Capital Injection, Monetary Policy, and Financial Accelerators

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Abstract

In this paper, we propose a framework to study the role of monetary policy and capital injection policy to mitigate financial crises. To this end, we extend the model developed by Hirakata, Sudo and Ueda (2009a) into a sticky price model with a central bank that operates monetary policy and a government that operates capital injection. Our model incorporates credit constrained financial intermediaries as well as entrepreneurs. Because of the credit market imperfection, adverse shocks hitting these sectors are propagated and amplified through a decrease in net worth and a rise in credit spreads. Using this model calibrated to the US economy, we first evaluate how alternative monetary policy rules targeting credit spreads would mitigate the impact of the adverse shocks. Next, we study the consequence of governmental capital injection to the financial intermediaries' net worth and to the entrepreneurial net worth. We find that welfare implications of these policies depend on the source and the type of the adverse shocks.

Keywords: Monetary Policy; Financial Accelerators; Market Spreads; Capital Injection

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1 Introduction

Following the financial turmoil that began in the summer of 2007, the U.S. and the world have been experiencing the one of the largest economic downturns in the post-war period. The importance of focusing on the financial intermediaries (hereafter FIs) in macroeconomic analyses is stressed among many macroeconomists, since they are considered to be playing an important role in the causes and outcomes of the crisis. Coherently, various conventional and unconventional policies have been undertaken to recover the malfunctioned financial market and financial system.

During the crisis, the collapse of financial intermediation mechanism of the credit market can be seen by a rise in the borrowing rates to the FIs (Taylor and Williams, 2008; Chari, Christiano and Kehoe, 2008). The upper panel of Figure 1 displays the historical movements of two spreads: (i) prime lending rate−TB3M and (ii) CD3M−TB3M. The first spread is a difference between FIs' lending rate and riskless rate that indicates the borrowing cost for the entrepreneurs, and the second spread is a difference FIs' borrowing rate and riskless rate that indicates the borrowing cost for the FIs. Since the year 2007, the two spreads have widened drastically, suggesting that the borrowing costs for both nonfinancial institutions and FIs have risen. To see the spreads in more detail, we decompose the first spread into the two spreads, prime lending rate−CD3M (hereafter FIs' loan spread) and CD3M−TB3M (hereafter FI's borrowing spread). The lower panel of Figure 1 displays these two spreads. The two series do not move in the same direction. Especially in the latest subsamples, FI's borrowing spread is quite high, while FIs' loan spread drops sharply. This observation is consistent with the view that attributes the cause of the current crisis to the FI sector, rather than to the entrepreneurial sector. The consequences of the failures in FIs on the macroeconomy are discussed in several studies, such as Holmstrom and Tirole (1997), Ashcraft (2005), and Mason (2003), Peek and Rosengren (1997, 2000) and Anari, Kolari and Mason (2005).[1]

To mitigate the consequence of the financial crisis, several unconventional policies are proposed from the policy makers as well as from the academics. One important proposal is a spread-adjusted Taylor rule (e.g., Taylor, 2008; and Curdia and Woodford, 2008). According to Curdia and Woodford (2008), this is a monetary policy rule that lowers the intercept of the standard Taylor rule responding to the rise in the credit spread between the interest received by savers and that paid by borrower in the economy. When a central bank adopts the spread-adjusted Taylor rule, the rise in the spread is met by a cut in the nominal interest rate.

One other unconventional policy is direct capital injection by the government to the borrowing sectors. In fact, as Figure 2 shows, during the financial crisis from 2007 to 2009, governments in several OECD countries, including the U.S. and Europe, have injected public capital to FIs. Capital injection increases the net worth of the FIs, and

[1] Hirakata, Sudo and Ueda (2009b, c) also report that banks' lending are more affected by an innovation in banks's net worth than by a monetary policy shock.

it is expected that they will increase their lending to the firms. These initiatives by the government are consistent with the findings of the existing literature that focuses on FIs' capital (e.g., Chen 2001; Aikman and Paustian 2006; Meh and Moran 2004, 2008; Gerali et al. 2008; Van den Heuvel 2008; Dib 2009; Gertler and Karadi 2009).[2] They show in the dynamic general equilibrium framework that a change in FIs' capital causes a large economic fluctuation through the credit market imperfection. However, these literature does not explain the surge in spreads.

In this paper, we conduct quantitative evaluations of these two proposals in a unified theoretical framework. We study how the spread-adjusted Taylor rules and the governmental capital injection policies mitigate the impact of the financial crisis, using the micro-founded model. In the model, FIs are capital constrained and there are more than one spread: FIs' loan spread and FI's borrowing spread. We clarify the interdependence between FIs and the rest of the economy. We simulate the response of two spreads when several types of shocks hit the economy, and their impacts on the macroeconomy. Using the model, we aim to find the appropriate monetary and capital injection policy in response to the financial crisis. As monetary policy, we consider several types of spread-adjusted Taylor rules, and compare with the Ramsey rule. Regarding spread-adjusted Taylor rules, we look at policies that react to FI's loan spread, FI's borrowing spread and the sum of the two spreads. Regarding capital injection policy, we consider a governmental transfer from a household to either FIs' net worth or entrepreneurs' net worth.

To this end, we choose the framework developed by Hirakata, Sudo and Ueda (2009a, hereafter HSU). The HSU model is built upon the financial accelerator model by Bernanke, Gertler and Gilchrist (1999, hereafter BGG) and Christiano, Motto and Rostagno (2004, hereafter CMR). In BGG and CMR, however, only entrepreneurs are credit constrained. FIs are treated as a veil. In HSU, both FIs and entrepreneurs are credit constrained, and the agency problems arises when FIs raise the fund from the ultimate lender of the fund as well as when FIs lend the fund to the entrepreneurs. Such chained credit contracts magnify the effect of the financial accelerator mechanism, reflecting the endogenous developments of the credit conditions of the FIs and the entrepreneurs. The advantage of using HSU for the current analysis is that it explicitly specifies the key financial variables, FIs' net worth, the entrepreneurial net worth, the FIs' borrowing rate and the FIs' loan rate in the model, and gives the theoretical framework for the relationships of these

[2] Van den Heuvel (2008) incorporates regulatory requirements for FIs' capital. Gerali et al. (2008) and Dib (2009) discuss monopolistically competitive banks in deposit and loan markets. Gertler and Karadi (2009) consturct a model in which depositors can force FIs into bankruptcy but cannot recover all of FIs' assets. Chen (2001), Aikman and Paustian (2006), and Meh and Moran (2004) are based on the model of Holmstrom and Tirole (1997). Their model is built upon the moral hazard problem between the entrepreneurs and FIs. On the other hand, as we will discuss below, our model is based on the financial acceralator model by Bernanke, Gertler and Gilchrist (1999). There are two separate costly state verification problems, where both FIs and entrepreneurs face their own idiosyncratic default risks.

variables. Because of this advantage, we can discuss the role of spread-adjusted Taylor rules and the capital injection policies in a common framework.

