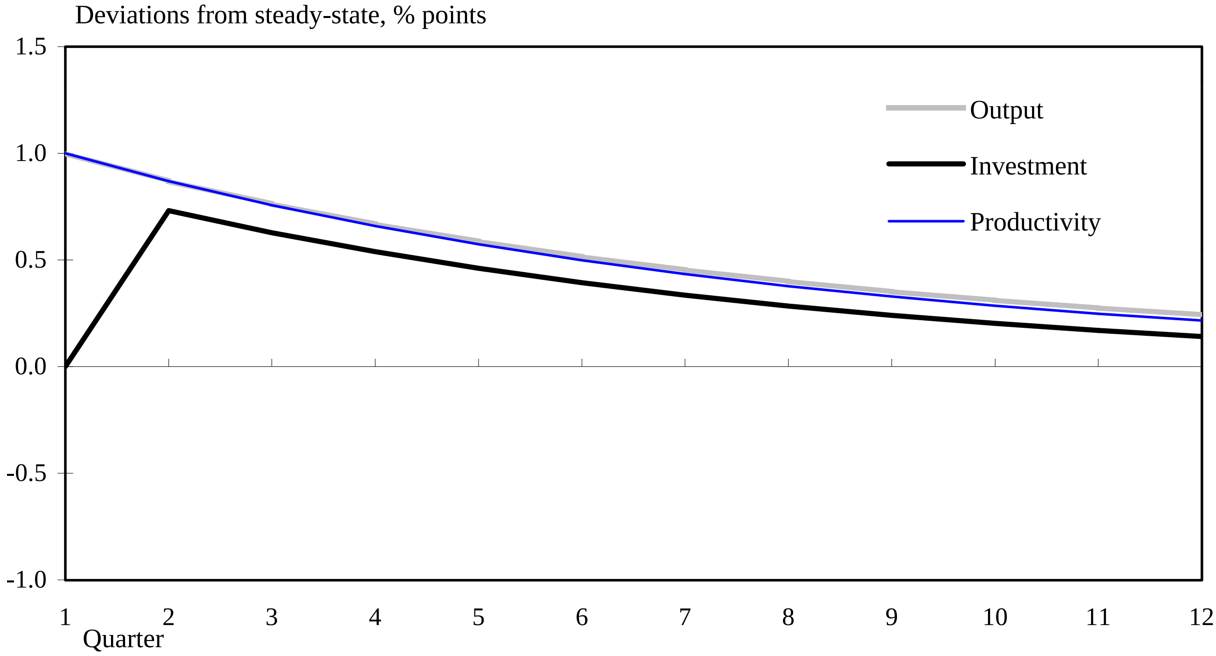


Note: Interest rate and Expected rate of return are annual rates.

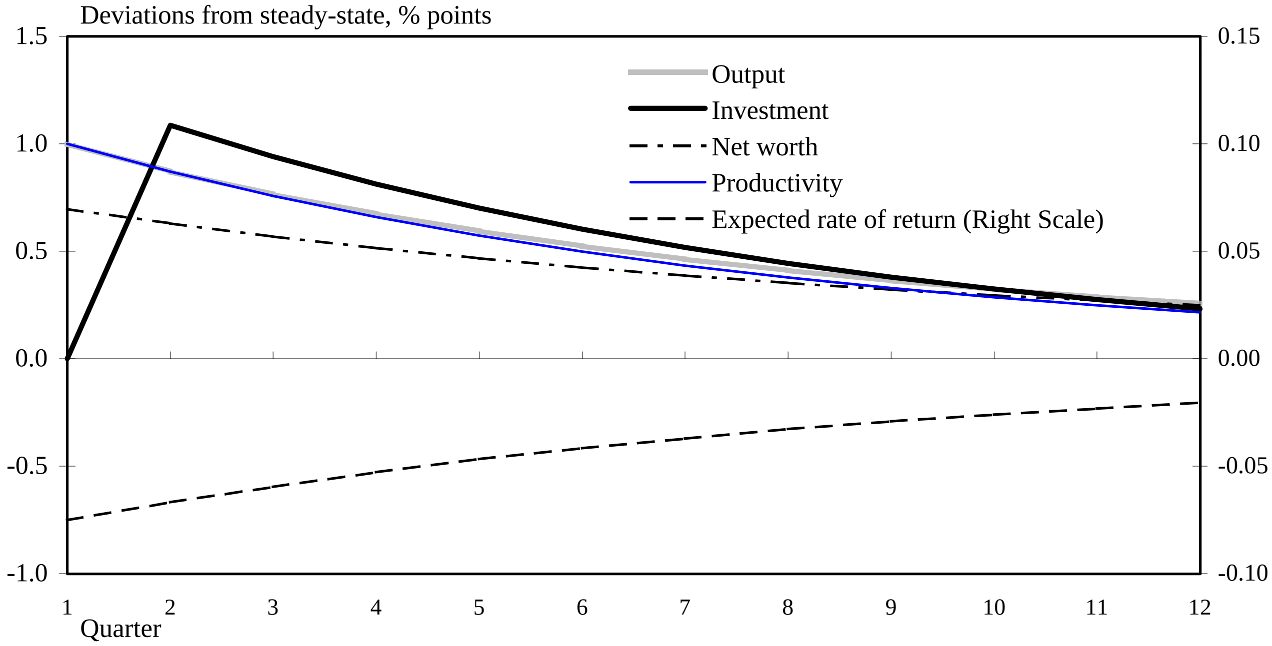
Responses to Technology Shock (The Core Model)

[Condition] Giving a positive technology shock consisting of 1% deviation from the steady-state only in the 1st quarter.

