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Abstract

In this paper we explore the role of financial intermediation malfunction in macroeconomic fluctuations in Japan. To this end we estimate, using Japanese data, a financial accelerator model in which the balance sheet conditions of entrepreneurs in a goods-producing sector and those of a financial intermediary affect macroeconomic activity. We find that shocks to the balance sheets of the two sectors have been quantitatively playing important role in macroeconomic fluctuations by affecting lending rates and aggregate investments. Their impacts are prominent in particular during financial crises. Shocks to the entrepreneurs' balance sheets have played a key role in lowering investment in the bubble burst during the early 1990s and in the global financial crisis during the late 2000s. Shocks to the financial intermediaries' balance sheets have persistently lowered investment throughout the 1990s.

Keywords: Japan's Lost Decade; Banks' Balance Sheet; Financial Accelerators.

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1 Introduction

Over the last twenty years, the Japanese economy has witnessed three large financial crises. The first crisis is the burst of the asset price bubble in February 1991 followed by a prolonged economic contraction. Stock and land prices that rose steadily from the mid-1980s plummeted at that time. These developments in asset prices have not only weakened aggregate demand through a negative wealth effect but also hampered financial intermediation functions as firms used land as collateral for business loans and banks held a large amount of stock, leading to a further decline of macroeconomic activity (Bayoumi, 2001).[1] The second crisis emerged as a series of collapses of financial institutions during the late 1990s. The crisis started with interbank market turmoil triggered by the default of Sanyo Securities in November 1997 and resulted in collapses of large banks and security companies such as Hokkaido Takushoku Bank and Yamaichi Securities. In most cases, these defaulting financial institutions had over the years failed to improve their balance sheets that had been impaired due to excessive investment in real estate or stocks during the bubble boom period. The third crisis is the spillover effect of the global recession in the United States following the global financial market turmoil since the summer of 2007. Though the crisis itself mainly originated from malfunctions of financial institutions in the United States and Europe, its impact was propagated to Japan's economy through trade relationship. The annual GDP growth rate in Japan in 2009 was -5.5 percent due to the severe decline in real exports by 26.2 percent.

Despite the crisis episodes, there has been no agreement regarding how important financial intermediation has been to macroeconomic fluctuations in Japan. A pioneering work by Hayashi and Prescott (2002), based on a simple growth model, showed that movements of total factor productivity (hereafter TFP), which are regarded as exogenous changes in the technology level in their model, explains the bulk of output decline from the early 1990s onward.[2] Braun and Shioji (2007) obtained a similar result based a growth model in which two classes of technology, investment-specific technology and TFP, drive macroeconomic fluctuations in Japan. From the perspective of a New Keynesian framework, Sugo and Ueda (2008) estimate a model that is close to the model of Smets and Wouters (2005) using Japanese data and show that TFP shocks and investment adjustment cost shocks are the two important shocks that account for output fluctuations in Japan. In contrast to these studies, several studies emphasize the importance of financial factors in accounting for macroeconomic fluctuations in Japan. Bayoumi (2001), based on the vector autoregression model, argues that the failure of financial intermediation is the major explanation for economic stagnation during the 1990s. Hirose and

[1] Kwon (1998) argues that a fall in land prices caused by the contractionary monetary policy leads to an economic downturn through the collateral effect.

[2] While Hayashi and Prescott (2002) argue that non-financial factor is important in explaining most of the output growth slowdown during the lost decade, they admit that for 1996–1998, the performance of the banking sector has played an exceptionally important role in economic activity in Japan.

Kurozumi (2010) estimate a New Keynesian model with investment-specific technology shocks and show that investment-specific technology shocks have played a quantitatively important role in investment fluctuations in Japan. They also argue that investment-specific technology is related to the function of financial intermediation because the time series of estimated investment-specific technology shocks moves together with that of firms' financial position index that is released from the Bank of Japan.[3]

In the present paper, we quantitatively study the roles of financial intermediation malfunction as well as technology growth slowdown in macroeconomic fluctuations in Japan. To do this, we estimate a dynamic stochastic general equilibrium model developed by Hirakata, Sudo, and Ueda (hereafter HSU, 2011) using Japanese data from the 1980s to the 2010s. The model is built on a financial accelerator model of Bernanke, Gertler, and Gilchrist (1999, hereafter BGG). It explicitly incorporates credit-constrained financial intermediaries (hereafter FIs) and credit-constrained entrepreneurs, both of which raise external funds by making credit contracts. In the model, financial shocks, such as an unexpected net worth shocks to FIs, affect aggregate investment by changing the functioning of financial intermediation and by affecting funding expenses that serve for production inputs. By estimating the model using U.S. data, HSU (2011) show that a sizable portion of macroeconomic fluctuation in the United States is attributed to financial shocks that are shocks to net worth in the FI sector and the goods producing sector.

By estimating the parameters of the HSU (2011) model using Japanese data, we disentangle macroeconomic fluctuations in Japan into those that are attributed to financial shocks and those that are attributed to non-financial shocks including technology shocks and preference shocks. Our data sample is from the 1980s to the 2010s, which covers three financial crises. We extract time series of various types of shocks from the data, including net worth shocks of FIs and entrepreneurs as well as TFP shocks, and investment adjustment cost shocks. We then study how and when net worth shocks have hampered financial intermediation and dampened key macroeconomic variables, such as GDP and investment.

We find that net worth shocks to FIs and entrepreneurs have been playing a quantitatively important role in macroeconomic fluctuations. These shocks impair the balance sheets of these two sectors, increase the external finance premium, and dampen aggregate investment. Their impacts on investment are prominent particularly during the three financial crises. Net worth shocks to entrepreneurs have played the key role in lowering investment during the periods of the bubble burst and the global financial crisis. Net worth shocks to FIs have contributed to investment decline in the early 1990s and persistently lowered investment throughout the 1990s. It is important to note, however, that contribution of these two shocks is not the largest shocks among structural shocks

[3] One other strand of literature includes Caballero, Hoshi, and Kashyap (2008). They consider the effect of malfunction of the financial intermediary sector on the economy, in particular on productivity, through zombie lending.

in accounting for investment and other macroeconomic variables. TFP shocks and investment adjustment cost shocks play a quantitatively larger role than these financial shocks. Our result is therefore consistent with studies that stress the role of non-financial factors such as Hayashi and Prescott (2006) and Ueda and Sugo (2008) though it is not inconsistent with studies that stress the role of financial factors such as Bayoumi (2001) and Hirose and Kurozumi (2010).

In addition, we explore how investment adjustment cost shocks are related to net worth shocks estimated in our model. As discussed by Justiniano, Primiceri, and Tambalotti (2008), the estimates of the New Keynesian model typically indicate that shocks to investment adjustment cost play an important role in producing business cycles. Hirose and Kurozumi (2010) by estimating a New Keynesian model using Japanese data also document that most of the Japanese investment variations are accounted for by these shocks. These shocks are considered to be related to the efficiency of financial intermediation in Hirose and Kurozumi (2008) and Justiniano, Primiceri, and Tambalotti (2011). To see how investment adjustment cost shocks are related to financial factors, we estimate alternative models that abstract from financial frictions and compare quantitative roles of estimated investment adjustment cost shocks in these models with those in our baseline model. We find that quantitative impacts of the shocks to investment adjustment cost are reduced when credit frictions are explicitly incorporated into the model. Our results suggest that some portion of investment adjustment cost shocks estimated in Hirose and Kurozumi (2008) and Justiniano, Primiceri, and Tambalotti (2011) may reflect shocks to financial intermediation.

The remainder of our paper is organized as follows. In Section 2, we briefly describe the model. In Section 3, we explain the estimation procedure. In Section 4, we report the estimation results. Section 5 contains discussion about our outcomes and comparison with other existing works. Section 6 concludes.

2 The Model

Our model setting is the same as that used in HSU (2011). The economy consists of a credit market, a goods market, and ten types of agents: investors, FIs, entrepreneurs, a household, final goods producers, retailers, wholesalers, capital goods producers, the government, and the monetary authority. The goods market is a standard one and the unique feature of the model comes from the credit market. In particular, the net worths of FIs together with those of entrepreneurs play key roles in macroeconomic fluctuations by affecting the cost of external finance that is realized in the credit market.

Since our settings for credit contracts are the same as those in HSU (2011), we do not explain them in detail in the main text. Instead, we describe them in Appendix A. We also describe the equilibrium conditions of our model in Appendix B.

2.1 The Credit Market

Overview of the two types of credit contracts

In each period, entrepreneurs conduct projects with size $Q(s^t)K(s^t)$, where $Q(s^t)$ is the price of capital and $K(s^t)$ is capital. Entrepreneurs own net worth, $N^E(s^t) < Q(s^t)K(s^t)$, and borrow funds, $Q(s^t)K(s^t) - N^E(s^t)$, from the FIs through credit contracts, which we call the FE contracts. The FIs also own net worth, $N^F(s^t) < Q(s^t)K(s^t) - N^E(s^t)$, and borrow funds, $Q(s^t)K(s^t) - N^F(s^t) - N^E(s^t)$, from investors through credit contracts which we call the IF contracts. In both credit contracts, agency problems arise from asymmetric information between borrower and lender. Borrowers of the FE and IF contracts, which are the entrepreneurs and the FIs, are subject to idiosyncratic productivity shocks, which we denote by $\omega^E(s^{t+1})$ and $\omega^F(s^{t+1})$. Lenders of the contracts, which are the FIs and investors, cannot observe the realizations of these shocks without paying monitoring costs. Under this setting, similar to credit contracts in BGG (1999), both the FE and IF contracts are formulated as one-period debt contracts with costly state verification. That is, in these contracts, there are cutoff values for the realization of idiosyncratic productivity shocks, which we denote as $\overline{\omega}^E(s^{t+1})$ and $\overline{\omega}^F(s^{t+1})$, such that borrowers declare defaults when the realization of idiosyncratic productivity shocks $\omega^E(s^{t+1})$ and $\omega^F(s^{t+1})$ are smaller than the cutoff values $\overline{\omega}^E(s^t)$ and $\overline{\omega}^F(s^t)$ and repay interest rates $Z^E(s^{t+1})$ and $Z^F(s^{t+1})$ otherwise. When borrowers of credit contracts default, lenders take all of the earnings of the defaulting borrowers.

The FIs are monopolistic suppliers of external funds to entrepreneurs. Taking the credit market imperfections described above as given, the FIs choose clauses of the two credit contracts, including cutoff values $\overline{\omega}^E(s^t)$ and $\overline{\omega}^F(s^t)$, so as to maximize their expected profits. The detail of the FIs' maximization problem is shown in Appendix A.

As a result of the FIs' profit maximization, for a given riskless rate of the economy $R(s^t)$, the external finance premium $\mathrm{E}_t\left\{R^E(s^{t+1})\right\}/R(s^t)$ is expressed by

$$\begin{aligned}
\frac{\mathrm{E}_t\left\{R^E(s^{t+1})\right\}}{R(s^t)} &= \overbrace{\Phi^F\left(\overline{\omega}^F\left(\frac{N^F(s^t)}{Q(s^t)K(s^t)}, \frac{N^E(s^t)}{Q(s^t)K(s^t)}\right)\right)^{-1}}^{\text{inverse of the share of profit going to the investors in the IF contract}} \\
&\times \overbrace{\Phi^E\left(\overline{\omega}^E\left(\frac{N^E(s^t)}{Q(s^t)K(s^t)}\right)\right)^{-1}}^{\text{inverse of the share of profit going to the FIs in the FE contract}} \\
&\times \overbrace{\left(1 - \frac{N^F(s^t)}{Q(s^t)K(s^t)} - \frac{N^E(s^t)}{Q(s^t)K(s^t)}\right)}^{\text{ratio of the debt to the size of the capital investment}} \\
&\equiv F\left(n^F(s^t), n^E(s^t)\right), \qquad (1)
\end{aligned}$$

with

$$\Phi^F\left(\overline{\omega}^F\left(s^{t+1}\right)\right) \equiv \overbrace{G^F\left(\overline{\omega}^F\left(s^{t+1}\right)\right)}^{\text{expected return from defaulting FIs}} + \overbrace{\overline{\omega}^F\left(s^{t+1}\right)\int_{\overline{\omega}^F(s^{t+1})}^{\infty} dF^F\left(\omega^F\right)}^{\text{expected return from nondefaulting FIs}} - \overbrace{\mu^F G^F\left(\overline{\omega}^F\left(s^{t+1}\right)\right)}^{\text{expected monitoring cost paid by investors}} \tag{2}$$

$$\Phi^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right) \equiv \overbrace{G^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)}^{\text{expected return from defaulting entrepreneurs}} + \overbrace{\overline{\omega}^E\left(s^{t+1}\right)\int_{\overline{\omega}^E(s^{t+1})}^{\infty} dF^E\left(\omega^E\right)}^{\text{expected return from nondefaulting entrepreneurs}} - \overbrace{\mu^E G^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)}^{\text{expected monitoring cost paid by FIs}} \tag{3}$$

where $n_t^F\left(s^t\right)$ and $n_t^E\left(s^t\right)$ are the ratios of net worth to aggregate capital in the two sectors, $\overline{\omega}^F\left(s^{t+1}\right)$ and $\overline{\omega}^E\left(s^{t+1}\right)$ are the cutoff value for the FIs' idiosyncratic shock $\omega^F\left(s^{t+1}\right)$ in the IF contract and the cutoff value for the entrepreneurial idiosyncratic shock $\omega^E\left(s^{t+1}\right)$ in the FE contract. Equation (1) is a key equation that links the net worth of the borrowing sectors to the external finance premium. The external finance premium is determined by three components: the share of profit in the IF contract going to the investors, the share of profit in the FE contract going to the FIs, and the ratio of total debt to aggregate capital. Lower profit shares going to the lenders cause a higher external finance premium through the first two terms of equation (1). Otherwise, the participation constraints of investors would not be met and financial intermediation fails. A higher ratio of the debt results in higher external costs, since it raises the default probability of the IF contracts and investors require higher returns from the IF contracts to satisfy their participation constraint. The presence of the first two channels suggests that not only the sum of both net worths but also the distribution of the two net worths matters in determining the external finance premium. See Appendix B for the explicit forms of $G^F\left(\overline{\omega}^F\left(s^{t+1}\right)\right)$ and $G^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)$.