In this paper, we extend the HSU model into a sticky price model. The extended model incorporates a central bank that operates monetary policy and a government that operates capital injection. We then calibrate model parameters to match the US economy. Using the model, we first examine the economic responses to the adverse shocks that cause the financial crisis. We consider four sources of the shocks: the shocks to the FI sector, the shocks to the entrepreneurial sector, the shock to a wholesaler's productivity, and the shock to monetary policy. The first two shocks are the shocks to the credit market, and other two shocks are aggregate shocks. We study the two types of shocks to the credit market: the net worth shock that reduces net worth of borrowing sectors, and, following CMR, the riskiness shock that increases the uncertainty of borrowers' productivity.

Our model reveals that the adverse shocks in common increase the external finance premium and reduce the aggregate investment. However, the dynamics of the spreads and borrowers' net worth (leverage) differ depending on the type of the shocks. For instance, FI's borrowing spread widens in response to adverse shocks to FIs, while it does not react much to adverse sectoral shocks to entrepreneurs. On the other hand, FI's loan spread widens to adverse shocks to entrepreneurs, while it does not react much to adverse sectoral shocks to FIs. Comparing the net worth shock and the riskiness shock, we find that a decrease in net worth is more persistent in response to the adverse net worth shock than it is to the adverse riskiness shock. In response to the adverse riskiness shock, asset prices decrease, which damages net worth on impact, but since then, deleveraging proceeds exceeding its steady state level so as to recover its net worth and lower widened finance premiums. The adverse technology shock yields a surge in FI's borrowing spread while it lowers FI's loan spread, which is consistent with Figure 1.

Next, we explore how the economic responses to the adverse shocks would change under the two unconventional policies discussed above. We first investigate the implications of the spread-adjusted Taylor rules. In contrast to Curdia and Woodford (2008), our model has three credit spreads, the FIs' borrowing spread, the FI's loan spread and the sum of the two spreads. We thus compare the three types of spread-adjusted Taylor rules targeting each of the spread. Secondly, we investigate the implications of the capital injection policies. Because there are two kinds of net worth that work differently in the model, capital injection to the FI sector and that to the entrepreneurial sector has potentially different impacts on the aggregate economy. We then quantitatively compare these five policies with a simple Taylor rule with inertia to see the gains from these policies.

In general, our policy analysis reveals that the policy that achieves the least welfare loss depends crucially on the source of the crisis. For the sectoral shock that hits FIs, unconventional policies can improve welfare better than the simple Taylor rule. However, it is not the case for the sectoral shock that hits the entrepreneurs and the aggregate shock. For the sectoral shock that hits entrepreneurs, it deteriorates welfare by reacting strongly to the distressed financial market. No single policy can achieve better welfare outcomes than the simple Taylor rule in response to all kinds of the shocks.

As for the government policy, capital injection to the FI sector is more effective than that to the entrepreneurs in mitigating the impact of the adverse shocks on the investment. This is because the agency problem associated with the FI sector is larger compared with that with the entrepreneurial sector. For instance, the capital injection to the FIs of one percent of GDP raises aggregate investment by 0.6% point and lowers external finance premium by 10 basis points. However, capital injection policy entails the cost of crowding out the economy via higher tax and increasing labor disutility. Consequently, the welfare loss under capital injection to the FI sector can be larger than that under the capital injection to the entrepreneurial sector, depending on the source of adverse shocks.

The rest of the paper is organized as follows. In section 2, we briefly describe our economy. In section 3, we report the responses of the economy to various kinds of adverse shocks. In section 4, we study consequence of the spread-adjusted Taylor rules and the capital injection policies during the financial crisis. Section 5 concludes.

2 The Economy

We consider an economy with a credit market and goods market. The economy consists of the ten types of agents: a household, investors, FIs, entrepreneurs, capital goods producers, final goods producers, retail goods producers, wholesale goods producers, the monetary authority and the government.

Our setting for the credit market is taken from HSU. The participants in the credit market are investors, FIs and entrepreneurs. Investors are subject to the perfect competition, earning zero profit. They collect deposits from a household in a competitive market, and invest what they collect as loans to FIs. FIs and entrepreneurs are both credit constrained, but they earn positive profits, accumulating the net worth. FIs are monopolistic lenders to entrepreneurs. FIs own net worth but not enough amount to finance their loans to entrepreneurs. Therefore, they engage credit contracts with investors in order to borrow the rest of the funds. Entrepreneurs make investment for their projects. They own net worth, but not enough amount to finance their projects. They thus engage in credit contracts with FIs by which they borrow the rest of the funds from FIs. These two contracts are chained so that the entrepreneurs cannot finance their projects if either of the credit contracts does not hold.

There are agency problems, arising from asymmetric information, in both of the credit contracts between FIs and entrepreneurs (hereafter FE contracts) and the credit contracts between investors and FIs (hereafter IF contracts). Consequently, the borrowing rates of the credit contracts are dependent on the borrowers' net worth. The contents of the two credit contracts are chosen by monopolistic FIs, so that FIs maximize their profits, ensuring the participation constraints of entrepreneurs and investors.

For the setup of the goods market, we closely follow BGG. There are three goods in the economy, final goods, retail goods and capital goods. Final goods are produced by the final goods producers using the Dixit-Stiglitz aggregator from the differentiated retail goods. These retail goods are produced by the monopolistic retail goods producers who set their goods prices *à* la Calvo (1983). Each differentiated retail goods is produced from the wholesale goods. The wholesale goods is produced by the competitive firms that own Cobb-Douglas production technology that converts capital and labor inputs into the wholesale goods. Capital is supplied by entrepreneurs, and labor inputs are supplied by household, FIs and entrepreneurs.

In what follows, we briefly describe our setting of the credit market and fully explain that of the goods market.

2.1 Credit Market

Overview of the Credit Contract

In this section, we briefly describe the framework of the credit market, and how the external finance premium and credit spreads are determined by the equilibrium (see HSU and the Appendix for details). At each period, the entrepreneurs conduct their project with size $Q(s^t) K(s^t)$, where $Q(s^t)$ is the price of capital, $K(s^t)$ is the capital, and $Q(s^t) K(s^t)$ is the size of the entrepreneurial project. Entrepreneurs own the net worth, $N^E(s^t) < Q(s^t) K(s^t)$, and the borrow the fund, $Q(s^t) K(s^t) - N^E(s^t)$, from the FIs through the FE contract. The FIs also own the net worth, $N^F(s^t) < Q(s^t) K(s^t) - N^E(s^t)$, and the borrow the fund, $Q(s^t) K(s^t) - N^F(s^t) - N^E(s^t)$, from the investors through the IF contract.

We assume that there are agency problems stemming from the asymmetric information for both contracts. More precisely, FIs and entrepreneurs are subject to idiosyncratic productivity shocks, and in the IF contract (FE contract), the investors (FIs) cannot costlessly observe the output of the FIs (entrepreneurs), unless they pay additional costs called bankruptcy costs. The standard deviation of idiosyncratic productivity shocks for FIs and entrepreneurs are denoted by $\sigma_t^F(s^t)$ and $\sigma_t^E(s^t)$, respectively. Following CMR, we call them riskiness, and assume that they follow stochastic processes. Because of these agency problems, the cost of external finance becomes higher than the return from the riskless asset.

