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June 2005

Bank of Japan Working Paper Series

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No.05-E-8
June 2005

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A Historical Evaluation of Financial Accelerator Effects in Japan's Economy*

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June, 2005

Abstract

In this paper, we carry out a historical evaluation of the financial accelerator effects, which were mainly generated by the changes in asset prices, operating on Japan's economy since the 1980s. For this purpose, we estimate a Japanese financial accelerator model, which is a modified version of Bernanke, Gertler and Gilchrist [1999]'s model, and identify the historical exogenous shocks affecting the evolution of firms' net worth. As a result, we confirm that the estimated parameter on the corporate balance sheet channel is statistically significant. We also find that the identified net worth shocks, which change the amount of firms' debt holdings relative to their total values, produced a large and persistent impact on Japan's output and prices. This result strongly suggests that the negative financial accelerator effects were indispensable to explain the mechanism behind Japan's long stagnation during the 1990s and early 2000s, as well as indicating that the deflation of general prices since the late 1990s has been at least partly attributed to the same cause.

JEL Classification: E30, E44

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*This paper is a detailed version of the analysis that was reported in Section II E and Appendix 1 of Baba, Nishioka, Oda, Shirakawa, Ueda, and Ugai [2005]. We would like to express our gratitude to Hitoshi Mio (The Bank of Japan (BOJ)) for excellent research assistance in carrying out the VAR analysis, and to Ichiro Fukunaga (BOJ) for helpful comments. We would also like to thank Masaaki Shirakawa (BOJ) and Kazuo Ueda (University of Tokyo, formerly, Member of the Policy Board of BOJ) for their encouragement and fruitful advice, as well as other colleagues at the BOJ. Of course, any remaining errors should be solely attributed to the authors. The views expressed herein are those of authors and do not reflect those of BOJ or the Monetary Affairs Department.

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1 Introduction

Japan's economy experienced prolonged adjustment from the early 1990s through 2002 when the economy started to recover. This period was characterized by declines in asset prices, the risk-taking ability of financial institutions, potential economic growth, and general prices. Various investigations have been carried out to examine which of these factors was the major cause of the stagnation of the economy. In this paper, we choose to focus on the effect of the fall in asset prices associated with the bursting of the bubble. This plunge in asset prices reduced firms' net worth, resulting in an increase in their debt/equity ratio which became a serious problem.

The effect by which excessive debt acts to constrain economic growth is explained in terms of the financial accelerator mechanism. When there is asymmetric information between borrowers and lenders (i.e., between firms and banks) there is a positive relation between the amount of debt holdings and the size of external finance premiums. If capital positions worsen due to a decline in stock prices, in other words if debt holdings increase relative to capital, firms face a higher external finance premium, and this in turn constrains their investment. A leading study of the financial accelerator mechanism has been provided by Bernanke, Gertler, and Gilchrist [1999], for the case of the United States.

The effect of the financial accelerator has been seen more distinctly in Japan. Since the latter half of the 1980s, Japan's economy has experienced the expansion and bursting of bubbles in asset prices (Okina, Shiratsuka, and Shirakawa [2001]). The Nikkei 225 experienced headlong growth between 1986 and 1989, hitting a peak of ¥38,915 at the end of 1989, which was 3.1 times higher than its level at the time of the Plaza Agreement in September 1985 (¥12,598). The index then fell sharply to ¥14,309 in August 1992, more than 60% below its peak. More recently, it plumbed new depths in April 2003 (¥7,909), at which point it was nearly 80% below its peak. On the other hand, Japan's economy emerged from a cyclical trough in November 1986 and expanded for 51 months until February 1991, with annual real GDP growth averaging around 5%. This was followed by a prolonged period of adjustment, including some small cyclical fluctuations, which bottomed out in fiscal 2001. Annual real GDP growth during this period averaged -1.2%. The rate of increase in the CPI (excluding fresh foods) recorded above 3% from the autumn of 1990 to the summer of 1991, but it has remained consistently under 0% since the middle of 1998.

In an effort to explain the theoretical background for these phenomena, Fukunaga [2002] used calibration to analyze financial accelerator effects in Japan. In our paper, we go a step further, providing a full-blown empirical examination of the effect of the financial accelerator on Japan's economy. More concretely, we estimate a version of the financial accelerator model using Japanese data, and identify the historical exogenous shocks to firms' net worth responsible for financial accelerator effects in Japan. In this way, we are able to investigate the extent to which Japanese macroeconomic variables such as investment, real GDP, and the CPI have historically been affected by the financial accelerator. Our model analysis demonstrates that firms' excessive debt problem was the major factor constraining aggregate demand for a long time.

This paper proceeds as follows. Section 2 uses vector auto regressions (VARs) to present a preliminary analysis of how changes in the value of firms triggered by the fall in asset prices have affected the Japanese economy and vice versa. Section 3 explains the structure of the Japanese financial accelerator model, which is a modified version of Bernanke, Gertler, and Gilchrist's model. Section 4 shows the GMM (generalized method of the moments) estimation results of the model presented in Section 3. Section 5 simulates the effect of the financial accelerator on economic activity and prices in Japan since the 1980s using the model estimated in Section 4. Based on the results obtained in Section 5, Section 6 discusses the reasons for the prolonged period of economic adjustment since the 1990s. Lastly, Section 7 offers our concluding remarks.

2 Preliminary Analysis of VARs

Before weighing into the main analysis, we confirm the statistical importance of firms' excessive debt in explaining the dynamics of Japan's economy. For this purpose, we first carry out a simple VAR analysis, which is independent of any specific economic theory.

Our methodology essentially follows Leeper, Sims and Zha [1996]. That is, as basic variables, we choose the CPI (log), real GDP (log), O/N call rate, and the money supply (M1, log). In addition, as an indicator of excessive firm debt, we include firms' equity-value ratio (EVR), which is calculated as the total value of firms' equity divided by the total value of firms given in the Flow of Funds Statistics [1]. Since 1-EVR represents the aggregate leverage ratio (ratio of debts / value of firms), a small EVR means that firms have heavy debt burdens.

The data is quarterly and the sample period is from 1971Q1 to 1999Q1. Because Japan's economy has recently come up against the zero bound on the short-term nominal interest rate, we intentionally leave out the recent data so as to exclude the influence of nonlinearity arising from the zero bound.

In identifying VARs, we tried many permutations of recursive ordering. Presenting all the results here would be tedious. In the event, we selected one specific ordering for our main VARs [2]. The main VAR ordering is (i) EVR, (ii) CPI, (iii) real GDP, (iv) O/N call rate, and (v) the money supply (M1). We consider this ordering to be fairly natural since many previous studies assume that real economic variables influence monetary variables within a single period, but that the converse does not hold. A slight complication was presented by EVR, since it was not immediately

[1] The movement of Japanese EVR over time is presented in Figure 1.

[2] However, in many trials, we find that the results do not substantially depend on ordering.

clear where it should be placed in the ordering because few VAR studies include this variable. The process of estimating many patterns of recursive ordering revealed, however, that the results do not substantially depend on the ordering of EVR and so, in the subsequent argument, we only refer to the results of our main VARs.

Figure 2 shows the impulse responses of the variables in our main VARs to a +1% temporary EVR shock [3]. In the absence of financial frictions, EVR should be irrelevant for the determination of real GDP, as the famous Modigliani and Miller [1958] theorem (MM theorem) suggests. However, the impulse response in Figure 2 indicates that, after a positive shock to EVR, real GDP goes persistently upward. The CPI also rises, after a lag (7 quarters). O/N call rate goes down to begin with, but afterwards rises. M1 goes persistently upward. Overall, we find that the directions of these responses are mostly consistent with the financial accelerator story [4].

Figure 3 shows the variance decomposition for the main VARs. The EVR shocks are seen to explain about 20% of the fluctuations in real GDP point estimates. In contrast, EVR contributes little to the CPI. These results are largely consistent with the impulse responses presented in Figure 2.

Next, we find that more than 80% of EVR fluctuations are explained by the EVR shock itself, even after 16 periods. This reflects two characteristics of EVR. First, EVR adjusts extremely slowly in Japan. The implication is that there exist quantitative constraints which prevent firms from freely adjusting their balance sheets. That is, firms may experience difficulties raising capital or obtaining liquidity to repay debts, and this prevents them from altering the make-up of the liability side of their balance sheets immediately. Second, the movement of EVR is fairly autonomous because it tends to be independent of feedback from real GDP or the CPI. Figure 4 helps us to understand this phenomenon. The solid line depicts the historical EVR shocks identified in the main VARs. This series is much alike the dashed line which indicates the percentage increase in the stock price index (TOPIX). Thus, we can imagine that not all, but a large part of the historical EVR shocks may be attributed to exogenous fluctuations in equity prices. This suggests that, in Japan, the financial accelerator has acted as an autonomous net worth shock affecting firms' balance sheets, rather than as an amplifier of other shocks, such as technological shocks or monetary policy shocks.

In this section, a statistical approach has been used to demonstrate that, in Japan, fluctuations in the leverage ratio, caused mainly by exogenous shocks to equity prices, have exerted a persistent influence on macroeconomic variables such as real GDP. In the next section, we present a version of the financial accelerator model, which can

[3] As in previous VAR studies using US data, we see the so-called liquidity and price puzzles here. That is, the call rate does not fall at all in response to a positive money supply shock; the CPI rises for some periods in response to a positive call rate shock.

[4] Unfortunately, since standard errors are somewhat large, it is not entirely certain whether these positive responses are statistically significant. This requires us to check the statistical significance of the parameter on the balance sheet channel in a more formal way, by estimating a structural model. This is done in Section 4.

replicate the main characteristics of this section's VARs.

3 Structural Model

In this section, we present a Japanese financial accelerator model, which is a modified version of the Bernanke, Gertler and Gilchrist [1999] (BGG) model. The main modifications are twofold. First, in order to replicate the sluggish adjustment of Japanese firms' EVR, observed in the VARs in the previous section, we modify the financial contract between lenders (households) and borrowers (intermediate goods firms). We assume that firms are faced with some quantitative constraints in raising external funds, so they cannot adjust EVR perfectly in every period. We consider such assumption necessary to explain the sluggish movement of Japanese EVR [5].

The second modification is to introduce heterogeneity in final output goods. Specifically, we assume that there are two types of final goods, consumption goods and investment goods. This modification is motivated by the fact that inflation rates for these two types of goods are quite different in Japan, mainly reflecting the rapid productivity growth in the investment goods sector. In order to bring this feature into our analysis, we divide the production sector into consumption goods sector and investment goods sector. As we will see later, this modification proves useful in estimating the Japanese financial accelerator model.

3.1 Overview of Model Structure

Figure 5 presents an overview of the model structure. The production sector consists of intermediate goods firms, consumption goods firms, and investment goods firms. All these firms are perfectly competitive.

Intermediate goods firms produce intermediate goods using labor and capital. They also produce new capital by combining old capital with purchased investment goods. Capital is traded across intermediate goods firms in the capital market. In purchasing capital, firms need to raise funds. This has to be done by (i) issuing stocks, (ii) uncollateralized borrowing, or (iii) collateralized borrowing. Households provide these external funds, but they are unable to observe the realized rate of return to capital, which is influenced by idiosyncratic shocks, without paying some monitoring costs even in the ex post stage. Because of this kind of asymmetric information problem, intermediate goods firms have to pay external fund premiums.