(1) No-FA case



(2) FA case

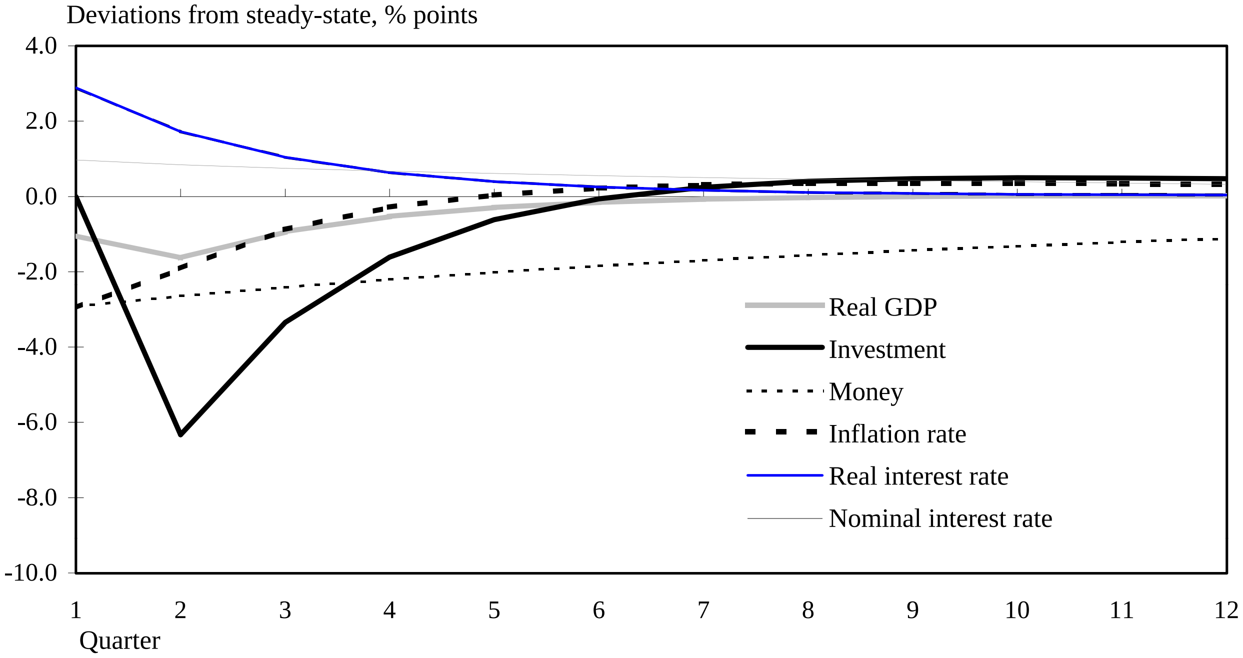


Note: Interest rate and Expected rate of return are annual rates.

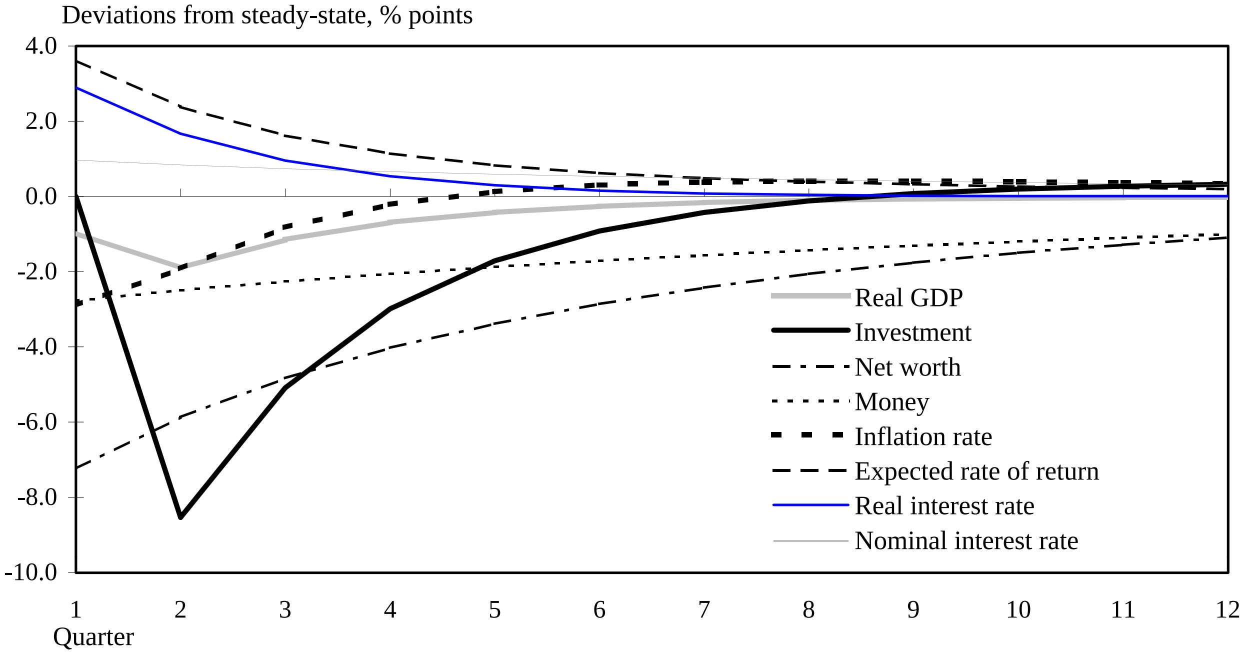
Responses to Monetary Policy Shock (The Whole Model)

[Condition] Giving a positive (tightning) monetary policy shock to the nominal interest rate consisting of annually 1% deviation from the steady-state only in the 1st quarter.