The relationship between the external finance premium and the credit conditions of the borrowers is given by the optimality conditions of the two credit contracts. Formally, these are derived as the FI's profit maximization problem subject to the conditions that allow both investors and entrepreneurs to participate in the credit contracts. Because the net worth and riskiness of the borrowing sectors affect the expected return from the credit contracts, the external finance premium is dependent on these variables. Consequently, for a given riskless rate of the economy $R(s^t)$, the external finance premium $\mathrm{E}_t R^E(s^{t+1})/R(s^t)$ is expressed by

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

where $n_t^F(s^t)$ and $n_t^E(s^t)$ are the ratios of the net worth to the aggregate capital level in the two sectors. Equation (1) is a key equation in our model that links the net worth and riskiness of the borrowing sectors to the external finance premium. The external finance premium is determined by the three components: a share of profits going to the investors in the IF contract, a share of profits going to FIs in the FE contract, and the ratio of the debt to the size of the capital investment. The first two terms are the inverse of the shares of profits going to the lenders. Because of the participation constraints of the investors, the expected return to the capital is high when the values of these terms are small. The last term is exogenous to the FIs. Other thing equal, a higher ratio of the debt causes a higher external finance premium. As we quantitatively showed in HSU, the external finance premium and the net worth are negatively related. Because the two credit contracts are chained and the two net worth works complementarily, the relationship is affected by the distribution of net worth as well as the sum of two net worth.

Credit Spreads

The two financial variables, the FIs' borrowing rate and the FIs' lending rate, are given by the two credit contracts. These variables correspond to those observed in the market, such as interest rates of interbank market and prime lending rate. FI's lending rate in our model, denoted by $Z^E(s^{t+1}|s^t)$, is given as the contractual interest rate that non-default entrepreneurs repay to the FIs. More precisely, we have

$$\begin{aligned}
Z^E\left(s^{t+1}|s^t\right) &\equiv \frac{\overline{\omega}^E\left(s^{t+1}|s^t\right)R^E\left(s^{t+1}|s^t\right)Q\left(s^t\right)K\left(s^t\right)}{Q\left(s^t\right)K\left(s^t\right)-N^E\left(s^t\right)} \\
&= \frac{\overline{\omega}^E\left(s^{t+1}|s^t\right)R^E\left(s^{t+1}|s^t\right)}{1-n^E\left(s^t\right)}, \qquad (2)
\end{aligned}$$

where $\overline{\omega}^E\left(s^{t+1}|s^t\right)$ is a cut-off value of entrepreneurial idiosyncratic shock $\omega^E\left(s^{t+1}\right)$ that is specified by the FIs in the FE contract. Because non-default entrepreneurs repay a fixed portion, $\overline{\omega}^E\left(s^{t+1}|s^t\right)$, of the earning from their projects, the numerator of the right-hand side of the equation indicates the amount that the non-default entrepreneurs repay to the FIs. Clearly, the denominator indicates the amount of the fund that entrepreneurs borrow from the FIs.

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

$$\begin{aligned}
Z^F\left(s^{t+1}|s^t\right) &\equiv \frac{\overline{\omega}^F\left(s^{t+1}|s^t\right)\overbrace{\left[\Gamma_t^E\left(\overline{\omega}^E\left(s^{t+1}|s^t\right)\right)-\mu^E G_t^E\left(\overline{\omega}^E\left(s^{t+1}|s^t\right)\right)\right]}^{\text{share of entrepreneurial earnings received by FI}}R^E\left(s^{t+1}|s^t\right)Q\left(s^t\right)K\left(s^t\right)}{Q\left(s^t\right)K\left(s^t\right)-N^F\left(s^t\right)-N^E\left(s^t\right)} \\
&= \frac{\overline{\omega}^F\left(s^{t+1}|s^t\right)\left[\Gamma_t^E\left(\overline{\omega}^E\left(s^{t+1}|s^t\right)\right)-\mu^E G_t^E\left(\overline{\omega}^E\left(s^{t+1}|s^t\right)\right)\right]R^E\left(s^{t+1}|s^t\right)}{1-n^F\left(s^t\right)-n^E\left(s^t\right)}, \qquad (3)
\end{aligned}$$

where $\overline{\omega}^F\left(s^{t+1}|s^t\right)$ is a cut-off value of FI's idiosyncratic shock $\omega^F\left(s^{t+1}\right)$, that is specified by the FIs in the IF contract. $\Gamma_t^E\left(\overline{\omega}^E\left(s^{t+1}|s^t\right)\right)$ and $\mu^E G_t^E\left(\overline{\omega}^E\left(s^{t+1}|s^t\right)\right)$ represent the gross expected share of profits that goes to the lenders, and the expected monitoring costs which the lenders pay in the FE contract, respectively. Because non-default FIs repay a fixed portion, $\overline{\omega}^F\left(s^{t+1}|s^t\right)$, of the earning from its loans to the entrepreneurs, the numerator of the right-hand side of the equation indicates the amount that the non-default FIs repay to the investors. Clearly, the denominator indicates the amount of the fund that FIs borrow from the investors.

FI's loan spread is defined as $Z^E\left(s^{t+1}|s^t\right)/Z^F\left(s^{t+1}|s^t\right)$. FI's borrowing spread is defined as $Z^F\left(s^{t+1}|s^t\right)/R\left(s^t\right)$. Different from the external finance premium $R^E\left(s^{t+1}|s^t\right)/R\left(s^t\right)$, FI's loan spread and FI's borrowing spread represent the credit rates in the unit of loans ($Q\left(s^t\right)K\left(s^t\right)-N^E\left(s^t\right)$ and $Q\left(s^t\right)K\left(s^t\right)-N^E\left(s^t\right)-N^F\left(s^t\right)$, respectively), not in the unit of total value of capital ($Q\left(s^t\right)K\left(s^t\right)$).

Dynamic Behavior of Net Worth

The net worth of FIs and entrepreneurs, $N^F\left(s^t\right)$ and $N^E\left(s^t\right)$, depends on their earnings from the credit contracts and their labor income. In addition to the profits stemming from entrepreneurial projects, both FIs and entrepreneurs inelastically supply a unit of labor to final goods producers and receive labor income $W^F\left(s^t\right)$ and $W^E\left(s^t\right)$.

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 worth of FIs and entrepreneurs is given by

$$N^F\left(s^{t+1}\right) = \gamma^F V^F\left(s^t\right) + W^F\left(s^t\right), \tag{4}$$

$$N^E\left(s^{t+1}\right) = \gamma^E V^E\left(s^t\right) + W^E\left(s^t\right), \tag{5}$$

with:

$$\begin{aligned} V^F\left(s^t\right) &\equiv \left(1-\Gamma_t^F\left(\overline{\omega}^F\left(s^{t+1}\right)\right)\right)\left(\Gamma_t^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)-\mu^E G_t^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)\right) \\ &\quad \cdot R^E\left(s^{t+1}\right) Q\left(s^t\right) K\left(s^t\right), \\ V^E\left(s^t\right) &\equiv \left(1-\Gamma_t^E\left(\overline{\omega}^E\left(s^{t+1}\right)\right)\right) R^E\left(s^{t+1}\right) Q\left(s^t\right) K\left(s^t\right). \end{aligned}$$

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.