Final goods (consumption goods and investment goods) firms use intermediate goods to produce final goods. Consumption goods and the investment goods have different productivity growth rates. Final goods are sold to monopolistic competitive

[5] In an empirical study of Japanese firms' capital structures using panel data, Baba and Nishioka [2004] introduces a process of partial adjustment from actual to optimal leverage ratios. They find that the partial adjustment process successfully captures the transition of the Japanese leverage ratio, and that the speed of adjustment significantly depends on firms' corporate governance structures.

retailers, who are specialized in each of the final goods. Consumption goods retailers sell consumption goods to households and the government, and investment goods retailers sell investment goods to intermediate goods firms.

Households consume, hold money, and provide labor. For simplicity, we treat the government as an "integrated" government, which includes the central bank. Therefore, the government not only purchases consumption goods and collects lump-sum taxes, but also creates money and controls the risk-free interest rate based on a monetary policy rule.

3.2 Intermediate Goods Firms

There are a number of intermediate goods firms. Each intermediate goods firm is engaged in (i) intermediate goods production and (ii) capital accumulation. We assume that an individual intermediate goods firm can participate in these two different activities simultaneously. That is, in intermediate goods production, a firm purchases labor from households and capital from other intermediate goods firms, and uses them to produce intermediate goods. In capital accumulation, the firm purchases investment goods from investment goods retailers, and combines investment goods with old capital to produce new capital. Capital is traded across intermediate goods firms in the capital market. As in BGG, when an intermediate goods firm purchases capital from another firm, the firm is faced with an asymmetric information problem.

3.2.1 Production Technology

Intermediate goods firms use capital and labor to produce intermediate goods. The aggregate production function is Cobb-Douglas:

$$Y_{m,t} = A_m K_{t-1}^{\alpha} H_t^{1-\alpha}, \tag{1}$$

where $Y_{m,t}$ is the aggregate quantity of intermediate goods, A_m is the aggregate productivity of intermediate goods production, K_{t-1} is the aggregate capital stock (held by intermediate goods firms at the end of period $t-1$ or at the beginning of period t), and H_t is total labor hours, which is the product of average hours (h_t) and labor (L_t). Here, we assume that aggregate productivity is time-invariant, which means that productivity growth does not arise in aggregate intermediate goods production [6].

3.2.2 Capital Accumulation

Intermediate goods firms purchase investment goods from investment goods retailers. Then, firms combine intermediate goods with old capital to produce new capital. The

[6] Later we allow productivity growth to arise in final goods production. Since our estimated model is based on only final goods production, the assumption of non-productivity growth in intermediate goods firms is not essential in this analysis.

technology governing aggregate capital stock accumulation is

$$K_t = (1-\delta)K_{t-1} + \Phi\left(\frac{I_t}{K_{t-1}}\right)K_{t-1}. \tag{2}$$

Here, δ is depreciation rate, and production function for new capital ($\Phi(\cdot)$) satisfies $\Phi(0) = 0$, $\Phi'(\cdot) > 0$, and $\Phi''(\cdot) < 0$.

3.2.3 Profit Maximization

In period t_0, intermediate goods firms maximize expected discounted profits, subject to production and capital accumulation technologies, as follows:

$$E_{t_0}\sum_{t=t_0}^{\infty}\Lambda_{t_0|t}\left(P_{m,t}Y_{m,t} - P_{i,t}I_t - W_tH_t\right), \tag{3}$$

where $\Lambda_{t_0|t}$ is the discount factor from period t_0 to t, $P_{m,t}$ is the price of intermediate goods, W_t is the nominal wage rate, and $P_{i,t}$ is the retail price of investment goods at period t [7]. We substitute (1) into (3), and maximize (3) subject to (2), by controlling capital ($\{K_t\}_{t=t_0}^{\infty}$), investment goods ($\{I_t\}_{t=t_0}^{\infty}$), and labor ($\{H_t\}_{t=t_0}^{\infty}$).

Let λ_t be the Lagrange multiplier for constraint (2) in period t. Then, for all $t = t_0, \cdots, \infty$, the first order conditions for capital, investment, and labor are as follows:

$$\Lambda_{t_0|t}\alpha P_{m,t}A_mK_{t-1}^{\alpha-1}H_t^{1-\alpha} + \lambda_{t-1} + \lambda_t\left\{-(1-\delta) - \Phi\left(\frac{I_t}{K_{t-1}}\right) + \Phi'\left(\frac{I_t}{K_{t-1}}\right)\frac{I_t}{K_{t-1}}\right\} = 0, \tag{4}$$

$$-\Lambda_{t_0|t}P_{i,t} - \lambda_t\Phi'\left(\frac{I_t}{K_{t-1}}\right) = 0, \tag{5}$$

$$(1-\alpha)P_{m,t}A_mK_{t-1}^{\alpha}H_t^{-\alpha} - W_t = 0. \tag{6}$$

In the above profit maximization problem, we do not explicitly describe capital trading activity, since this activity is cancelled out at the aggregate level. However, at the individual firm level, trading is actually carried out in the capital market at some price. Let $Q_{k,t}$ be the unit market price of capital in period t. Individual firms' profit maximization determines $Q_{k,t}$ as follows [8]:

$$Q_{k,t} = \Phi'\left(\frac{I_t}{K_{t-1}}\right)^{-1}P_{i,t}. \tag{7}$$

[7] $\Lambda_{t_0|t}$ is determined later in the household's optimization problem (Section 3.5).

[8] Here we assume that individual firm j accumulates capital ($K_t(j)$) according to

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

where $K_{t-1}(j)$ is the capital held by j at the beginning of period t, and $I_t(j)$ is the investment goods purchased by j and used to produce new capital during period t.

Next, let $R_{k,t}$ be the rate of return to capital from period $t-1$ to t. Notice that, in equilibrium, $R_{k,t}$ must be equal to the discount rate $(\Lambda_{t_0|t-1}/\Lambda_{t_0|t})$. Then, from equations (4), (5), and (7), $R_{k,t}$ is determined as follows [9]:

$$R_{k,t} = \frac{P_{i,t}}{P_{i,t-1}} \left\{ \frac{\frac{P_{m,t}}{P_{i,t}} \frac{\alpha Y_{m,t}}{K_{t-1}} + \frac{Q_{k,t}}{P_{i,t}}(1-\delta)}{\frac{Q_{k,t-1}}{P_{i,t-1}}} \right\}. \tag{8}$$

3.2.4 Financial Constraints in Purchasing Capital

As in BGG, our intermediate goods firms have to raise external funds in purchasing capital. Suppose that, in period $t-1$, an individual intermediate goods firm j has purchased capital $(K_{t-1}(j))$ at price $Q_{k,t-1}$. Firm j has financed this purchase using three kinds of financial instruments; (i) stock issuing $(S_{t-1}(j))$, (ii) uncollateralized borrowing $(D_{t-1}(j))$, and (iii) collateralized borrowing $(F_{t-1}(j))$. Thus, given the stock price $Q_{s,t-1}$, the following equation has to hold in period $t-1$:

$$Q_{k,t-1}K_{t-1}(j) = Q_{s,t-1}S_{t-1}(j) + D_{t-1}(j) + F_{t-1}(j). \tag{9}$$

The rates of return on uncollateralized borrowing $(R_{d,t-1})$ and collateralized borrowing $(R_{f,t-1})$ are fixed by contract in period $t-1$.

In period t, the return on capital is realized. The rate of return is $\omega_t(j)R_{k,t}$, which is a mixture of the idiosyncratic shock $(\omega_t(j))$ and the aggregate rate of return on capital $(R_{k,t})$. The idiosyncratic shock is i.i.d. It has a c.d.f $F(\omega_t(j))$, over a non-negative support, with $E(\omega_t(j)) = 1$ for all j and t. The rate of return to firm j's stock holders $(R_{s,t}(j))$ is thus determined as follows:

$$\omega_t(j)R_{k,t}Q_{k,t-1}K_{t-1}(j) = R_{s,t}(j)Q_{s,t-1}S_{t-1}(j) + R_{d,t-1}D_{t-1}(j) + R_{f,t-1}F_{t-1}(j). \tag{10}$$

Thus, stock holders only receive the residual return $(R_{s,t}(j)Q_{s,t-1}S_{t-1}(j))$, which is the total return on capital minus the total return on debts. Because the rate of return on capital is subject to an idiosyncratic shock, the rate of return on stocks $(R_{s,t}(j))$ is also affected by this shock.

Here we assume that stock holders cannot observe the realized return on capital $(\omega_t(j)R_{k,t})$, without paying monitoring costs. Stock holders have to pay monitoring cost τ_s (in gross term) per unit of nominal stock [10]. That is, the total monitoring cost of holding firm j's stocks is $\tau_s Q_{s,t-1}S_{t-1}(j)$.

Let $\overline{\omega}_t(j)$ be the threshold value of $\omega_t(j)$, which makes $R_{s,t}$ zero:

$$\overline{\omega}_t(j)R_{k,t}Q_{k,t-1}K_{t-1}(j) = R_{d,t-1}D_{t-1}(j) + R_{f,t-1}F_{t-1}(j). \tag{11}$$

[9] Here we normalize the adjustment cost function so that $\Phi(1) = 1$ and $\Phi'(I/K)^{-1} = 1$ in steady state.

[10] In this analysis, we do not derive the monitoring costs within the framework of optimal contracts, but simply assume external lenders incur constant monitoring costs (per unit). Here, we consider that the monitoring costs symbolically represent the degree of imperfection in financial markets.

$R_{d,t-1}$ and $R_{f,t-1}$ are determined before the realization of $\omega_t(j)$. So, if the realized $\omega_t(j)$ is below $\overline{\omega}_t(j)$, then the firm j defaults. In the case of default, uncollateralized lenders cannot obtain all the contracted return $R_{d,t-1}D_{t-1}(j)$. If firm j defaults, uncollateralized lenders have to pay monitoring costs to observe the realized return. The monitoring cost for uncollateralized lenders is τ_d (in gross term) per unit nominal debt. Here we assume that τ_d is strictly larger than τ_s, considering the existence of bankruptcy costs paid by debt holders, which include accounting costs, legal costs, and losses associated with asset liquidation [11, 12].

Because we have assumed that collateralized borrowing does not require any monitoring costs, the lending rate on collateralized borrowing ($R_{f,t-1}$) must be lower than the expected return on stocks ($E_{t-1}R_{s,t}$) and the lending rate on uncollateralized borrowing ($R_{d,t-1}$) in equilibrium. So, firm j has an incentive to raise as much funds as possible via collateralized borrowing. However, we assume that firms cannot raise all its desired funds via collateralized borrowing because of the following quantitative constraint:

$$F_{t-1}(j) \leqq \gamma Q_{s,t-1} S_{t-1}(j), \quad where\ 0 < \gamma < 1. \tag{12}$$

The introduction of this constraint is motivated from Kiyotaki and Moore [1997] [13]. As we can see in (12), a decline in equity prices ($Q_{s,t-1}$) reduces available funds for collateralized borrowing. Therefore, if firm j needs to raise more funds, the firm has to issue more stock or increase uncollateralized borrowing, which require higher monitoring costs than collateralized borrowing [14].