Borrowing rates The two credit borrowing rates, namely, the entrepreneurial borrowing rate and the FIs' borrowing rate, are given by the FE and the IF contracts, respectively. The entrepreneurial borrowing rate, denoted by $Z^E\left(s^{t+1}\right)$, is given as the

contractual interest rate that nondefaulting entrepreneurs repay to the FIs:

$$Z^E\left(s^{t+1}\right) \equiv \frac{\overline{\omega}^E\left(s^{t+1}\right) R^E\left(s^{t+1}\right) Q\left(s^t\right) K\left(s^t\right)}{Q\left(s^t\right) K\left(s^t\right) - N^E\left(s^t\right)}. \tag{4}$$

Similarly, the FIs' borrowing rate, denoted by $Z^F\left(s^{t+1}\right)$, is given by the contractual interest rate that nondefaulting FIs repay to the investors. That is

$$Z^F\left(s^{t+1}\right) \equiv \frac{\overline{\omega}^F\left(s^{t+1}\right) \Phi^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right) R^E\left(s^{t+1}\right) Q\left(s^t\right) K\left(s^t\right)}{Q\left(s^t\right) K\left(s^t\right) - N^F\left(s^t\right) - N^E\left(s^t\right)}. \tag{5}$$

Dynamic behavior of net worth The main sources of net worth accumulation of the FI and the goods-producing sector are the earnings from the credit contracts discussed above. In addition, there are two other sources of earnings that serve for the net worth accumulation. First, FIs and entrepreneurs inelastically supply a unit of labor to the goods producers and receive in return labor incomes that are depicted by $W_F\left(s^t\right)$ and $W_E\left(s^t\right)$, respectively.[4] Second, the net worths of the two sectors are subject to exogenous disturbances $\varepsilon_{N_F}\left(s^{t+1}\right)$ and $\varepsilon_{N_E}\left(s^{t+1}\right)$. The aggregate net worths of the FIs and the entrepreneurs then evolve according to equations below:

$$N^F\left(s^{t+1}\right) = \gamma^F V^F\left(s^t\right) + W^F\left(s^t\right) + \varepsilon_{N_F}\left(s^{t+1}\right), \tag{6}$$

$$N^E\left(s^{t+1}\right) = \gamma^E V^E\left(s^t\right) + W^E\left(s^t\right) + \varepsilon_{N_E}\left(s^{t+1}\right), \tag{7}$$

with

$$V^F\left(s^t\right) \equiv \left(1 - \Gamma^F\left(\overline{\omega}^F\left(s^{t+1}\right)\right)\right) \Phi^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right) R^E\left(s^{t+1}\right) Q\left(s^t\right) K\left(s^t\right),$$
$$V^E\left(s^t\right) \equiv \left(1 - \Gamma^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)\right) R^E\left(s^{t+1}\right) Q\left(s^t\right) K\left(s^t\right).$$

where

$$\Gamma_F\left(\overline{\omega}_F\left(s^{t+1}\right)\right) \equiv \int_{\overline{\omega}_F(s^{t+1})}^{\infty} \overline{\omega}_F\left(s^{t+1}\right) dF\left(\omega_E\right) + \int_0^{\overline{\omega}_F\left(s^{t+1}\right)} \omega_E dF_E\left(\omega_E\right) \text{ and}$$
$$\Gamma_E\left(\overline{\omega}_E\left(s^{t+1}\right)\right) \equiv \int_{\overline{\omega}_E(s^{t+1})}^{\infty} \overline{\omega}_E\left(s^{t+1}\right) dF\left(\omega_E\right) + \int_0^{\overline{\omega}_E\left(s^{t+1}\right)} \omega_E dF_E\left(\omega_E\right).$$

Note that each FI and entrepreneur in the goods-producing sector survives to the next period with probability γ_F and γ_E, and those who are in business in period t and fail to survive in period $t+1$ consume $\left(1-\gamma_E\right) V_E\left(s^t\right)$ and $\left(1-\gamma_F\right) V_F\left(s^t\right)$, respectively.

[4] See BGG (1999), Christiano, Motto, and Rostagno (2008) and HSU (2011) for the technical reason for introducing inelastic labor supply from the FIs and the entrepreneurs.

The exogenous net worth disturbances represented by $\varepsilon_{N_F}(s^t)$ and $\varepsilon_{N_E}(s^t)$ are i.i.d. and orthogonal to the earnings from the credit contracts. These shocks capture an "asset bubble," "irrational exuberance," or an "innovation in the efficiency of credit contracts," hitting the FI sector or the goods-producing sector.[5]

2.2 The Rest of the Economy

Household A representative household is infinitely lived and maximizes the following utility function:

$$\max_{C(s^t),H(s^t),D(s^t)} \mathrm{E}_t \sum_{l=0}^{\infty} \exp(e^B(s^{t+l}))\beta^{t+l} \left\{ \log C\left(s^{t+l}\right) - \chi \frac{H\left(s^{t+l}\right)^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \right\}, \tag{8}$$

subject to

$$C\left(s^t\right) + D\left(s^t\right) \leq W\left(s^t\right) H\left(s^t\right) + R\left(s^t\right) D\left(s^{t-1}\right) + \Pi\left(s^t\right) - T\left(s^t\right),$$

where $C(s^t)$ is final goods consumption, $H(s^t)$ is hours worked, $D(s^t)$ is real deposits held by the investors, $W(s^t)$ is the real wage measured by the final goods, $R(s^t)$ is the real risk-free return from the deposit $D(s^t)$ between time t and $t+1$, $\Pi(s^t)$ is the dividend received from the ownership of retailers, and $T(s^t)$ is a lump-sum transfer. $\beta \in (0,1)$, η, and χ are the subjective discount factor, the elasticity of leisure, and the utility weight on leisure, respectively. $e^B(s^t)$ is a preference shock with mean one that provides the stochastic variation in the discount factor.

Final goods producer The final goods $Y(s^t)$ are composites of a continuum of retail goods $Y(h, s^t)$. The final goods producer purchases retail goods in the competitive market and sells the output to a household and capital producers at price $P(s^t)$. $P(s^t)$ is the aggregate price of the final goods. The production technology of the final goods is given by

$$Y\left(s^t\right) = \left[\int_0^1 Y\left(h, s^t\right)^{\frac{\epsilon-1}{\epsilon}} dh\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{9}$$

where $\epsilon > 1$. The corresponding price index is given by

$$P\left(s^t\right) = \left[\int_0^1 P\left(h, s^t\right)^{1-\epsilon} dh\right]^{\frac{1}{1-\epsilon}}. \tag{10}$$

[5] The similar shocks that affect the net worth of goods producers are considered in existing studies including Gilchrist and Leahy (2002), Christiano, Motto and Rostagno (2003, 2008) and Nolan and Thoenissen (2009).

Retailers The retailers $h \in [0,1]$ are populated over a unit interval, each producing differentiated retail goods $Y(h, s^t)$, with production technology:

$$Y\left(h, s^t\right) = y\left(h, s^t\right), \tag{11}$$

where $y(h, s^t)$ for $h \in [0,1]$ are the wholesale goods used for producing the retail goods $Y(h, s^t)$ by retailer $h \in [0,1]$. The retailers are price takers in the input market and choose their inputs taking the input price $1/X(s^t)$ as given. However, they are monopolistic suppliers in their output market and set their prices to maximize profits. Consequently, the retailer h faces a downward-sloping demand curve:

$$Y\left(h, s^t\right) = \left(\frac{P(h, s^t)}{P(s^t)}\right)^{-\epsilon} Y\left(s^t\right).$$

Retailers are subject to nominal rigidity. They can change prices in a given period only with probability $(1-\xi)$, following Calvo (1983). Retailers who cannot reoptimize their price in period t, say $h = \overline{h}$, set their prices according to

$$P\left(\overline{h}, s^t\right) = \left[\pi\left(s^{t-1}\right)^{\gamma_p} \pi^{1-\gamma_p}\right] P\left(\overline{h}, s^{t-1}\right),$$

where $\pi(s^{t-1})$ denotes the gross rate of inflation in period $t-1$, that is, $\pi(s^{t-1}) = P(s^{t-1})/P(s^{t-2})$. π denotes a steady-state inflation rate, and $\gamma_p \in [0,1]$ is a parameter that governs the size of price indexation. Denoting the price set by the active retailers by $P^*(h, s^t)$ and the demand curve the active retailer faces in period $t+l$ by $Y^*\left(h, s^{t+l}\right)$, retailer h's optimization problem with respect to its product price $P^*(h, s^t)$ is written in the following way:

$$\sum_{l=0}^{\infty} \xi E_t \Lambda\left(s^{t+l}\right) \left(\pi^{\left(1-\gamma_p\right)l} \left(\prod_{k=0}^{l-1} \pi^{\gamma_p}\left(s^{t+k}\right)\right) P^*\left(h, s^t\right) Y\left(h, s^{t+l}\right) - \left(\frac{P\left(s^{t+l}\right)}{X\left(s^{t+l}\right)}\right) Y\left(h, s^{t+l}\right)\right) = 0,$$

where $\Lambda\left(s^{t+l}\right)$ is given by

$$\Lambda\left(s^{t+l}\right) = \beta^{t+l}\left(\frac{C(s^t)}{C\left(s^{t+l}\right)}\right).$$

Using equations (9), (10), and (11), the final goods $Y(s^t)$ produced in period t are expressed with the wholesale goods produced in period t as the following equation:

$$y\left(s^t\right) = \int_0^1 y\left(h, s^t\right) dh = \left[\int_0^1 \left(\frac{P_t(h, s^t)}{P(s^t)}\right)^{-\epsilon} dh\right] Y\left(s^t\right).$$

Moreover, because of stickiness in the retail goods price, the aggregate price index for final goods $P\left(s^t\right)$ evolves according to the following law of motion:

$$P\left(s^t\right)^{1-\epsilon} = (1-\xi)\, P^*\left(h, s^t\right)^{1-\epsilon} + \xi\left(\pi\left(s^{t-1}\right)^{\gamma_p} \overline{\pi}^{1-\gamma_p} P\left(s^{t-1}\right)\right)^{1-\epsilon}.$$

Wholesalers The wholesalers produce wholesale goods $y\left(s^t\right)$ and sell them to the retailers with the relative price $1/X\left(s^t\right)$. They hire three types of labor inputs, $H\left(s^t\right)$, $H^F\left(s^t\right)$, and $H^E\left(s^t\right)$, and capital $K\left(s^{t-1}\right)$. These labor inputs are supplied by the household, the FIs, and the entrepreneurs for wages $W\left(s^t\right)$, $W^F\left(s^t\right)$, and $W^E\left(s^t\right)$, respectively. Capital is supplied by the entrepreneurs with the rental price $R^E\left(s^t\right)$. At the end of each period, the capital is sold back to the entrepreneurs at price $Q\left(s^t\right)$. The maximization problem for the wholesaler is given by

$$\begin{aligned}\max_{y(s^t),K(s^{t-1}),H(s^t),H^F(s^t),H^E(s^t)} \; & \frac{1}{X_t\left(s^t\right)} y\left(s^t\right) + Q\left(s^t\right) K\left(s^{t-1}\right)(1-\delta) \\ & - R^E\left(s^t\right) Q\left(s^{t-1}\right) K\left(s^{t-1}\right) - W\left(s^t\right) H\left(s^t\right) \\ & - W^F\left(s^t\right) H^F\left(s^t\right) - W^E\left(s^t\right) H^E\left(s^t\right),\end{aligned}$$

subject to

$$y\left(s^t\right) = A \exp\left(e^A\left(s^t\right)\right) K\left(s^{t-1}\right)^{\alpha} H\left(s^t\right)^{(1-\Omega_F-\Omega_E)(1-\alpha)} H^F\left(s^t\right)^{\Omega_F(1-\alpha)} H^E\left(s^t\right)^{\Omega_E(1-\alpha)}, \tag{12}$$

where $A \exp\left(e^A\left(s^t\right)\right)$ denotes the level of technology of wholesale production and $\delta \in (0,1]$, α, Ω_F and Ω_E are the depreciation rate of capital goods, the capital share, the share of the FIs' labor inputs and the share of entrepreneurial labor inputs, respectively.