2.2 The Rest of the Economy

Household

A representative household is infinitely lived, and maximizes the following utility function subject to the budget constraint

$$\max_{C(s^t),H(s^t),D(s^t)} \sum_{l=0} \beta^{t+l} \mathrm{E}_t \left\{ \log C\left(s^{t+l}\right) - \chi \frac{H\left(s^{t+l}\right)^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \right\}. \tag{6}$$

subject to

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

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 investors, $P\left(s^t\right)$ is the aggregate price of the final goods, $W\left(s^t\right)$ is the nominal 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 $t+1$, and $T\left(s^t\right)$ is the 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.

Final goods producer

The final goods $Y\left(s^t\right)$ are composites of continuum of the retail goods $Y\left(h, s^t\right)$. The final goods producer purchases retails goods in the competitive market, and sells the output to a household and capital producers with price $P(s^t)$. Production technology of the final goods is given by

$$Y\left(s^t\right) = \left[\int_0^1 Y\left(h, s^t\right)^{\frac{\epsilon-1}{\epsilon}} dh\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{7}$$

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

$$P\left(s^t\right) = \left[\int_0^1 P\left(h, s^t\right)^{1-\epsilon} dh\right]^{\frac{1}{1-\epsilon}}. \tag{8}$$

Retailer

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

$$Y\left(h, s^t\right) = y\left(h, s^t\right), \tag{9}$$

where $y_t(h, s^t)$ for $h \in [0,1]$ is the wholesale goods that is used for producing the retail goods $Y_t(h, s^t)$ 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. They are monopolistic suppliers in their output market, and set their prices so as to maximize their profits. Consequently, the retailer h faces the downward 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 the nominal rigidity. They are able to change the prices in a given period only with probability $(1-\xi)$, following Calvo (1983). Retailers who cannot repotimize 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 at period $t-1$, i.e., $\pi(s^{t-1}) = P(s^{t-1})/P(s^{t-2})$. 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 at period $t+l$ by $Y^*\left(h, s^{t+l}\right)$, retailer h 's optimization problem with respect to its products's price $P^*(h, s^t)$ is written in the following way

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

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 (7), (8) and (9), final goods $Y\left(s^{t}\right)$ produced at period t are expressed with wholesale goods produced at period t as the following equation:

$$\begin{aligned}
y\left(s^{t}\right) &= \int_{0}^{1}y\left(h,s^{t}\right)dh=\int_{0}^{1}\left(\frac{P\left(h,s^{t}\right)}{P\left(s^{t}\right)}\right)^{-\epsilon}Y\left(s^{t}\right)dh \\
&= \left[\int_{0}^{1}\left(\frac{P_{t}\left(h,s^{t}\right)}{P\left(s^{t}\right)}\right)^{-\epsilon}dh\right]Y\left(s^{t}\right). \qquad (10)
\end{aligned}$$

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

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

Wholesaler

The wholesalers produce wholesale goods $y_{t}\left(s^{t}\right)$ and sell them to the retailers with the relative price $1/X_{t}\left(s^{t}\right)$. 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 from household, FIs and entrepreneurs with the wages $W\left(s^{t}\right)$, $W^{F}\left(s^{t}\right)$ and $W^{E}\left(s^{t}\right)$, respectively. Capital is supplied from 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 with price $Q\left(s^{t}\right)$. The maximization problem for the wholesaler is given by

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

subject to

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

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

Capital producer

The capital goods producers own technology that converts the final goods to the capital goods. At each period, the capital goods producers purchase $I\left(s^t\right)$ amount of final goods from the final goods producers. In addition, they purchase $K\left(s^{t-1}\right)(1-\delta)$ of the 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 with price $Q\left(s^t\right)$. Consequently, the capital goods producer's problem is to maximize the profit function below.

$$\max_{I(s^t)}\sum_{l=0}^{\infty}\mathrm{E}_t\Lambda\left(s^{t+l}\right)\left[Q\left(s^{t+l}\right)\left(1-F_I\left(I\left(s^{t+l}\right),I\left(s^{t+l-1}\right)\right)\right)I\left(s^{t+l}\right)-I\left(s^{t+l}\right)\right], \quad (11)$$

where F_I is defined as follows:

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

Note that κ is a parameter that is associated with investment technology with adjustment cost.[3] Here, the evolvement of total capital available at period t is described as:

$$K\left(s^t\right) = \left(1-F_I\left(I\left(s^t\right),I\left(s^{t-1}\right)\right)\right)I\left(s^t\right)+(1-\delta)K\left(s^{t-1}\right). \quad (12)$$

Government

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

$$G\left(s^t\right) = T\left(s^t\right). \quad (13)$$

[3]Equation (11) does not have 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, that the price of old capital with which 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.

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:

$$R^n\left(s^t\right) = \theta R^n\left(s^{t-1}\right) + (1-\theta)\left(\phi_\pi \pi\left(s^t\right) + \phi_y \log\left(\frac{Y\left(s^t\right)}{Y}\right)\right) + e^R\left(s^t\right), \tag{14}$$

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 output gap $\log\left(\frac{Y\left(s^t\right)}{Y}\right)$, respectively. Because the monetary authority determines the nominal interest rate, the real interest rate in the economy is given by the following Fisher equation:

$$R\left(s^t\right) \equiv \mathrm{E}_t\left\{\frac{R^n\left(s^t\right)}{\pi\left(s^{t+1}\right)}\right\}. \tag{15}$$

Resource constraint

Resource constraint for final goods is written as:

$$\begin{aligned} Y\left(s^t\right) \;=\; & C\left(s^t\right) + I\left(s^t\right) + G\left(s^t\right) \\ & + \mu^E G_t^E\left(\overline{\omega}^E\left(s^t\right)\right) R^E\left(s^t\right) Q\left(s^{t-1}\right) K\left(s^{t-1}\right) \\ & + \mu^F G_t^F\left(\overline{\omega}^F\left(s^t\right)\right) R^F\left(s^t\right)\left(Q\left(s^{t-1}\right) K\left(s^{t-1}\right) - N^E\left(s^{t-1}\right)\right) \\ & + C^F\left(s^t\right) + C^E\left(s^t\right). \end{aligned} \tag{16}$$

Note that the fourth and the fifth terms in the right-hand side of the equation correspond to the bankruptcy costs spent by FIs and investors, respectively. The last two equations are FIs' consumption and entrepreneurial consumption.