(1) No-FA case



(2) FA case

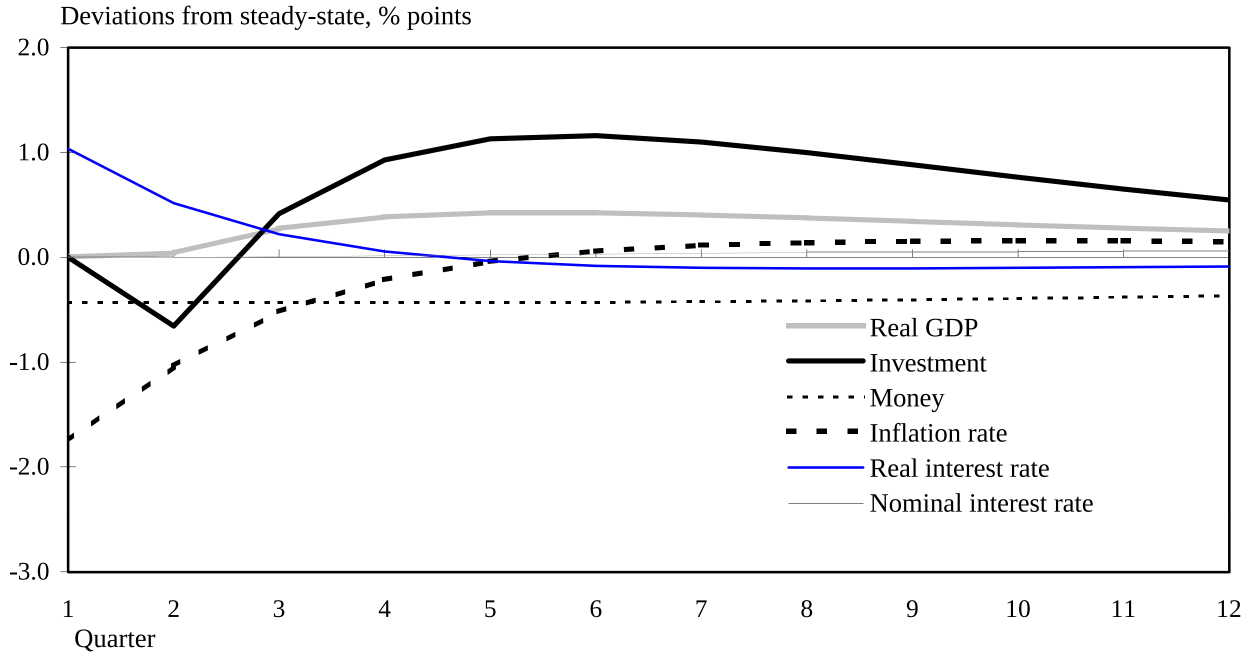


Note: Interest rate, Expected rate of return, and Inflation rate are annual rates.

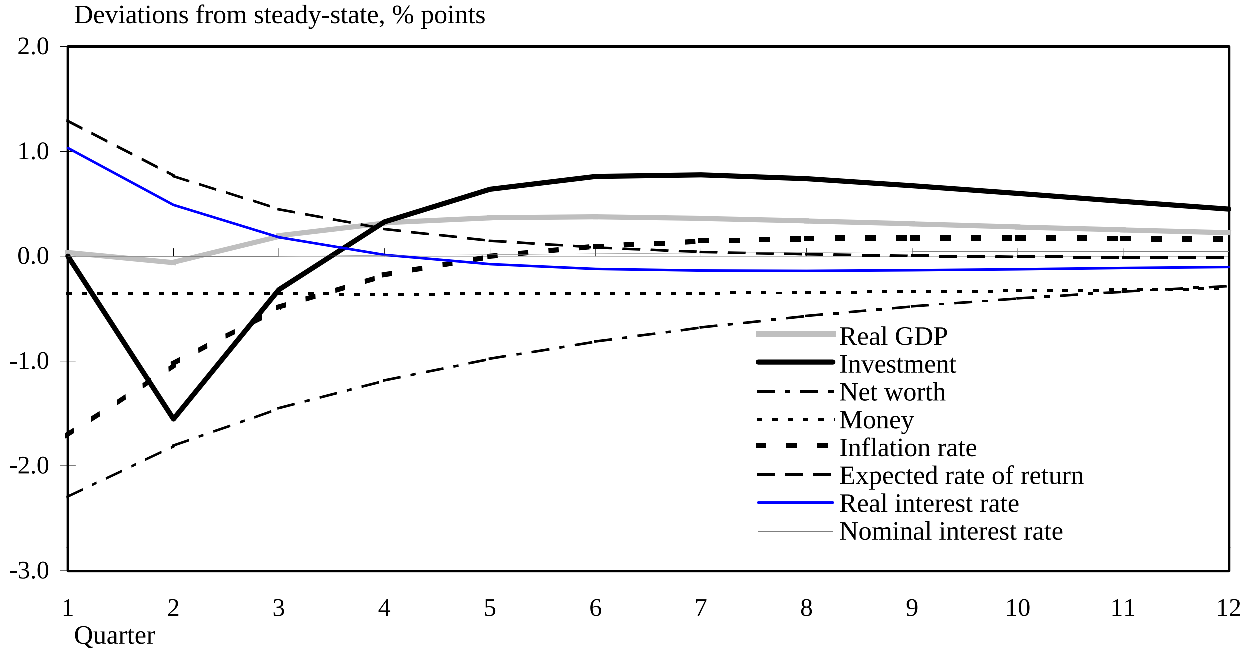
Responses to Technology Shock (The Whole Model)

[Condition] Giving a positive technology shock consisting of 1% deviation from the steady-state only in the 1st quarter.

(1) No-FA case



(2) FA case

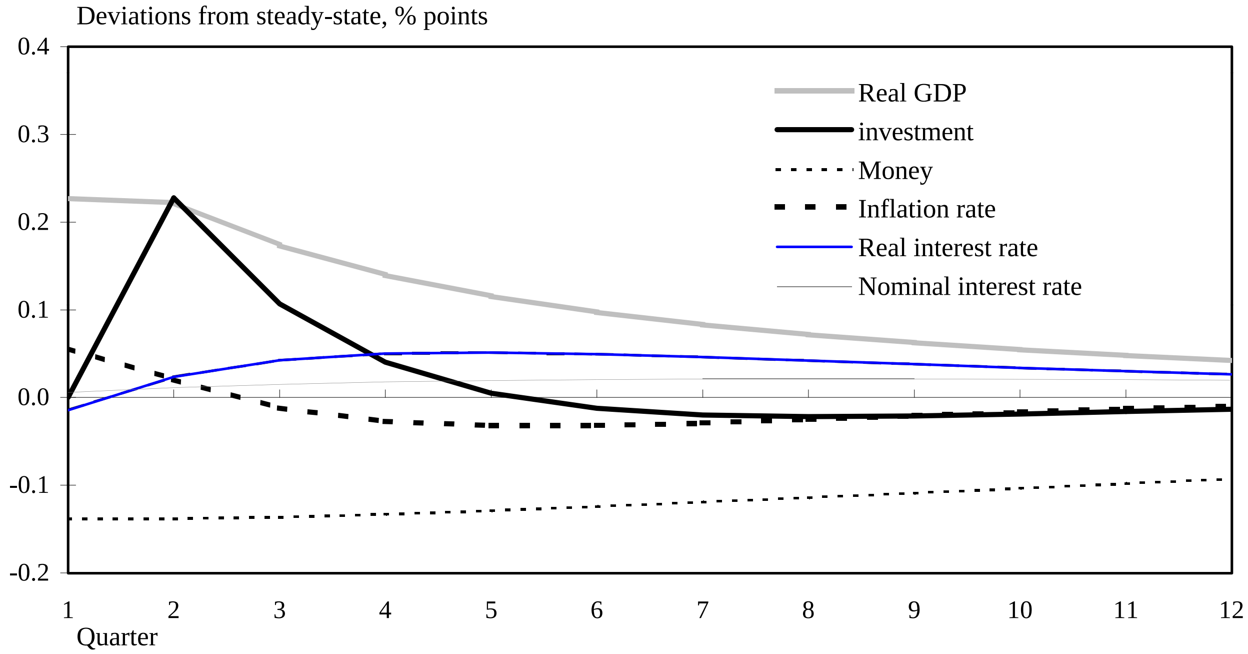


Note: Interest rate, Expected rate of return, and Inflation rate are annual rates.