Next, we should determine the allocation between stock issuing and uncollateralized borrowing. Because we have assumed that τ_d is strictly larger than τ_s, firms prefer issuing stock to uncollateralized borrowing. However, here we assume that firms are faced with some quantitative constraints in issuing stocks. We adopt the following specification to capture this kind of constraint:

$$S_{t-1}(j) \leqq \phi K_{t-1}(j), \quad where\ 0 < \phi. \tag{13}$$

We consider that this constraint roughly captures the financial constraints facing Japanese firms. In Japan, small and medium-sized firms cannot issue stocks in major stock markets such as the Tokyo stock exchange. Private placements are also highly limited. We therefore think that (13) approximates the key features of the quantitative financial constraints facing Japanese firms.

[11] Further justification for the assumption of $\tau_s < \tau_d$ is the fact that the statistics for S_t, which is used to calculate the EVR series, include firms' internal finances, which require no monitoring cost to corroborate.

[12] BGG explicitly introduces the cost of bankruptcy, though we do not. In an empirical study, Levin, Natalucci, and Zakrajsek [2004] estimates the relevant parameter on bankruptcy costs using a panel-dataset. They find that the parameter is significant, and that it is large in recent periods.

[13] Kiyotaki and Moore introduces a quantitative credit constraint, in which debt repayments cannot exceed the market value of land held by borrowers.

[14] Because τ_s and τ_d are assumed to be strictly larger than unity, constraint (12) is virtually always binding.

So far we have explained the financial constraints facing individual intermediate goods firms. Because idiosyncratic shocks ($\omega_t(j)$) are cancelled out at the aggregate level, the aggregate return on capital is written as follows:

$$R_{k,t}Q_{k,t-1}K_{t-1} = R_{s,t}Q_{s,t-1}S_{t-1} + R_{d,t-1}D_{t-1} + R_{f,t-1}F_{t-1}, \tag{14}$$

where K_{t-1}, S_{t-1}, D_{t-1}, and F_{t-1} are all aggregated variables. $R_{s,t}$ is the average rate of return on stock holding [15]. For the purposes of later discussion, we represent EVR, which is the aggregate value of stocks divided by the aggregate value of capital, as s_t:

$$s_t \equiv \frac{Q_{s,t}S_t}{Q_{k,t}K_t}. \tag{15}$$

3.3 Final Goods Firms

Aggregate production by final goods firms in the two sectors (consumption goods sector and investment goods sector, indexed by $\psi = c, i$) is determined as follows:

$$Y_{\psi,t} = A_{\psi,t}Y_{\psi,m,t}, \quad \psi = c, i, \tag{16}$$

where $Y_{\psi,t}$ is aggregate production in sector ψ, $A_{\psi,t}$ is aggregate productivity in sector ψ, and $Y_{\psi,m,t}$ is intermediate goods used in sector ψ (where $Y_{m,t} = Y_{c,m,t} + Y_{i,m,t}$). Based on each sector's aggregate production, the economy-wide aggregate production ($Y_t = Y_{c,t} + Y_{i,t}$) can be represented in Cobb-Douglas form as:

$$Y_t = A_t {K_{t-1}}^{\alpha} {H_t}^{1-\alpha}, \quad \text{where } A_t \equiv \left(A_{c,t}\frac{Y_{c,m,t}}{Y_{m,t}} + A_{i,t}\frac{Y_{i,m,t}}{Y_{m,t}} \right) A_m. \tag{17}$$

Under the assumption of perfect competition in final goods markets, the wholesale price of final goods in sector ψ ($P_{\psi,w,t}$) is determined as follows:

$$P_{\psi,w,t} = \frac{P_{m,t}}{A_{\psi,t}}, \quad \psi = c, i. \tag{18}$$

3.4 Retailers

In each sector, there are monopolistic competitive retailers. Following Calvo[1983], we assume that each retailer in sector ψ gets an opportunity to change his retail price only with probability $1 - \alpha_{\psi}$. Suppose that retailer h in sector ψ gets a chance to change his retail price ($P_{\psi,t}(h)$) in period t_0. He maximizes his expected discounted

[15] For simplicity, we assume that there is no dividend paid to stock holders. Therefore, $R_{s,t}$ is solely composed of capital gains ($Q_{s,t}/Q_{s,t-1}$).

profits subject to the demand for his goods ($Y_{\psi,t}(h)$) as follows [16]:

$$\max_{\{P_{\psi,t}(h)\}} E_{t_0} \sum_{t=t_0}^{\infty} \alpha_{\psi}^{t-t_0} \left[\Lambda_{t_0|t} \left\{ \frac{P_{\psi,t_0}(h) - P_{\psi,w,t}}{P_{\psi,t}} Y_{\psi,t}(h) \right\} \right]$$

$$s.t. \;\; Y_{\psi,t}(h) = \left(\frac{P_{\psi,t}(h)}{P_{\psi,t}} \right)^{-\theta} Y_{\psi,t}, \quad \psi = c, i. \tag{19}$$

Let $P^*_{\psi,t_0}(h)$ be retailer h's optimal price at t_0. Then, $P^*_{\psi,t_0}(h)$ must satisfy the following first order condition:

$$\sum_{t=t_0}^{\infty} \alpha_{\psi}^{t-t_0} \left[\Lambda_{t_0|t} \left(\frac{P^*_{\psi,t_0}(h)}{P_{\psi,t}} \right)^{-\theta} Y_{\psi,t_0}(h) \left\{ \frac{P^*_{\psi,t_0}(h)}{P_{\psi,t}} - \left(\frac{\theta}{\theta-1} \right) X_{\psi,t} \right\} \right], \tag{20}$$

where $X_{\psi,t}$ is defined as the inverse of markup in sector ψ:

$$X_{\psi,t} \equiv \frac{P_{\psi,w,t}}{P_{\psi,t}}. \tag{21}$$

Let P^*_{ψ,t_0} be the optimal price for retailers in sector ψ who get the opportunity to revise their prices at the same time as retailer j. Then, the aggregate retail price of final goods in sector ψ in period t_0 (P_{ψ,t_0}) becomes

$$P_{\psi,t} = \left\{ \alpha_{\psi} P_{\psi,t}^{1-\theta} + (1-\alpha_{\psi})(P^*_{\psi,t})^{1-\theta} \right\}^{\frac{1}{1-\theta}}, \quad \psi = c, i. \tag{22}$$

3.5 Households

In period t, the representative household is faced with the following budget constraint:

$$\begin{aligned} P_{c,t}C_t + M_t &= W_t H_t - T_t + M_{t-1} + (R_{s,t} Q_{s,t-1} S_{t-1} + R_{d,t-1} D_{t-1} \\ &\quad + R_{f,t-1} F_{t-1}) - (\tau_s Q_{s,t} S_t + \tau_d D_t + F_t). \end{aligned} \tag{23}$$

The household allocates current wealth between consumption (C_t) and money holding (M_t). Wealth consists of current labor income (W_t: wage rate) minus tax (T_t), the initial money holding (M_{t-1}), return on last period's external fund provisions ($R_{s,t}Q_{s,t-1}S_{t-1} + R_{d,t-1}D_{t-1} + R_{f,t-1}F_{t-1}$) minus current period's expenditure on external funds ($\tau_s Q_{s,t} S_t + \tau_d D_t + F_t$).

[16] The demand function for retailer h's intermediate goods ($Y_{\psi,t}(h)$) is derived assuming the following production function for aggregate final goods production:

$$Y_{\psi,t} = \left(\int_0^1 Y_{\psi,t}(h)^{\frac{\theta-1}{\theta}} dh \right)^{\frac{\theta}{\theta-1}}.$$

Lifetime utility is given by

$$E_{t_0} \sum_{t=t_0}^{\infty} \beta^{t-t_0} \left\{ \ln C_t + \zeta \ln \frac{M_t}{P_t} + \xi \ln(1 - H_t) \right\}. \tag{24}$$

Thus, instantaneous utility is separable in consumption, real money holding, and leisure. β is fixed discount factor. The household maximizes its lifetime utility (24) subject to the budget constraint (23). Let μ_t be the Lagrange multiplier for the budget constraint (23) in period t. Then, for all $t = t_0, \cdots, \infty$, the first order conditions can be written [17]:

$$\frac{E_t C_{t+1}}{\beta C_t} = R_{f,t} \left(\frac{E_t P_{c,t+1}}{P_{c,t}} \right)^{-1}, \tag{25}$$

$$\frac{W_t}{P_{c,t} C_{c,t}} = \frac{\xi}{1 - H_t}, \tag{26}$$

$$\frac{M_t}{P_{c,t}} = \zeta C_t \frac{R_{f,t}}{R_{f,t} - 1}, \tag{27}$$

$$E_t R_{s,t+1} = \tau_s R_{f,t}, \tag{28}$$

$$R_{d,t} = \tau_d R_{f,t}, \tag{29}$$

$$R_{f,t} = \frac{\mu_t}{\beta E_t \mu_{t+1}}. \tag{30}$$

3.6 Government

The government purchases consumption goods (this expenditure is denoted G_t). The clearing condition in the final goods market is then as follows:

$$Y_t = C_t + I_t + G_t. \tag{31}$$

Government expenditure is financed by money creation $(M_t - M_{t-1})$ and lump-sum taxes $(P_{c,t} T_t)$. Thus, the government's budget constraint is given by

$$G_t = \frac{M_t - M_{t-1}}{P_{c,t}} + T_t. \tag{32}$$

3.7 Linearized Model with Monetary Policy Rule

Here we derive the log-linearized version of our structural model. In order to make each variable stationary, we redefine $y_t \equiv Y_t/(A_t L_t)$, $c_t \equiv C_t/(A_{c,t} L_t)$, $i_t \equiv I_t/(A_{i,t} L_t)$, $g_t \equiv G_t/(A_t L_t)$, $k_t \equiv K_{t-1}/(A_{i,t} L_t)$, and $h_t \equiv H_t/L_t$. We also define the productivity growth rate in the consumption goods sector to be $a_{c,t} \equiv \Delta A_{c,t}/A_{c,t}$, the population growth rate to be $n_t \equiv \Delta L_t/L_t$, and the real capital price to be $q_t \equiv Q_{k,t}/P_{i,t}$.

[17] From (25), discount factor used in (3) is determined as $\Lambda_{t_0|t} = \frac{\beta C_{t_0}}{E_{t_0} C_t}$

For other variables, lowercase letters simply correspond to the equivalent upper case letters.

