Japan's Banking Crisis and Lost Decades

Naohisa Hirakata[*], Nao Sudo[†] and Kozo Ueda[‡]

November 26, 2010

Abstract

There are two opposing views as to the cause of Japan's prolonged stagnation during the lost decade. The first view argues that the deteriorated balance sheets of banks and entrepreneurs dampen the economy by impairing financial intermediation. The second view stresses the role played by the nonfinancial factors such as productivity slowdown. To quantitatively evaluate these views in an integrated framework, we estimate a dynamic stochastic general equilibrium (DSGE) model with credit-constrained banks and entrepreneurs. Using the Japanese data from 1981 to 2007, we distill shocks to the net worth of banks and entrepreneurs together with non-financial shocks to assess their impacts on the economy. We find that these net worth shocks constitute a important portion of macro economic fluctuations during the lost decade. Shocks to the entrepreneurial net worth disrupt the economy mainly in the early 1990, and those to the bank's net worth continuously dampen the economy over the 1990s. Quantitatively, the two net worth shocks explain 43% of investment variation, 11% of output variation, and 34% of inflation variation during the 1990s.

JEL Class: E52; E58; F41

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

[*]Deputy Director, Research and Statistics Department, Bank of Japan (E-mail: naohisa.hirakata@boj.or.jp)

[†]Deputy Director, Institute for Monetary and Economic Studies, Bank of Japan (E-mail: nao.sudou@boj.or.jp).

[‡]Director, Institute for Monetary and Economic Studies, Bank of Japan (E-mail: kouzou.ueda@boj.or.jp). The views expressed in this paper are those of the authors and do not necessarily reflect the official views of the Bank of Japan.

1 Introduction

Over the years, there have been two opposing views on the cause of the prolonged Japanese stagnation called lost decades. The first view emphasizes the impaired functionings of financial system during the economic downturn. According to this view, the widely observed phenomena in the slump, a deterioration of balance sheet in the banking and corporate sector, a reduction of banks' lendings, and bankruptcies of large banks, has a substantial important implication to the macroeconomics. For example, Bayoumi (2001) evaluates the possible causes of the stagnation by VAR and concludes that the failure of financial intermediation is the major explanation for the lost decade.[1]

The second view, in contrast, stresses the role played by non-financial factors. The pioneering work of this line of study, Hayashi and Prescott (2002), based on the simple growth model, demonstrates that a slow growth rate of total factor productivity (TFP) explains a bulk of output declines in the 1990s.[2] Researches based on the New Keynesian model also claim the importance of the non-financial shocks. For example, Sugo and Ueda (2008) and Hirose and Kurozumi (2010) agree that shocks to the investment adjustment cost together with those to TFP explain a sizable fluctuations of output and investment during the lost decade.[3]

In the present paper, we address this question by conducting Bayesian estimation of the New Keynesian DSGE model of Hirakata, Sudo, and Ueda (hereafter HSU, 2010). Essential feature of HSU (2010) is that it explicitly incorporates the credit-constrained banking sector as well as the credit-constrained entrepreneurial sector. Through the financial accelerator

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

[2] While Hayashi and Prescott (2002) argue that non-financial factor is important in explaining most of the periods during the lost decade, they admit that for the 1996-98 the performance of banking sector plays exceptionally important role in the economic activity.

[3] One other strand of literature includes Hoshi and Kashyap (2004) and Caballero, Hoshi, and Kashyap (2008). While they consider the effect of malfunction of financial intermediary sector on the economy, their argument focus on the productivity slowdown brought by the zombie lending rather than the disruption of bank loan steming from the credit crunch.

mechanism à la Bernanke, Gertler, and Gilchrist (1999, hereafter BGG), the model provides the theoretical linkages between the balance sheets of the banks and entrepreneurs and the aggregate economic activities. Based on the Japanese data covering from 1981 to 2007, we estimate the model and distill the shocks to the net worth of banks and entrepreneurs together with non-financial shocks. We then evaluate the relative importance of each shock in accounting for the Japan's macroeconomic variables at that time.

Compared with related works that employ the Bayesian estimation of DSGE models using the Japan's data, the novelty of our paper arises from the presence of banking sector. Our model consists of what we describe as chained credit contracts. There, credit-constrained banks intermediate funds from investors to credit-constrained entrepreneurs by making the credit contracts with each of them. Since the contracts are subject to the informational friction, the borrowing rates are affected by the borrowers' net worth. Consequently, a disruption in the net worth increases the cost of the external finance, leading to a decline in investment.

There are two main findings in our paper. Most importantly, we find that banks' net worth shocks and the entrepreneurial net worth shocks are important determinants of macroeconomic variations during the lost decades. At the impact, both shocks affect the credit spreads but they are propagated to the macroeconomy through the credit market imperfection. The effects of the two shocks are, however, substantially different in the Japanese economy. While shocks to the entrepreneurial net worth contribute lowering of output, investment, and inflation only in the early 1990s, the shocks to the banks' net worth ceaselessly disrupt the financial intermediation, reducing the macroeconomic variables over the 1990s. Quantitatively, the shocks to the net worth explain 43% of investment variation, 11% of output variation, and 34% of inflation variation during the 1990s.

Second, we find that the shocks to the banks' net worth are closely related to those to the investment adjustment cost. As discussed by Justiniano, Primiceri, and Tambalotti (2010), the estimates of the New Keynesian model typically indicate that shocks to investment adjustment cost play are substantially important in the business cycle. Relatedly, Hirose and Kurozumi (2010) report that most of the Japanese investment variations are accounted for by these shocks.[4] By estimating the current model as well as the models that abstract from credit-constrained banks and entrepreneurs, we find that quantitative impact of the shocks to the investment adjustment cost is reduced when credit frictions are explicitly incorporated into the model.

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(2010). The economy consists of a credit market and a goods market, and 10 types of agents: investors, banks, 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, banks' net worth together with the entrepreneurial net worth plays the key role in the economic fluctuations by affecting the cost of external finance that realizes in the credit market.

2.1 The Credit Market

Overview of the two types of credit contract In each period, entrepreneurs conduct projects with size $Q\left(s^t\right) K\left(s^t\right)$, where $Q\left(s^t\right)$ is the price of capital and $K\left(s^t\right)$ is capital.[5] Entrepreneurs own the net worth, $N^E\left(s^t\right) < Q\left(s^t\right) K\left(s^t\right)$, and borrow funds, $Q\left(s^t\right) K\left(s^t\right) - N^E\left(s^t\right)$, from the FIs through the FE contracts. The FIs also own net worth, $N^F\left(s^t\right) < Q\left(s^t\right) K\left(s^t\right) - N^E\left(s^t\right)$, and borrow funds, $Q\left(s^t\right) K\left(s^t\right) - N^F\left(s^t\right) - N^E\left(s^t\right)$, from investors through the IF contract. In both contracts, agency problems stemming from asymmetric information are present. The borrowers are subject to idiosyncratic

[4] By showing the correlation between the shocks to the investment adjustment cost and Tankan, Hirose and Kurozumi (2010) claim that these shocks are related to financial intermediation costs facing firms.

[5] s^t stands for the state at period t.

productivity shocks and the lenders cannot observe the realizations of these shocks without paying additional monitoring costs. Taking these credit market imperfections as given, the FIs choose the clauses of the two contracts so as to maximize their expected profits. Consequently, for a given riskless rate of the economy $R\left(s^t\right)$, the external finance premium $\mathrm{E}_t\left\{R^E\left(s^{t+1}\right)\right\}/R\left(s^t\right)$ is expressed by[6]

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

with

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

[6] See Appendix A for the details of credit contracts. See Appendix B for the explicit forms of $G^F\left(\overline{\omega}^F\left(s^{t+1}|s^t\right)\right)$ and $G^E\left(\overline{\omega}^E\left(s^{t+1}|s^t\right)\right)$.

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

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, $\overline{\omega}^F\left(s^{t+1}|s^t\right)$ and $\overline{\omega}^E\left(s^{t+1}|s^t\right)$ are the cutoff value for the FIs' idiosyncratic shock $\omega^F\left(s^{t+1}\right)$ in the IF contract, and that 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 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 matter in determining the external finance premium.

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 $Z^E\left(s^{t+1}|s^t\right)$, is given as the contractual interest rate that nondefaulting entrepreneurs repay to the FIs:

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

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

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

Dynamic behavior of net worth In addition to the earnings stemming from credit contracts, both FIs and entrepreneurs earn labor income $W^F\left(s^t\right)$ and $W^E\left(s^t\right)$ by inelastically supplying a unit of labor to final goods producers. The FIs and entrepreneurs accumulate their net worth through the two types of earnings.

We assume that each FI and entrepreneur survives to the next period with a constant probability γ^F and γ^E, then the aggregate net worths of FIs and entrepreneurs are given by

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

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

with

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

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

FIs and entrepreneurs that fail to survive at period t consume $\left(1-\gamma^F\right)V^F\left(s^t\right)$ and $\left(1-\gamma^E\right)V^E\left(s^t\right)$, respectively.[7]

2.2 The Rest of the Economy

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

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

[7] See Appendix B for the definition of $\Gamma^F\left(\overline{\omega}^F\left(s^{t+1}\right)\right)$ and $\Gamma^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)$.