Law of motion for exogenous variables:

The exogenous shocks to the model, that is, the technology shock, the monetary policy shock, the shocks to the riskiness of FIs, and the shocks to the riskiness of entrepreneurs follow the processes as

$$e^A\left(s^t\right) = \rho_A e^A\left(s^{t-1}\right) + \varepsilon^A\left(s^t\right), \tag{17}$$

$$e^R\left(s^t\right) = \rho_R e^R\left(s^{t-1}\right) + \varepsilon^R\left(s^t\right), \tag{18}$$

$$\log\left(\frac{\sigma^F\left(s^t\right)}{\overline{\sigma}^F}\right) = \rho_{\sigma_F}\log\left(\frac{\sigma^F\left(s^{t-1}\right)}{\overline{\sigma}^F}\right) + \varepsilon^{\sigma_F}\left(s^t\right), \tag{19}$$

$$\log\left(\frac{\sigma_t^E}{\overline{\sigma}^E}\right) = \rho_{\sigma_E}\log\left(\frac{\sigma_{t-1}^E}{\overline{\sigma}^E}\right) + \varepsilon_t^{\sigma_E}, \tag{20}$$

where ρ_A, ρ_R, ρ_{σ_F} and $\rho_{\sigma_E} \in (0,1)$ are autoregressive roots of the exogenous variables, and $\varepsilon^A(s^t)$, $\varepsilon^R(s^t)$, $\varepsilon^{\sigma_E}(s^t)$ and $\varepsilon^{\sigma_F}(s^t)$ are innovations that are mutually independent, serially uncorrelated and normally distributed with mean zero and variances σ_A^2, σ_R^2, $\sigma_{\sigma^F}^2$ and $\sigma_{\sigma^E}^2$, respectively.

2.3 Equilibrium Condition

An equilibrium consists of a set of prices, $\{P(h,s^t)$ for $h \in [0,1]$, $P(s^t)$, $X(s^t)$, $R(s^t)$, $R^F(s^t)$, $R^E(s^t)$, $W(s^t)$, $W^F(s^t)$, $W^E(s^t)$, $Q(s^t)$, $R^F(s^{t+1}|s^t)$, $R^E(s^{t+1}|s^t)$, $Z^F(s^{t+1}|s^t)$, $Z^E(s^{t+1}|s^t)\}_{t=0}^{\infty}$, and the allocations $\{\overline{\omega}_i^F(s^{t+1}|s^t)\}_{t=0}^{\infty}$, $\{\overline{\omega}_{j_i}^E(s^{t+1}|s^t)\}_{t=0}^{\infty}$, $\{N_i^F(s^t)\}_{t=0}^{\infty}$, $\{N_{j_i}^E(s^t)\}_{t=0}^{\infty}$ $\{\{y(h,s^t)),\ Y(h,s^t)$ for $h \in [0,1]$, $Y(s^t)$, $C(s^t)$, $D(s^t)$, $I(s^t)$, $K(s^t)$, $H(s^t)\}\}_{t=0}^{\infty}$, for a given government policy $\{i_t(s^t), G_t(s^t), T(s^t)\}_{t=0}^{\infty}$, realization of exogenous variables $\{\varepsilon^A(s^t), \varepsilon^R(s^t), \varepsilon^{\sigma_E}(s^t), \varepsilon^{\sigma_F}(s^t)\}_{t=0}^{\infty}$ and initial conditions N_{-1}^F, N_{-1}^E, K_{-1} such that for all t and h: (i) a household maximizes her utility given the prices; (ii) the FIs maximize their profits given the prices; (iii) the entrepreneurs maximize their profits given the prices; (iv) the final goods producers maximize their profits given the prices; (v) the retail goods producers maximize their profits given the input prices; (vi) the wholesale goods producers maximize their profits given the prices; (vii) capital goods producers maximizes its profit given the prices; $(viii)$ the government budget constraint holds; (ix) and markets clear.

3 Simulating the Model

3.1 Credit Market

We now report the quantitative implication of the model. We take the parameter values from HSU that were calibrated to the US data and choose the standard values for the other parameters. See the Appendix for details.

We begin with checking the results pointed out by HSU. HSU construct the same model but without price stickiness, and argue that the effect on the external finance premium $\mathrm{E}_t R_{t+1}^E - R_t$ is larger to a shock to FIs rather than that to entrepreneurs. This arises from the interaction between the two credit market imperfections. In our model, a contract in which borrowers are more severely credit-constrained or a contract in which lenders need to pay higher bankruptcy cost is more likely to affect capital investment, since both two credit contracts are vertically chained and work complementarily. According to the calibration of our model to the US data, net worth distribution of the US economy is biased to the entrepreneurial sector and bankruptcy cost is higher for FIs than entrepreneurs. These features of the credit market yield more magnified effects of the sectoral shock to FIs than to entrepreneurs. Furthermore, they yield more magnified effects of the aggregate shock than a case in which FIs are not credit constrained as in the standard BGG model or a case in which net worth is more distributed from entrepreneurs to FIs.

Figure 3, 4 and 5 illustrate these properties of the model. Figure 3 depicts the cost-of-fund curve of the model, calibrated to the US economy. As discussed in HSU, given the steady state distribution of the net worth across sectors in the U.S., $N^F\left(N^F+N^E\right)^{-1}=0.17$, a marginal decrease of the FIs' net worth has a quantitatively larger impact on the external finance premium, than does a marginal decrease of the entrepreneurial net worth. Figure 4 shows the impact of a change in net worth on the external finance premium. Figure 5 shows the impact of a change in riskiness on the external finance premium. These figures suggest that a shock to FIs has a larger impact on the external finance premium than a shock to entrepreneurs.

3.2 Equilibrium Response to Adverse Shocks

We next compute the equilibrium response of the economy to adverse shocks. We study six types of adverse shocks: (1) a net worth shock in the FI sector, (2) a net worth shock in the entrepreneurial sector, (3) a shock to the riskiness in the FI sector, (4) a shock to the riskiness in the entrepreneurial sector, (5) a TFP shock to the technology in the wholesale goods sector, and (6) a monetary policy shock. (1), (2), (3), and (4) are sectoral shocks that hit the credit market, and (5) and (6) are aggregate shocks.

3.2.1 Net Worth Shocks

We first discuss the macroeconomic impacts of the adverse net worth shock in the borrowing sectors. The shock is described as a once-and-for-all exogenous decline of the net worth taken from the right-hand side of either of equations (4) and (5). As discussed by Gilchrist and Leahy (2002), a reduction in net worth in the borrowing sectors affects the agency problem of the credit contracts and rises the borrowing rate, reducing the aggregate investment. In this section, we compare the quantitative impacts of the shock to the FI sector and that to the entrepreneurial sector.

Figure 6 shows the responses of endogenous variables to the decline of the net worth by 10% of the steady state GDP.[4] Solid line with black circles shows the response when the shock hits the FI sector and dotted line shows the response when the shock hits the entrepreneurial sector. Because net worth declines more than the capital size, the external finance premium as well as the two credit spreads, the FIs' lending rate and the FIs' borrowing rate, rise, reducing the aggregate investment. Quantitatively, the decline in FIs' net worth by 10% of the steady state GDP decreases aggregate investment by 1% and GDP by 0.8%. The external finance premium rises by 30 basis points.