Capital goods producers The capital goods producers own the technology that converts final goods to capital goods. In each period, the capital goods producers purchase $I\left(s^t\right)$ amounts of final goods from the final goods producers. In addition, they purchase $K\left(s^{t-1}\right)(1-\delta)$ of used capital goods from the entrepreneurs at price $Q\left(s^t\right)$. They then produce new capital goods $K\left(s^t\right)$, using the technology F_I, and sell them in the competitive market at price $Q\left(s^t\right)$. Consequently, the capital goods producer's problem is to maximize the following profit function:

$$\max_{I(s^t)} \sum_{l=0}^{\infty} \mathrm{E}_t \Lambda\left(s^{t+l}\right)\left[Q\left(s^{t+l}\right)\left(1 - F_I\left(I\left(s^{t+l}\right), I\left(s^{t+l-1}\right)\right)\right) I\left(s^{t+l}\right) - I\left(s^{t+l}\right)\right], \tag{13}$$

where F_I is defined as follows:

$$F_I\left(I\left(s^{t+l}\right), I\left(s^{t+l-1}\right)\right) \equiv \frac{\kappa}{2}\left(\frac{\exp(e^I(s^t))I\left(s^{t+l}\right)}{I\left(s^{t+l-1}\right)} - 1\right)^2. \tag{14}$$

Note that κ is a parameter that is associated with investment technology with an adjustment cost, where $e^I(s^t)$ is the shock to the adjustment cost.[6] Here, the development of the total capital available at period t is described as

$$K\left(s^t\right) = \left(1 - F_I\left(I\left(s^t\right), I\left(s^{t-1}\right)\right)\right) I\left(s^t\right) + (1-\delta) K\left(s^{t-1}\right). \tag{15}$$

Government The government collects a lump-sum tax from the household $T\left(s^t\right)$ and spends $G\left(s^t\right)$. A budget balance is maintained for each period t. Thus, we have

$$G\left(s^t\right)\exp\left(e^G(s^t)\right) = T\left(s^t\right), \tag{16}$$

where $e^G(s^t)$ is the stochastic component of government spending.

Monetary authority In our baseline model, the monetary authority sets the nominal interest rate $R^n\left(s^t\right)$ according to a standard Taylor rule with inertia:

$$R^n\left(s^t\right) = \theta R^n\left(s^{t-1}\right) + (1-\theta)\left(\phi_\pi(\pi\left(s^t\right)) + \phi_y \log\left(\frac{Y\left(s^t\right)}{Y}\right)\right) + e^R\left(s^t\right), \tag{17}$$

where θ is the autoregressive parameter of the policy rate, ϕ_π and ϕ_y are the policy weight on the inflation rate of final goods $\pi\left(s^t\right)$ and the output gap $\log\left(\frac{Y\left(s^t\right)}{Y}\right)$, respectively, and $e^R(s^t)$ is the shock to the monetary policy rule. Because the monetary authority determines the nominal interest rate, the real interest rate in the economy is given by the following Fisher equation:

$$R\left(s^t\right) \equiv \mathrm{E}_t\left\{\frac{R^n\left(s^t\right)}{\pi\left(s^{t+1}\right)}\right\}. \tag{18}$$

Resource constraint The resource constraint for final goods is written as

$$\begin{aligned} Y\left(s^t\right) &= C\left(s^t\right) + I\left(s^t\right) + G\left(s^t\right)\exp\left(e^G(s^t)\right) \\ &+ \mu^E G^E\left(\overline{\omega}^E\left(s^t\right)\right) R^E\left(s^t\right) Q\left(s^{t-1}\right) K\left(s^{t-1}\right) \\ &+ \mu^F G^F\left(\overline{\omega}^F\left(s^t\right)\right) R^F\left(s^t\right)\left(Q\left(s^{t-1}\right) K\left(s^{t-1}\right) - N^E\left(s^{t-1}\right)\right) \\ &+ C^F\left(s^t\right) + C^E\left(s^t\right). \end{aligned} \tag{19}$$

[6] Equation (13) does not include a term for the purchase of the used capital $K\left(s^{t-1}\right)$ from the entrepreneurs at the end of the period. This is because we assume, following BGG (1999), that the price of old capital that the entrepreneurs sell to the capital goods producers, which we denote as $\overline{Q}\left(s^t\right)$, is close to the price of the newly produced capital $Q\left(s^t\right)$ around the steady state.

Note that the fourth and the fifth terms on the right-hand side of the equation correspond to the monitoring costs incurred by the FIs and investors, respectively. The last two terms are the FIs' and entrepreneurs' consumption.

Law of motion for exogenous variables There are five equations for the shock processes, $e^A(s^t), e^I(s^t)$, $e^B(s^t), e^G(s^t)$, and $e^R(s^t)$, following processes as below:

$$e^A\left(s^t\right) = \rho_A e^A\left(s^{t-1}\right) + \varepsilon^A\left(s^t\right), \tag{20}$$

$$e^I\left(s^t\right) = \rho_I e^I\left(s^{t-1}\right) + \varepsilon^I\left(s^t\right), \tag{21}$$

$$e^B\left(s^t\right) = \rho_\beta e^B\left(s^{t-1}\right) + \varepsilon^\beta\left(s^t\right), \tag{22}$$

$$e^G\left(s^t\right) = \rho_G e^G\left(s^{t-1}\right) + \varepsilon^G\left(s^t\right), \tag{23}$$

$$e^R\left(s^t\right) = \rho_R e^R\left(s^{t-1}\right) + \varepsilon^R\left(s^t\right), \tag{24}$$

where ρ_A, ρ_I, ρ_B, ρ_G, and $\rho_R \in (0,1)$ are autoregressive roots of the exogenous variables and $\varepsilon^A(s^t), \varepsilon^I(s^t), \varepsilon^B(s^t), \varepsilon^G(s^t)$, and $\varepsilon^R(s^t)$ are innovations that are mutually independent, serially uncorrelated, and normally distributed with mean zero and variances σ_A^2, σ_I^2, σ_β^2, σ_G^2, and σ_R^2, respectively.

2.3 Equilibrium Condition

An equilibrium consists of a set of prices, $\{P(h,s^t)$ for $h \in [0,1]$, $P(s^t)$, $X(s^t)$, $R(s^t)$, $R^F(s^t)$, $R^E(s^t), W(s^t)$, $W^F(s^t)$, $W^E(s^t)$, $Q(s^t)$, $R^F(s^{t+1})$, $R^E(s^{t+1})$, $Z^F(s^{t+1})$, $Z^E(s^{t+1})\}_{t=0}^{\infty}$, and the allocations $\{\overline{\omega}^F(s^{t+1})\}_{t=0}^{\infty}$, $\{\overline{\omega}^E(s^{t+1})\}_{t=0}^{\infty}$, $\{N^F(s^t)\}_{t=0}^{\infty}$, $\{N^E(s^t)\}_{t=0}^{\infty}$ $\{\{y(h,s^t)), Y(h,s^t)$ for $h \in [0,1]$, $Y(s^t)$, $C(s^t)$, $D(s^t)$, $I(s^t)$, $K(s^t)$, $H(s^t)$, $H^F(s^t)$, $H^E(s^t)\}\}_{t=0}^{\infty}$, for a given government policy $\{R^n(s^t), G(s^t), T(s^t)\}_{t=0}^{\infty}$, realization of exogenous variables $\{\varepsilon^A(s^t)$, $e^B(s^t)$, $e^G(s^t)$, $e^I(s^t)$, $\varepsilon^R(s^t)$, $\varepsilon^{N^E}(s^t)$, $\varepsilon^{N^F}(s^t)\}_{t=0}^{\infty}$ and initial conditions N_{-1}^F, N_{-1}^E, K_{-1} such that for all t and h:

(1) a household maximizes its utility given the prices;
(2) the FIs maximize their profits given the prices;
(3) the entrepreneurs maximize their profits given the prices;
(4) the final goods producers maximize their profits given the prices;
(5) the retail goods producers maximize their profits given the prices;
(6) the wholesale goods producers maximize their profits given the prices;
(7) the capital goods producers maximize their profits given the prices;
(8) the government budget constraint holds; and
(9) markets clear.

3 Data and Estimation Strategy

Following Christensen and Dib (2008) and HSU (2011), we set some of the parameters to the values used in the existing studies. These include the quarterly discount factor β, the labor supply elasticity η, the capital share α, the quarterly depreciation rate δ, and the steady-state share of government expenditure in total output G/Y. See Table 1 for the values of these parameters.

In addition, we calibrate six parameters for the credit contracts: the lenders' monitoring cost in the IF contract μ^F, the lenders' monitoring cost in the FE contract μ^E, the standard error of the idiosyncratic productivity shock in the FI sector σ^F, the standard error of the idiosyncratic productivity shock in the entrepreneurial sector σ^E, the survival rate of FIs γ^F, and the survival rate of entrepreneurs γ^E, so that the following six equilibrium conditions are met at the steady state:

(1) the risk spread, $R^E - R$, is 200 basis points annually;

(2) the ratio of net worth held by FIs to the aggregate capital, N^F/QK, is 0.1, a historical average in the Japanese economy;

(3) the ratio of net worth held by entrepreneurs to the aggregate capital, N^E/QK, is 0.5, a historical average in the Japanese economy;

(4) the annualized failure rate of FIs is 3%;

(5) the annualized failure rate of entrepreneurs is 3%; and

(6) the ratio of the spread between the FIs' borrowing rate and the entrepreneurial borrowing rate, $Z^E - Z^F$, to the spread between the entrepreneurial borrowing rate and the riskless rate, $Z^F - R$, is 186/32, the value taken from a historical average.

We estimate the rest of parameters of the model using a Bayesian method. Estimated parameters are the frequency of price adjustment ξ, the degree of price indexation γ_p, a parameter that controls the capital adjustment cost κ, the coefficients of the policy rule θ, ϕ_π and ϕ_y, the autoregressive parameters of the shock process ρ_A, ρ_I, ρ_B, ρ_G, and ρ_R, the variances of these shocks σ_A^2, σ_I^2, σ_B^2, σ_G^2, and σ_R^2; and the variances of the shocks to net worth $\sigma_{N_F}^2$ and $\sigma_{N_E}^2$. To calculate the posterior distribution and to evaluate the marginal likelihood of the model, the Metropolis-Hastings algorithm is employed. To do this, a sample of 200,000 draws was created, neglecting the first 100,000 draws.

3.1 Data

Our dataset includes seven time series for the Japanese economy: the growth rate of real GDP, the growth rate of real consumption, the growth rate of real investment, the log difference of the GDP deflator, the call rate, and the growth rates of real net worth of the banking sector and the entrepreneurial sector.[7,8] In estimating the model, we demean these variables, assuming that the mean of each variable in the model coincides with that in the data, following CMR (2008). Following Sugo and Ueda (2008), the variables other than the GDP deflator and the call rate are demeaned with a trend break in 1991Q2.

Our dataset covers the period from 1981Q1 to 2013Q4.[9] All data series used for estimation are shown in Figure 1. The shaded areas are recessions which start at the peak of business cycles and end at the trough. The reference dates are specified by the Economic and Social Research Institute of the Japanese government.

3.2 Prior Distribution of the Parameters

Table 2 shows the prior distributions of parameters. The adjustment cost parameter for investment κ is normally distributed with a mean of 4.0 and a standard error of 1.5; the Calvo probability ξ is beta distributed with a mean of 0.5 and a standard error of 0.15; the degree of indexation to past inflation γ_p is beta distributed with a mean of 0.5 and a standard error of 0.2; the policy weight on the lagged policy rate θ is normally distributed with a mean of 0.75 and a standard error of 0.1; the policy weight on inflation ϕ_π is normally distributed with a mean of 1.5 and a standard error of 0.125; and the policy weight on the output gap ϕ_y is normally distributed with a mean of 0.125 and a standard error of 0.05.

The priors on the autoregressive parameters ρ_A, ρ_I, ρ_B, ρ_G, and ρ_R are beta distributed with a mean of 0.5 and a standard deviation of 0.2. The variances of the innovations in exogenous variables σ_A^2, σ_I^2, σ_β^2, σ_G^2, $\sigma_{N_F}^2$, $\sigma_{N_E}^2$, and σ_R^2 are assumed to follow an inverse-gamma distribution with a mean of 0.01 and a standard deviation of 2.

[7] The first five variables are expressed in per capita terms. The two net worth series are deflated by the GDP deflator.

[8] The two net worth series are constructed based on the flow of funds accounts.

[9] While existing studies such as Sugo and Ueda (2008) and Hirose and Kurozumi (2010) estimate their Dynamic Stochastic General Equilibrium models using only the periods where the nominal interest rate has been well above zero, our sample includes the periods where it has been close to zero. The reason we take this approach is that the goal of the current paper is to study the role of financial intermediation malfunction throughout the 1990s and 2000s, which covers the three financial crises. We confirmed that our parameter estimates and impulse response of key macroeconomic variables to structural shocks hardly change when we instead use the sample periods until 1995Q4.

4 Estimation Results

In this section, we show the estimated parameter values and distilled structural shocks. In addition, we examine the model-generated time series of credit spreads. While credit spreads play the key role in transmitting the FIs' shocks to the real activities in the model, because of the data limitation, we do not make use of the spread data in estimating the model. By comparing the model-generated series with a number of actual financial stress indicators, we show how well our model captures the developments of credit market conditions during the lost decade(s).