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 $C\left(s^t\right)$ is final goods consumption, $H\left(s^t\right)$ is hours worked, $D\left(s^t\right)$ is real deposits held by the investors, $W\left(s^t\right)$ is the real wage measured by the final goods, $R\left(s^t\right)$ is the real risk-free return from the deposit $D\left(s^t\right)$ between time t and $t+1$, $\Pi\left(s^t\right)$ is dividend received from the ownership of retailers, and $T\left(s^t\right)$ 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 $Y\left(s^t\right)$ are composites of a continuum of retail goods $Y\left(h,s^t\right)$. The final goods producer purchases retail goods in the competitive market, and sells the output to a household and capital producers at price $P\left(s^t\right)$. $P\left(s^t\right)$ is the aggregate price of the final goods. The production technology of the final goods is given by

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

where $\epsilon(s^t)>1$. The corresponding price index is given by

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

We assume that $\epsilon(s^t)$ fluctuates responding to price-mark-up disturbance $e^P(s^t)$. That is,

$$\log(\epsilon(s^t)-1)=e^P(s^t).$$

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

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

where $y_t\left(h,s^t\right)$ for $h\in[0,1]$ are the wholesale goods used for producing the retail goods $Y_t\left(h,s^t\right)$ by retailer $h\in[0,1]$. The retailers are price takers in the input market and choose their inputs taking the input price $1/X\left(s^t\right)$ 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:

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

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 $\pi\left(s^{t-1}\right)$ denotes the gross rate of inflation in period $t-1$, that is, $\pi\left(s^{t-1}\right)=P\left(s^{t-1}\right)/P\left(s^{t-2}\right)$. 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 $P^*\left(h,s^t\right)$ 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 $P^*\left(h,s^t\right)$ is written in the following way:

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

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

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

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

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

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:

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

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

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

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:

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

where F_I is defined as follows:

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

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.[8] Here, the development of the total capital available at period t is described as

$$K\left(s^t\right)=\left(1-F_I\left(I\left(s^t\right), I\left(s^{t-1}\right)\right)\right) I\left(s^t\right)+(1-\delta) K\left(s^{t-1}\right). \quad (14)$$

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

$$G\left(s^t\right) \exp\left(e^G(s^t)\right)=T\left(s^t\right), \quad (15)$$

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

$$R^n\left(s^t\right)=\theta R^n\left(s^{t-1}\right)+(1-\theta)\left(\phi_\pi \pi\left(s^t\right)+\phi_y \log\left(\frac{Y\left(s^t\right)}{Y}\right)\right)+e^R\left(s^t\right), \quad (16)$$

[8] We assume, following BGG (1999), that the price of old capital that the entrepreneurs sell to the capital goods producers, say $\overline{Q}\left(s^t\right)$, is close to the price of the newly produced capital $Q\left(s^t\right)$ around the steady state.

where θ is the autoregressive parameter of the policy rate, ϕ_π and ϕ_y are the policy weight on 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:

$$R\left(s^t\right) \equiv \mathrm{E}_t\left\{\frac{R^n\left(s^t\right)}{\pi\left(s^{t+1}\right)}\right\}. \tag{17}$$

Resource constraint The resource constraint for final goods is written as

$$\begin{aligned}
Y\left(s^t\right) &= C\left(s^t\right) + I\left(s^t\right) + G\left(s^t\right)\exp\left(e^G(s^t)\right) \\
&+ \mu^E G^E\left(\overline{\omega}^E\left(s^t\right)\right) R^E\left(s^t\right) Q\left(s^{t-1}\right) K\left(s^{t-1}\right) \\
&+ \mu^F G^F\left(\overline{\omega}^F\left(s^t\right)\right) R^F\left(s^t\right)\left(Q\left(s^{t-1}\right) K\left(s^{t-1}\right) - N^E\left(s^{t-1}\right)\right) \\
&+ C^F\left(s^t\right) + C^E\left(s^t\right).
\end{aligned} \tag{18}$$

Note that the fourth and the fifth terms on the right-hand side of the equation correspond to the monitoring costs incurred by 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, $e^A\left(s^t\right), e^I\left(s^t\right)$, $e^B\left(s^t\right), e^G\left(s^t\right)$, and $e^R\left(s^t\right)$, following processes as below:

$$e^A\left(s^t\right) = \rho_A e^A\left(s^{t-1}\right) + \varepsilon^A\left(s^t\right), \tag{19}$$

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

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

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

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

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

where ρ_A, ρ_I, ρ_B, ρ_G, ρ_R, $\rho_P \in (0,1)$ are autoregressive roots of the exogenous variables, and $\varepsilon^A\left(s^t\right), \varepsilon^I\left(s^t\right), \varepsilon^B\left(s^t\right), \varepsilon^G\left(s^t\right), \varepsilon^R\left(s^t\right)$, and $\varepsilon^P\left(s^t\right)$ 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, σ_R^2, and σ_P^2, respectively.

In addition, we consider shocks to the credit market, following Gilchrist and Leahy (2002). We assume that both FIs and entrepreneurs face an unexpected disruption (rise) in their net worth, denoted by $\varepsilon^{N^F}\left(s^t\right)$, $\varepsilon^{N^E}\left(s^t\right)$. These innovations directly affect net worth accumulation through equations (6) and (7). As discussed in Nolan and Thoenissen (2009), we interpret these shocks to the net worth as a shock to the efficiency of the contractual relations in the IF contract and the FE contract, respectively.[9]

2.3 Equilibrium Condition

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

[9] CMR (2008) and Nolan and Thoenissen (2009) assume that the exit ratio of entrepreneurs γ^E obeys the stochastic law of motion, generating an unexpected change in entrepreneurial net worth. CMR (2008) interprets these shocks as a reduced form of an "asset bubble" or "irrational exuberance."

(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

3.1 Data

Our data set includes seven time series for the Japanese economy: growth rate of real GDP, growth rate of real consumption, growth rate of real investment, the log difference of the GDP deflator, the call rate, and the growth rate of real net worth of the banking sector and the entrepreneurial sector.[10][11] 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). The variables other than the GDP deflator and the call rate are demeaned with a trend break in 1991Q2. Our sample period covers from 1981Q1 to 1998Q4, the period during which zero nominal interest rate policy is maintained.[12] All data series used in the estimation are shown in Figure 1.

3.2 Calibration

Following Christensen and Dib (2008), 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

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

[11] The two net worth series are constructed based on the Flow of Funds Accounts.

[12] Existing studies that estimate DSGE model using Japanese data, including Sugo and Ueda (2008) and Hirose and Kurozumi (2010), also focus on the periods where nominal interest rates are nonzero.

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 0.6, a historical average in the Japanese economy;

(4) the annualized failure rate of FIs is 2%;

(5) the annualized failure rate of entrepreneurs is 2%;

3.3 Baynesian Estimation

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 investment 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, ρ_R, and ρ_P, the variances of these shocks σ_A^2, σ_I^2, σ_B^2, σ_G^2, σ_R^2, and σ_P^2, as well as 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.[13]

As the nominal interest rates are maintained at zero after 1998Q4, we estimate parameter values using the sample period from 1981Q1 to 1998Q4.

[13] All estimations are done with Dynare.

3.4 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 the 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, ρ_R, and ρ_P 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, σ_R^2, $\sigma_{N_F}^2$, $\sigma_{N_E}^2$, and σ_P^2 are assumed to follow an inverse-gamma distribution with a mean of 0.01 a standard deviation of 2.

4 Estimation Results

In this section, we report 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 banks' 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 developments in credit market conditions during the lost decades.

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 $\kappa = 7.53$. This value falls between the estimate 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, frequency of price adjustment and the degree of price indexation, are $\xi = 0.796$ and $\gamma_p = 0.286$; These values are smaller than the findings in Meier and Muller (2006). The estimated monetary policy rule exhibits aggressive reaction to current inflation $\phi_\pi = 1.49$, with inertia of the interest rate $\theta = 0.795$, and mild reaction to the current output $\phi_y = 0.027$.

Shocks to government expenditure and preference are particularly persistent with AR(1) coefficients of 0.79, and 0.88, respectively, compared with other shocks. The shocks to the entrepreneurial net worth, those to the FIs' net worth, and those to productivity are the most volatile shocks in the economy. The standard deviation of the first shocks is, however, more than five times greater than that of the other two shocks.

4.2 Identified Shocks to the net worth

Identified shocks to the bank's net worth together with those to the entrepreneurial net worth are displayed in Figure 2.[14] The Japanese recession periods announced by the ESRI (Economic and Social Research Institute) are denoted by the shaded area. Because the nominal interest rates are virtually zero after 1998Q4, the shocks beyond 1999Q1 are recovered based on the model parameters estimated from the sample from 1981Q1 to 1998Q4.

Clearly, the realizations of both two financial shocks $\varepsilon^{N^F}(s^t)$ and $\varepsilon^{N^E}(s^t)$ are related to the business cycle. The shocks typically exceed zero in the slump, indicating their contributions to the economic downturns. In particular, the adverse shocks reach the peak in the middle of each recession.

4.3 Estimated Credit Spreads

We compare the two borrowing spreads in the model, entrepreneurial borrowing spread, $Z^E\left(s^{t+1}|s^t\right) - R\left(s^t\right)$ and bank's borrowing spread $Z^F\left(s^{t+1}|s^t\right) - R\left(s^t\right)$, with the indicators of financial stress. Though we do not make use of the spread data in estimating the model,

[14]The two series are smoothed by taking the four quarter centered moving average.

the model generated series capture the financial stress reflected in some of the indicators.

The model-generated entrepreneurial borrowing spread $Z^E\left(s^{t+1}|s^t\right)-R\left(s^t\right)$ is to some extent consistent with the indicators. Figure 3 displays the time path of seven indicators of the entrepreneurial borrowing spread together with the model-generate series. They are, the lending rates on contracted short-term loan, the lending rate on newly contracted short-term loan, the Financial Position and the Lending Attitude of Financial Institutions Diffusion Indexes of the *Tankan,* and the DIs for Spreads of Loan Rates in the Senior Loan Opinion Survey (the three DI series for different level of the rating, high, medium, and low). Table 3a, b, c report the cross-correlation coefficients between the model-generated and each of the seven indicators. [15] Clearly, the model-generated series are related to the general movement of the indicators. For example. the highest contemporaneous correlation coefficients is that with the DI of low rating spread, yielding +.83.