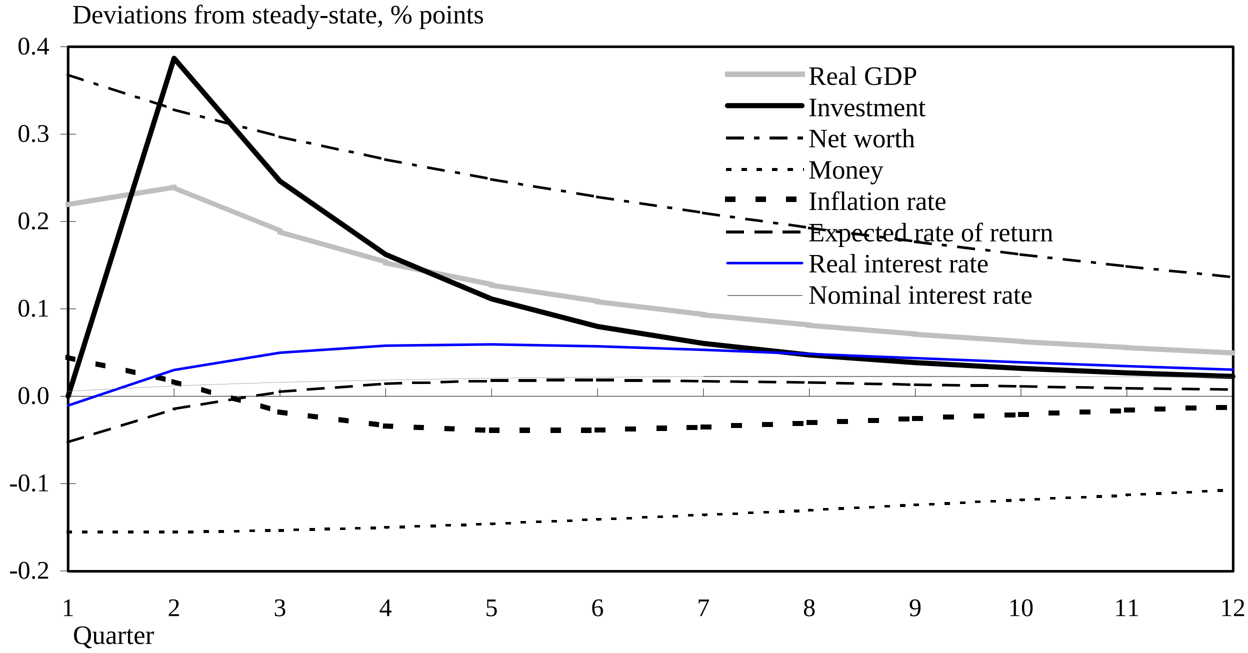
Responses to Demand Shock (The Whole Model)

[Condition] Giving a positive demand shock consisting of 1% deviation from the steady-state only in the 1st quarter.

(1) No-FA case



(2) FA case



Note: Interest rate, Expected rate of return, and Inflation rate are annual rates.

Chart 11

Results of the Model (by Calculation)

(1) Standard deviations

	No-FA case	FA case
Real GDP	1.02 <1.00>	1.07 <1.00>
Corporate fixed investment	3.36 <3.31>	4.36 <4.07>
Private consumption	1.06 <1.04>	1.03 <0.96>
Total working hours	2.17 <2.13>	2.32 <2.17>
Inflation rate	2.28 <2.24>	2.26 <2.11>
Monetary aggregate	1.65 <1.63>	1.56 <1.45>
Nominal interest rate	0.50 <0.49>	0.50 <0.47>

(2) Cross correlations with GDP

1. No-FA case

	-4	-3	-2	-1	0	1	2	3	4
Real GDP	-0.04	0.12	0.37	0.75	1.00	0.75	0.37	0.12	-0.04
Corporate fixed investment	-0.06	0.04	0.19	0.44	0.83	0.81	0.39	0.12	-0.04
Private consumption	0.01	0.16	0.38	0.72	0.70	0.38	0.17	0.03	-0.05
Total working hours	-0.31	-0.24	-0.06	0.33	0.62	0.51	0.29	0.15	0.06
Inflation rate	-0.24	-0.16	0.04	0.44	0.55	0.33	0.17	0.07	0.01
Monetary aggregate	-0.35	-0.31	-0.14	0.26	0.45	0.35	0.26	0.19	0.13
Nominal interest rate	0.24	0.15	-0.06	-0.46	-0.62	-0.43	-0.28	-0.17	-0.08

2. FA case

	-4	-3	-2	-1	0	1	2	3	4
Real GDP	-0.06	0.10	0.34	0.73	1.00	0.73	0.34	0.10	-0.06
Corporate fixed investment	-0.15	-0.06	0.09	0.37	0.84	0.76	0.38	0.14	-0.01
Private consumption	0.08	0.22	0.43	0.73	0.59	0.26	0.06	-0.06	-0.12
Total working hours	-0.27	-0.19	0.01	0.42	0.67	0.52	0.27	0.12	0.02
Inflation rate	-0.18	-0.08	0.14	0.56	0.55	0.29	0.10	0.00	-0.06
Monetary aggregate	-0.32	-0.24	-0.03	0.40	0.52	0.39	0.28	0.19	0.12
Nominal interest rate	0.22	0.10	-0.13	-0.57	-0.66	-0.45	-0.29	-0.17	-0.08

< Lead GDP **Lag GDP >**

Notes:

1. All variables are percentage deviations from their steady-state values and have been detrended by the Hodrick-Prescott (HP) filter (λ=1600).
2. Inflation rate and Nominal interest rate are annual rates.
3. Numbers <…> in table (1) represent the relative volatility to GDP.
4. Shaded sells in tables (2) represent the peak.