4.1 Parameter Estimates

Table 2 reports the estimated values of the structural parameters and the standard deviations of the shocks. For the investment adjustment cost, we obtain $\kappa = 8.67$. This value falls between the estimates of 0.65 (Meier and Muller, 2006) and 32.1 (Ireland, 2003) reported in the existing studies for the U.S. economy. Our estimates of the degree of nominal price rigidity, the frequency of price adjustment and the degree of price indexation, are $\xi = 0.606$ and $\gamma_p = 0.074$, respectively. These values, in particular the latter, are smaller than the findings in Meier and Muller (2006). The estimated monetary policy rule exhibits an active response to current inflation $\phi_\pi = 1.48$, with inertia of the interest rate $\theta = 0.845$, and a mild reaction to the current output $\phi_y = 0.024$.

Shocks to government expenditure and preference are particularly persistent with AR(1) coefficients of 0.87 and 0.91, respectively, compared with other shocks. The standard deviation of the entrepreneurial net worth shocks is 0.335, being the largest among the shocks. Comparing these estimates with those for the U.S. data reported in HSU (2011), the value is larger than that of the United States, which is 0.179. The estimate of the standard deviation of the FIs' net worth shocks is almost double that of the United States, which is 0.041.

4.2 Identified Shocks to Net Worth

We identify time series of seven structural shocks, $\varepsilon^A(s^t)$, $e^B(s^t)$, $e^G(s^t)$, $e^I(s^t)$, $\varepsilon^R(s^t)$, $\varepsilon^{N^E}(s^t)$, and $\varepsilon^{N^F}(s^t)$, from 1981Q1 to 2013Q4 based on the estimation. The identified shocks to the FI's net worth and the entrepreneurial net worth $\varepsilon^{N^F}(s^t)$ and $\varepsilon^{N^E}(s^t)$ are displayed in Figure 2a. Similarly to Figure 1, the shaded areas are recessions in Japanese business cycles. Realized values of the two financial shocks are negatively related to business cycles: values of the two shocks typically fall below zero during recessions, suggesting that they are contributing to economic downturns. Net worth shocks to entrepreneurs have a large negative value for several years after the asset bubble burst in the early 1990s, during the early 2000s after the dot-com boom ended, and during the late 2000s when the global financial crisis took place. Net worth shocks to the FIs have

continuously shown negative values since the asset bubble burst from the early 1990s to the 2000s.

We compare the time series of net worth shocks estimated for Japan's economy with those estimated for the U.S. economy. Figure 2b displays identified time series of net worth shocks in the United States that are taken from HSU (2011) as well as those in Japan. Note that in HSU (2011) we estimate the same model as the model in the current paper using time series of the U.S. macroeconomic variables. During the global financial crisis, the United States witnessed a large negative net worth shock to both entrepreneurs and FIs. In contrast, Japan witnessed a large negative net worth shock only to entrepreneurs and only a moderate negative shock to FIs. This observation demonstrates that Japanese FIs hardly suffered from the global financial crisis, though the Japanese economy was severely dampened due to net worth shocks to entrepreneurs.

4.3 Checking the Estimation Results

Following Nolan and Thoenissen (2009), we check the reasonableness of our estimation results by making use of actual time series of an indicator of external finance premium $Z^E - R$. Note that since we do not employ an external finance premium in estimating model parameters and shocks, we can assess the validity of our estimation results by comparing indicators and the model-generated external finance premium. As discussed in De Graeve (2008), however, the data series of the external finance premium that corresponds to the model's external finance premium is often difficult to observe, and this is why we did not use the data for estimation. To this end, we compare time series data of four indicators of the external finance premium with the time series of the external finance premium $Z^E(s^t) - R(s^t)$ generated from our model. The four indicators include two market spreads: the spread between bank lending rates on contracted short-term loans and short-term government bond rates and the spread between bank lending rates on newly contracted short-term loans and short-term government bond rates, and two diffusion indices, the Financial Position Diffusion Index and the Lending Attitude of Financial Institutions Diffusion Index. The index series are of the Tankan (Short-Term Economic Survey of Enterprises in Japan) released from the Bank of Japan. They indicate the strain that non-financial firms face in raising external funds from financial institutions.[10]

Table 3 presents cross-correlation coefficients between those four measures and the model-generated series $Z^E(s^t) - R(s^t)$ for a one-year range of leads and lags that are computed from the sample period from 1981 to 2013.[11] The model-generated series

[10] The Financial Position Diffusion Index is constructed from the number of firms that report "Easy" minus the number of firms that report "Tight." The Lending Attitude Diffusion Index is constructed from the number of firms that report "Accommodative" minus the number of firms that report "Severe."

[11] Correlation coefficients regarding the second measure are computed from the data series from 1993 onward because of the data availability of the series.

positively correlates with the first, third, and forth indicators in a statistically significant manner, indicating that our estimated model well captures developments in cost that are associated with external funding or those of demand for funding of non-financial firms in Japan. Though the model generated series displays a weaker statistical relationship with the second indicator, the coefficients are positive in most leads and lags.

5 Financial Factors in Japanese Business Cycles

In this section, we study the role of net worth shocks to the FI and entrepreneurial sector in generating macroeconomic dynamics in the Japanese economy. We first describe the impacts of net worth shocks on the macroeconomy and discuss how they differ from the impacts of other shocks. We then examine the relative significance of net worth shocks in accounting for variations in key macroeconomic variables.

5.1 Impulse Responses

Figure 3 shows the impulse responses of key macroeconomic variables to shock to FIs' net worth, and entrepreneurial net worth, productivity, and investment adjustment cost $\varepsilon^{N^F}(s^t)$, $\varepsilon^{N^E}(s^t)$, $\varepsilon^A(s^t)$, and $\varepsilon^I(s^t)$. We normalize the size of the shocks to be one standard deviation. We give positive shocks to the investment adjustment cost and negative shocks to the other three variables.

The net worth shocks to the FIs and entrepreneurs are those that arise as innovations to equations (6) and (7), respectively. At the impact, they influence the terms of credit contracts $Z^F(s^{t+1})$ and $Z^E(s^{t+1})$ and they are propagated to the rest of the economy by changing volume of financial intermediation. For instance, when the balance sheets of FIs are impaired by a negative net worth shock, investors require a higher expected return $Z^F(s^{t+1})$ in their credit contracts with the FIs because the borrower FIs are now less creditworthy than otherwise. The increase in the FIs' borrowing rate is translated to the entrepreneurial borrowing rate as shown in the panel (8). With a higher cost of borrowing external funds, the entrepreneurs purchase less capital goods $K(s^t)$ from capital goods producers. This results in a lower capital input supply, dampening investment and GDP. Inflation falls, reflecting the weakened aggregate demand. The decline in demand for capital goods $K(s^t)$ causes the second-round effect on the endogenous developments in the net worths of FI's and those of entrepreneurs by affecting the capital goods price $Q(s^t)$. That is, a reduced value of capital goods price, shown in the panel (3), hampers the net worth accumulation of the two sectors since the retained earnings in the these sectors decrease following equations (6) and (7). The deteriorated net worths result in the further rise in borrowing rates, dampening investment and GDP further.

In response to a negative shock to productivity in the wholesaler's production function (12), because less output is produced from the same amount of production inputs, investment and output are reduced. Inflation increases as the real marginal cost of the

wholesaler increases. The increase in inflation leads the central bank to raise the nominal interest rate according to the Taylor rule (17), having a contractionary effect on output. Similarly to the consequence of net worth shocks, a decline in aggregate investment demand lowers the capital goods price $Q(s^t)$. Consequently, as shown in the panels (5) and (6), the financial accelerator effect emerges through endogenous deterioration of net worth in both the FI and entrepreneurial sectors. Impaired balance sheets in these sectors reinforce the adverse effects of the productivity shock on the aggregate economy.

In response to a positive shock to the investment adjustment cost (14), the capital goods price $Q(s^t)$ increases, while the other types of shocks lower it. This is because other things being equal capital goods producers need to purchase more final goods to produce the same amount of capital goods $K(s^t)$. Since capital goods become more expensive than otherwise, capital input supply is reduced, resulting in a lower aggregate investment and GDP. Although the increase in the capital goods price helps the accumulation of net worth in the FI and entrepreneurial sectors as shown in the panels (5) and (6) and reduces the entrepreneurial borrowing rate, this favorable effect is dominated by the adverse effect due to the increase in the capital goods price.

5.2 Historical Decomposition

Using the time series of structural shocks that are extracted from the estimation above, we next evaluate how shocks to the net worth of FIs and entrepreneurs affected macroeconomic fluctuations in Japan over the last thirty years. Figure 4 plots historical decompositions of fluctuations in investment, GDP, and inflation into structural shocks.

This figure suggests that shocks to the net worth of entrepreneurs have contributed substantially to the declines in investment during the period of the first crisis in the early 1990s and during the period of the third crisis in the late 2000s. As illustrated in Figure 3, negative entrepreneurial net worth shocks cause financial intermediation malfunction by increasing entrepreneurs' borrowing rates and reducing the amount of funds that are intermediated from households to entrepreneurs, leading to economic downturn. It is seen that the net worth shocks also contributed to a decline in investment during the recession that started from November 2000 as the boom in IT industry ended. The GDP and inflation rate have been dampened by the shocks as well particularly during the first and the third crises. In contrast to fluctuations in investment, fluctuations in these variables are more affected by TFP shocks.

Compared with entrepreneurial net worth shocks, the effects on fluctuations in investment of net worth shocks to the FIs have been relatively minor. In particular, the contribution of these shocks to investment decline during the third crisis was negligible. This observation is consistent with the view that the origin of the current global financial crisis is the deterioration of the balance sheets of U.S. banks rather than those of Japanese banks. The FIs' net worth shocks, however, have been continuously dampening investment since the burst of the asset price bubble, and the impact of these shocks

has been sizable throughout the 1990s. As documented by Hoshi and Kashyap (2010), Japanese banks have been suffering from non-performing loan problems and recorded loan losses of about 13 trillion yen in 1996, 1998, and 1999, and their balance sheets were severely impaired. Our estimation results show that the impaired balance sheets of the FIs have dampened financial intermediation and reduced loan supply to firms, which is consistent with the documentation. The adverse effects of the shocks have been gradually diminishing since early 2000. This timing is consistent with the time the Financial Revival Program was launched by the Japanese Financial Service Agency led by Heizo Takenaka and when the Japanese government started to increase pressure on large Japanese banks to strengthen their capital conditions. The shocks also have been contributing to lower GDP and inflation throughout the 1990s.

Shocks to the investment adjustment cost have been an important driver of investment declines during periods other than the three financial crisis periods. For instance, during the recession that started in June 1985 and during the period of moderate economic slowdown around the mid-2000s, these shocks were the key determinant of fluctuations in investment.

Table 4 computes the average contribution of each shock in accounting for three macroeconomic variables over the full sample period, the 1990s, and the late 1990s. It is seen that the quantitatively most important shocks in explaining investment fluctuations are shocks to the investment adjustment cost. The net worth shocks to entrepreneurs are the second most important shocks. The contribution to investment fluctuations of net worth shocks to the FIs is small for the full sample basis, though it is relatively large for the late 1990s.

6 Financial Friction and Investment Adjustment Cost

In addition, we explore how the investment adjustment cost shocks are related to the net worth shocks estimated in our model. As discussed by Justiniano, Primiceri, and Tambalotti (2008), the estimates of the New Keynesian model typically indicate that shocks to investment adjustment cost play an important role in producing business cycles. Christensen and Dib (2008) also report that more than 90% of investment variations originate in the shocks to investment efficiency in the U.S. economy. Hirose and Kurozumi (2010) by estimating a New Keynesian model using Japanese data also document that most of the Japanese investment variations are accounted for by these shocks. These shocks are considered to be related to the efficiency of financial intermediation in Hirose and Kurozumi (2008) and Justiniano, Primiceri, and Tambalotti (2011).

To see how investment adjustment cost shocks are related to financial factors, we estimate models that abstract from financial frictions and compare the role of estimated investment adjustment cost shocks in these models with that in the current model. The alternative models are the BGG model and the Non-FA (non-financial-accelerator) model. In the BGG model, entrepreneurs are credit constrained but FIs are not. In the

Non-FA model, no credit market imperfection prevails in the economy. To illustrate the role that shocks to the FIs' net worth play, we estimate the BGG model and the Non-FA model along with the benchmark model by a Bayesian method.

Table 5 reports the variance decompositions of investment under the three models. Under the Non-FA model, a bulk of the variations comes from the shocks to investment adjustment cost ε_t^I, accounting for 94% of the investment variations. When shocks originating in the credit market are incorporated, the contribution of the shocks to investment adjustment cost decreases. The estimated contribution of ε_t^I is 77% and 64%, respectively, in the BGG model and the benchmark model. On the other hand, under the two models, a significant portion of investment variation is attributed to the contributions of shocks originating in the credit market, $\varepsilon_t^{N^E}$ and $\varepsilon_t^{N^F}$. The contribution of $\varepsilon_t^{N^E}$ under the benchmark model is larger than under the BGG model. This is because the amplification and propagation mechanism is increased under the benchmark model.