Compared with entrepreneurial borrowing spread $Z^E\left(s^{t+1}|s^t\right)-R\left(s^t\right)$, the relationship between model-generated bank's borrowing spread $Z^F\left(s^{t+1}|s^t\right)-R\left(s^t\right)$ and the data counterpart is less clear. Figure 4 displays the time path of the four proxies of the bank's borrowing spread. Those are Japan Premium, spread of three-month certificated deposit, spread of bank debenture bond, and spread of interest rate on short term time deposit. The model well captures the rise of the spread $Z^F\left(s^{t+1}|s^t\right)-R\left(s^t\right)$ in the period of a financial crisis that are observed in the four indicators. The model however implies a rise of the spread around 2003 that contrasts with the data.

5 Financial shocks in the Japanese Economy

In this section, using the estimated parameters and distilled structural shocks, we study the role of the financial shocks and non-financial shocks in the Japanese economy. To this end, we first describe how the economy responds to the adverse macroeconomic shocks, and calculate the quantitative impact of these shocks during the sample period.

[15] De Graeve (2008) also reports that the model-consistent external finance premium is more closely related to the spreads to lower grade firms, the Bbb-Aaa and the high-yield spread, than Baa-Aaa and spread of prime lending rate in the U.S. economy.

5.1 Impulse Responses

Figure 5 shows the impulse responses of macro variables to one standard error innovation to $\varepsilon^F\left(s^t\right)$, $\varepsilon^{NE}\left(s^t\right)$, $\varepsilon^I\left(s^t\right)$, and $\varepsilon^A\left(s^t\right)$. The disruption of net worth in the two borrowing sectors leads to an increase in the cost of external finance, making the investment more expensive. Consequently, investment and output decline. As the demand for capital goods shrinks, Tobin's Q and inflation fall. It is noticeable that while the standard deviation of the entrepreneurial net worth shock is more than five times larger than that of banks' net worth shock, the difference of economic response to the two shocks is far smaller. As discussed in HSU (2009), everything being equal, the shocks to the banks' net worth causes disproportionately large impact on the economy since the leverage of the banking sector is higher than the entrepreneurial sector. This result shows the same argument holds for the Japanese economy.

The two non-financial shocks, a positive shock to the investment adjustment cost and a negative shock to the technology, also cause the economic downturn. Notice, however, that implications of these shocks to Tobin's Q and inflation are different from those of financial shocks. With a higher investment adjustment cost, Tobin's Q rises instead of declines, and firms reduce investment and output. With a lower productivity of goods producing sector, a marginal cost of production for retailers rises, resulting an increase in inflation and a fall in investment and output.

5.2 Historical Decomposition

To see the quantitative significance of the structural shocks in explaining the macroeconomic fluctuations, we decompose the variations of investment, output, and inflation into the eight shocks. Figure 8, 9, and 10 display the historical time path of these variables from 1981 to 2007 together with the contributions of the structural shocks. Shocks to the bank's net worth and the entrepreneurial net worth play the important role in the variations of these variables, particularly investment. The shocks to the entrepreneurial net worth are the key determinants of the fall in the three variables in the early 1990s, the period where the bubble collapse occurs. These effect of shocks become less important in the rest of the

1990s. In contrast, the shocks to bank's net worth work have the persistent effects on the economy, putting downward pressure continuously on the three variables throughout the entire 1990s.

Table 4 reports the variance decomposition statistics for output, investment, and inflation. In the whole sample period, the shock to the two net worth explain 38% of investment variation, 9% of output variation, and 25% of inflation variation. As for the 1990s, the shock to the two net worth explain 43% of investment variation, 11% of output variation, and 33% of inflation variation. Most of the variation comes from the shocks to the entrepreneurial net worth rather than the shocks to the bank's net worth. The shocks to banking sector play the significant role in investment variations particularly the late 1990s. During this period where the financial crisis involving a number of bankruptcy of banking sector takes place, the shocks to banking sector explain 12% of investment variations. Among the non-financial shocks, the shocks to investment adjustment cost play the dominant role in investment variations and the important role in output variations. They explain about a half of investment variations and about 20% of output variations regardless the sample period. The shocks to productivity play the important role in output variations. They explain about 30% of the variations throughout the period.

6 The role of financial sector in DSGE model

In contrast to the existing studies on the Japanese economy, such as Hirose and Kurozumi (2010) and Kaihatsu and Kurozumi (2010), our model introduce the banking sector and analyze the role of shocks hitting the sector in the Japanese business cycle. To see the implication of this novel setting, we compare our benchmark model with two alterative models. The alternative models are the BGG model and the Non-FA model. In the BGG model, entrepreneurs are credit constrained and banks are not constrained. In the Non-FA model, no credit market imperfection prevails in the economy. To illustrate the role that the shocks to the banks' net worth play, we estimate the BGG model and Non-FA model along with the benchmark model by a Bayesian method.

Natural way to evaluate the implication of the shocks to bank's net worth is to see how the historical decomposition of macro variables changes by the inclusion of credit-constrained banks and entrepreneurs. Early studies that abstract from the shocks associated with credit market imperfection report that bulk of economic variations is attributed to the shocks to the investment technology. For example, Hirose and Kurozumi (2010) estimate a DSGE model using Japanese data and demonstrate that investment fluctuations in Japan are mainly driven by shocks to investment adjustment costs. Chistensen and Dib (2008) also report that more than 90% of investment variations originate in the shocks to investment efficiency in the U.S. economy.

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 89% of the investment variations. When shocks originating in the credit market are incorporated, however, the contribution of the shocks to investment adjustment cost decrease. The estimated contribution of ε_t^I is 71% and 54%, respectively, in the BGG model and the benchmark model. On the other hand, under the two models, a significant portion of investment variation is attribute to the contributions of the shocks originating in the credit market, ε_t^{NE} and ε_t^{NF}. The contribution of ε_t^{NE} under the benchmark model is larger than under the BGG model. This is because the amplification and propagation mechanism are increased under the benchmark model.

7 Conclusion

The cause of prolonged Japanese recession has attracted many macroeconomists' attentions. In this paper, we decompose the macroeconomic variations during the slump into the financial shocks and non-financial shocks using the model developed in HSU (2010). The financial shocks consist of the shocks to the banks' and entrepreneurial net worth. A shortfall of the net worth affects credit contracts through the deterioration of balance sheets, and dampens the investment and output through the financial accelerator mechanism. The non-financial shocks include shocks to productivity and investment adjustment cost that directly affect the real side of economy.

Based on a Bayesian estimation methodology, we distill the financial shocks together with the non-financial shocks from the Japanese data. We find that the two financial shocks, banks' and entrepreneurial net wort shocks, are both important source of economic fluctuations during the lost decade. The adverse shocks to the banks' net worth continuously cause a disruption in financial system, causing a recessionary pressure on the economy throughout the entire 1990s. The adverse shocks to the entrepreneurial net worth result in weakening in economic activity particularly early 1990s. Quantitatively, during the 1990s, the shocks to the two net worth explain 43% of investment variation, 11% of output variation, and 34% of inflation variation.

In addition, our result sheds the light on the interpretation of the shocks to investment adjustment cost that are emphasized in the existing studies. We construct alternative two models that abstract from credit-constrained banks and/or credit-constrained entrepreneurs and estimate these models using the Japanese data. The comparison of the historical decomposition of investment shows that investment variation explained by the shocks to investment adjustment cost is reduced drastically by the inclusion of the credit market imperfection, suggesting that a portion of the shocks to investment adjustment cast may reflect the shocks hitting the financial system.

A Credit Contract

In this section, 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:

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

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

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

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

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 the investors.

There is a participation constraint in each of the credit contracts. In the FE contract, the entrepreneurs' expected return is set to equal to 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 to $R^E\left(s^{t+1}\right)N^E\left(s^t\right)$. Therefore the FE contract is agreed by the entrepreneurs only when the following inequality is expected to hold:

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

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

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 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:

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

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

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

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

Using equations (26) and (28), we obtain the 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**

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

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

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

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

with:

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

(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:

$$\Delta_{p}\left(s^{t}\right)=(1-\xi)\left(\frac{K_{p}\left(s^{t}\right)}{F_{p}\left(s^{t}\right)}\right)^{-\epsilon}+\xi\left(\frac{\pi\left(s^{t-1}\right)^{\gamma_{p}}}{\pi\left(s^{t}\right)}\right)^{-\epsilon}\Delta_{p}\left(s^{t-1}\right),$$
$$F_{p}\left(s^{t}\right)=1+\xi\beta\exp\left(e^{B\left(s^{t+1}\right)}\right)\frac{C\left(s^{t}\right)Y\left(s^{t+1}\right)}{C\left(s^{t+1}\right)Y\left(s^{t}\right)}\left(\frac{\pi\left(s^{t}\right)^{\gamma_{p}}}{\pi\left(s^{t+1}\right)}\right)^{1-\epsilon}F_{p}\left(s^{t+1}\right),$$
$$K_{p}\left(s^{t}\right)=\frac{\epsilon\left(s^{t}\right)}{\epsilon\left(s^{t}\right)-1}MC\left(s^{t}\right)+\xi\beta\exp\left(e^{B\left(s^{t+1}\right)}\right)\frac{C\left(s^{t}\right)Y\left(s^{t+1}\right)}{C\left(s^{t+1}\right)Y\left(s^{t}\right)}\left(\frac{\pi\left(s^{t}\right)^{\gamma_{p}}}{\pi\left(s^{t+1}\right)}\right)^{-\epsilon}K_{p}\left(s^{t+1}\right),$$