Results of the Model (by Simulation)

(1) Standard deviations

	No-FA case			FA case		
Real GDP	0.93	(0.13)	<1.00>	1.05	(0.15)	<1.00>
Corporate fixed investment	3.17	(0.35)	<3.39>	4.32	(0.51)	<4.10>
Private consumption	0.98	(0.13)	<1.05>	1.00	(0.13)	<0.95>
Total working hours	2.12	(0.22)	<2.26>	2.26	(0.32)	<2.15>
Inflation rate	2.24	(0.21)	<2.39>	2.23	(0.28)	<2.12>
Monetary aggregate	1.59	(0.20)	<1.70>	1.52	(0.21)	<1.44>
Nominal interest rate	0.48	(0.06)	<0.51>	0.49	(0.07)	<0.46>

(2) Cross correlations with GDP

1. No-FA case

	-4	-3	-2	-1	0	1	2	3	4
Real GDP	-0.11	0.03	0.28	0.71	1.00	0.71	0.28	0.03	-0.11
	(0.13)	(0.15)	(0.14)	(0.07)	(0.00)	(0.07)	(0.14)	(0.15)	(0.13)
Corporate fixed investment	-0.12	-0.03	0.12	0.38	0.82	0.79	0.32	0.04	-0.11
	(0.13)	(0.14)	(0.15)	(0.13)	(0.04)	(0.05)	(0.13)	(0.15)	(0.12)
Private consumption	-0.06	0.08	0.31	0.69	0.68	0.31	0.09	-0.04	-0.11
	(0.15)	(0.15)	(0.13)	(0.08)	(0.09)	(0.15)	(0.17)	(0.16)	(0.15)
Total working hours	-0.29	-0.24	-0.06	0.36	0.65	0.52	0.26	0.10	0.00
	(0.13)	(0.14)	(0.16)	(0.14)	(0.10)	(0.12)	(0.15)	(0.17)	(0.18)
Inflation rate	-0.23	-0.16	0.04	0.47	0.58	0.33	0.14	0.02	-0.04
	(0.14)	(0.14)	(0.14)	(0.11)	(0.11)	(0.15)	(0.17)	(0.16)	(0.15)
Monetary aggregate	-0.37	-0.34	-0.17	0.27	0.48	0.36	0.26	0.18	0.12
	(0.15)	(0.14)	(0.13)	(0.13)	(0.13)	(0.14)	(0.16)	(0.17)	(0.18)
Nominal interest rate	0.29	0.22	0.01	-0.44	-0.62	-0.41	-0.26	-0.15	-0.07
	(0.14)	(0.13)	(0.12)	(0.10)	(0.10)	(0.13)	(0.17)	(0.17)	(0.17)

2. FA case

	-4	-3	-2	-1	0	1	2	3	4
Real GDP	-0.10	0.04	0.29	0.71	1.00	0.71	0.29	0.04	-0.10
	(0.14)	(0.14)	(0.13)	(0.07)	(0.00)	(0.07)	(0.13)	(0.14)	(0.14)
Corporate fixed investment	-0.18	-0.10	0.05	0.34	0.84	0.75	0.34	0.10	-0.04
	(0.14)	(0.13)	(0.13)	(0.11)	(0.04)	(0.06)	(0.13)	(0.14)	(0.13)
Private consumption	0.04	0.18	0.41	0.74	0.59	0.23	0.04	-0.08	-0.14
	(0.14)	(0.15)	(0.14)	(0.10)	(0.11)	(0.14)	(0.14)	(0.15)	(0.16)
Total working hours	-0.29	-0.22	-0.02	0.42	0.67	0.50	0.24	0.08	0.00
	(0.15)	(0.13)	(0.14)	(0.11)	(0.09)	(0.13)	(0.17)	(0.18)	(0.17)
Inflation rate	-0.19	-0.10	0.13	0.57	0.54	0.26	0.07	-0.02	-0.07
	(0.14)	(0.14)	(0.14)	(0.11)	(0.11)	(0.15)	(0.17)	(0.16)	(0.15)
Monetary aggregate	-0.33	-0.27	-0.06	0.41	0.53	0.37	0.25	0.17	0.09
	(0.16)	(0.17)	(0.18)	(0.17)	(0.17)	(0.18)	(0.19)	(0.19)	(0.19)
Nominal interest rate	0.25	0.15	-0.10	-0.57	-0.66	-0.43	-0.26	-0.14	-0.04
	(0.15)	(0.17)	(0.17)	(0.13)	(0.13)	(0.16)	(0.17)	(0.17)	(0.18)

Notes: Numbers (…) represent the simulation-based sample standard error for the above moment.

Chart 13

Variance Decomposition

(1) Decomposition

1. No-FA case

	All shocks **(Benchmark)**	Monetary shock (σn=0.104)	Technology shock (σa=0.890)	Demand shock (σg=1.275)
Real GDP	1.02 (1.00)	0.79 (0.61)	0.51 (0.26)	0.38 (0.14)
Corporate fixed investment	3.36 (1.00)	2.87 (0.73)	1.71 (0.26)	0.31 (0.01)
Private consumption	1.06 (1.00)	0.86 (0.67)	0.54 (0.26)	0.28 (0.07)
Total working hours	2.17 (1.00)	1.25 (0.33)	1.67 (0.59)	0.59 (0.07)
Inflation rate	2.28 (1.00)	1.45 (0.40)	1.75 (0.59)	0.11 (0.00)
Monetary aggregate	1.65 (1.00)	1.55 (0.87)	0.53 (0.10)	0.25 (0.02)
Nominal interest rate	0.50 (1.00)	0.50 (0.99)	0.05 (0.01)	0.03 (0.00)

2. FA case

	All shocks **(Benchmark)**	Monetary shock (σn=0.104)	Technology shock (σa=0.890)	Demand shock (σg=1.275)
Real GDP	1.07 (1.00)	0.88 (0.68)	0.47 (0.19)	0.39 (0.13)
Corporate fixed investment	4.36 (1.00)	3.89 (0.80)	1.88 (0.19)	0.53 (0.01)
Private consumption	1.03 (1.00)	0.79 (0.58)	0.59 (0.33)	0.31 (0.09)
Total working hours	2.32 (1.00)	1.40 (0.37)	1.74 (0.56)	0.61 (0.07)
Inflation rate	2.26 (1.00)	1.45 (0.41)	1.74 (0.59)	0.11 (0.00)
Monetary aggregate	1.56 (1.00)	1.47 (0.89)	0.44 (0.08)	0.28 (0.03)
Nominal interest rate	0.50 (1.00)	0.50 (0.99)	0.04 (0.01)	0.03 (0.00)