[4] The shock amounts to 1.25% of the steady state asset QK. For the net worth shock to FIs, it amounts to a decline of their net worth by 12.5%.

It is also clear from the figure that the economy responds larger to a shock to the FIs than to a shock to the entrepreneurs. The net worth in the two borrowing sectors work complementarily, because the IF contracts and the FE contracts are vertically chained in the credit market. Consequently, the macroeconomy is more affected by a shock to the sector subject to more severe agency problem.

The two credit spreads react differently depending on the shock. In response to the shock to the FI sector, both two spreads widen. In response to the entrepreneurial sector, on the contrary, only the FIs' loan spread widens drastically while the FIs' borrowing spread does not widen much.

3.2.2 Riskiness Shocks

We next discuss the macroeconomic impacts of the unexpected rise in the riskiness. Other things being equal, a rise in the riskiness increases the default probability of the borrowers and the bankruptcy cost of the lenders (see, for example, HSU). This affects the external finance premium and the aggregate investment. Furthermore, it decreases asset prices, and in turn, the net worth of the sector. This accelerates the impact of the riskiness shock on the aggregate investment. Different from the net worth shock, a decrease in net worth arises as a result not as a cause. Similarly to the net worth shock, we illustrate the quantitative impacts of the shocks to the endogenous variables, and compare the consequence of the riskiness shock to the FI sector and that to the entrepreneurial sectors.

Figure 7 shows the responses of endogenous variables to 10% increase in the riskiness, the standard deviation of idiosyncratic productivity shocks, for each of the borrowing sectors. We assume that the riskiness gradually returns to its steady state with the autoregressive parameter of .85, following equations (19) and (20) . Solid line with black circles shows the response when the shock hits the FI sector and dotted line shows the response when the shock hits the entrepreneurial sector. Again, the two credit spread react differently, depending on the shock. After the shock to the FI sector, both two spreads widen compared with the steady state level. After the shock to the entrepreneurial sector, on the contrary, only the FIs' loan spread widens drastically while the FIs' borrowing spread does not react much.

These features resemble those for the net worth shocks. However, the figure shows that an increase in the external finance premium after a year or two after the shock is no longer brought by the scarcity of the net worth but by the riskiness of borrowing sectors. In response to the adverse riskiness shock, deleveraging proceeds exceeding its steady state level so as to lower widened finance premiums. In particular, the entrepreneurial net worth ratio to aggregate capital does not decrease but increase due to the adverse riskiness shocks. This suggests that a decrease in aggregate capital dominates a decrease in entrepreneurial net worth.

3.2.3 Technology Shock

In this subsection, we discuss the macroeconomic impacts of the technology (TFP) shock. The size of the shock amounts to a 10% decrease in the productivity of the wholesale goods sector. The shock gradually goes back to the steady state level with the autoregressive parameter of .85.

Figure 8 shows the adverse technology shock raises the external finance premium, reducing aggregate investment and GDP. Because a drop in Q_t causes the declines of the net worth through equations (4) and (5), agency problems of the two credit contracts become severer. In particular, net worth of the FI sector drops more prominently than that of the entrepreneurial sector, reflecting the following reason. Because the FI sector pays greater monitoring costs from the increased bankruptcy costs to maintain the participation constraints of investors and entrepreneurs, a profit flow to the FIs sector becomes smaller.

All of the credit rates including the riskless rate, the FIs' lending rate and the FIs' borrowing rate rise in response to the adverse technology shock, but the size is different across credit rates. Consequently, the two credit spread react differently. Figure 8 implies that as a consequence of the decline in the return from the capital investment, capital investment drops further than the net worth. As equation (3) illustrates, $Z^F\left(s^{t+1}|s^t\right)$ decreases with $n\left(s^t\right)$, suggesting that the FIs' borrowing spread widens and the FIs' loan rate shrinks.

3.2.4 Monetary Policy Shock

Here, we discuss the macroeconomic impacts of the monetary policy shock. The nominal interest rate is raised by .25% (1% annually) at period $t = 0$, and reverts back to the steady state following equation (14).

Figure 9 shows the economic response to the monetary policy shock. The contractional policy shock lowers inflation and the asset price $Q\left(s^t\right)$. It also raises the external finance premium, reducing aggregate investment and GDP. Similarly to the technology shock, net worth of the FI sector drops more prominently than that of the entrepreneurial sector.

The responses of credit spreads are different from those of the technology shock. In contrast to the effect of the technology shock, there are two notable differences in how a policy shock affects the economy. First, a contractional monetary policy shock causes a large increase of the riskless rate. Second, the reduction of capital investment is not as large as the reduction of the net worth, causing a decline in a net worth-capital ratio $n\left(s^t\right)$. According to equation (3), a rise of the the FIs' borrowing rate, $Z^F\left(s^{t+1}|s^t\right)$ is mitigated while the rise in the riskless rate rises. Consequently, FIs' borrowing spread declines while FIs' loan rate widens.

4 Evaluating Monetary Policy and Capital Injection under Financial Crisis

In this section, we seek a policy that mitigates the impact of financial crisis originated from the adverse shocks discussed above. First, we study the consequences of several classes of monetary policy rules: Spread-adjusted Taylor rules, the Ramsey rule and a simple Taylor rule with inertia. Second, we study the consequence of the capital injection by the government to the borrowing sectors. Lastly, we discuss welfare implications from these policies.

4.1 Monetary Policy: Taylor Rule, Spread-adjusted Taylor Rule, and Ramsey Rule

First, we consider a set of policies that include spread-adjusted Taylor rules and the Ramsey rule as well as a simple Taylor rule with inertia. A spread-adjusted Taylor rule is a rule that lowers the intercept of the Taylor rule, responding to the credit spread, and proposed by several macroeconomists (e.g., Taylor, 2008; and Curdia and Woodford, 2008). We investigate above the cases where the economic downturns are associated with a rise in the external finance premium. If a central bank adopts the spread-adjusted Taylor rule, the rise in the external finance premium is met by a cut in the nominal interest rate, boosting the economy.

In Curdia and Woodford (2008), a central bank attaches a positive weight on a spread between the interest received by savers and that paid by borrowers in the economy. In our economy, because there are two borrowers, there are three spreads, the external finance premium, the FIs' borrowing spread and the FI's loan spread. In the following exercise, therefore, three types of the spread-adjusted Taylor rules.