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

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

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

(3) **FIs' Problems**

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

$$
G^{F}\left(\overline{\omega}_{t}^{F}\right)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\frac{\log\overline{\omega}_{t}^{F}-0.5\sigma_{F}^{2}}{\sigma_{F}}}\exp\left(-\frac{v_{F}^{2}}{2}\right)dv_{F}, \tag{38}
$$

$$
G^{E}\left(\overline{\omega}_{t}^{E}\right)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\frac{\log\overline{\omega}_{t}^{E}-0.5\sigma_{E}^{2}}{\sigma_{E}}}\exp\left(-\frac{v_{E}^{2}}{2}\right)dv_{E}, \tag{39}
$$

$$
G'^{F}\left(\overline{\omega}_{t}^{F}\right)=\left(\frac{1}{\sqrt{2\pi}}\right)\left(\frac{1}{\overline{\omega}_{t}^{F}\sigma_{F}}\right)\exp\left(-.5\left(\frac{\log\overline{\omega}_{t}^{F}-0.5\sigma_{F}^{2}}{\sigma_{F}}\right)^{2}\right), \tag{40}
$$

$$
G'^{E}\left(\overline{\omega}_{t}^{E}\right)=\left(\frac{1}{\sqrt{2\pi}}\right)\left(\frac{1}{\overline{\omega}_{t}^{E}\sigma_{E}}\right)\exp\left(-.5\left(\frac{\log\overline{\omega}_{t}^{E}-0.5\sigma_{E}^{2}}{\sigma_{E}}\right)^{2}\right), \tag{41}
$$

$$\Gamma^F\left(\overline{\omega}_t^F\right) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\frac{\log \overline{\omega}_t^F - 0.5\sigma_F^2}{\sigma_F}} \exp\left(-\frac{v_F^2}{2}\right) dv_F + \frac{\overline{\omega}_t^F}{\sqrt{2\pi}} \int_{\frac{\log \overline{\omega}_t^F + 0.5\sigma_F^2}{\sigma_F}}^{\infty} \exp\left(-\frac{v_F^2}{2}\right) dv_F, \quad (42)$$

$$\Gamma^E\left(\overline{\omega}_t^E\right) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\frac{\log \overline{\omega}_t^E - 0.5\sigma_E^2}{\sigma_E}} \exp\left(-\frac{x^2}{2}\right) dx + \frac{\overline{\omega}_t^E}{\sqrt{2\pi}} \int_{\frac{\log \overline{\omega}_t^E + 0.5\sigma_E^2}{\sigma_E}}^{\infty} \exp\left(-\frac{v_E^2}{2}\right) dv_E, \quad (43)$$

$$\begin{aligned}
\Gamma'^F\left(\overline{\omega}_t^F\right) &= \frac{1}{\sqrt{2\pi}\overline{\omega}_t^F \sigma_F} \exp\left(-.5\left(\frac{\log \overline{\omega}_t^F - 0.5\sigma_F^2}{\sigma_F}\right)^2\right) dx \\
&+ \frac{1}{\sqrt{2\pi}} \int_{\frac{\log \overline{\omega}_t^F + 0.5\sigma_F^2}{\sigma_F}}^{\infty} \exp\left(-\frac{v_F^2}{2}\right) dv_F \\
&- \frac{1}{\sqrt{2\pi}\sigma_F} \exp\left(-\frac{\left(\frac{\log \overline{\omega}_t^F + 0.5\sigma_F^2}{\sigma_F}\right)^2}{2}\right) dx, \qquad (44)
\end{aligned}$$

$$\begin{aligned}
\Gamma'^E\left(\overline{\omega}_t^E\right) &= \frac{1}{\sqrt{2\pi}\overline{\omega}_t^E \sigma_E} \exp\left(-.5\left(\frac{\log \overline{\omega}_t^E - 0.5\sigma_E^2}{\sigma_E}\right)^2\right) dx \\
&+ \frac{1}{\sqrt{2\pi}} \int_{\frac{\log \overline{\omega}_t^E + 0.5\sigma_E^2}{\sigma_E}}^{\infty} \exp\left(-\frac{v_E^2}{2}\right) dv_E \\
&- \frac{1}{\sqrt{2\pi}\sigma_E} \exp\left(-.5\left(\frac{\log \overline{\omega}_t^E + 0.5\sigma_E^2}{\sigma_E}\right)^2\right) dx, \qquad (45)
\end{aligned}$$

$$\left[\Gamma^E\left(\overline{\omega}^E\left(s^{t+1}|s^t\right)\right) - \mu^E G^E\left(\overline{\omega}^E\left(s^{t+1}|s^t\right)\right)\right] R^E\left(s^{t+1}|s^t\right) Q\left(s^t\right) K\left(s^t\right)$$

$$= R_t^F\left(s^{t+1}|s^t\right)\left(Q\left(s^t\right) K\left(s^t\right) - N^E\left(s^t\right)\right). \qquad (46)$$

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

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

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

$$N^{E}\left(s^{t+1}\right)=\gamma^{E}V^{E}\left(s^{t}\right)+W^{E}\left(s^{t}\right), \tag{49}$$

with:

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

(5) **Policies and Shock Process**

Policies for the shock process are given by equations (15), (16), (19), (20), (21), (22) and (23).

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 (15), (16), (19), (20), (21), (22), (23), (30), (31), (32), (34), (35), (36), (37), and (47), and the following equations instead of equations (33) and (36) under the benchmark model, respectively:

$$Y\left(s^t\right) = C\left(s^t\right) + I\left(s^t\right) + G\left(s^t\right)\exp\left(e^G(s^t)\right), \tag{50}$$

$$R\left(s^t\right) = \mathrm{E}_t \frac{\alpha Y\left(s^t\right)/K\left(s^t\right) + Q\left(s^{t+1}\right)(1-\delta)}{Q\left(s^t\right)}. \tag{51}$$

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), (15), (16), (19), (20), (21), (22), (23), (30), (31), (32), (34), (35), (36), (37), (39), (41), (43), (45) and (47), and the following three equations instead of equations (29), (33) and (36) under the benchmark model, respectively:

$$\begin{aligned} 0 = & \sum_{s^{t+1}|s^t} \Pi\left(s^{t+1}|s^t\right)\left(1-\Gamma^E\left(\overline{\omega}^E\left(s^{t+1}|s^t\right)\right)\right) R^E\left(s^{t+1}|s^t\right) \\ & + \frac{\Gamma'^E\left(\overline{\omega}^F\left(s^{t+1}|s^t\right)\right)}{\Phi'^E\left(s^{t+1}|s^t\right)} \Phi^E\left(s^{t+1}|s^t\right) R^E_{t+1}\left(s^{t+1}|s^t\right) - \frac{\Gamma'^E\left(\overline{\omega}^E\left(s^{t+1}|s^t\right)\right)}{\Phi'^E\left(s^{t+1}|s^t\right)} \Phi^E\left(s^{t+1}|s^t\right) R(s_t), \end{aligned} \tag{52}$$

$$\begin{aligned} Y\left(s^t\right) = & \, C\left(s^t\right) + I\left(s^t\right) + G\left(s^t\right)\exp\left(e^G(s^t)\right) \\ & + \mu^E G^E\left(\overline{\omega}^E\left(s^t\right)\right) R^E\left(s^t\right) Q\left(s^{t-1}\right) K\left(s^{t-1}\right) + C^E\left(s^t\right), \end{aligned} \tag{53}$$

with:

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

$$\left[\Gamma^E\left(\overline{\omega}^E\left(s^{t+1}|s^t\right)\right)-\mu^E G^E\left(\overline{\omega}^E\left(s^{t+1}|s^t\right)\right)\right]R^E\left(s^{t+1}|s^t\right)Q\left(s^t\right)K\left(s^t\right)$$

$$=R_t\left(s^{t+1}|s^t\right)\left(Q\left(s^t\right)K\left(s^t\right)-N^E\left(s^t\right)\right). \tag{54}$$

References

[1] Aikman, D. and M. Paustian (2006). “Bank Capital, Asset Prices and Monetary Policy,” Bank of England Working Papers 305, Bank of England.

[2] Anari A., J. Kolari and J. Mason (2005). “Bank Asset Liquidation and the Propagation of the U.S. Great Depression.” Journal of Money, Credit, and Banking, Vol. 37, No. 4, pp. 753-773.

[3] Ashcraft, A. B. (2005). “Are Banks Really Special? New Evidence from the FDIC-Induced Failure of Healthy Banks,” American Economic Review, Vol. 95 No. 5, pp. 1712–1730.

[4] Baba, Naohiko, Shinichi Nishioka, Nobuyuki Oda, Masaaki Shirakawa, Kazuo Ueda, and Hiroshi Ugai (2005), “Japan’s Deflation, Problems in the Financial System and Monetary Policy,” Monetary and Economic Studies, Bank of Japan.

[5] Bayoumi, T. (1999), “The Morning After: Explaining the Slowdown in Japanese Growth in the 1990s,” Journal of International Economics; 53, April 2001, 241-59.

[6] Bernanke, B. S., M. Gertler and S. Gilchrist (1999). “The Financial Accelerator in a Quantitative Business Cycle Framework,” in Handbook of Macroeconomics, J. B. Taylor and M. Woodford (eds.), Vol. 1, chapter 21, pp. 1341–1393.

[7] Braun, R. A., and E. Shioji. (2007). “Investment Specific Technological Changes in Japan,” Seoul Journal of Economics, 20, 165–99.

[8] Caballero, R., T. Hoshi, and A. Kashyap (2008). “Zombie lending and depressed restructuring in Japan.” American Economic Review 98, pp. 1943–1977.

[9] Calomiris, C. W., and J. R. Mason (2003). “Consequences of Bank Distress during the Great Depression,” American Economic Review, Vol. 93, pp. 937–947.

[10] Calvo, G.A. (1983). “Staggered prices in a utility-maximizing framework,” Journal of Monetary Economics 12, 383–398.