(2) Varying Composition (FA case)

	All Shocks **(Benchmark)**	Monetary shock (σn=0.1265)	Technology shock (σa=2.035)	Demand shock (σg=3.495)
Real GDP	1.07 <1.00>	1.07 <1.00>	1.07 <1.00>	1.07 <1.00>
Corporate fixed investment	4.36 <4.07>	4.73 <4.42>	4.31 <4.02>	1.45 <1.35>
Private consumption	1.03 <0.96>	0.95 <0.89>	1.35 <1.26>	0.86 <0.80>
Total working hours	2.32 <2.17>	1.71 <1.59>	3.99 <3.72>	1.68 <1.56>
Inflation rate	2.26 <2.11>	1.76 <1.64>	3.97 <3.71>	0.30 <0.28>
Monetary aggregate	1.56 <1.45>	1.78 <1.66>	1.01 <0.94>	0.75 <0.70>
Nominal interest rate	0.50 <0.47>	0.60 <0.56>	0.10 <0.09>	0.09 <0.08>

Notes:

1. Each value is the standard deviation by calculation. (See footnotes in Chart 11.)
2. Numbers (…) in table (1) represent the share of the variance caused by each shock in the variance caused by all shocks.
3. Numbers <…> in table (2) represent the relative volatility to GDP.

Varying Parameter Values

(1) Ratio of internal funds

	No-FA case (Benchmark)			FA case (Benchmark)		
	25%	50%	75%	25%	50%	75%
Real GDP	1.02	1.02	1.02	1.18	1.07	1.01
Corporate fixed investment	3.36	3.36	3.36	5.13	4.36	3.77
Private consumption	1.06	1.06	1.06	1.02	1.03	1.04
Total working hours	2.17	2.17	2.17	2.47	2.32	2.21
Inflation rate	2.28	2.28	2.28	2.31	2.26	2.22
Monetary aggregate	1.65	1.65	1.65	1.59	1.56	1.56
Nominal interest rate	0.50	0.50	0.50	0.50	0.50	0.50
	< External funds		**Internal > funds**	**< External funds**		**Internal > funds**

(2) Price stickiness

	No-FA case (Benchmark)			FA case (Benchmark)		
	θ=0.9	θ=0.75	θ=0.65	θ=0.9	θ=0.75	θ=0.65
Real GDP	1.47	1.02	0.93	1.70	1.07	0.93
Corporate fixed investment	6.65	3.36	2.60	8.72	4.36	2.92
Private consumption	1.07	1.06	1.04	1.00	1.03	1.04
Total working hours	3.21	2.17	1.70	3.58	2.32	1.77
Inflation rate	0.67	2.28	3.23	0.65	2.26	3.21
Monetary aggregate	1.35	1.65	1.76	1.25	1.56	1.68
Nominal interest rate	0.49	0.50	0.51	0.49	0.50	0.51
	< Sticky		**Flexible >**	**< Sticky**		**Flexible >**

(3) Elasticity of labor supply to wage

	No-FA case (Benchmark)			FA case (Benchmark)		
	$\eta_h=\infty$	η_h=2.737	η_h=0.035	$\eta_h=\infty$	η_h=2.737	η_h=0.035
Real GDP	1.05	1.02	0.98	1.11	1.07	0.94
Corporate fixed investment	3.47	3.36	3.12	4.40	4.36	1.98
Private consumption	1.07	1.06	1.26	1.03	1.03	1.93
Total working hours	2.28	2.17	0.75	2.43	2.32	0.61
Inflation rate	1.91	2.28	7.50	1.86	2.26	7.63
Monetary aggregate	1.62	1.65	2.02	1.54	1.56	1.73
Nominal interest rate	0.50	0.50	0.53	0.50	0.50	0.53
	< Elastic		**Inelastic >**	**< Elastic**		**Inelastic >**

Note: Each value is the standard deviation by calculation. (See footnotes in Chart 11.)

Alternative Monetary Policy Rules

(1) Varying parameterization (the price-level reaction rule)

1. No-FA case

				Benchmark					
ν_y	**0.000**	**0.084**	**0.000**	**0.084**	**1.000**	**2.000**	**0.084**	**0.084**	**2.000**
ν_p	**0.000**	**0.000**	**0.004**	**0.004**	**0.000**	**0.000**	**1.000**	**2.000**	**2.000**
Real GDP	1.21	1.03	1.19	1.02	0.99	0.90	0.96	0.98	0.67
Corporate fixed investment	3.91	3.46	3.81	3.36	4.45	4.39	2.73	2.83	1.79
Private consumption	1.20	1.07	1.18	1.06	1.22	1.20	1.01	1.04	0.84
Total working hours	2.10	2.23	2.05	2.17	2.97	2.90	1.09	1.00	1.21
Inflation rate	2.11	2.37	2.03	2.28	4.06	4.42	0.60	0.44	1.07
Monetary aggregate	1.81	1.72	1.76	1.65	2.61	2.81	0.98	1.03	0.71
Nominal interest rate	0.54	0.50	0.54	0.50	0.78	1.29	0.47	0.46	0.41

2. FA case

				Benchmark					
ν_y	**0.000**	**0.084**	**0.000**	**0.084**	**1.000**	**2.000**	**0.084**	**0.084**	**2.000**
ν_p	**0.000**	**0.000**	**0.004**	**0.004**	**0.004**	**0.004**	**1.000**	**2.000**	**2.000**
Real GDP	1.34	1.09	1.31	1.07	0.86	0.77	0.96	0.99	0.63
Corporate fixed investment	5.25	4.49	5.10	4.36	5.01	4.91	2.78	2.90	1.49
Private consumption	1.19	1.04	1.17	1.03	1.01	1.00	1.02	1.05	0.88
Total working hours	2.38	2.38	2.32	2.32	2.77	2.69	1.13	1.02	1.21
Inflation rate	2.24	2.34	2.16	2.26	3.39	3.63	0.61	0.45	1.04
Monetary aggregate	1.81	1.60	1.76	1.56	2.00	2.15	0.98	1.03	0.72
Nominal interest rate	0.54	0.50	0.54	0.50	0.69	1.08	0.47	0.45	0.41