The log-linearized model is summarized as follows [18]:

$$\begin{aligned}
\widehat{y}_t &= \varpi_c \widehat{c}_t + \varpi_i \widehat{i}_t + (1-\varpi_c-\varpi_i)\widehat{g}_t, && (33)\\
\widehat{c}_t &= E_t\widehat{c}_{t+1} - (\widehat{r}_{f,t} - E_t\widehat{\pi}_{c,t+1}) + E_t\widehat{a}_{c,t+1}, && (34)\\
\widehat{r}_{k,t} &= (1-\beta_k)(\widehat{y}_t - \widehat{k}_t + \widehat{x}_{i,t}) + \widehat{\pi}_{i,t} + \frac{\beta_k}{1-\delta}\widehat{q}_t - \widehat{q}_{t-1}, && (35)\\
E_t\widehat{r}_{k,t+1} &= \widehat{r}_{f,t} - \nu\widehat{s}_t, && (36)\\
\widehat{q}_t &= \varphi(\widehat{i}_t - \widehat{k}_t), && (37)\\
\widehat{k}_t &= \delta\widehat{i}_{t-1} + (1-\delta)\widehat{k}_{t-1} - \widehat{a}_{i,t} - \widehat{n}_t, && (38)\\
\widehat{s}_t &= \beta_s\widehat{s}_{t-1} + \frac{1}{\varpi_s}\widehat{r}_t^k - \frac{1-\varpi_s}{\varpi_s}\widehat{r}_{f,t-1} - \widehat{\pi}_{i,t} - (\widehat{q}_t - \widehat{q}_{t-1}), && (39)\\
\widehat{y}_t &= \alpha\widehat{k}_t + (1-\alpha)\widehat{h}_t, && (40)\\
\widehat{y}_t &= (1+1/\eta)\widehat{h}_t + \widehat{c}_t - \widehat{x}_{c,t}, && (41)\\
\widehat{x}_{c,t} - \widehat{x}_{c,t-1} &= \widehat{x}_{i,t} - \widehat{x}_{i,t-1} + \widehat{\pi}_{i,t} - \widehat{\pi}_{c,t} + \widehat{a}_{i,t} - \widehat{a}_{c,t}, && (42)\\
\widehat{\pi}_{c,t} &= \beta E_t\widehat{\pi}_{c,t+1} + \frac{(1-\alpha_c)(1-\alpha_c\beta)}{\alpha_c}\widehat{x}_{c,t}, && (43)\\
\widehat{\pi}_{i,t} &= \beta E_t\widehat{\pi}_{i,t+1} + \frac{(1-\alpha_i)(1-\alpha_i\beta)}{\alpha_i}\widehat{x}_{i,t}. && (44)
\end{aligned}$$

$$\begin{aligned}
\text{where } \varpi_c &\equiv \overline{C/Y}, \varpi_i \equiv \overline{I/Y},\ \beta_k \equiv \frac{1-\delta}{A_m\overline{X}_i\alpha(\overline{y/k}) + (1-\delta)},\\
\nu &\equiv \frac{-\{\tau_s - \tau_d(1+\gamma)+\gamma\}}{\tau_d + \{\tau_s - \tau_d(1+\gamma)+\gamma\}},\ \varphi \equiv \frac{\Phi'(\overline{I/K})^{-1}}{\Phi''(\overline{I/K})^{-1}},\\
\beta_s &\equiv \frac{\{(1+\gamma)\tau_d - \gamma\}(\tau_s\overline{s} + \tau_d)}{\left[\{(1+\gamma)\tau_d - \gamma\}\overline{s} + \overline{R_k}/\overline{R_f}\right]\tau_s},\ \ \varpi_s \equiv \frac{\left[\{(1+\gamma)\tau_d - \gamma\}\overline{s}\,\overline{R_f}/\overline{R_k} + 1\right]\tau_s\overline{s}}{(\tau_s\overline{s} + \tau_d)}.
\end{aligned}$$

(33) is the log-linealized version of (31). (34) is linearized consumption Euler equation (from (25)). (35) is the return on capital (from (8)). (36) is arbitrage condition relating the expected return on capital and the cost of capital. ν is the key parameter, and a strictly positive ν indicates that the balance sheet channel is

[18] A hat (^) over a variable denotes the deviation of that variable from its steady state. A variable or ratio with an upper bar (and without a time notation) indicates the steady state value of that variable or ratio. Since we assume that the growth rates of A_c and A_i converge in the very long run, ϖ_c, ϖ_i, and β_k are constant values.

active [19]. (37) is the price of capital relative to that of investment goods (from(7)). (38) describes the accumulation of capital (from (2)). (39) captures the evolution of EVR. β_s is the parameter generating sluggish adjustment of EVR [20]. (40) is the production function for final goods (from (17)). (41) is the labor market clearing condition (from (1), (6), (18), (21), and (26)). (42) gives the relationship between $x_{c,t}$ and $x_{i,t}$ (from(18) and (21)). (43) and (44) are Phillips curves for consumption goods and investment goods respectively (from (20) and (22)).

In order to close the model, we need to introduce a monetary policy rule. Here, we select an "average inflation" rule which responds to a 4-quarter moving average inflation rate for consumption goods [21]:

$$\widehat{r}_{f,t} = \widehat{a}_{c,t} + \phi_\pi(\widehat{\pi}_{c,t} + \widehat{\pi}_{c,t-1} + \widehat{\pi}_{c,t-2} + \widehat{\pi}_{c,t-3})/4. \tag{45}$$

We have now completely linearized the model. In the next section, we estimate this linearized model using actual Japanese data.

4 Estimation and Shock Identification

4.1 GMM Estimation

The sample period is from 1981Q1 to 2003Q1. Details about data sources are given in Appendix C. The estimation method is GMM [22]. Instruments used are the lagged variables for each equation. In identifying a weighting matrix, we use Newey and West's [1987] method [23,24].

[19] Note that ν becomes zero when there is no monitoring cost ($\tau_s = \tau_d = 1$). See Appendix A for details about the derivation of equation (36).

[20] See Appendix B for the details about the derivation of equation (39).

[21] In the simulations in later sections, we introduce the zero-lower bound on the O/N call rate. We consider that this combination of an average inflation rule and the zero lower bound roughly approximates the actual monetary policy conducted by the Bank of Japan – specifically the zero interest rate policy (ZIRP) followed during 1999-2000, which the Bank committed itself to continue until concern about deflation was dispelled; and the quantitative monetary easing policy (QMEP) adopted in March 2001, which the Bank is committed to continue until the CPI inflation rate becomes zero or higher on a sustainable basis. It should be noted that this policy rule does not capture these commitments precisely. In particular, it neglects the effects of expanding current account balances at the BOJ far more than the reserve requirements.

[22] Some recent empirical studies involving dynamic stochastic general equilibrium (DSGE) models use Bayesian estimation as an alternative (Smets and Wouters [2004]).

[23] Because we do not have accurate data for the return on capital ($R_{k,t}$), we cannot directly estimate equation (36). Therefore, we jointly estimate the following equation, which is obtained by substituting (35) into (36):

$$(1-\beta_k)(E_t\widehat{y}_{t+1} - E_t\widehat{k}_{t+1} + E_t\widehat{x}_{i,t+1}) + E_t\widehat{\pi}_{i,t+1} + \frac{\beta_k}{1-\delta}E_t\widehat{q}_{t+1} - \widehat{q}_t = \widehat{r}_{f,t} - \nu\widehat{s}_t$$

[24] Because we do not know the steady state value of each variable *a priori*, we estimate the model by including constant terms, and identify each variable's steady state value from the estimated

The estimated parameters are presented in Figure 6. The most important parameter in this analysis is ν, which quantifies the importance of the balance sheet channel. That is, a large (small) ν indicates a wide (narrow) balance sheet channel. As a limiting case, if ν is zero, it means that balance sheet channel does not exist and EVR is irrelevant to the determination of investment.

As we see in Figure 6, the estimated ν is 0.038. In order to examine the statistical significance of this estimate, we carry out a likelihood ratio test. Figure 7 shows the test result. The result shows that the estimated ν is statistically meaningful at the 5% significant level. Therefore, based on our GMM result, we can state that, in Japan, the balance sheet channel is active.

Next, we should consider whether the estimated ν is large or small. In the original BGG, ν is calibrated to 0.05 [25]. Hall and Wehterilt[2002] tries various different calibrations for ν, ranging from 0.029 to 0.089. In a recent empirical study, Christensen and Dib [2004] estimates a BGG-style model by maximum likelihood method, and shows that the point estimate of ν to be 0.0377 for the sample period from 1979Q3 to 2003Q3 [26]. This result is surprisingly close to ours. Of course, since sample countries are different, we do not have any reason to expect that our ν should be close to theirs. However, this result may be thought to broadly support the plausibility of our point estimate [27].

β_s is another important parameter in our framework. We can interpret (39) as a partial EVR adjustment process. Therefore, if β_s is close to 1 (but less than 1), it means the speed of adjustment is slow. Our estimated β_s (0.942) supports this picture of sluggish EVR adjustment.

Among the other parameters, the so-called "Calvo parameters" (α_c, α_i) are of interest. Our estimates are 0.742 for α_c, and 0.824 for α_i. These values may be considered fairly plausible in light of Fuchi and Watanabe [2002], which reports that the Calvo parameter for the overall Japanese inflation rate ranges from 0.754 to 0.909, depending on the specification of the regression form [28, 29].

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constant term and parameters.

[25] Fukunaga [2002] also uses this value.

[26] The standard error is 0.0143.

[27] In another empirical study using US data, Meier and Muller [2004] matches the impulse responses from a BGG-type model to the responses of VARs. Their estimates of ν range from 0.0658 to 0.0797, depending on the weighting matrix in the distance between the impulse responses of the BGG-type model and the VARs, as well as the number of matching periods. Although these values are larger than ours, the significance of their estimates is somewhat unclear since their standard errors are large. The difference with our result need not, therefore, be a cause of undue concern.

[28] Fuchi and Watanabe also estimates a New Keynesian Phillips curve specified in first-differences. However, because our estimates are specified in levels, here we only refer to their level-based Calvo parameters.

[29] The result that α_c is less than α_i is also consistent with Fuchi and Watanabe's industry-specific level estimates, which show that the Calvo parameters are low in foods (0.768) and textiles (0.670), but are high in metal products (0.828), general machinery (0.843), electrical machinery (0.825), and transportation equipment (0.872).

In the monetary policy rule, the responsiveness to the average inflation rate is 1.448, which satisfies the so-called "Taylor Principle". The estimated target inflation rate is about 1.65% annually, which is also reasonable in light of economic arguments which support the desirability of a small but positive target inflation rate [30].