[11] Chen, N. K. (2001). "Bank Net Worth, Asset Prices and Economic Activity," Journal of Monetary Economics, Vol. 48, No. 2, pp.415–436.

[12] Christensen, I. and A. Dib (2008). "The Financial Accelerator in an Estimated New Keynesian Model." Review of Economic Dynamics. Vol. 11, No. 1, pp. 155–178.

[13] Christiano, L., R. Motto, and M. Rostagno (2003). "The great depression and the Friedman–Schwartz hypothesis," Journal of Money, Credit and Banking 35 (6,2), 1119–1198.

[14] Christiano, L., R. Motto, and M. Rostagno (2007). "Financial factors in business cycles," Manuscript

[15] Christiano, L., R. Motto, and M. Rostagno (2008). "Shocks, structures or monetary policies? The Euro Area and US after 2001," Journal of Economic Dynamics and Control, Vol. 32, pp. 2476-2506.

[16] De Graeve, F. (2008). "The external finance premium and the macroeconomy: US post-WWII evidence," Journal of Economic Dynamics and Control, Vol. 32, pp.3415–3440.

[17] Fukao, M., (2003), "Financial sector profitability and double gearing," in Structural Impediments to Growth in Japan, Magnus Blomstrom, Jenny Corbett, Fumio Hayashi, and Anil Kashyap (eds.), Chicago: University of Chicago Press.

[18] Gilchrist, S. and J. V. Leahy (2002). "Monetary Policy and Asset Prices," Journal of Monetary Economics, Vol. 49, No. 1, pp. 75–97.

[19] Gilchrist, S., V. Yankov, and E. Zakrajsek (2009). Credit Risks and the Macroeconomy: Evidence from an Estimated DSGE Model. Unpublished. manuscript, Boston University and Federal Reserve Board.

[20] Hayashi F., and E. C. Prescott (2002) "The 1990s in Japan: A Lost Decade," Review of Economic Dynamics, vol. 5(1), pages 206-235.

[21] Hirakata, N., N. Sudo and K. Ueda (2009a). "Chained Credit Contracts and Financial Accelerators," IMES Discussion Paper 2009-E-30, Institute for Monetary and Economic Studies, Bank of Japan;

[22] Hirakata, N., N. Sudo and K. Ueda (2009b). "Capital Injection, Monetary Policy and Financial Accelerators," Draft, Bank of Japan.

[23] Hirakata, N., N. Sudo and K. Ueda (2010). "Do Banking Shocks Matter for the U.S. Economy?," IMES Discussion Paper 2010-E-13, Institute for Monetary and Economic Studies, Bank of Japan.

[24] Hirose, Y., and T. Kurozumi (2010). "Do Investment-Specific Technological Changes Matter for Business Fluctuations? Evidence from Japan," Bank of Japan Working Paper Series, Bank of Japan.

[25] Holmstrom, B. and J. Tirole (1997). "Financial Intermediation, Loanable Funds, and the Real Sector," Quarterly Journal of Economics, Vol. 112, No. 3, pp. 663–691.

[26] Hoshi, T. and A. K. Kashyap (2004). "Japan's Financial Crisis and Economic Stagnation" Journal of Economic Perspectives, 18(1), 2004, pp. 3-26.

[27] Hoshi, T. and A. K. Kashyap (2010). "Will the U.S. bank recapitalization succeed? Eight lessons from Japan" JournalofFinancialEconomics, forthcoming.

[28] Hoshi, T., A. Kashyap and D. Scharfstein (1991) "Corporate Structure, Liquidity and Investment: Evidence from Japanese Industrial Groups," Quarterly Journal of Economics, 1991, vol. 106, pp 33-60.

[29] Ireland, Peter N (2003). "Endogenous money or sticky prices?," Journal of Monetary Economics, Elsevier, vol. 50(8), pages 1623-1648, November.

[30] Jermann U. and V. Quadrini (2009). "Macroeconomic Effects of Financial Shocks," NBER Working Papers 15338, National Bureau of Economic Research, Inc.

[31] Jermann U. and V. Quadrini (2009). "Macroeconomic Effects of Financial Shocks," NBER Working Papers 15338, National Bureau of Economic Research, Inc.

[32] Kashyap, A., “Sorting Out Japan’s Financial Crisis,” Federal Reserve Bank of Chicago Economic Perspectives, 4th Quarter 2002, pp. 42-55.

[33] Kaihatsu S. and T. Kurozumi (2010). “Source of Business Fluctuations, Financial or Technology Shock?,” mimeo, Bank of Japan.

[34] Kwon, E. (1998), “Monetary Policy, Land Prices, and Collateral Effects on Economic Fluctuations: Evidence from Japan,” Jour. of Japanese and International Economies, 12, 175-203.

[35] Meh C., and K. Moran (2004). “Bank Capital, Agency Costs, and Monetary Policy,” Working Papers 04-6, Bank of Canada.

[36] Meier, A. and G. J. Muller (2006). “Fleshing out the Monetary Transmission Mechanism: Output Composition and the Role of Financial Frictions.” Journal of Money, Credit, Banking Vol. 38, pp. 1999–2133.

[37] Nolan, C. and C. Thoenissen (2009). “Financial Shocks and the US Business Cycle,” Journal of Monetary Economics, Vol. 56, No. 4, pp. 596–604.

[38] Peek, J. and E. S. Rosengren (1997). “The International Transmission of Financial Shocks: Case of Japan,” American Economic Review, Vol. 87, No. 4, pp. 625–638.

[39] Peek, J. and E. S. Rosengren (2000). “Collateral Damage: Effects of the Japanese Bank Crisis on Real Activity in the United States,” American Economic Review, Vol. 97, No. 3, pp. 30–45.

[40] Smets, F and R. Wouters (2005). “Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach,” American Economic Review, Vol. 90, No. 1, pp. 586–606.

[41] Sugo, T. and K. Ueda (2008). “Estimating a dynamic stochastic general equilibrium model for Japan,” Journal of the Japanese and International Economies, Elsevier, vol. 22(4), pages 476-502, December.

Table 1A: Parameters[16]

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 Government Expenditure at Steady State

Table 1B: Calibrated Parameters[17]

Parameter	Value	Description
σ_F	0.107366	S.E. of FIs' Idiosyncratic Productivity at Steady State
σ_E	0.312687	S.E. of Entrepreneurial Idiosyncratic Productivity at Steady State
μ_F	0.033046	Bankruptcy Cost associated with FIs
μ_E	0.013123	Bankruptcy Cost associated with entrepreneurs
γ_F	0.963286	Survival Rate of FIs
γ_E	0.983840	Survival Rate of Entrepreneurs

Table 1C: 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 $.006^{.25}$.
$F\left(\overline{\omega}^F\right) = .02$	Default probability in the IF contract is .02.
$F\left(\overline{\omega}^E\right) = .02$	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.

Table 2: Parameter Estimates

	Prior distribution			Posterior distribution		
	Distr.	Mean	St. Dev.	Mean	5%	95%
ξ_p	Beta	0.5	0.15	0.5269	0.4452	0.6033
κ	Normal	4	1.5	7.3146	5.3142	9.3830
γ_p	Beta	0.5	0.2	0.1448	0.0128	0.2683
θ	Beta	0.75	0.1	0.7710	0.7209	0.8173
ϕ_π	Gamma	1.5	0.125	1.4784	1.3240	1.6293
ϕ_y	Gamma	0.125	0.05	0.0223	0.0087	0.0351
ρ_B	Beta	0.5	0.2	0.8560	0.8037	0.9071
ρ_I	Beta	0.5	0.2	0.6001	0.4668	0.7314
ρ_A	Beta	0.5	0.2	0.8927	0.8276	0.9604
ρ_G	Beta	0.5	0.2	0.8131	0.7124	0.9138
ρ_R	Beta	0.5	0.2	0.1213	0.0310	0.2061
ρ_P	Beta	0.5	0.2	0.8790	0.8029	0.9556
$\sigma(\epsilon_B)$	Inv. Gamma	0.01	2	0.0028	0.0019	0.0037
$\sigma(\epsilon_I)$	Inv. Gamma	0.01	2	0.0206	0.0157	0.0254
$\sigma(\epsilon_G)$	Inv. Gamma	0.01	2	0.0068	0.0059	0.0077
$\sigma(\epsilon_A)$	Inv. Gamma	0.01	2	0.0099	0.0086	0.0113
$\sigma(\epsilon_R)$	Inv. Gamma	0.01	2	0.0020	0.0016	0.0023
$\sigma(\epsilon_{N_F})$	Inv. Gamma	0.01	2	0.0522	0.0449	0.0588
$\sigma(\epsilon_{N_E})$	Inv. Gamma	0.01	2	0.2728	0.2361	0.3080
$\sigma(\epsilon_P)$	Inv. Gamma	0.01	2	0.0716	0.0581	0.0861
Log likelihood	1622.0					

Table 3a: Correlation with Alternative Indicators

	spread of interest rate on contracted short-term loan rate	spread of interest rate on new short-term loan rate
$Z^E - R(+4)$	0.563	0.342
$Z^E - R(+3)$	0.564	0.332
$Z^E - R(+2)$	0.575	0.363
$Z^E - R(+1)$	0.600	0.372
$Z^E - R(0)$	0.651	0.448
$Z^E - R(-1)$	0.703	0.546
$Z^E - R(-2)$	0.730	0.635
$Z^E - R(-3)$	0.743	0.678
$Z^E - R(-4)$	0.742	0.720

Table 3b: Correlation with Alternative Indicators

	DI for Financial Position	DI for Lending Attitude of FIs
$Z^E - R(+4)$	0.573	0.704
$Z^E - R(+3)$	0.617	0.712
$Z^E - R(+2)$	0.655	0.726
$Z^E - R(+1)$	0.689	0.734
$Z^E - R(0)$	0.718	0.725
$Z^E - R(-1)$	0.757	0.729
$Z^E - R(-2)$	0.772	0.712
$Z^E - R(-3)$	0.759	0.665
$Z^E - R(-4)$	0.728	0.607