Following Taylor (2008) and Curdia and Woodford (2008), we modify our policy rule (14) to

$$\begin{aligned} R^n\left(s^t\right) &= \theta R^n\left(s^{t-1}\right) \\ &\quad +(1-\theta)\{\phi_\pi \pi\left(s^t\right)+\phi_y \log\left(\frac{Y\left(s^t\right)}{Y}\right) \\ &\quad -\phi_2(\mathrm{E}_t\left[Z^E\left(s^{t+1}\right)|s^t\right]-R\left(s^t\right)) \\ &\quad -\phi_3(\mathrm{E}_t\left[Z^E\left(s^{t+1}\right)|s^t\right]-\mathrm{E}_t\left[Z^F\left(s^{t+1}\right)|s^t\right]) \\ &\quad -\phi_4(\mathrm{E}_t\left[Z^F\left(s^{t+1}\right)|s^t\right]-R\left(s^t\right))+e_t^R, \end{aligned} \tag{21}$$

where ϕ_2, ϕ_3 and ϕ_4 are nonnegative coefficients that are attached to each of the three types of credit spread. When one of the coefficient takes a positive value, the nominal interest rate is cut for the increase in the corresponding spreads. For the convenience of the analysis, we define six policy rules, depending on the spread and the amplitude of the coefficient. In Weak (Strong) Policy II, the central bank concentrates on the credit spread between FIs' loan rate and the riskless rate, $\mathrm{E}_t\left[Z^E\left(s^{t+1}\right)|s^t\right]-R\left(s^t\right)$, and attaches the positive weight of $\phi_2=0.5$ ($\phi_2=1.0$), keeping both ϕ_3 and ϕ_4 equal to zero. In Weak (Strong) Policy III, the central bank concentrates on the credit spread between the FIs' loan rate and the FIs' borrowing rate, $\mathrm{E}_t\left[Z^E\left(s^{t+1}\right)|s^t\right]-\mathrm{E}_t\left[Z^F\left(s^{t+1}\right)|s^t\right]$, and attaches the positive weight of $\phi_3=0.5$ ($\phi_3=1.0$), keeping both ϕ_2 and ϕ_4 equal to zero. In Weak (Strong) Policy IV, the central bank concentrates on the credit spread between the FIs' borrowing rate and the riskless rate, $\mathrm{E}_t\left[Z^F\left(s^{t+1}\right)|s^t\right]-R\left(s^t\right)$, and attaches the positive weight of $\phi_4=0.5$ ($\phi_4=1.0$), keeping both ϕ_2 and ϕ_3 equal to zero. In all of the six rules, the coefficients of other endogenous variables, θ, ϕ_π, and ϕ_y are set equal to those of the benchmark.

For the comparisons with the spread adjusted rules, we derive the time paths of the policy rate under the Ramsey Policy, in response to the adverse shocks. The Ramsey policy is an optimal monetary policy that is defined as

$$\left\{R^n\left(s^t\right)\right\}_{t=0}^{\infty}=\arg\max\sum_{t=0}^{\infty}\beta^t\left\{\log C\left(s^t\right)-\chi\frac{H\left(s^t\right)^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}}\right\}, \tag{22}$$

subject to equilibrium conditions other than a monetary policy rule. Note that period $t=0$ is a period when the shock hits the economy.

Figures 10 to 12 exhibit the economic responses to the four sectoral adverse shocks and the TFP shock. In the figures, we exhibit the case under a strong type for each of the spread-adjusted Taylor rules. Economic responses under spread-adjusted Taylor rules are depicted together in one figure for comparison. Because the policy rate under the Ramsey policy varies a lot, it is drawn separately.

We first describe the optimal time path given by the Ramsey policy. In response to all of the adverse shocks, except the entrepreneurial riskiness shock, it is optimal to cut the interest rate on impact, mitigating the output drop. Consequently, the decrease of the net worth becomes smaller, suppressing the increase in the external finance premium. In response to the entrepreneurial riskiness shock, the cut of the policy rate is delayed, resulting in the stabilization of inflation.

Under spread-adjusted Taylor rules, economic responses to sectoral shocks are mitigated compared to the benchmark rule. By cutting the policy rate to a rise in the corresponding spread, the net worth accumulation is enhanced, causing less decline of the investment.

Although some of the spread-adjust Taylor rules appear to mitigate the macroeconomic downturns, it does not imply that they outperform the benchmark policy. For example, in response to the sectoral shocks, all of the spared-adjust Taylor rules generate higher inflation than does the benchmark policy, because the policy weight on the inflation becomes smaller. To do the comparison, we conduct below the welfare analysis for each of the policy rules and for each of the adverse shocks.

4.2 Capital Injection

In this section, we investigate the quantitative implications of capital injection policies to the macroeconomy. We formulate the capital injection policy by introducing a sequence of variables $\left\{v^F\left(s^t\right),\ v^E\left(s^t\right)\right\}_{t=0}^{\infty}$. We define the policy, as a set that includes a tax collection and the same size of transfer from government to either FIs sector or entrepreneurial sector. Government first collects $v^E\left(s^t\right)+v^F\left(s^t\right)$ of final goods from a household by lump-sum tax. At the same period, it re-distributes the tax revenue either to the FIs or to the entrepreneurs by helping their net worth accumulation. Under the capital injection policy, equations (4), (5), (13) and (16) are modified as follows, respectively.

(law of motions for FIs' net worth)

$$N^F(s^t) = \gamma^F V^F\left(s^{t-1}\right) + W^F\left(s^{t-1}\right) + v_t^F \tag{23}$$

(law of motions for entrepreneurs' net worth)

$$N^E\left(s^t\right) = \gamma^E V^E\left(s^{t-1}\right) + W^E\left(s^{t-1}\right) + v_t^E \tag{24}$$

(budget constraint of government)

$$v_t^E + v_t^F + G\left(s^t\right) = T\left(s^t\right) \tag{25}$$

(resource constraint for final goods)

$$\begin{aligned} Y\left(s^t\right) &= C\left(s^t\right)+I\left(s^t\right)+G\left(s^t\right) \\ &\quad +\mu^E G_t^E\left(\overline{\omega}^E\left(s^t\right)\right) R^E\left(s^t\right) Q\left(s^{t-1}\right) K\left(s^{t-1}\right) \\ &\quad +\mu^F G_t^F\left(\overline{\omega}^F\left(s^t\right)\right) R^F\left(s^t\right)\left(Q\left(s^{t-1}\right) K\left(s^{t-1}\right)-N^E\left(s^{t-1}\right)\right) \\ &\quad +C^F\left(s^t\right)+C^E\left(s^t\right)+v^E\left(s^t\right)+v^F\left(s^t\right). \end{aligned} \tag{26}$$

For convenience, we further assume that a central bank maintains the benchmark policy described by the policy rule equation (14) regardless of the type of capital injection policies conducted.

We discuss the four types of capital injection policies, targeting either of the borrowing sectors. In what follows, we call the capital injection policy to the FI's net worth, "CIFN (Capital Injection to the FIs' Net worth)," and the capital injection policy to the entrepreneurial net worth, "CIEN (Capital Injection to the Entrepreneurial Net worth)." In the Weak (Strong) CIFN policy, we set $v_{t=s}^F$ equals to 0.1% (1.0%) of steady state value of GDP at the period s, setting $v_t^F = 0$ for $t > s$, and $v_t^E = 0$ for all time periods. In the Weak (Strong) CIEN, we set $v_{t=s}^E$ equals to 0.1% (1.0%) of steady state value of GDP for specific period s, setting $v_{t=s}^E = 0$ for $t > s$,and $v_t^F = 0$ for all time periods.