4.2 Identifying Net Worth Shocks

In Section2, we looked into the characteristics of EVR shocks identified by VAR analysis. Here, we identify the corresponding shocks using the Japanese financial accelerator model. Following Gilchrist and Leahy [2002], we refer to this type of shock as a "net worth shock". In our framework, a net worth shock corresponds to the disturbance term ($\varepsilon_{s,t}$) in the determination of $\widehat{s}_t$ below:

$$\widehat{s}_t = \beta_s \widehat{s}_{t-1} + \frac{1}{\varpi_s}\widehat{r}_{k,t} - \frac{1-\varpi_s}{\varpi_s}\widehat{r}_{f,t-1} - \widehat{\pi}_{i,t} - (\widehat{q}_t - \widehat{q}_{t-1}) + \varepsilon_{s,t} \tag{46}$$

Net worth shocks ($\varepsilon_{s,t}$) capture that part of the movements of $\widehat{s}_t$, which cannot be explained by the structural equations. There are two main reasons why net worth shocks appear in the determination of $\widehat{s}_t$. First, observed $\widehat{q}_t$ departs from simulated $\widehat{q}_t$ in the determination of the stock price (37) because the actual stock price includes non-fundamental factors. This departure comes into the fifth term ($\widehat{q}_t - \widehat{q}_{t-1}$) in the above equation. Second, the stock price is included in the determination of the return on capital ($\widehat{r}_{k,t}$). Thus, the departure of observed $\widehat{q}_t$ from simulated $\widehat{q}_t$ again influences EVR (s_t) in the second term of (46) through the determination of the return on capital ($\widehat{r}_{k,t}$) [31].

The solid line in Figure 8 shows net worth shocks identified by the Japanese financial accelerator model. Surprisingly, net worth shocks are quite closely correlated with the EVR shocks identified by the VARs in Section 2 (the correlation coefficient between the two shocks is 0.94). This result is noteworthy because we have no *a priori* reason to expect the evolution of firms' net worth in these two models to coincide. One possible interpretation of this result is to appeal to the idea that Japanese EVR is largely determined by some exogenous factors. Such an interpretation is supported by Figure 4, which points to a high correlation between EVR shocks and changes in equity prices. Based on the identified shocks in these two models, we can reasonably conjecture that fluctuations in Japanese firms' balance sheets are mostly caused by exogenous shocks to equity prices.

[30] For example, Summers [1991] and Akerlof, Dickens, and Perry [1996].
[31] The backward-looking nature of equation (46) makes this identification possible.

5 Simulations

5.1 Impulse Response to Net Worth Shock

In this section, we use the Japanese financial accelerator model to provide a quantitative evaluation of financial accelerator effects. Here, we look at the impulse responses of macroeconomic variables to a temporary net worth shock.

Figure 9 shows the impulse responses of endogenous variables to a -1% temporary net worth shock ($\varepsilon_{s,t}$) in equation (46). Because our point estimate of β_s in equation (39) is close to 1 (0.942), the impulse response of EVR is highly persistent. Since the balance sheet channel is active ($\nu > 0$), a fall in EVR raises the cost of capital, so there is a persistent decline in investment. This persistence is the main characteristic of responses to a net worth shock. That is, for other exogenous shocks such as productivity or monetary policy shocks, the response to a temporary shock typically disappears within a few periods. However, in the case of a net worth shock, the response remains for a considerable period.

The simulated response indicates that a -1% net worth shock has a significant impact on investment (-0.4% at its peak). The decline in investment directly reduces real GDP and real marginal costs, thereby pushing down the CPI. In response to the decline in the CPI, the call rate also drops, so that investment slowly returns to its baseline.

These impulse responses to a net worth shock are largely consistent with the responses of the VARs in Section 2. In both VARs and the Japanese financial accelerator model, the responses of EVR persist for more than 16 quarters. As a result, the responses of real GDP to changes in EVR are also persistent in both models. We consider that this persistence captures the key feature of the dynamics of the Japanese economy, which experienced a prolonged adjustment lasting from the bursting of the asset price bubbles until the early 2000s [32].

5.2 Historical Impacts of Net Worth Shocks

Our goal in this section is to evaluate the historical impact of net worth shocks on Japan's economy. For this purpose, we now add the identified historical net worth shocks to the disturbance term in equation (46).

Figure 10 shows the impact of identified net worth shocks on Japanese investment, real GDP, and CPI. The shaded bar in the upper figure shows the historical impact of net worth shocks on investment. First of all, we notice that, during Japan's "asset price bubble" period in the latter half of 1980s, net worth shocks pushed up investment considerably. At its peak, investment deviated above its steady state

[32] We believe this interpretation to be natural because the alternative hypothesis, namely that the persistent decline in Japanese investment sprang from productivity or other shocks, would require these shocks to have hit the Japanese economy almost continuously.

level by about 50% due to this factor. From the middle of 1990, investment declined sharply because of negative net worth shocks caused by the collapse of Japan's bubble economy. From the middle of 1990 to the beginning of 1993, EVR persistently acted to constrain investment, to the tune of about -30%.

From the beginning of 1997, EVR again pushed down investment. In particular, there was a sharp fall in stock prices at the end of 1997 as the bankruptcy of several large financial institutions triggered a rise in firms' uncertainty about funding availability, and this acted as a major drag on investment during 1998. EVR also contributed to a further decline in investment from the latter half of 2000, when the collapse of the "IT bubble" in the US pushed down Japanese stock prices.

The middle panel shows the impact of EVR on real GDP. Since consumption is not directly influenced by EVR, the total impact of net worth shocks on real GDP is smaller than on investment. However, positive net worth shocks contributed considerably to the rise in real GDP during the bubble, and negative net worth shocks acted as a fairly persistent drag on real GDP, especially after 1997. Based on the results here, we can infer that the financial accelerator played a major role in the long stagnation of Japan's economy since the 1990s.

Negative net worth shocks also pushed down Japan's inflation rate. The shaded bar in the bottom panel shows the impact of net worth shocks on the CPI. This panel indicates that, after 1990, net worth shocks contributed considerably to the decline in the CPI during at least three periods: 1990-92, 1996-98, and 2000-03. In particular, it is striking that, without net worth shocks, Japan would have not experienced deflation in recent years. Therefore, according to this result, recent deflation in the CPI is almost entirely explained by this negative financial accelerator effect. However, it should be noted that this result may be partially attributed to the linearity of the Phillips curve in our model. In light of other empirical studies which emphasize the nonlinearity of the Phillips curve around a zero inflation rate (such as Nishizaki and Watanabe [2000]), it would be fair to say that the actual impact on the CPI may be somewhat smaller than suggested by this study.

6 Discussion

The above analysis suggests that the formation and collapse of the asset price bubble were the major reasons for the large swings observed in business cycles during this period, especially during the long stagnation during 1990s and early 2000s. We now consider the relationship between our study and other explanations of Japan's long stagnation.

Based on a traditional "growth accounting" approach, Hayashi and Prescott [2002] explains that the major cause of the long stagnation is a decline in total factor productivity (TFP) growth coupled with a reduction in the working week. The implications of our study may be seen as complementing their explanation, because in the simulations in Section 5 of our analysis, real economic variables such as GDP, consumption, and investment, are de-trended by their respective productivity growth rates, all of which are seen to decline significantly in the 1990s. In other words, our study shows that financial accelerator effects were important in explaining *business cycles*, which are defined in terms of deviations of real economic variables from their steady states.

We do not, however, mean to assert that financial accelerator effects are totally independent of the decline in TFP growth. Rather, our view is that some part of the decline in asset prices may be attributed to the decline in TFP growth because asset prices are largely determined by investors' perceptions regarding future productivity growth. From this view point, we can conjecture that some part of financial accelerator effects was originally caused by the decline in TFP growth.

Furthermore, it is even conceivable that the causality may have run in the other direction, in other words that financial accelerator effects contributed to the decline in TFP growth. This possibility is suggested by the recent empirical studies of Kawamoto [2004] and Nakakuki, Otani, and Shiratsuka [2004], which show that the decline in TFP growth mainly comes from the inefficient allocation of resource inputs. Although our BGG-style framework cannot incorporate this kind of distributional mechanism in an explicit way, a scenario in which financial market imperfections prevent resources from being reallocated efficiently seems plausible. In this sense, a comprehensive assessment of the influence of excessive debt on Japanese economic growth will require more detailed research into the relationship between financial market imperfections and resource reallocation.

The remaining issue is to find a way to lessen the persistence associated with the impact of net worth shocks on the real economy. One policy option would be to try to reduce the monitoring costs (τ_s, τ_d) directly. In our model, these costs symbolically represent the extent to which financial systems are imperfect. Therefore, policies aimed at enhancing the functioning of financial systems, such as the promotion of securitization, may help reduce τ_s and τ_d, and thereby weaken the long run impact of net worth shocks.

The other policy option would be to identify an optimal policy response to net worth shocks. This issue is related to the argument whether monetary policy should respond to fluctuations in asset prices, which is discussed in Bernanke and Gertler [2001]. Further investigation in this area is warranted if we are to successfully identify monetary policy options capable of mitigating the undesirable economic fluctuations caused by exogenous shocks to asset prices.

7 Conclusion

In this paper, we have carried out a historical evaluation of the financial accelerator effects, which were mainly generated by the changes in asset prices, operating on Japan's economy since the 1980s. We have found that the balance sheet channel is statistically significant and that the identified net worth shocks had a large and persistent impact on Japanese macroeconomic variables during the last two decades. This result strongly suggests that the financial accelerator effects were indispensable to explain the mechanism behind Japan's long stagnation during the 1990s and early 2000s, as well as indicating that the deflation of general prices since the late 1990s has been at least partly attributed to the same cause.

Appendix A: Derivation of (36)

Multiply (14) by $\beta\mu_t/\mu_{t-1}$ like this:

$$\beta\frac{\mu_t}{\mu_{t-1}}R_{k,t}Q_{k,t-1}K_{t-1}=\beta\frac{\mu_t}{\mu_{t-1}}R_{s,t}Q_{s,t-1}S_{t-1}+\beta\frac{\mu_t}{\mu_{t-1}}R_{d,t-1}D_{t-1}+\beta\frac{\mu_t}{\mu_{t-1}}R_{f,t-1}F_{t-1}. \tag{A1}$$

Insert (28), (29), (30) into (A1). The result is as follows:

$$\beta\frac{\mu_t}{\mu_{t-1}}R_{k,t}Q_{k,t-1}K_{t-1}=\tau_s Q_{s,t-1}S_{t-1}+\tau_d D_{t-1}+F_{t-1}. \tag{A2}$$

Use (12) and (15) to yield the following:

$$R_{k,t}=R_{f,t-1}\left[\tau_d+\{\tau_s-\tau_d(1+\gamma)+\gamma\}\,s_{t-1}\right]. \tag{A3}$$

Then, by log-linearizing (A3), we obtain (36).

Appendix B: Derivation of (39)

Combination of (9), (12), (14), and (15) yields the following equation:

$$\{(1+\gamma)\tau_d-\gamma\}\,R_{f,t-1}s_{t-1}+R_{k,t}=R_{s,t}s_{t-1}+\tau_d R_{f,t-1}. \tag{A4}$$

The log-linearized version of (A4) is as follows:

$$\varpi'(\widehat{R}_{f,t-1}+\widehat{s}_{t-1})+(1-\varpi')\widehat{R}_{k,t}=\varpi''(\widehat{R}_{s,t}+\widehat{s}_{t-1})+(1-\varpi'')\widehat{R}_{f,t-1}, \tag{A5}$$

$$\text{where } \varpi'\equiv\frac{\{(1+\gamma)\tau_d-\gamma\}\,\overline{R_f}\,\overline{s}}{\{(1+\gamma)\tau_d-\gamma\}\,\overline{R_f}\,\overline{s}+\overline{R_k}},\ \varpi''\equiv\frac{\overline{R_s}\,\overline{s}}{\overline{R_s}\,\overline{s}+\tau_d\overline{R_f}}$$

From (12), (13), and the definition of $R_{s,t}\equiv Q_{s,t}/Q_{s,t-1}$, we get the following expression:

$$R_{s,t}=\frac{s_t}{s_{t-1}}\frac{q_t}{q_{t-1}}\frac{P_{i,t}}{P_{i,t-1}}. \tag{A6}$$

Substitute the log-linearized version of (A6) into (A5). Then, we can obtain the following equation:

$$\widehat{s}_t = \frac{\varpi'}{\varpi''}\widehat{s}_{t-1} + \frac{1-\varpi'}{\varpi''}\widehat{R}_{k,t} - \frac{1-\varpi'-\varpi''}{\varpi''}\widehat{R}_{f,t-1} - (\widehat{q}_t - \widehat{q}_{t-1}) - \widehat{\pi}_{i,t}. \tag{A7}$$

This is the same form as (39).