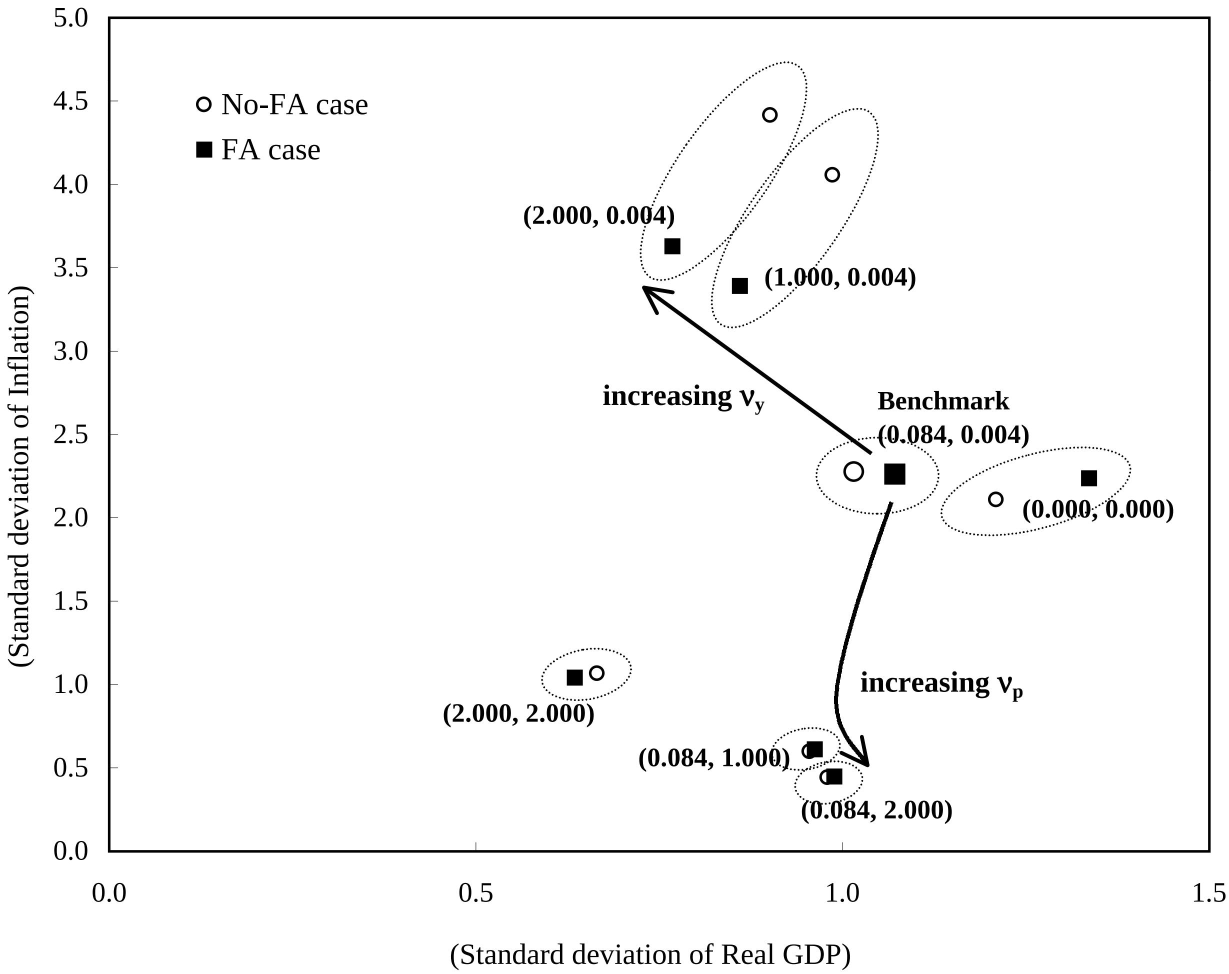
(2) Considering the reaction to inflation

	No-FA case				FA case			
ν_y	**0.084**	**0.084**	**0.084**	**0.084**	**0.084**	**0.084**	**0.084**	**0.084**
ν_p	**0.000**	**0.000**	**0.000**	**0.004**	**0.000**	**0.000**	**0.000**	**0.004**
ν_π	**0.000**	**0.500**	**2.000**	**2.000**	**0.000**	**0.500**	**2.000**	**2.000**
Real GDP	1.03	1.12	(0.95)	0.95	1.09	1.19	(1.02)	1.01
Corporate fixed investment	3.46	3.88	(2.90)	2.86	4.49	5.16	(3.85)	3.76
Private consumption	1.07	1.16	(0.99)	0.98	1.04	1.10	(0.99)	0.99
Total working hours	2.23	2.45	(1.84)	1.81	2.38	2.62	(2.04)	2.00
Inflation rate	2.37	2.78	(2.01)	1.95	2.34	2.74	(2.11)	2.05
Monetary aggregate	1.72	1.95	(1.31)	1.28	1.60	1.81	(1.31)	1.29
Nominal interest rate	0.50	0.43	(0.42)	0.41	0.50	0.43	(0.42)	0.42

Notes:

1. Each value is the standard deviation by calculation. (See footnotes in Chart 11.)
2. (…) in table (2) are calculated regardless of the indeterminacy of the steady state equilibrium.