Table 3c: Correlation with Alternative Indicators

	DI for spreads of loan rates high ratings	DI for spreads of loan rates medium ratings	DI for spreads of loan rates low ratings
$Z^E - R(+4)$	0.136	0.473	0.613
$Z^E - R(+3)$	0.256	0.558	0.704
$Z^E - R(+2)$	0.367	0.632	0.782
$Z^E - R(+1)$	0.393	0.690	0.852
$Z^E - R(0)$	0.465	0.753	0.873
$Z^E - R(-1)$	0.464	0.731	0.893
$Z^E - R(-2)$	0.422	0.713	0.895
$Z^E - R(-3)$	0.358	0.687	0.881
$Z^E - R(-4)$	0.309	0.587	0.817

Table 4: Variance decompositions

	ε^A	ε^B	ε^G	ε^I	ε^{N^F}	ε^{N^E}	ε^P	ε^R
Investment	0.037	0.015	0.000	0.535	0.052	0.333	0.026	0.002
GDP	0.277	0.106	0.191	0.220	0.015	0.074	0.080	0.038
Inflation	0.172	0.269	0.015	0.116	0.065	0.188	0.044	0.132
During 1990-1999								
Investment	0.026	0.018	0.000	0.500	0.058	0.374	0.021	0.002
GDP	0.276	0.106	0.171	0.227	0.027	0.086	0.072	0.036
Inflation	0.148	0.208	0.011	0.127	0.115	0.223	0.031	0.137
During 1995-1999								
Investment	0.047	0.012	0.000	0.431	0.123	0.350	0.035	0.002
GDP	0.313	0.095	0.263	0.137	0.043	0.034	0.075	0.039
Inflation	0.192	0.187	0.014	0.078	0.215	0.117	0.033	0.164

Table 5: Variance Decomposition of Investment under Different Models

	ε^A	ε^B	ε^G	ε^I	ε^{N^F}	ε^{N^E}	ε^P	ε^R
Benchmark: Chained BGG	0.037	0.015	0.000	0.535	0.052	0.333	0.026	0.002
BGG	0.054	0.018	0.001	0.706	0.000	0.171	0.049	0.000
noBGG	0.060	0.021	0.000	0.892	0.000	0.000	0.026	0.001

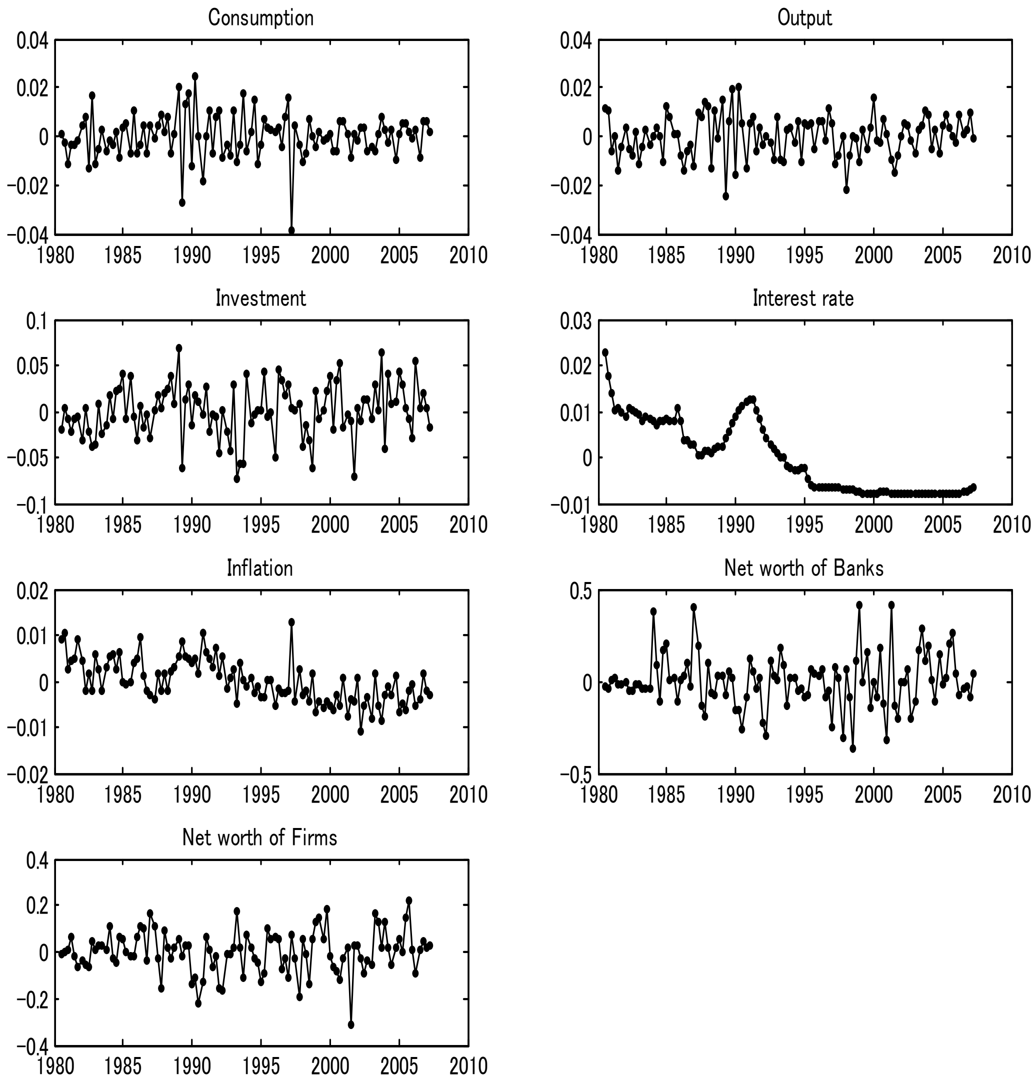
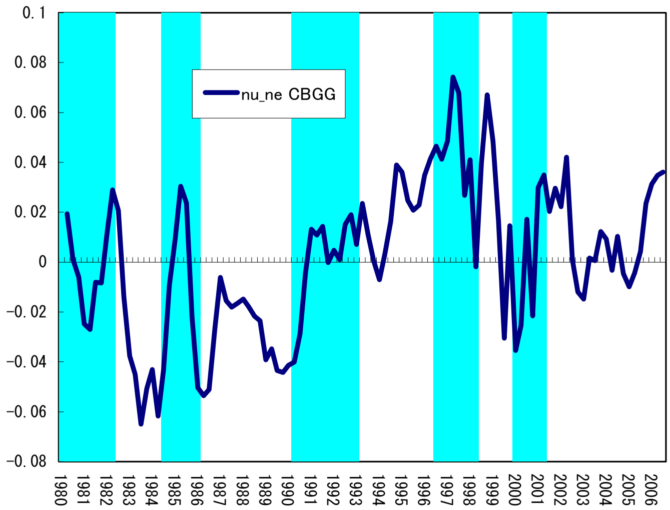


Figure 1: The time paths of macroeconomic variables used for estimating the model.



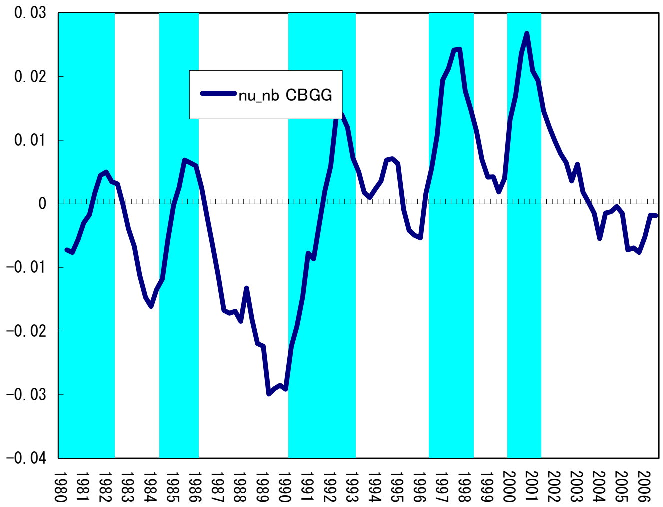


Figure 2: Time paths of the identified shocks to the banks' net worth (upper panel) and entrepreneurial net worth (lower panel). Shaded area are period of the recession.