Appendix C: Data Sources

All data is quarterly. GDP (Y_t), consumption (C_t), investment (I_t), and government expenditure (G_t) are from Cabinet Office's National Accounts (93SNA). As for labor, we generate the series H_t, by multiplying the number of 'employed persons' in the Statistics Bureau's Labor Force Survey with the 'total hours worked for establishments with at least 5 employees' in the Ministry of Health, Labor and Welfare's Monthly Labor Survey. For L_t, we use the 'population of 15 years old or more' in the Labor Force Survey. For the capital stock (K_t), we use 'gross capital stock including the construction in progress' from the Cabinet Office's Statistics on the Capital Stock of Private Enterprises. For prices, we use the Statistics Bureau's 'CPI excluding fresh food' as $P_{c,t}$ and the 'investment deflator' from the National Accounts for $P_{i,t}$. Q_t is calculated as the total value of firms (see Note 2 in Figure 1) divided by the capital stock. $R_{f,t}$ is the O/N call rate.

Because we have to measure some variables in efficiency unit (such as y_t, c_t, i_t, g_t, and k_t), we need to obtain the data on the productivity trends for consumption and investment. Since we assume Cobb-Douglas technology, productivity growth can be interpreted as "Harrod-neutral" technological progress. In such a case, trend productivity for each type of good (consumption goods and investment goods) must be equivalent to the ratio between the wage rate and the price of the corresponding good. We thus use the HP-filtered ratio of the wage rate to each good's price as the productivity for that good ($A_{c,t}$, and $A_{i,t}$), where we use 'total cash earnings' from the Monthly Labor Survey divided by 'employed persons' in the Labor Force Survey as the wage rate (W_t). Real marginal costs for each of the final goods ($X_{c,t}$ and $X_{i,t}$) are calculated as the ratio of the wholesale price to the price of the corresponding final goods ($P_{c,t}$ and $P_{i,t}$). Wholesale prices ($P_{c,w,t}$ and $P_{i,w,t}$) are taken from 'consumer goods' and 'capital goods' in the Bank of Japan's Corporate Goods Price Index (CGPI).

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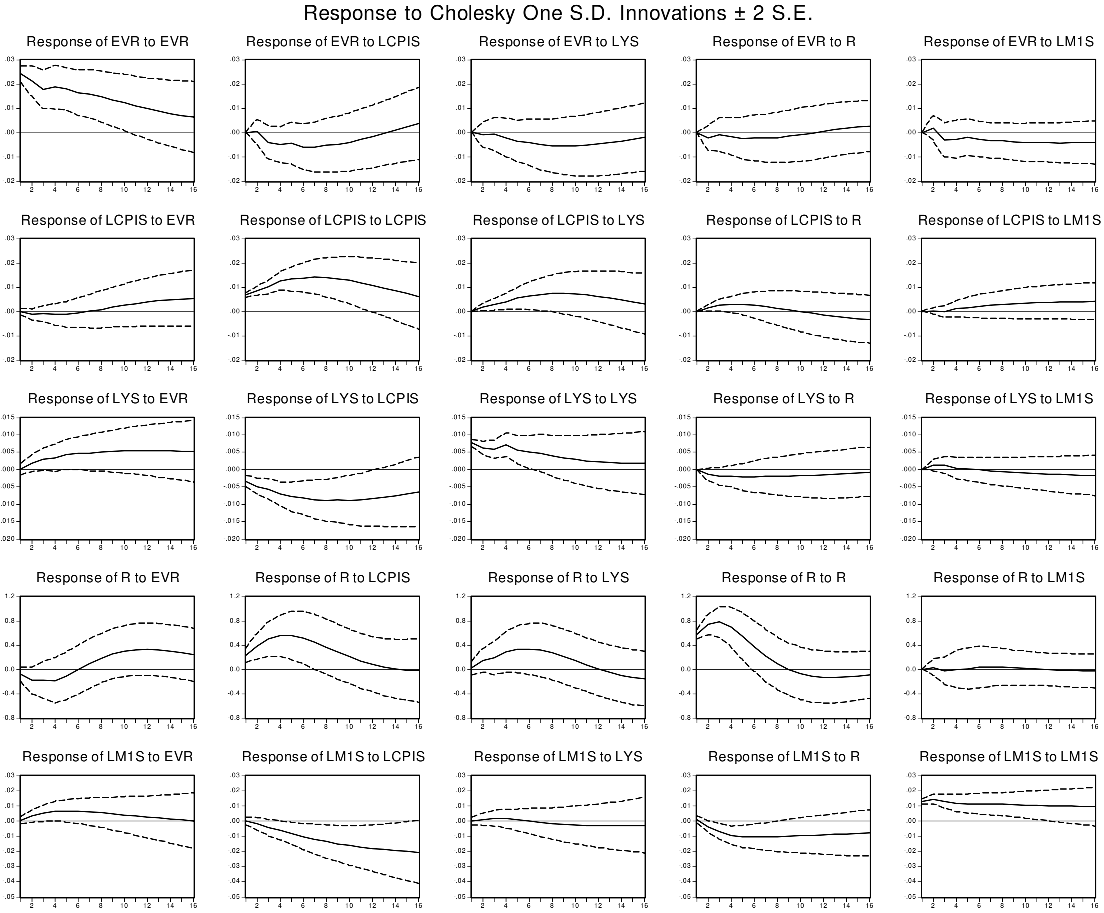
Figure 1: Ratio of Firms' Equity Value to Their Total Value (EVR)

Notes : 1. The value of equity is "Shares and other equities" of "Private nonfinancial corporations", Flow of Funds Account. Data up to 1997Q3 are calculated from "Total market value of listed Stocks (Tokyo stock market 1st section)".

2. The value of the firm is the sum of the value of debt and the value of equity. The value of debt is the sum of "Loans" and "Securities other than shares" of "Private nonfinancial corporations", the Flow of Funds Account. Data up to 1997Q3 are calculated from the Flow of Funds Account based on 68SNA.

Figure 2: Impulse Responses of the VARs

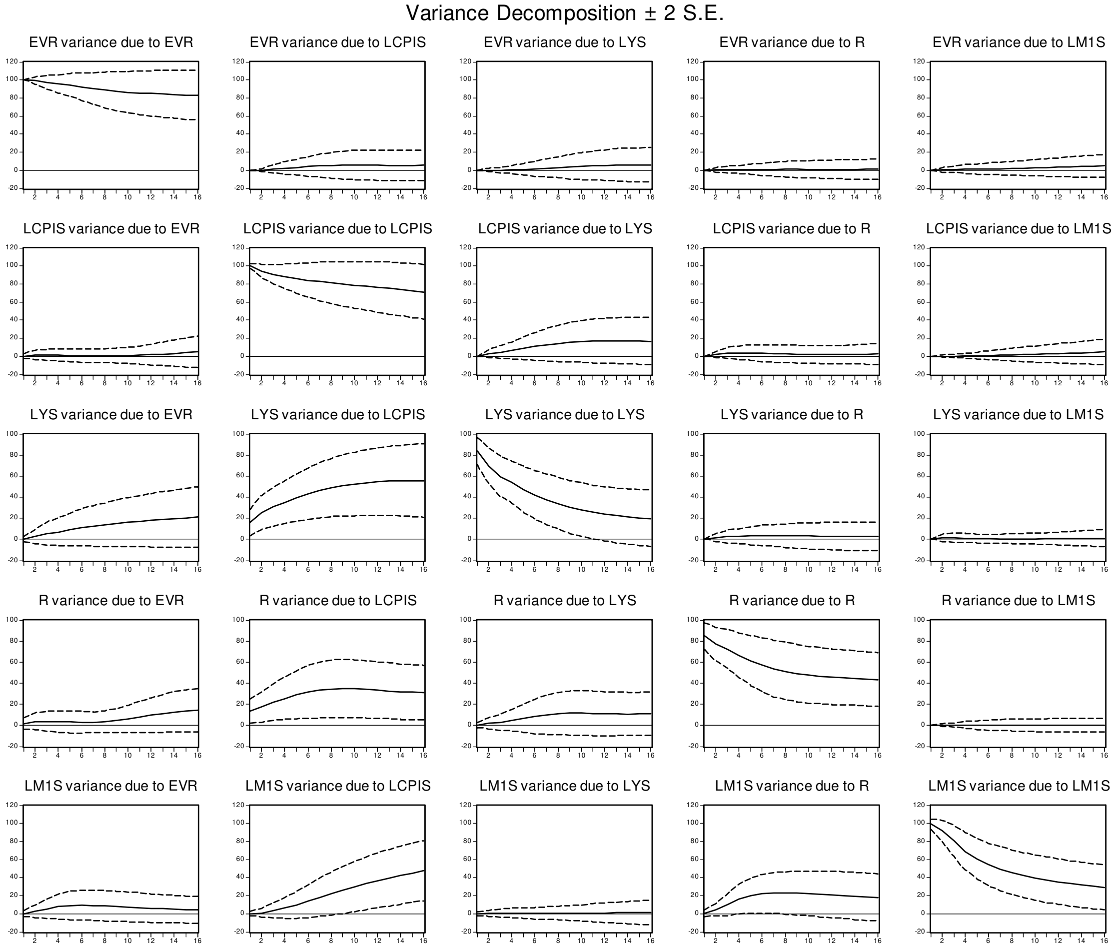


Notes: 1. EVR, LCPIS, LYS, R, and M1S are the ratio of firms' equity value to their total value, real GDP, overnight call rate, and M1, respectively. CPI, real GDP, and M1 are in logarithmic form and seasonally adjusted. EVR and R are in level form and are not seasonally adjusted.

2. Each Panel shows the sixteen-quarter response of the given row variable to a shock to a given column variable. Impulse responses are orthogonalized recursively in the order shown above. Dashed lines indicate two standard error bands, calculated by Monte Carlo method with ten thousand repetitions.