7 Conclusion

In this paper, we have assessed the roles of financial shocks in accounting for macroeconomic fluctuations in Japan particularly during the periods when financial crises have taken place. To this end, we have borrowed a version of financial accelerator model developed by Hirakata, Sudo, and Ueda (2011). In this model, unexpected shocks to the net worths of FIs and entrepreneurs affect macroeconomic fluctuations by affecting the terms of credit contracts and external finance premiums that are relevant to the volume of aggregate investment. We have estimated the model using Japanese data from the 1980s to the 2010s to obtain model parameters and underlying structural shocks. Using the estimation results, we have decomposed fluctuations of macroeconomic variables into those attributed to financial shocks and those attributed to non-financial shocks.

We have found that the two financial shocks, shocks to the net worths of FIs and entrepreneurs, are both important sources of macroeconomic fluctuation. These shocks impair the balance sheets of the two sectors, increase the external finance premium, and dampen aggregate investment. Their impacts on investment are prominent particularly during the three financial crises. Net worth shocks to entrepreneurs have played the key role in lowering investment during the periods of the bubble burst and the global financial crisis. Net worth shocks to FIs have contributed to investment decline in the early 1990s and persistently lowered investment throughout the 1990s.

In addition, our result suggests that the shocks to investment adjustment cost that are emphasized in the existing studies may be capturing shocks to the financial sector. The comparison with other models that abstract from credit-constrained banks, credit-constrained entrepreneurs, or both, illustrates that investment variations explained by the shocks to capital adjustment cost are reduced drastically by inclusion of the credit market imperfection.

Finally, let us propose three important directions for future research. The first is

to incorporate the zero lower bound of nominal interest rates and/or unconventional monetary policy. The second direction is to embed the stochastic trend in the current model to explain a kinked decline in GDP growth rates since the burst of the bubble. Third, another model for financial shocks is possible. Specifically, riskiness shocks rather than net worth shocks have attracted attention following the work of Christiano, Motto, and Rostagno (2014).

A Credit Contracts

In this appendix, we discuss how the contents of the two credit contracts are determined by the profit maximization problem of the FIs. We first explain how the FIs earn profit from the credit contracts and then explain the participation constraints of the other participants in the credit contracts.

In each period t, the expected net profit of an FI from the credit contracts is expressed by:

$$\sum_{s^{t+1}} \Pi\left(s^{t+1}\right) \overbrace{\left[1-\Gamma^F\left(\overline{\omega}^F\left(s^{t+1}\right)\right)\right]}^{\text{share of FIs earnings received by FI}} R^F\left(s^{t+1}\right)\left(Q_t\left(s^t\right)K\left(s^t\right)-N^E\left(s^t\right)\right), \tag{25}$$

where $\Pi\left(s^{t+1}\right)$ is a probability weight for state s^{t+1}. Here, the expected return on the loans to entrepreneurs, $R^F\left(s^{t+1}\right)$ is given by:

$$\overbrace{\left[\Gamma^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)-\mu^E G^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)\right]}^{\text{share of entrepreneurial earnings received by FI}} R^E\left(s^{t+1}\right)Q\left(s^t\right)K\left(s^t\right)$$

$$\equiv R^F\left(s^{t+1}\right)\left(Q\left(s^t\right)K\left(s^t\right)-N^E\left(s^t\right)\right) \text{ for } \forall s^{t+1}. \tag{26}$$

This equation indicates that the two credit contracts determine the FIs' profits. In the FE contract, the FIs receive a portion of what entrepreneurs earn from their projects as their gross profit. In the IF contract, the FIs receive a portion of what they receive from the FE contract as their net profit and pay the rest to investors.

There is a participation constraint in each of the credit contracts. In the FE contract, the entrepreneurs' expected return is set to equal the return from their alternative option. We assume that without participating in the FE contract, entrepreneurs can purchase capital goods with their own net worth $N^E\left(s^t\right)$. Note that the expected return from this option equals $R^E\left(s^{t+1}\right)N^E\left(s^t\right)$. Therefore the FE contract is agreed upon the entrepreneurs only when the following inequality is expected to hold:

$$\overbrace{\left[1-\Gamma^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)\right]}^{\text{share of entrepreneurial earnings kept by the entrepreneur}} R^E\left(s^{t+1}\right)Q\left(s^t\right)K\left(s^t\right)$$

$$\geq R^E\left(s^{t+1}\right)N^E\left(s^t\right) \text{ for } \forall s^{t+1}. \tag{27}$$

We next consider a participation constraint of the investors in the IF contract. We assume that there is a risk-free rate of return in the economy $R\left(s^t\right)$ and that investors

may alternatively invest in this asset. Consequently, for investors to join the IF contract, the loans to the FIs must equal the opportunity cost of lending. That is:

$$\overbrace{\left[\Gamma^F\left(\overline{\omega}^F\left(s^{t+1}\right)\right)-\mu^F G^F\left(\overline{\omega}^F\left(s^{t+1}\right)\right)\right]}^{\text{share of FIs' earnings received by the investors}} R^F\left(s^{t+1}\right)\left(Q\left(s^t\right)K\left(s^t\right)-N^E\left(s^t\right)\right)$$

$$\geq R\left(s^t\right)\left(Q\left(s^t\right)K\left(s^t\right)-N^F\left(s^t\right)-N^E\left(s^t\right)\right). \tag{28}$$

The FI maximizes its expected profit (25) by optimally choosing the variables $\overline{\omega}^F\left(s^{t+1}\right)$, $\overline{\omega}^E\left(s^{t+1}\right)$, and $K\left(s^t\right)$, subject to the entrepreneurial participation constraint (27) and the investors' participation constraint (28). Combining the first-order conditions yields the following equation:

$$\begin{aligned}
0 = \sum_{s^{t+1}} \Pi\left(s^{t+1}\right) \Big\{ & \left(1-\Gamma^F\left(\overline{\omega}^F\left(s^{t+1}\right)\right)\right)\Phi^E\left(s^{t+1}\right)R^E\left(s^{t+1}\right) \\
& + \frac{\Gamma'^F\left(\overline{\omega}^F\left(s^{t+1}\right)\right)}{\Phi'^F\left(s^{t+1}\right)}\Phi^F\left(s^{t+1}\right)\Phi^E\left(s^{t+1}\right)R^E_{t+1}\left(s^{t+1}\right) \\
& - \frac{\Gamma'^F\left(\overline{\omega}^F\left(s^{t+1}\right)\right)}{\Phi'^F\left(s^{t+1}\right)}R(s_t) \\
& + \frac{\left\{1-\Gamma^F\left(\overline{\omega}^F\left(s^{t+1}\right)\right)\right\}\Phi'^E\left(s^{t+1}\right)}{\Gamma'^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)}\left(1-\Gamma^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)\right)R^E\left(s^{t+1}\right) \\
& + \frac{\Gamma'^F\left(\overline{\omega}^F\left(s^{t+1}\right)\right)\Phi^F\left(s^{t+1}\right)\Phi'^E\left(s^{t+1}\right)}{\Phi'^F\left(s^{t+1}\right)\Gamma'^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)}\left(1-\Gamma^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)\right)R^E\left(s^{t+1}\right)\Bigg\}.
\end{aligned} \tag{29}$$

Using equations (26) and (28), we obtain equation (1) in the text.

B Equilibrium Conditions of the Benchmark Model

In this appendix, we describe the equilibrium system of our benchmark model. We express it in five blocks of equations.

(1) **Household's Problem and Resource Constraint**

$$\frac{1}{C\left(s^{t}\right)}=E_{t}\left\{\beta\exp\left(e^{B\left(s^{t+1}\right)}\right)\frac{1}{C\left(s^{t+1}\right)}R_{t}\right\}, \tag{30}$$

$$W\left(s^{t}\right)=\chi H\left(s^{t}\right)^{\frac{1}{\eta}}C\left(s^{t}\right), \tag{31}$$

$$R_{t}=\mathrm{E}_{t}\left\{\frac{R_{t}^{n}}{\pi_{t+1}}\right\}, \tag{32}$$

$$\begin{aligned}Y\left(s^{t}\right)=&\,C\left(s^{t}\right)+I\left(s^{t}\right)+G\left(s^{t}\right)\exp\left(e^{G}(s^{t})\right)\\&+\mu^{E}G_{t}^{E}\left(\overline{\omega}^{E}\left(s^{t}\right)\right)R^{E}\left(s^{t}\right)Q\left(s^{t-1}\right)K\left(s^{t-1}\right)\\&+\mu^{F}G_{t}^{F}\left(\overline{\omega}^{F}\left(s^{t}\right)\right)R^{F}\left(s^{t}\right)\left(Q\left(s^{t-1}\right)K\left(s^{t-1}\right)-N^{E}\left(s^{t-1}\right)\right)\\&+C^{F}\left(s^{t}\right)+C^{E}\left(s^{t}\right),\end{aligned} \tag{33}$$

with:

$$\begin{aligned}C^{F}\left(s^{t}\right)&\equiv\left(1-\gamma^{F}\right)\left(1-\Gamma^{F}\left(\overline{\omega}^{F}\left(s^{t+1}\right)\right)\right)\Phi^{E}\left(\overline{\omega}^{E}\left(s^{t+1}\right)\right)R^{E}\left(s^{t+1}\right)Q\left(s^{t}\right)K\left(s^{t}\right),\\C^{E}\left(s^{t}\right)&\equiv\left(1-\Gamma^{E}\left(\overline{\omega}^{E}\left(s^{t+1}\right)\right)\right)R^{E}\left(s^{t+1}\right)Q\left(s^{t}\right)K\left(s^{t}\right).\end{aligned}$$

(2) **Firms' Problems**

$$Y\left(s^{t}\right)=\frac{A\exp\left(e^{A}\left(s^{t}\right)\right)K\left(s^{t-1}\right)^{\alpha}H\left(s^{t}\right)^{(1-\Omega_{F}-\Omega_{E})(1-\alpha)}H^{F}\left(s^{t}\right)^{\Omega_{F}(1-\alpha)}H^{E}\left(s^{t}\right)^{\Omega_{E}(1-\alpha)}}{\Delta_{p}\left(s^{t}\right)}, \tag{34}$$

with:

$$\Delta_p\left(s^t\right) = (1-\xi)\left(\frac{K_p\left(s^t\right)}{F_p\left(s^t\right)}\right)^{-\epsilon} + \xi\left(\frac{\pi\left(s^{t-1}\right)^{\gamma_p}}{\pi\left(s^t\right)}\right)^{-\epsilon}\Delta_p\left(s^{t-1}\right),$$

$$F_p\left(s^t\right) = 1 + \xi\beta\exp\left(e^{B\left(s^{t+1}\right)}\right)\frac{C\left(s^t\right)Y\left(s^{t+1}\right)}{C\left(s^{t+1}\right)Y\left(s^t\right)}\left(\frac{\pi\left(s^t\right)^{\gamma_p}}{\pi\left(s^{t+1}\right)}\right)^{1-\epsilon}F_p\left(s^{t+1}\right),$$

$$K_p\left(s^t\right) = \frac{\epsilon\left(s^t\right)}{\epsilon\left(s^t\right)-1}MC\left(s^t\right) + \xi\beta\exp\left(e^{B\left(s^{t+1}\right)}\right)\frac{C\left(s^t\right)Y\left(s^{t+1}\right)}{C\left(s^{t+1}\right)Y\left(s^t\right)}\left(\frac{\pi\left(s^t\right)^{\gamma_p}}{\pi\left(s^{t+1}\right)}\right)^{-\epsilon}K_p\left(s^{t+1}\right),$$

$$\begin{aligned} H\left(s^t\right)W\left(s^t\right) = {} & A\exp\left(e^A\left(s^t\right)\right)K\left(s^{t-1}\right)^{\alpha}H\left(s^t\right)^{(1-\Omega_F-\Omega_E)(1-\alpha)}H^F\left(s^t\right)^{\Omega_F(1-\alpha)}H^E\left(s^t\right)^{\Omega_E(1-\alpha)} \\ & \cdot MC\left(s^t\right)(1-\alpha)\left(1-\Omega_F-\Omega_E\right), \end{aligned} \tag{35}$$

$$R^E\left(s^t\right) = \frac{\alpha Y\left(s^t\right)/K\left(s^t\right) + Q\left(s^{t+1}\right)(1-\delta)}{Q\left(s^t\right)}, \tag{36}$$

$$\begin{aligned} & Q\left(s^t\right)\left(1-0.5\kappa\left(\frac{I\left(s^t\right)\exp(e^I(s^t))}{I\left(s^{t-1}\right)}-1\right)^2\right) \\ & - Q\left(s^t\right)\left(\kappa\left(\frac{I\left(s^t\right)\exp(e^I(s^t))}{I\left(s^{t-1}\right)}\right)\left(\frac{I\left(s^t\right)\exp(e^I(s^t))}{I\left(s^{t-1}\right)}-1\right)\right)-1 \\ & = \mathrm{E}_t\left\{\beta\exp\left(e^{B\left(s^{t+1}\right)}\right)\frac{C\left(s^t\right)Q\left(s^{t+1}\right)}{C\left(s^{t+1}\right)}\kappa\left(\frac{I\left(s^{t+1}\right)\exp(e^I(s^{t+1}))}{I\left(s^t\right)}\right)^2\left(\frac{I\left(s^{t+1}\right)}{I\left(s^t\right)}-1\right)\exp(e^I(s^{t+1}))\right\}. \end{aligned} \tag{37}$$