Alternative Monetary Policy Rules



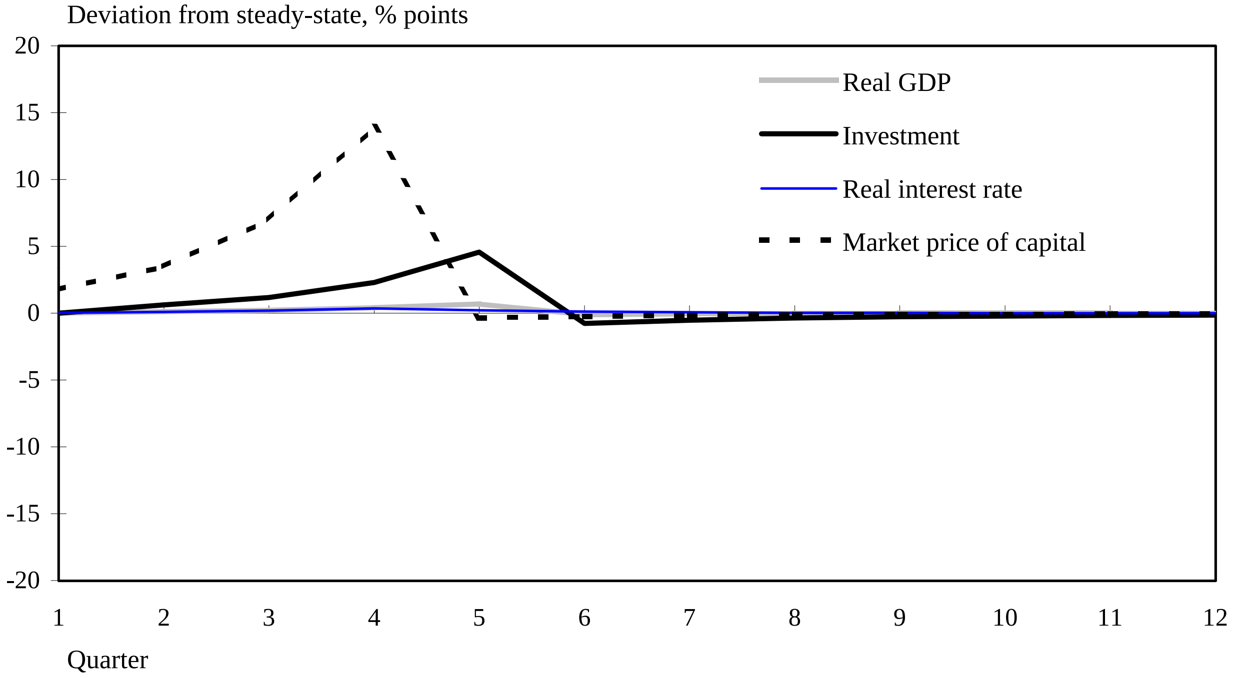
Notes:

1. The standard deviations of GDP and Inflation for each parameterization of our benchmark price-level reaction rule in both No-FA and FA cases (tables (1) in Chart 15) are plotted.
2. (…. , ...) represents the set of reaction parameter values (ν_y , ν_p).

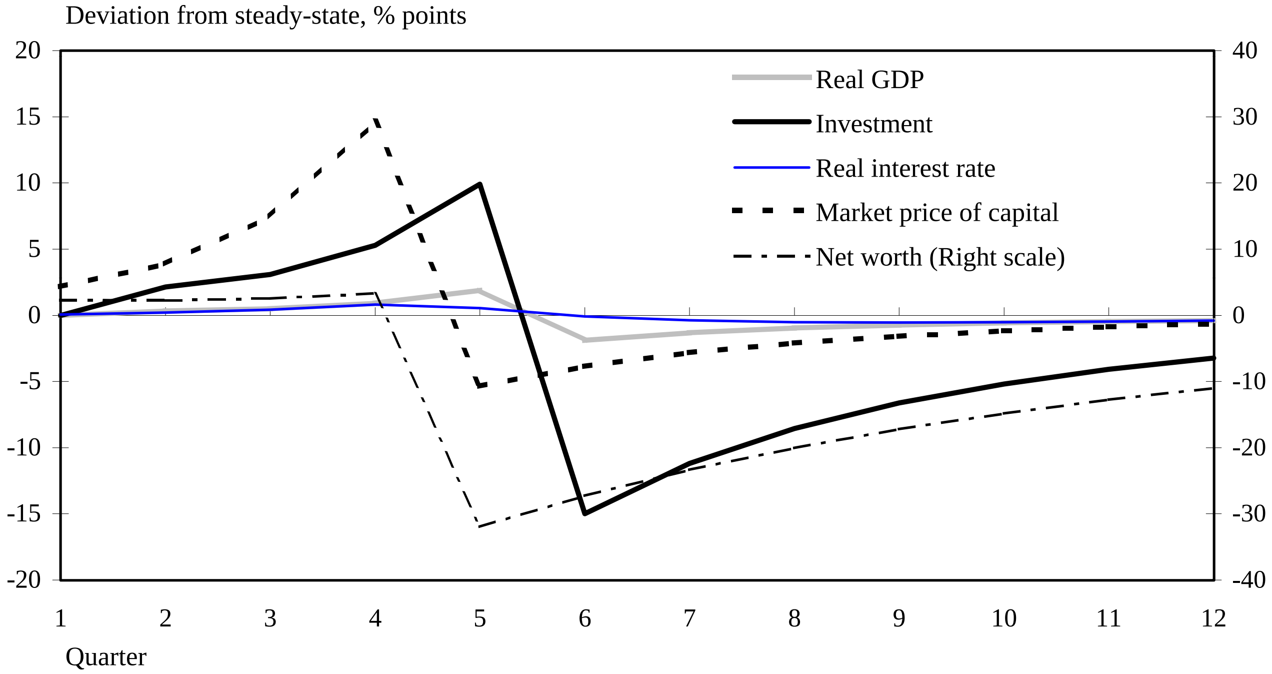
Responses to Bubble Process

[Condition] Generating a bubble that begins with one percentage point increase above the fundamental value in the 1st quarter and bursts in the 5th quarter.

(1) No-FA case



(2) FA case



Note: Real Interest rate is an annual rate.

Chart 18

Adding Bubble Effects

	No-FA case		FA case	
	Benchmark	Adding Bubble	Benchmark	Adding Bubble
Real GDP	1.02 <1.00>	1.02 <1.00>	1.07 <1.00>	1.14 <1.00>
Corporate Fixed Investment	3.36 <3.31>	3.41 <3.34>	4.36 <4.07>	5.20 <4.55>
Private Consumption	1.06 <1.04>	1.06 <1.04>	1.03 <0.96>	1.06 <0.93>
Total Working Hours	2.17 <2.13>	2.17 <2.13>	2.32 <2.17>	2.39 <2.10>
Price Level	2.28 <2.24>	2.28 <2.23>	2.26 <2.11>	2.27 <1.99>
Monetary Aggregate	1.65 <1.63>	1.65 <1.62>	1.56 <1.45>	1.58 <1.39>
Nominal Interest Rate	0.50 <0.49>	0.50 <0.49>	0.50 <0.47>	0.50 <0.44>

Notes:

1. Each value is the standard deviation by calculation. (See footnotes in Chart 11.)
2. Numbers <…> represent the relative volatility to GDP.