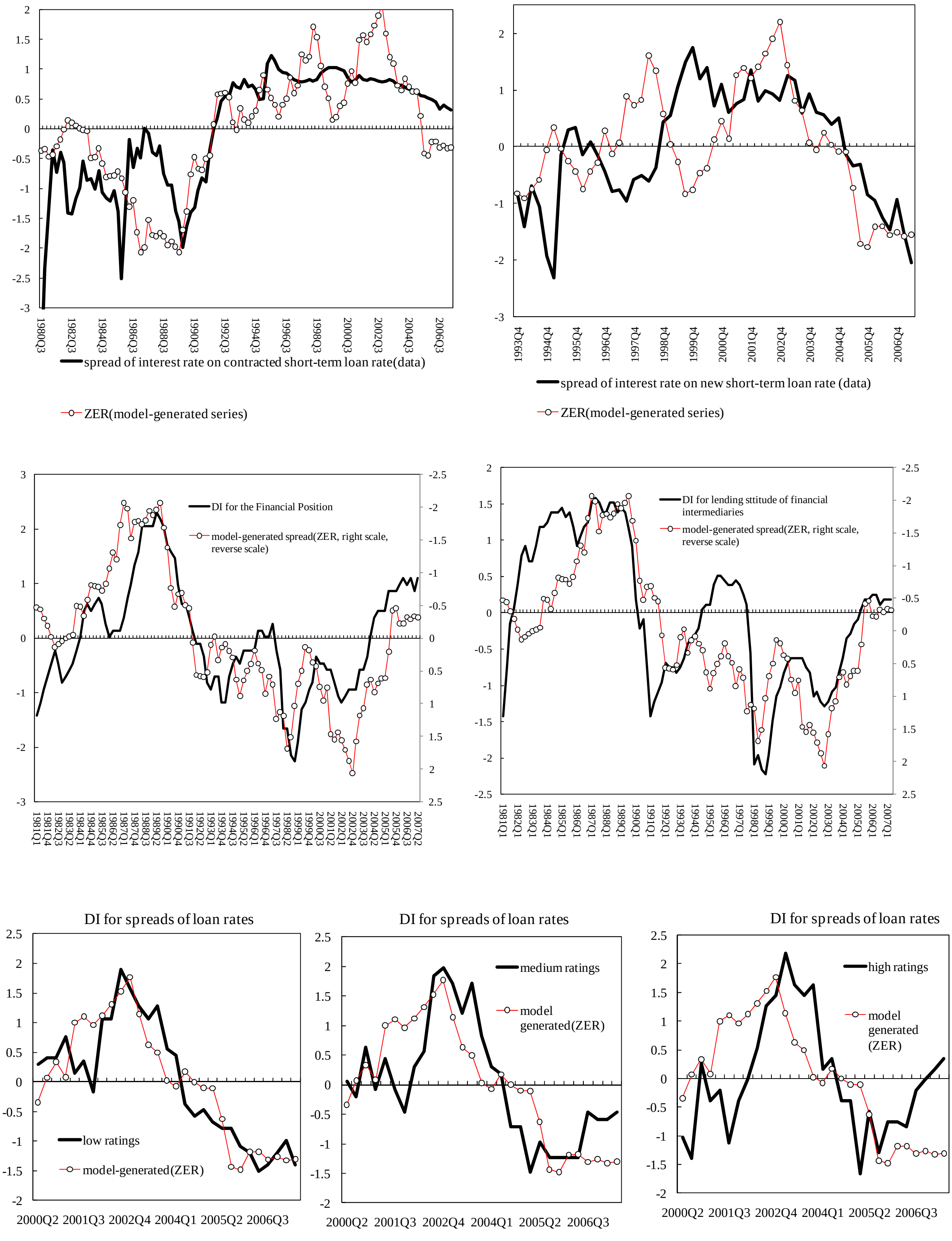


Figure 3: Time path of model-generated entrepreneurial borrowing spread $(Z^E - R)$ and time path of proxies for the entrepreneurial borrowing spread.

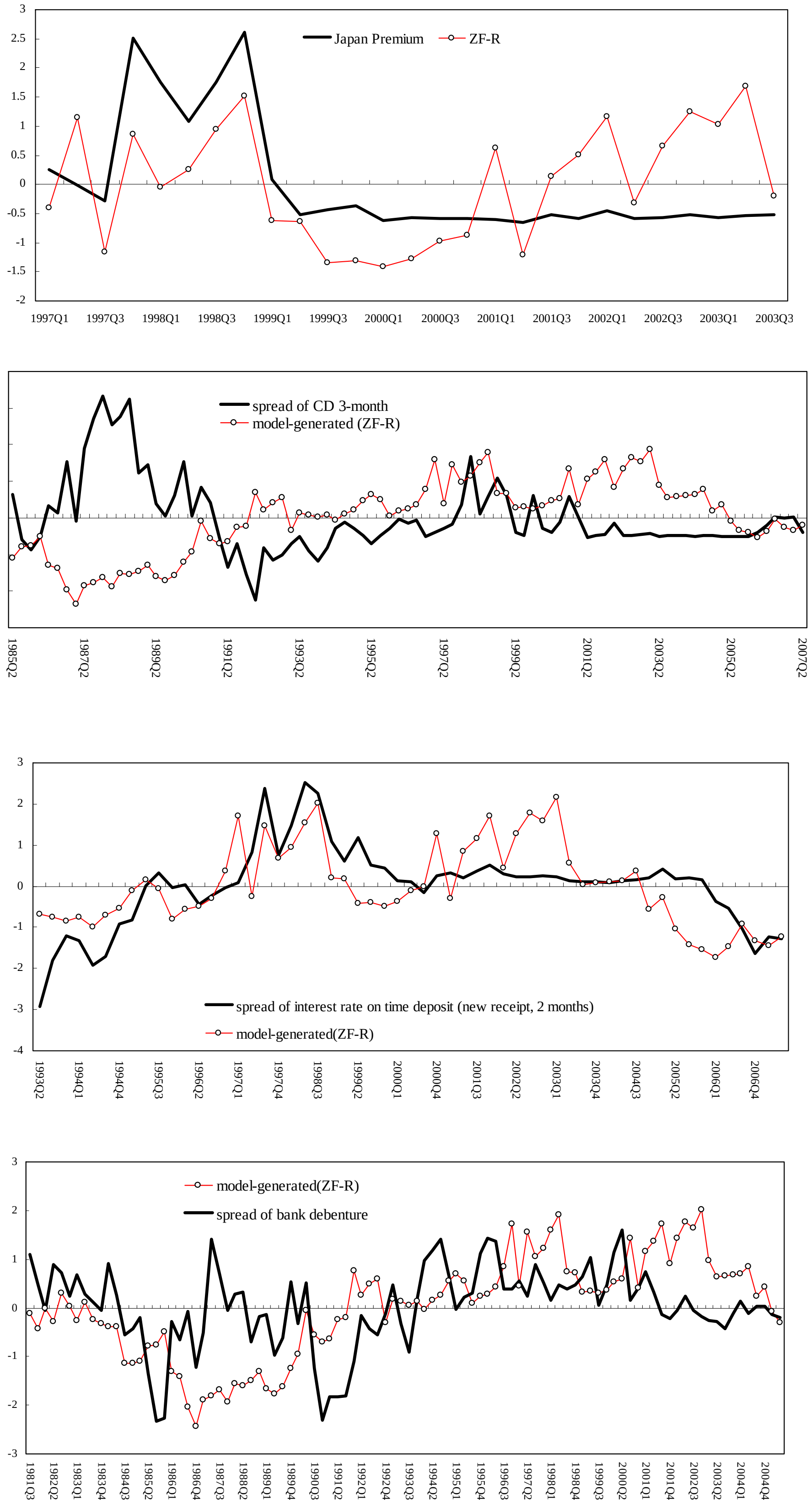


Figure 4: Time path of model-generated FIs borrowing spread $(Z^F - R)$ and time path of proxies for the FIs borrowing spread.

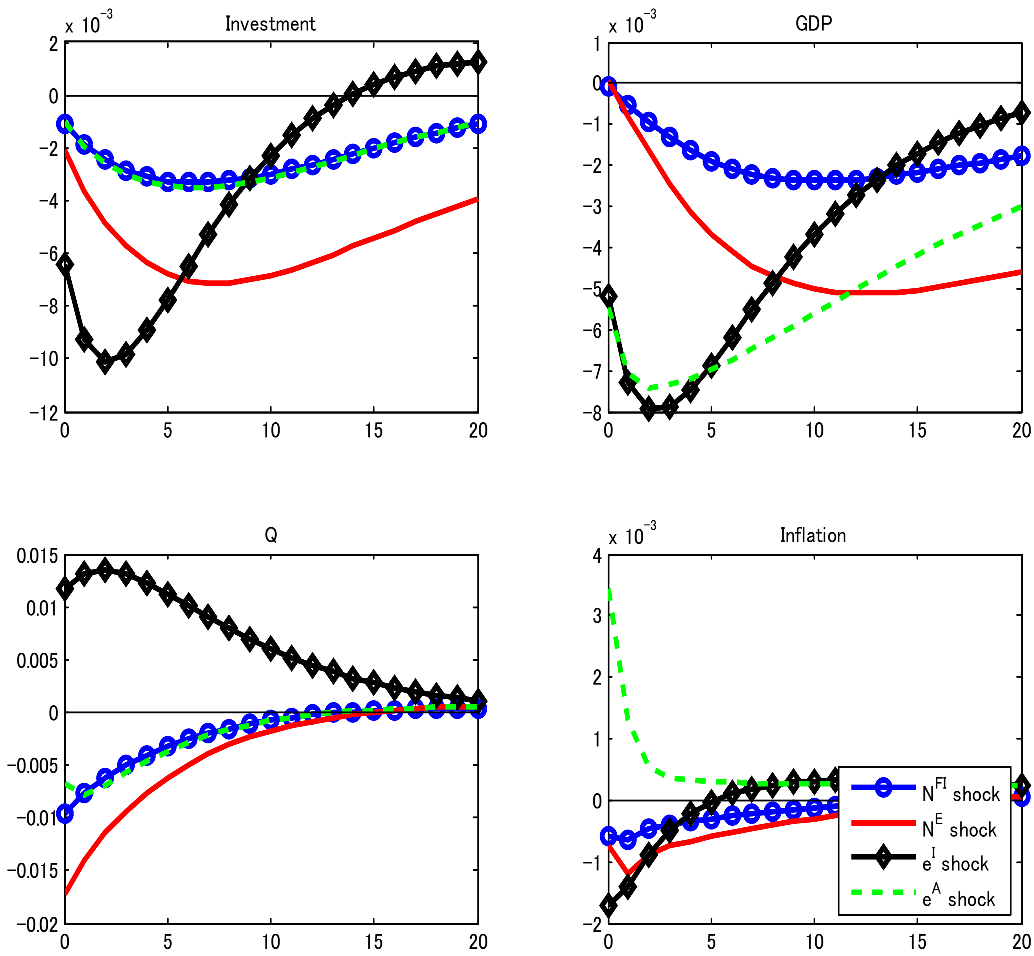


Figure 5: Impulse responses of the macroeconomic variables to the unexpected disruption of bank's net worth and entrepreneurial net worth, the unexpected increase in investment adjustment cost, and the unexpected decline of technology.