(3) **FIs' Problems**

Equilibrium conditions for credit contracts are given by (27), (28), and (29) and by the following equations:

$$G^F\left(\overline{\omega}^F\left(s^t\right)\right) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\frac{\log\overline{\omega}^F\left(s^t\right)-0.5\sigma_F^2}{\sigma_F}}\exp\left(-\frac{v_F^2}{2}\right)dv_F, \tag{38}$$

$$G^E\left(\overline{\omega}^E\left(s^t\right)\right)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\frac{\log\overline{\omega}^E\left(s^t\right)-0.5\sigma_E^2}{\sigma_E}}\exp\left(-\frac{v_E^2}{2}\right)dv_E, \tag{39}$$

$$\begin{aligned}&G'^F\left(\overline{\omega}^F\left(s^t\right)\right)\equiv\frac{\partial G^F\left(\overline{\omega}^F\left(s^t\right)\right)}{\partial\overline{\omega}^F\left(s^t\right)}\\&=\left(\frac{1}{\sqrt{2\pi}}\right)\left(\frac{1}{\overline{\omega}^F\left(s^t\right)\sigma_F}\right)\exp\left(-.5\left(\frac{\log\overline{\omega}^F\left(s^t\right)-0.5\sigma_F^2}{\sigma_F}\right)^2\right),\end{aligned} \tag{40}$$

$$\begin{aligned}&G'^E\left(\overline{\omega}^E\left(s^t\right)\right)\equiv\frac{\partial G^E\left(\overline{\omega}^E\left(s^t\right)\right)}{\partial\overline{\omega}^E\left(s^t\right)}\\&=\left(\frac{1}{\sqrt{2\pi}}\right)\left(\frac{1}{\overline{\omega}^E\left(s^t\right)\sigma_E}\right)\exp\left(-.5\left(\frac{\log\overline{\omega}^E\left(s^t\right)-0.5\sigma_E^2}{\sigma_E}\right)^2\right),\end{aligned} \tag{41}$$

$$\begin{aligned}&\Gamma^F\left(\overline{\omega}^F\left(s^t\right)\right)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\frac{\log\overline{\omega}^F\left(s^t\right)-0.5\sigma_F^2}{\sigma_F}}\exp\left(-\frac{v_F^2}{2}\right)dv_F\\&+\frac{\overline{\omega}^F\left(s^t\right)}{\sqrt{2\pi}}\int_{\frac{\log\overline{\omega}^F\left(s^t\right)+0.5\sigma_F^2}{\sigma_F}}^{\infty}\exp\left(-\frac{v_F^2}{2}\right)dv_F,\end{aligned} \tag{42}$$

$$\begin{aligned}&\Gamma^E\left(\overline{\omega}_t^E\right)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\frac{\log\overline{\omega}^E\left(s^t\right)-0.5\sigma_E^2}{\sigma_E}}\exp\left(-\frac{x^2}{2}\right)dv_E\\&+\frac{\overline{\omega}^E\left(s^t\right)}{\sqrt{2\pi}}\int_{\frac{\log\overline{\omega}^E\left(s^t\right)+0.5\sigma_E^2}{\sigma_E}}^{\infty}\exp\left(-\frac{v_E^2}{2}\right)dv_E,\end{aligned} \tag{43}$$

$$\begin{aligned}\Gamma'^F\left(\overline{\omega}^F\left(s^t\right)\right)\equiv\frac{\partial\Gamma^F\left(\overline{\omega}^F\left(s^t\right)\right)}{\partial\overline{\omega}^F\left(s^t\right)}&=\frac{1}{\sqrt{2\pi}\overline{\omega}^F\left(s^t\right)\sigma_F}\exp\left(-.5\left(\frac{\log\overline{\omega}^F\left(s^t\right)-0.5\sigma_F^2}{\sigma_F}\right)^2\right)\\&+\frac{1}{\sqrt{2\pi}}\int_{\frac{\log\overline{\omega}^F\left(s^t\right)+0.5\sigma_F^2}{\sigma_F}}^{\infty}\exp\left(-\frac{v_F^2}{2}\right)dv_F-\frac{1}{\sqrt{2\pi}\sigma_F}\exp\left(-\frac{\left(\frac{\log\overline{\omega}^F\left(s^t\right)+0.5\sigma_F^2}{\sigma_F}\right)^2}{2}\right),\end{aligned} \tag{44}$$

$$\Gamma'^{E}\left(\overline{\omega}^{E}\left(s^{t}\right)\right) \equiv \frac{\partial \Gamma^{E}\left(\overline{\omega}^{E}\left(s^{t}\right)\right)}{\partial \overline{\omega}^{E}\left(s^{t}\right)} = \frac{1}{\sqrt{2\pi}\overline{\omega}^{E}\left(s^{t}\right)\sigma_{E}} \exp\left(-.5\left(\frac{\log \overline{\omega}^{E}\left(s^{t}\right) - 0.5\sigma_{E}^{2}}{\sigma_{E}}\right)^{2}\right)$$
$$+ \frac{1}{\sqrt{2\pi}} \int_{\frac{\log \overline{\omega}^{E}\left(s^{t}\right)+0.5\sigma_{E}^{2}}{\sigma_{E}}}^{\infty} \exp\left(-\frac{v_{E}^{2}}{2}\right) dv_{E} - \frac{1}{\sqrt{2\pi}\sigma_{E}} \exp\left(-.5\left(\frac{\log \overline{\omega}^{E}\left(s^{t}\right) + 0.5\sigma_{E}^{2}}{\sigma_{E}}\right)^{2}\right), \tag{45}$$

$$\left[\Gamma^{E}\left(\overline{\omega}^{E}\left(s^{t+1}\right)\right) - \mu^{E} G^{E}\left(\overline{\omega}^{E}\left(s^{t+1}\right)\right)\right] R^{E}\left(s^{t+1}\right) Q\left(s^{t}\right) K\left(s^{t}\right)$$
$$= R_{t}^{F}\left(s^{t+1}\right)\left(Q\left(s^{t}\right) K\left(s^{t}\right) - N^{E}\left(s^{t}\right)\right). \tag{46}$$

(4) **Laws of Motion of State Variables**

$$K\left(s^{t}\right) = \left(1 - 0.5\kappa\left(\frac{I\left(s^{t}\right)\exp(e^{I}(s^{t}))}{I\left(s^{t-1}\right)}\right)^{2}\right) I\left(s^{t}\right) + (1-\delta) K\left(s^{t-1}\right), \tag{47}$$

$$N^{i}\left(s^{t+1}\right) = \gamma^{i} V^{i}\left(s^{t}\right) + W^{i}\left(s^{t}\right), \tag{48}$$

with:

$$\begin{aligned}
V^{F}\left(s^{t}\right) &\equiv \left(1 - \Gamma^{F}\left(\overline{\omega}^{F}\left(s^{t+1}\right)\right)\right) \Phi^{E}\left(\overline{\omega}^{E}\left(s^{t+1}\right)\right) R^{E}\left(s^{t+1}\right) Q\left(s^{t}\right) K\left(s^{t}\right), \\
V^{E}\left(s^{t}\right) &\equiv \left(1 - \Gamma^{E}\left(\overline{\omega}^{E}\left(s^{t+1}\right)\right)\right) R^{E}\left(s^{t+1}\right) Q\left(s^{t}\right) K\left(s^{t}\right), \\
W^{i}\left(s^{t}\right) &\equiv (1-\alpha)\,\Omega_{i} Y\left(s^{t}\right),
\end{aligned}$$

where $i = F$ or E.

(5) **Policies and Shock Process**

Policies for the shock process are given by equations (16), (17), (20), (21), (22), (23) and (24).

C Equilibrium Conditions of Alternative Models

In addition to the benchmark model, we consider two alternative models for comparative convenience. The first is the Non-FA model, in which no financial accelerator mechanism is incorporated. The equilibrium conditions under this model are given by equations (16), (17), (20), (21), (22), (23), (24), (30), (31), (32), (34), (35), (36), (37), and (47), and by the following equations instead of equations (33) and (36), respectively, under the benchmark model, :

$$Y\left(s^t\right) = C\left(s^t\right) + I\left(s^t\right) + G\left(s^t\right)\exp\left(e^G(s^t)\right), \tag{49}$$

$$R\left(s^t\right) = \mathrm{E}_t \frac{\alpha Y\left(s^t\right)/K\left(s^t\right) + Q\left(s^{t+1}\right)(1-\delta)}{Q\left(s^t\right)}. \tag{50}$$

The second model is the BGG model in which only entrepreneurs are credit constrained. The equilibrium conditions in this model are given by equations (7), (16), (17), (20), (21), (22), (23), (24), (30), (31), (32), (34), (35), (36), (37), (39), (41), (43), (45) and (47), and by the following three equations instead of equations (29), (33), and (36), respectively, under the benchmark model:

$$\begin{aligned} 0 = &\sum_{s^{t+1}} \Pi\left(s^{t+1}\right)\left(1-\Gamma^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)\right) R^E\left(s^{t+1}\right) \\ &+ \frac{\Gamma'^E\left(\overline{\omega}^F\left(s^{t+1}\right)\right)}{\Phi'^E\left(s^{t+1}\right)}\Phi^E\left(s^{t+1}\right) R^E\left(s^{t+1}\right) - \frac{\Gamma'^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)}{\Phi'^E\left(s^{t+1}\right)}\Phi^E\left(s^{t+1}\right) R(s_t), \end{aligned} \tag{51}$$

$$\begin{aligned} Y\left(s^t\right) = &C\left(s^t\right) + I\left(s^t\right) + G\left(s^t\right)\exp\left(e^G(s^t)\right) \\ &+ \mu^E G^E\left(\overline{\omega}^E\left(s^t\right)\right) R^E\left(s^t\right) Q\left(s^{t-1}\right) K\left(s^{t-1}\right) + C^E\left(s^t\right), \end{aligned} \tag{52}$$

with:

$$C^E\left(s^t\right) \equiv \left(1-\Gamma^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)\right) R^E\left(s^{t+1}\right) Q\left(s^t\right) K\left(s^t\right),$$

$$\begin{aligned} &\left[\Gamma^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right) - \mu^E G^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)\right] R^E\left(s^{t+1}\right) Q\left(s^t\right) K\left(s^t\right) \\ &= R\left(s^t\right)\left(Q\left(s^t\right) K\left(s^t\right) - N^E\left(s^t\right)\right). \end{aligned} \tag{53}$$

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Table1: Parameters

(1) Parameters

Parameter	Value	Description
β	.99	Discount Factor
δ	.025	Depreciation Rate
α	.35	Capital Share
R	$.99^{-1}$	Risk Free Rate
ε	6	Degree of Substitutability
η	3	Elasticity of Labor
χ	.3	Utility Weight on Leisure
GY^{-1}	.2	Share of Governement Expenditure at Steady State

(2) Calibrated Parameters

Parameter	Value	Description
σ_E	0.107366	S.E. of FIs' Idiosyncratic Productivity at Steady State
σ_B	0.312687	S.E. of Entrepreneurial Idiosyncratic Productivity at Steady State
μ_E	0.033046	Bankruptcy Cost Associated with FIs
μ_B	0.013123	Bankruptcy Cost Associated with Entrepreneurs
γ^F	0.963286	Survival Rate of FIs
γ^B	0.983840	Survival Rate of Entrepreneurs

(3) Steady State Conditions

Condition	Description
$R=.99^{-1}$	Risk free rate is the inverse of the subjective discount factor.
$Z^E=Z^F+.023^{.25}$	Premium for entrepreneurial borrowing rate is $.023^{.25}$.
$Z^F=R+.006^{.25}$	Premium for FIs' borrowing rate is $.006^{.25}$.
$F(\omega^F)=.02$	Default probability in the IF contract is .02.
$F(\omega^E)=.02$	Default probability in the FE contract is .02.
$n^F=.1$	Fis' net worth/capital ratio is set to .1
$n^E=.5$	Entrepreneurial net worth/capital ratio is set to .5.