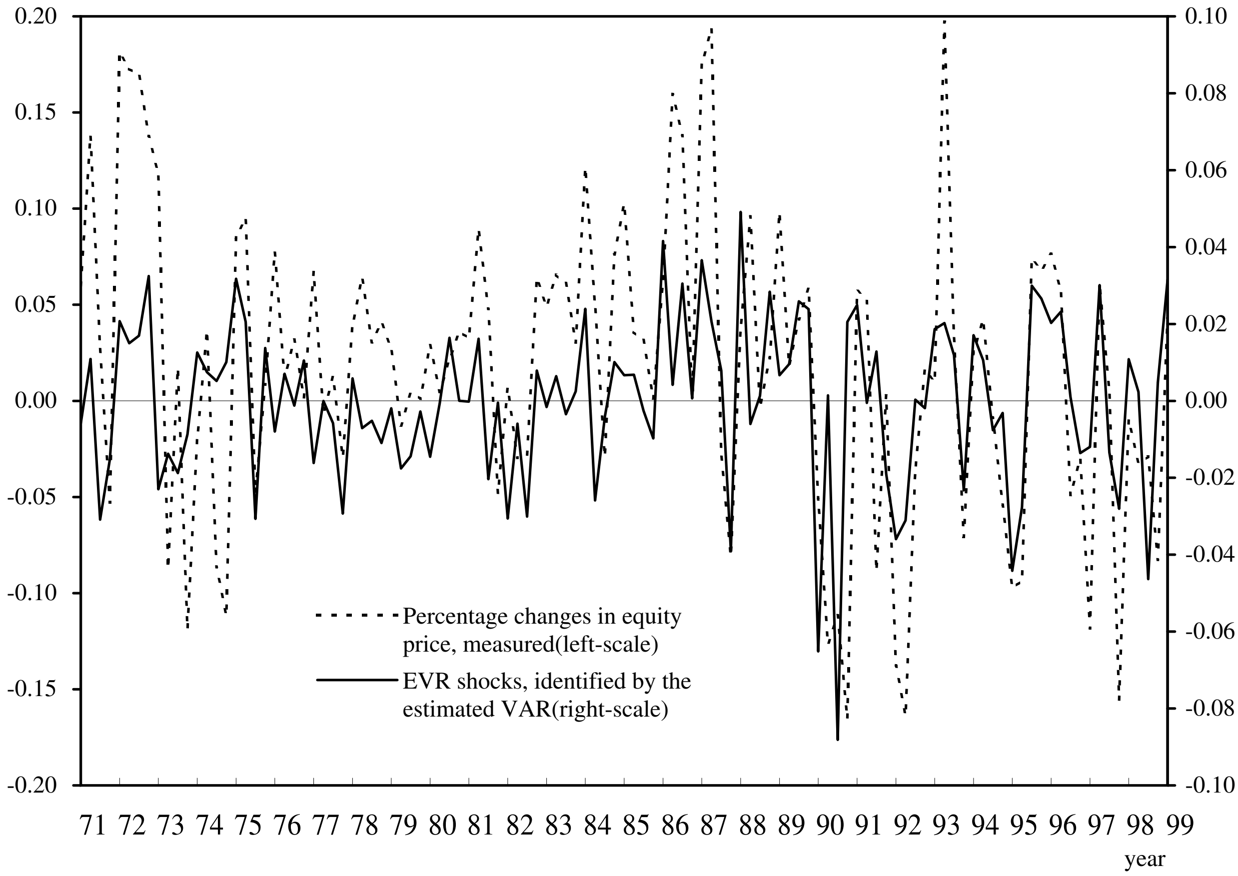
3. The estimation includes four lags and a constant.

Figure 3: Variance Decomposition of the VARs



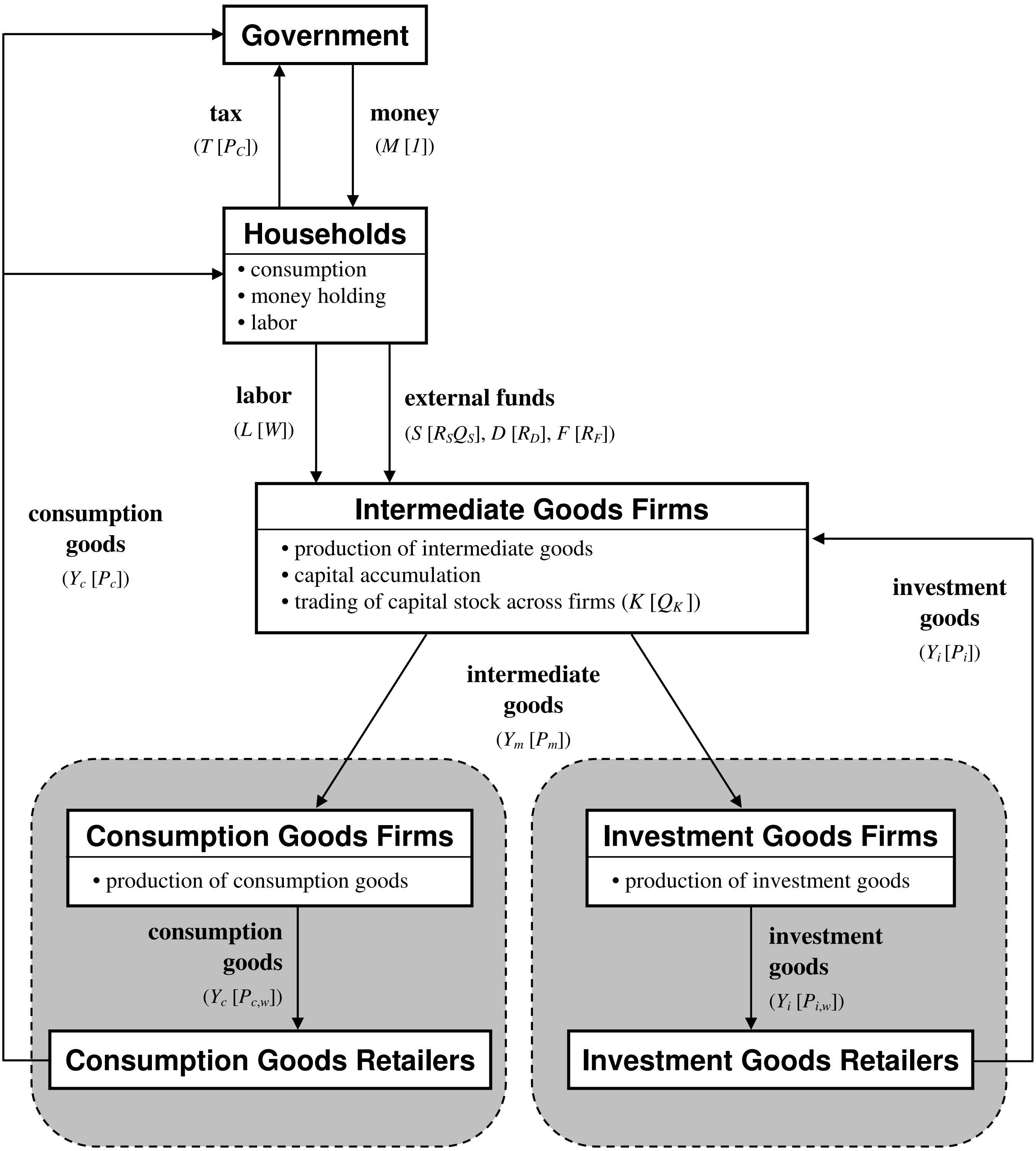
Note: Each Panel shows the sixteen-quarter forecast error variance decomposition, based on the main VARs. Dashed lines indicate two standard error bands, calculated by Monte Carlo method with ten thousand repetitions.

Figure 4: EVR Shocks Identified by the VARs



Note : The equity price is the Tokyo Stock Price Index (TOPIX, 1st section).

Figure 5: Overview of the Japanese Financial Accelerator Model



Note: The notation (A [B]) means that the goods or service A is traded at price B.

Figure 6. Estimation Results of the Japanese Financial Accelerator Model

Method: GMM, quarterly data over the period 1981/QI -2003/QI.

Parameter	Estimate	Standard Error
ϖ_c	0.564	0.002
ϖ_i	0.168	0.001
β_k	0.987	0.005
ν	0.038	0.019
φ	0.866	0.053
δ	0.019	0.000
β_s	0.942	0.011
ϖ_s	0.497	0.016
α	0.661	0.003
η	6.353	0.018
β	0.997	0.000
α_c	0.742	0.049
α_i	0.824	0.319
ϕ_π	1.448	0.073

Note: The parameters $\varpi_c, \varpi_i, \alpha$, and η are separately estimated. For these parameters, the instruments used include two lags of the variables and a one-lag Newey-West estimate of the covariance matrix is used (*J*-statistics = 37.415 [p-value 0.136]). For other variables, the instruments used include one lag of the variables of each equation. Also a two-lag Newey-West estimate of the covariance matrix is used (*J*-statistics = 28.963 [p-value 0.571]).

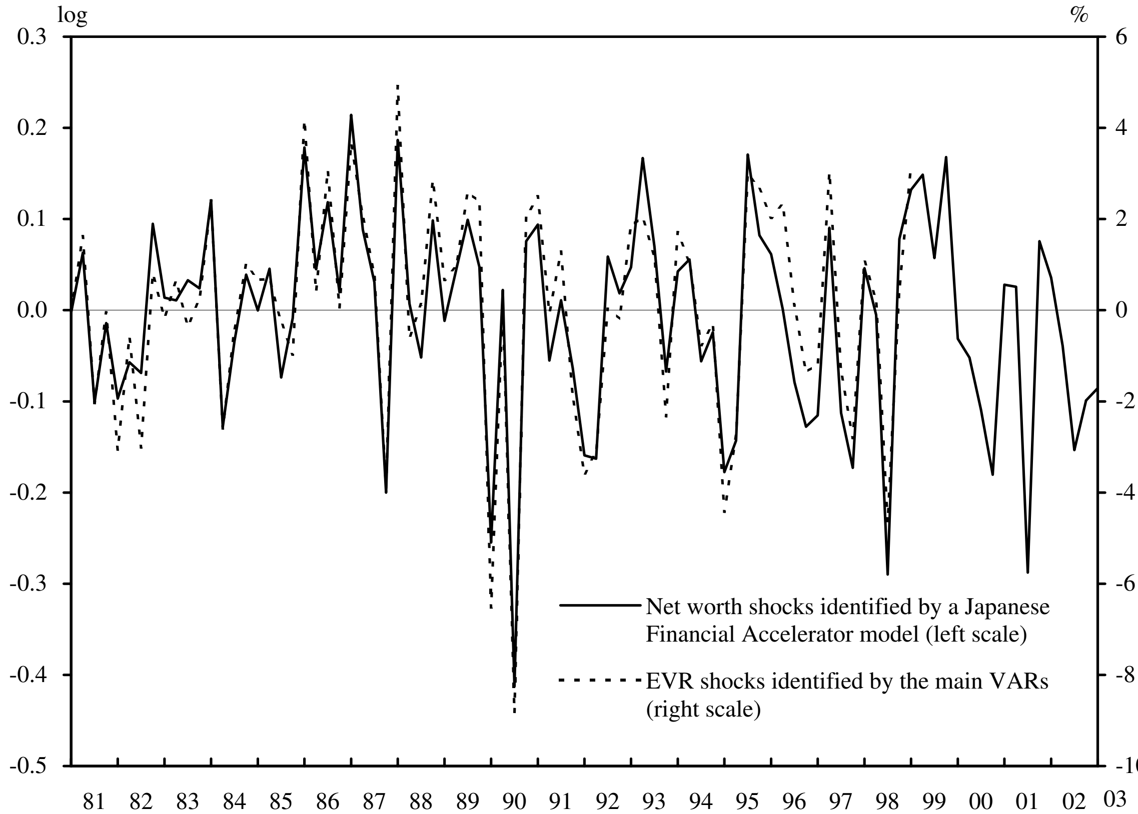
Figure 7. Likelihood Ratio Test on the Balance Sheet Channel Parameter