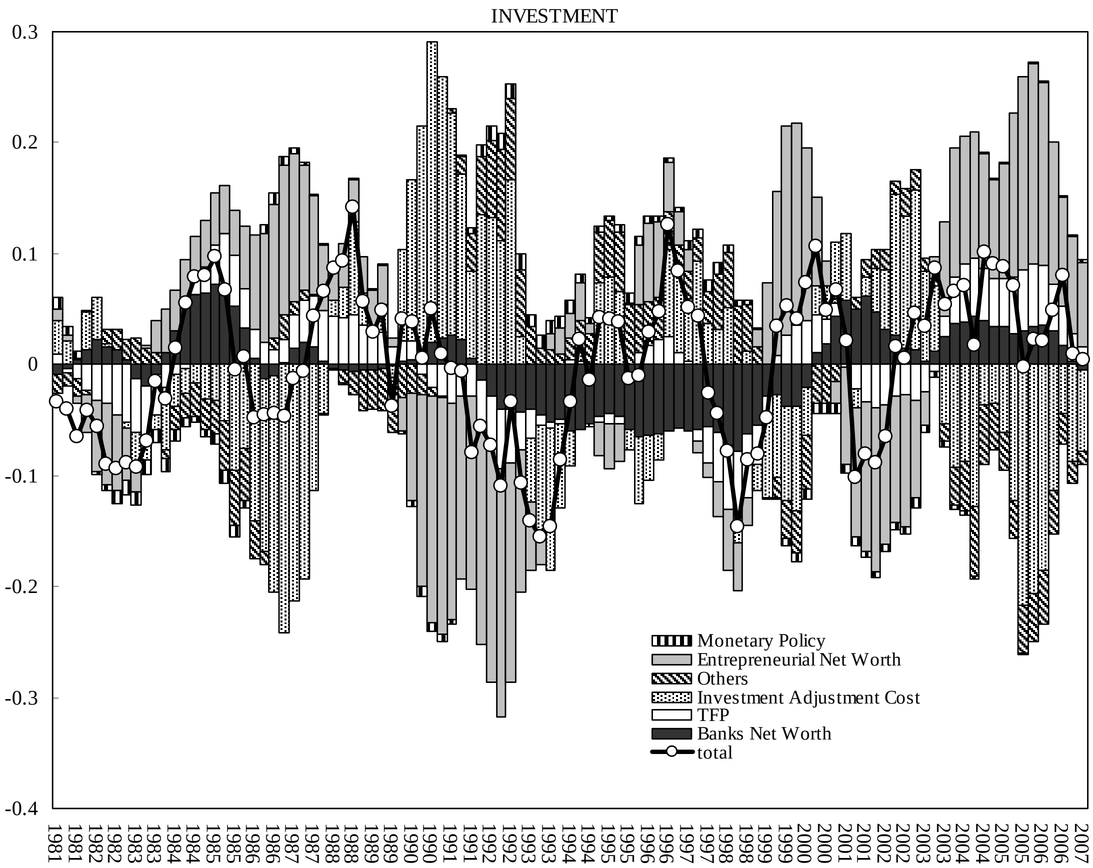


Figure 6: Historical contribution of each structural shocks in investment variations.

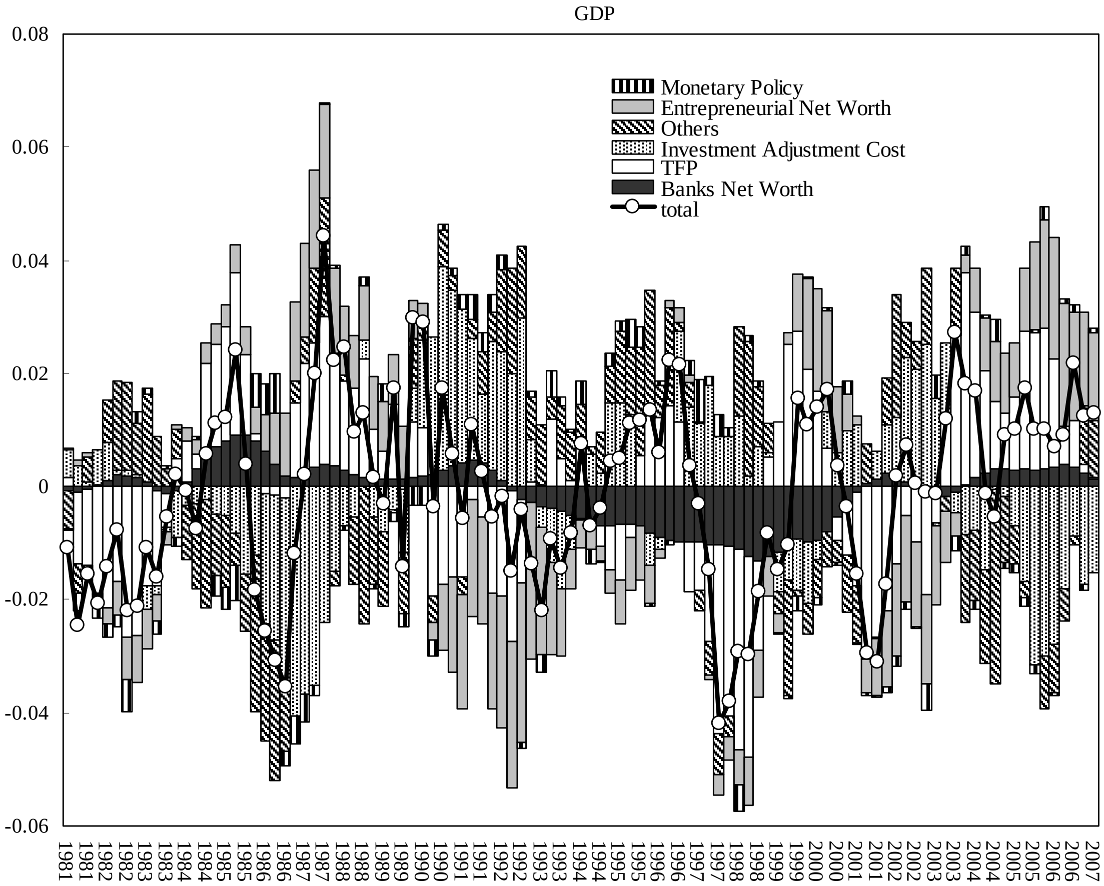


Figure 7: Historical contribution of each structural shocks in output variations.

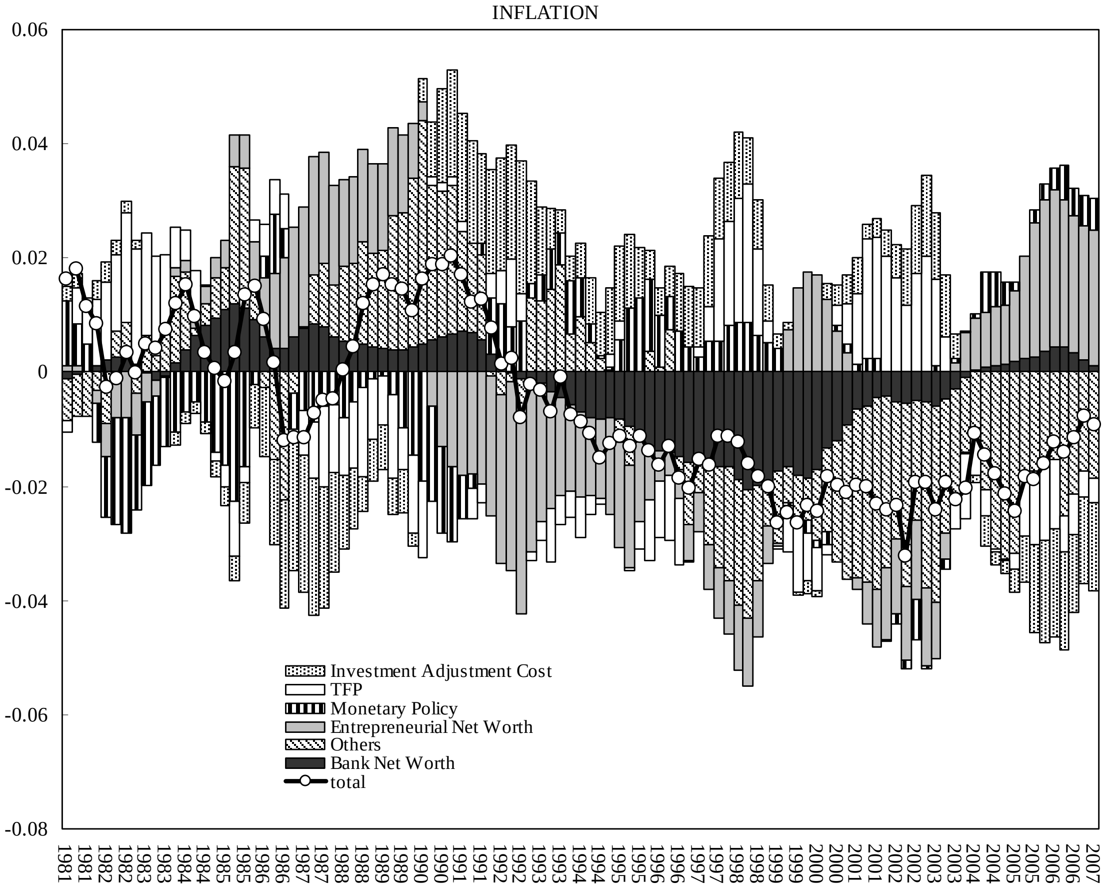


Figure 8: Historical contribution of each structural shocks in inflation variations.