Table2: Parameter estimates

	Prior distribution			Posterior distribution		
	Distr.	Mean	S.D.	Mean	10th percentiles	90th percentiles
ξ_p	Beta	0.5	0.15	0.6064	0.5536	0.6588
κ	Normal	4	1.5	8.6739	6.6539	10.5424
γ_p	Beta	0.5	1.5	0.0739	0.0080	0.1386
θ	Beta	0.75	0.1	0.8447	0.8193	0.8706
φ_π	Normal	1.5	0.125	1.4832	1.3486	1.6277
φ_y	Gamma	0.125	0.5	0.0238	0.0104	0.0364
ρ_B	Beta	0.5	0.2	0.9145	0.8899	0.9371
ρ_I	Beta	0.5	0.2	0.3770	0.2444	0.5039
ρ_A	Beta	0.5	0.2	0.8719	0.8258	0.9210
ρ_G	Beta	0.5	0.2	0.8045	0.7303	0.8744
ρ_R	Beta	0.5	0.2	0.0590	0.0108	0.1057
ρ_P	Beta	0.5	0.2	0.6800	0.5268	0.8257
σ_E	Normal	0.27	0.01	0.2655	0.2493	0.2817
σ_B	Normal	0.092	0.005	0.0762	0.0700	0.0829
μ_E	Normal	0.016	0.002	0.0146	0.0116	0.0181
μ_B	Normal	0.078	0.01	0.0620	0.0434	0.0804
γ^{μ}	Beta	0.984	0.01	0.9843	0.9708	0.9984
γ^{B}	Beta	0.962	0.01	0.9621	0.9459	0.9780
$\sigma(\varepsilon_B)$	Inv. Gamma	0.01	Inf	0.0019	0.0015	0.0023
$\sigma(\varepsilon_I)$	Inv. Gamma	0.01	Inf	0.0256	0.0211	0.0299
$\sigma(\varepsilon_G)$	Inv. Gamma	0.01	Inf	0.0080	0.0072	0.0088
$\sigma(\varepsilon_A)$	Inv. Gamma	0.01	Inf	0.0111	0.0100	0.0123
$\sigma(\varepsilon_R)$	Inv. Gamma	0.01	Inf	0.0015	0.0013	0.0017
$\sigma(\varepsilon_{NF})$	Inv. Gamma	0.01	Inf	0.0814	0.0702	0.0911
$\sigma(\varepsilon_{NE})$	Inv. Gamma	0.01	Inf	0.3736	0.3351	0.4137
$\sigma(\varepsilon_P)$	Inv. Gamma	0.01	Inf	0.0896	0.0677	0.1114

Table3: Correlation with alternative indicators

	Spread of interest rate on contracted short-term loan rate	Spread of interest rate on new short-term loan rate	DI for financial position	DI for lending attitude of FIs
Z^E(+4)-R(+4)	0.463	0.244	0.422	0.587
Z^E(+3)-R(+3)	0.502	0.230	0.469	0.604
Z^E(+2)-R(+2)	0.532	0.209	0.523	0.636
Z^E(+1)-R(+1)	0.544	0.163	0.575	0.667
Z^E(0)-R(0)	0.559	0.091	0.626	0.689
Z^E(-1)-R(-1)	0.571	0.039	0.673	0.697
Z^E(-2)-R(-2)	0.579	0.022	0.715	0.693
Z^E(-3)-R(-3)	0.576	-0.012	0.724	0.667
Z^E(-4)-R(-4)	0.568	-0.042	0.689	0.609

Table4: Variance decompositions

Table4a: The Full Sample Period

	ε^{A}	ε^{B}	ε^{G}	ε^{I}	ε^{NF}	ε^{NE}	ε^{R}
Investment	0.049	0.034	0.001	0.644	0.046	0.222	0.004
Output	0.230	0.148	0.299	0.226	0.010	0.036	0.051
Inflation	0.261	0.358	0.017	0.057	0.030	0.066	0.144

Table4b: During 1990-1999

	ε^{A}	ε^{B}	ε^{G}	ε^{I}	ε^{NF}	ε^{NE}	ε^{R}
Investment	0.016	0.050	0.001	0.654	0.062	0.211	0.006
Output	0.174	0.150	0.285	0.287	0.023	0.041	0.041
Inflation	0.194	0.267	0.014	0.079	0.071	0.082	0.211

Table4c: During 1995-1999

	ε^{A}	ε^{B}	ε^{G}	ε^{I}	ε^{NF}	ε^{NE}	ε^{R}
Investment	0.034	0.030	0.001	0.615	0.135	0.181	0.004
Output	0.209	0.107	0.397	0.202	0.040	0.012	0.033
Inflation	0.274	0.200	0.018	0.042	0.143	0.042	0.211

Notes: The variance decompositions are given by the variance of macroeconomic variables accounted for by each of the listed shocks divided by the variance of corresponding macroeconomic variables accounted for by all of the shocks, based on the full sample period(the upper table), and lost decades(the middle and low table).

Table5: Variance decompositions under alternative models

Table5a: Variance decompositions of investment under alternative models

	ε^{A}	ε^{B}	ε^{G}	ε^{I}	ε^{NF}	ε^{NE}	ε^{R}
Chained BGG	0.049	0.034	0.001	0.644	0.046	0.222	0.004
BGG	0.030	0.036	0.000	0.736	n.a.	0.188	0.009
noBGG	0.037	0.028	0.000	0.935	n.a.	n.a.	0.000

Notes: The variance decompositions are given by the variance of investment accounted for by each of the listed shocks divided by the variance of investment accounted for by all of the shocks, based on the full sample period.

Table5b: Variance decompositions of spreads under the alternative model

(1) Entrepreneurial Borrowing Spread (Z^{E}-R)

	ε^{A}	ε^{B}	ε^{G}	ε^{I}	ε^{NF}	ε^{NE}	ε^{R}
Chained BGG	0.004	0.005	0.000	0.022	0.253	0.697	0.012
BGG	0.001	0.017	0.001	0.008	n.a.	0.955	0.018

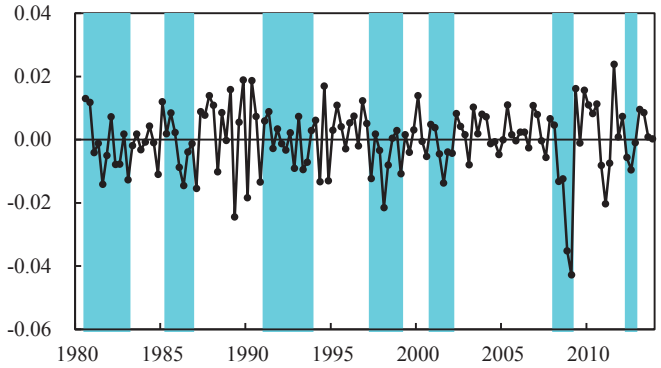
(2) FIs' Borrowing Spread (Z^{F}-R)

	ε^{A}	ε^{B}	ε^{G}	ε^{I}	ε^{NF}	ε^{NE}	ε^{R}
Chained BGG	0.303	0.267	0.025	0.083	0.020	0.012	0.191
BGG	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

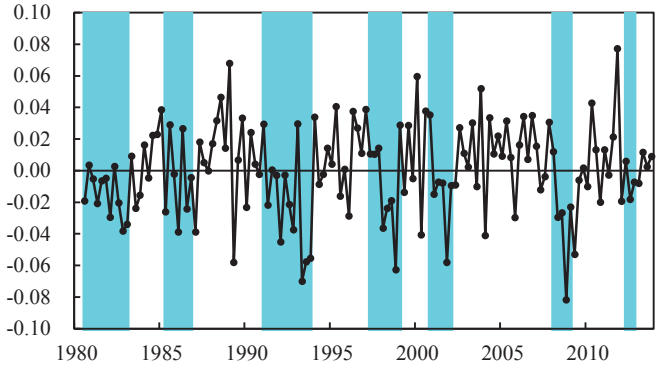
Notes: The variance decompositions are given by the variance of spreads accounted for by each of the listed shocks divided by the variance of spreads accounted for by all of the shocks, based on the full sample period.

Figure 1: The time paths of macroeconomic variables used for estimating the model.

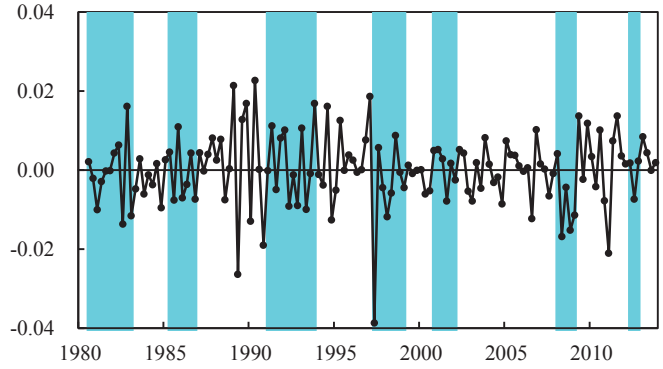
(1) Output



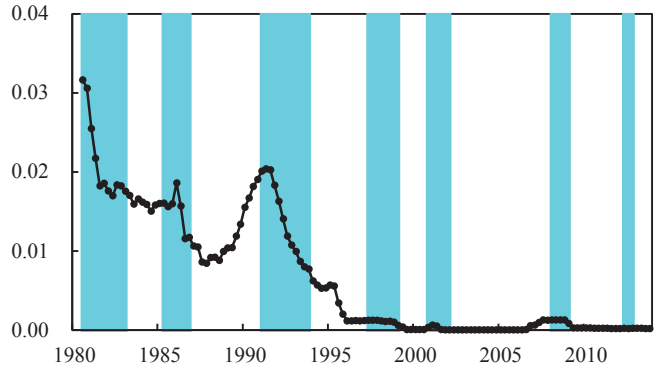
(2) Investment



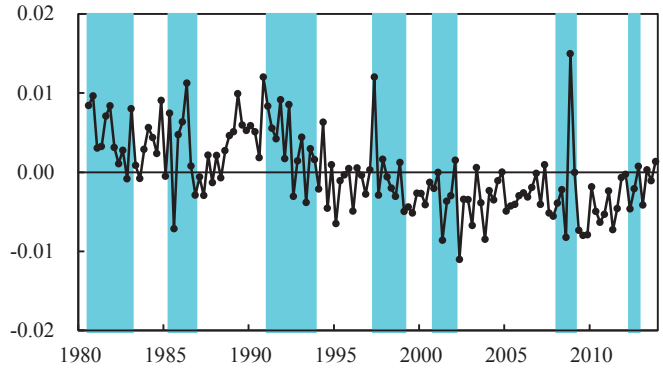
(3) Consumption



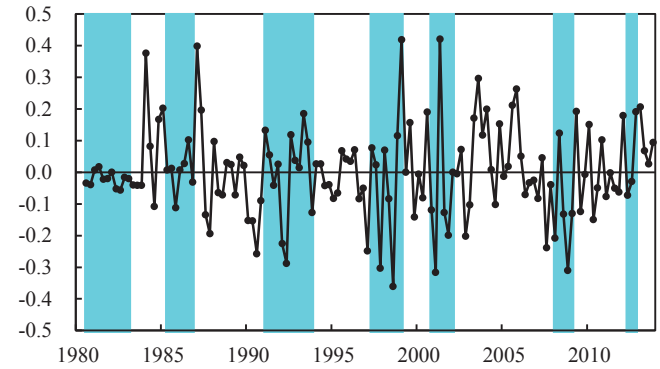
(4) Interest Rate



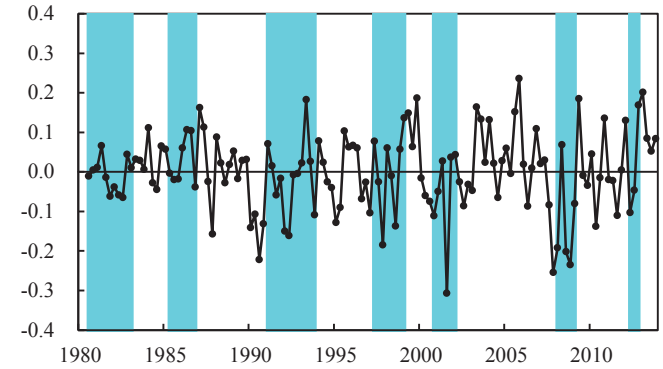
(5) Inflation



(6) Net Worth of FIs



(7) Net Worth of Entrepreneurs

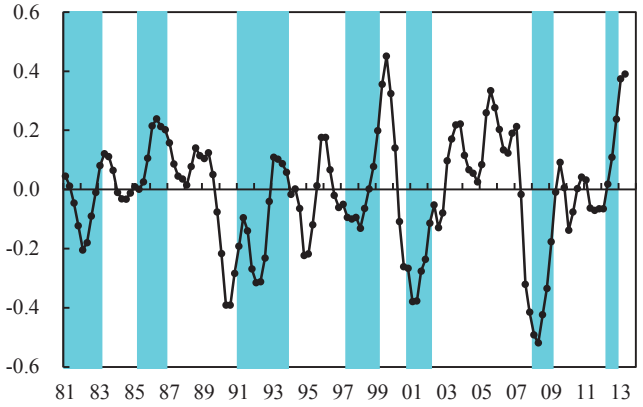


Notes: Shaded area are period of the recession.

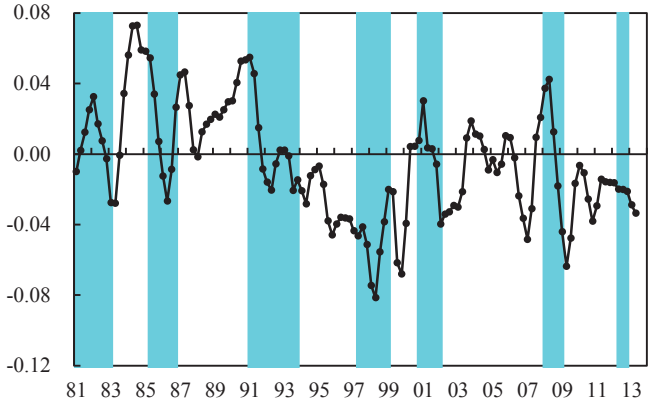
Figure 2: Identified shocks to entrepreneurial net worth and FIs' net worth.