Likelihood ratio test with the null hypothesis of $\nu = 0$

Number of Observations	Degrees of Freedom	LR-statistic	P-value
89	29	4.317	0.038

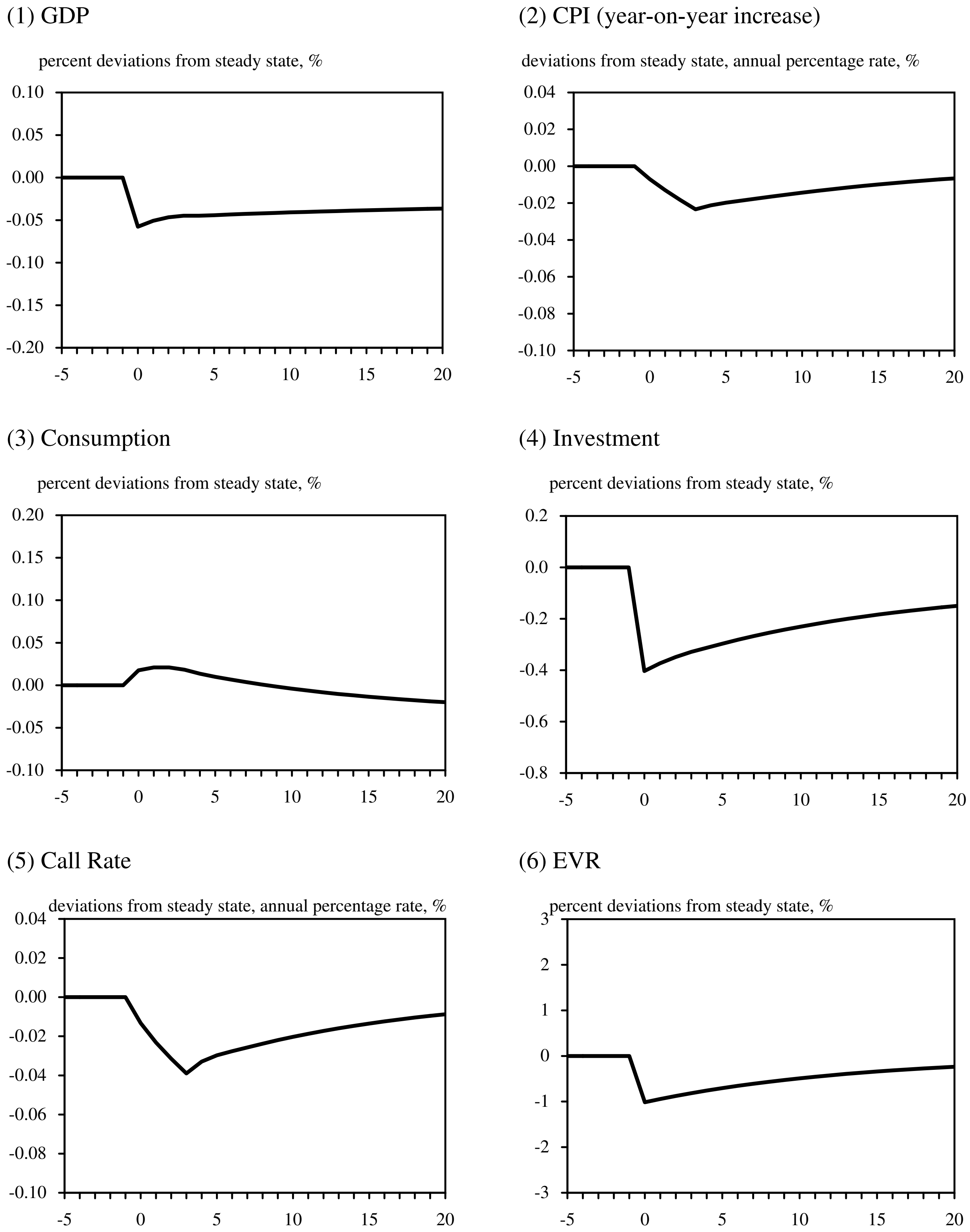
Note: LR statistic follows a χ^2 distribution.

Figure 8: Net Worth Shocks Identified by the Japanese Financial Accelerator Model



Note : The correlation coefficient between the two shocks is 0.94.

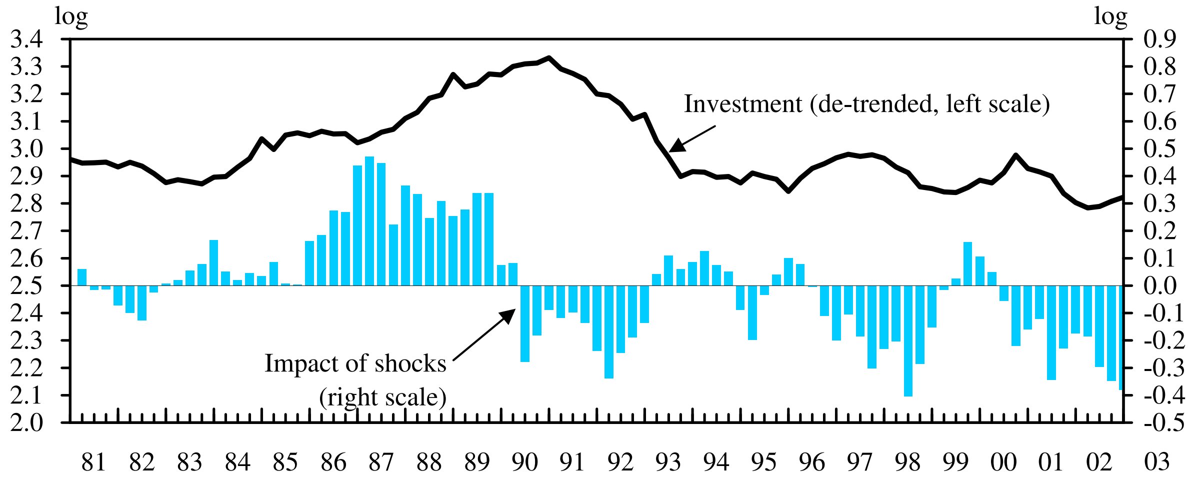
Figure 9: Impulse Responses to a Net Worth Shock



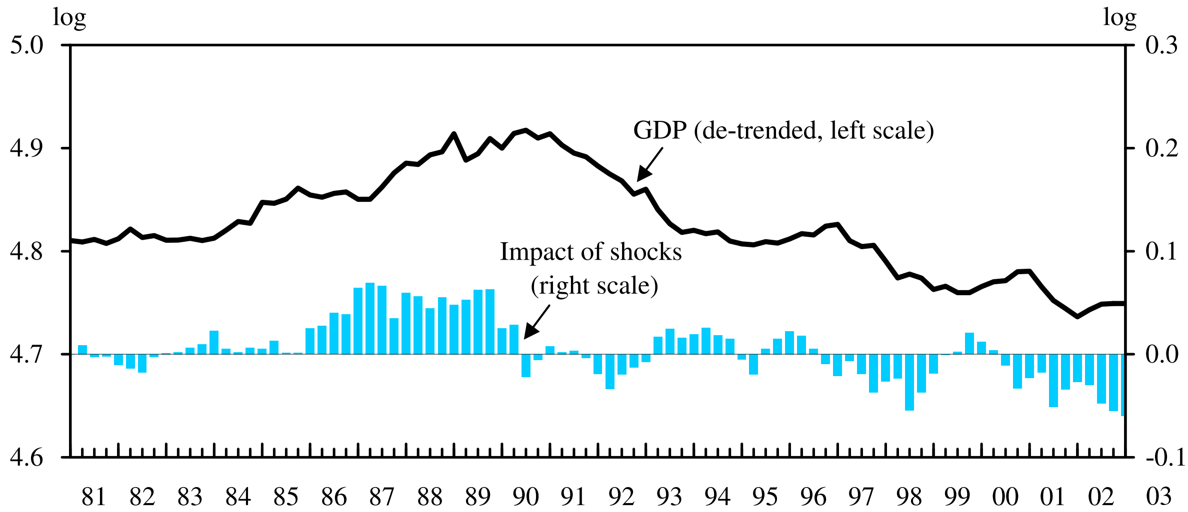
Note : Responses to a negative 1 percent shock in the error term of equation (46).

Figure 10: Impact of Net Worth Shocks on the Japan's Economy

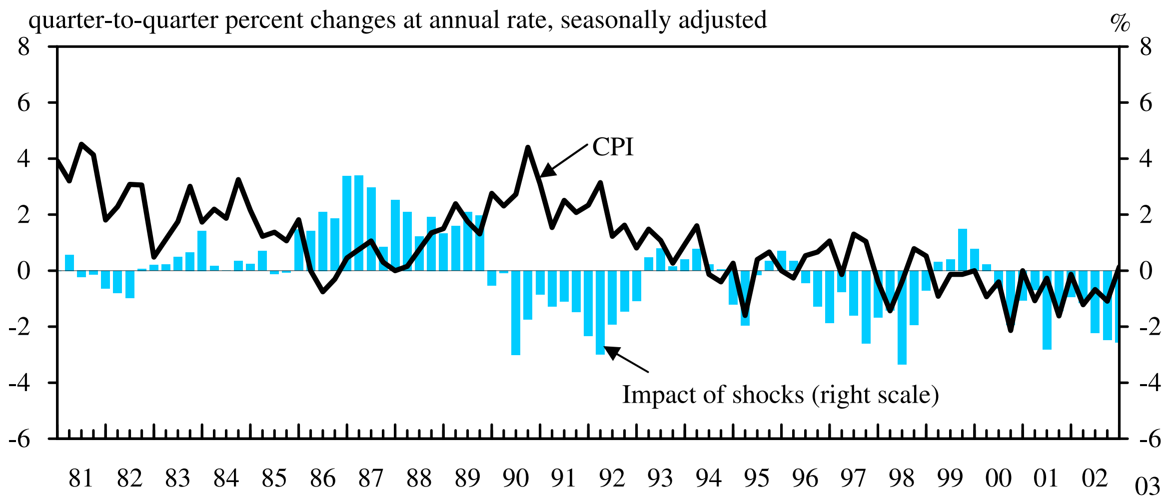
(i) Investment



(ii) GDP



(iii) CPI



Note : Impact of shocks shows the responses of endogenous variables to net worth shocks identified by the Japanese financial accelerator model (presented in Figure 8). It is expressed in deviations from steady state.