Figure2a: Time Paths of the identified shocks to entrepreneurial net worth and FIs' net worth.

(1) Shocks to Entrepreneurial Net Worth



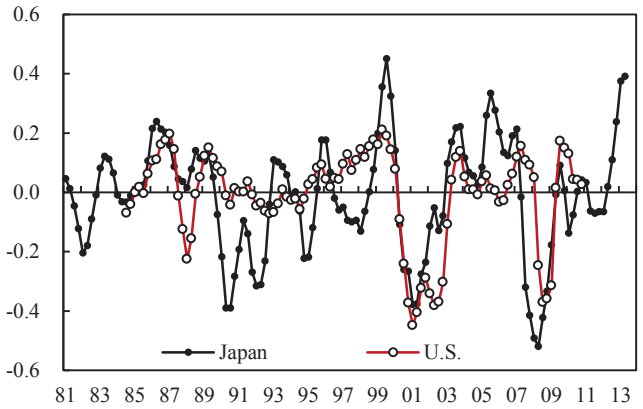
(2) Shocks to FIs' Net Worth



Notes: Shaded area are period of the recession.

Figure2b: Comparision of the identified shocks between Japanese economy and U.S. economy

(1) Shocks to Entrepreneurial Net Worth



(2) Shocks to FIs' Net Worth

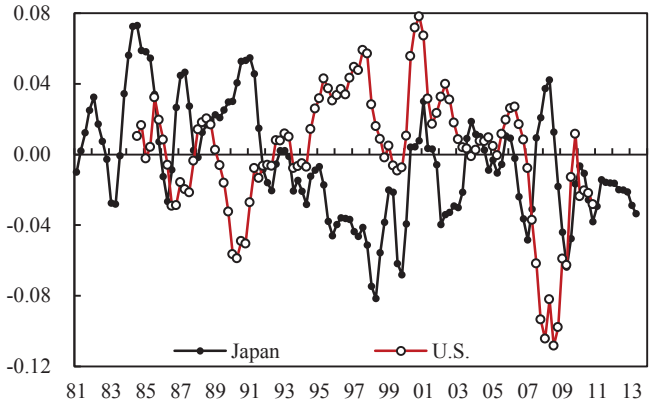


Figure 3: Impluse responses of the macroeconomic variables to the unexpected impairment of FIs' networth and entrepreneurial net worth, the unexpected increase in investment adjustment cost, and the unexpected decline of technology level.

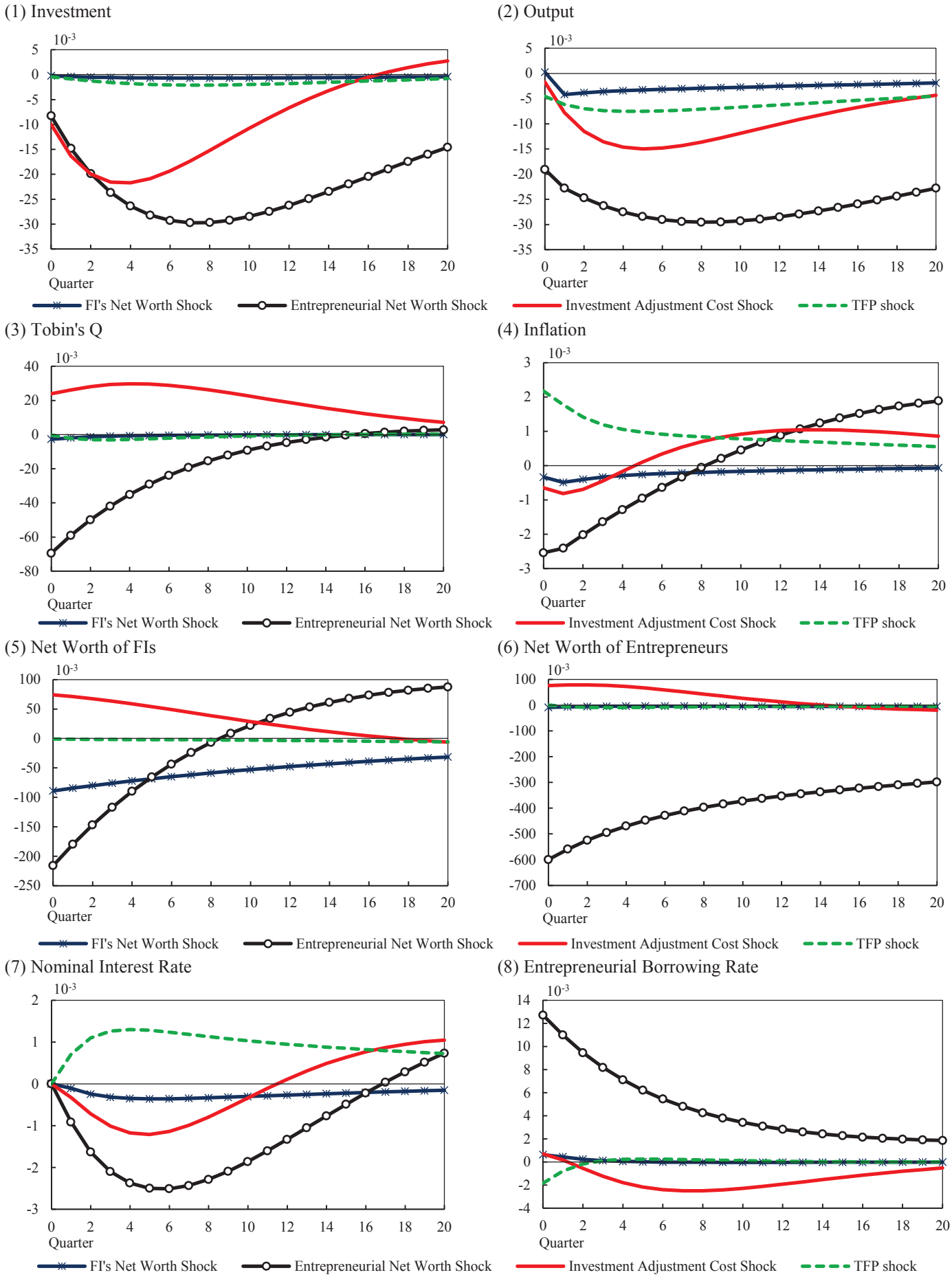
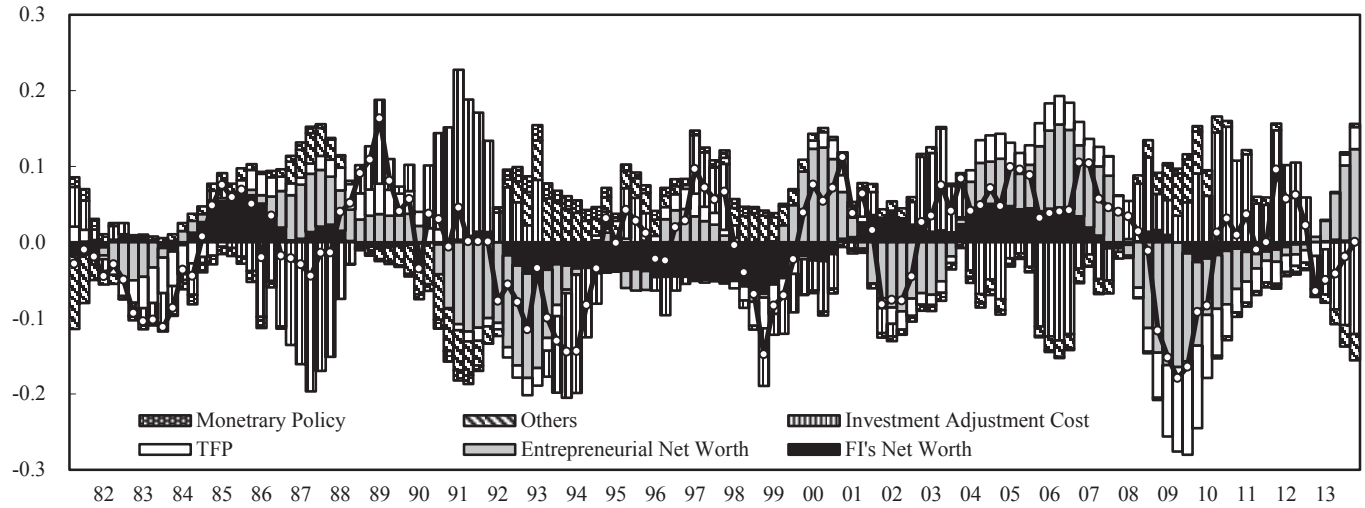
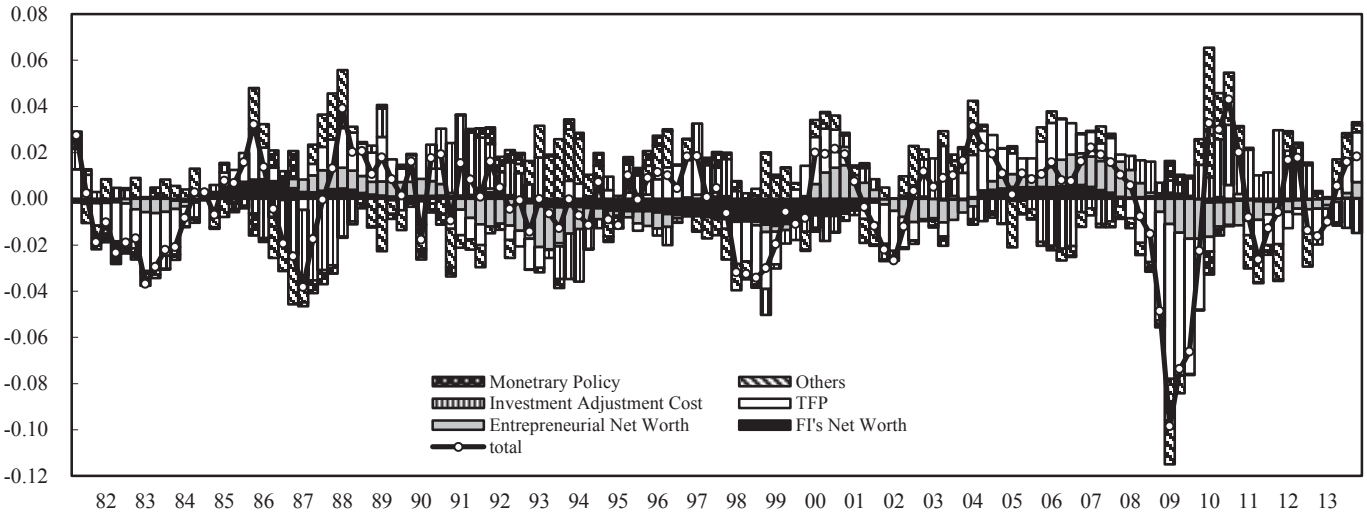
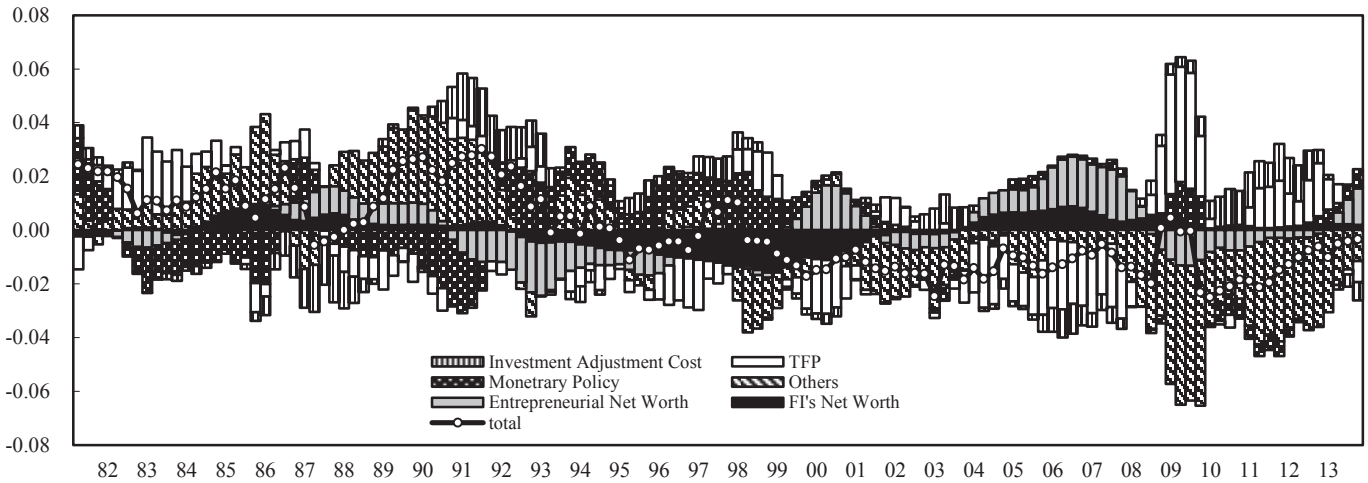


Figure 4: Historial contribution of each structural shocks in investment variations, output variations, and inflation variations.

(1) Investment



(2) Output



(3) Inflation