In a word, CIFN is a one-shot transfer of final goods from a household to FIs at period s, and CIEN is a one-shot transfer of final goods from a household to entrepreneurs at period s.

In Figure 13, 14 and 15, we display the economic responses to the adverse shocks under capital injection policies. In each figure, we report three alternative policies, simple benchmark policy, strong CIFN and strong CIEN. Under the latter two policies, we set s is the period at which an adverse shock occurs. Similarly to the cases for the spread-adjusted Taylor rules, the capital injection policies have a large quantitative impact on the aggregate economy. For example, capital injection to the FIs by 1% of GDP raises aggregate investment by 0.6% point and lowers external finance premium by 10 basic points. Because the net worth is added to the borrowing sector, the credit constraints under the adverse shocks are mitigated. Consequently, external finance premium rises less, causing a smaller decline of the investment, compared with the economy under the benchmark policy. As shown in HSU, the FI sector has less net worth than does the entrepreneurial sector and therefore is more severely credit constrained. CIFN is thus more effective in softening an investment decline than CIEN under all of the shocks.

4.3 Welfare

Table 1 reports a change in the welfare of the representative household subject to the above five shocks, under six monetary policy rules and four capital injection policies. We calculate the numbers in the following way. First, for each policy, we derive the rational expectation solution of the model, up to the second-order. Second we give once-for-all innovation to one of the shocks in the model at period 0, setting other shocks equal to zero, and calculate the second-order change of the welfare defined by equation (6) from its steady state level. Lastly, we calculate the difference between the change in welfare under a specific policy rule and the change in the welfare under the Ramsey Policy that is defined above. To compare the welfare under the Ramsey rule with that under other policies, we set the initial values of Lagrange multipliers in the Ramsey rule as well as other state variables equal to zero.

We give the sequence of each adverse shock as follows. For the riskiness shock, we set ε^{σ_F} and ε^{σ_E} equal to plus one percent of the size of σ^F and σ^E at the steady state level, respectively. For the TFP shock, we set ε^A equal to the negative one percent of the technology level at the steady state. After the initial period, they follow the law of motions specified by equations (17), (19), and (20). For the net worth shock, we set once-for-all decline in net worth that amounts to the one percent of the final goods output at the steady state.

In the Table 1, each row represents the deviation of the changes in welfare under a specific policy from that under the Ramsey policy. The column represents each type of shocks. All units are in final goods consumption. To make a comparison between the benchmark policy and the alternative policies, we also give the relative sizes of welfare.

Signs (+, −, 0) in parenthesis represent the improvement, deterioration, and no change of the welfare under a specific policy, compared with the welfare under the benchmark policy.

First of all, the table indicates that, except for the Ramsey policy, no policy outperforms the other policies for all of the shocks. The best policy changes depending on whether the shock hits the credit market or the aggregate economy, or on whether the shock hits the FI sector or the entrepreneurial sectors. Although all of these alternative policies mitigate the rise in the external finance premium and the decline in the investment either by cutting interest rate or by capital injection, there are also costs associated with these policies, such as inflation. Consequently, some policies generates a larger welfare loss compared with the benchmark policy, depending on the shock. Especially, in response to the shock to the entrepreneurial sector and to the aggregate shock, the unconventional policies do not improve welfare compared with the benchmark policy.

Second, the comparisons among the spread-adjusted Taylor rules indicate that, as far as the shocks to the credit markets are concerned, the Policy IV that targets the spread between the FIs' borrowing rate and the riskless rate works at least as well as does the benchmark policy. On the other hand, the Policy II and Policy III, that target the spread between the FIs' borrowing rate and the FIs' lending rate, improve the welfare when the technology shock is a source of the financial turmoil.

Third, the comparison among the capital injection policies indicate that welfare ordering of these policies also depend on the source of the shock. Although capital injection to the FI sector always mitigates the investment decline compared to that to the entrepreneurial sector regardless of the shocks, their welfare implications differ since there are also costs for these policies.

5 Conclusion

In this paper, we develop a New Keynesian DSGE model that gives the theoretical relationship among market spreads, net worth of financial intermediaries, entrepreneurial net worth, and the macroeconomy. In the model, financial intermediaries are credit constrained. They are monopolistic, and intermediate investors' fund to entrepreneurs by making the borrowing contract with investors and the lending contracts with entrepreneurs. These contracts are associated with asymmetric information, and the contents of contracts are determined based on the borrowers' net worth and riskiness. Consequentially, when an adverse shock that hits either of the borrowers worsens the borrower's economic conditions, the contracts are revised and their borrowing costs rise, causing the fall in aggregate investment and GDP.

Based on the calibration to the US data, we show the theoretical relationship between the financial variables that include the market spreads and the external finance premium, and macroeconomic variables in a unified way. Especially, we find that the dynamics of market spread differ much across the type of shocks hitting the economy. In consistent with our earlier study, we found that among the sectoral shocks, an adverse shock to the financial intermediaries causes larger downturns of the macroeconomy than that to entrepreneurs. Since financial intermediaries intermediate funds in the economy, sectoral shock to them is easily transmitted to the macroeconomy.

Using the model, we compare the implications of policies that include spread-adjusted Taylor rules and the Ramsey rule as well as the simple Taylor rule, in response to the financial crisis. We seek which policy best mitigates the impact of adverse shocks to the economy, on the welfare basis. Our welfare analysis reveals that the policy that achieves the least welfare loss alters depending on the source of the crisis. For example, a simple Taylor rule outperforms spread-adjusted Taylor rules, when an entrepreneurial sectoral shock is a source of economic downturn. On the other hand, spread-adjusted Taylor rule achieves higher welfare than simple rule, when a financial intermediaries sectoral shock is a source of downturn. Our result suggests that policy makers need the information about the source of the financial crisis, in order to choose the appropriate policy.

Capital injection softens a decrease in investment in a wake of an adverse shock. Capital injection to financial intermediaries is more effective than that to entrepreneurs. However, capital injection is considered to raise the future real interest rates, which induces crowding-out of consumption and an increase in labor supply. Therefore, further investigation is needed to assess the effects of capital injection on welfare quantitatively.

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 the profit from the credit contracts, and then explain the participation constraints of other participants in the credit contracts.

At each period t, expected net profit of a FI from the two credit contracts is expressed by

$$\sum_{s^{t+1}} \Pi\left(s^{t+1}|s^t\right) \overbrace{\left[1-\Gamma_t^F\left(\overline{\omega}^F\left(s^{t+1}|s^t\right)\right)\right]}^{\text{share of FIs earnings received by FIs}} R^F\left(s^{t+1}|s^t\right)\left(Q_t\left(s^t\right)K\left(s^t\right)-N^E\left(s^t\right)\right), \quad (27)$$

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 by:

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

$$\equiv R_t^F\left(s^{t+1}|s^t\right)\left(Q\left(s^t\right)K\left(s^t\right)-N^E\left(s^t\right)\right) \text{ for } \forall s^{t+1}|s^t. \quad (28)$$

This equation indicates that the FIs' profits are determined by the two credit contracts. 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 are two participation constraints associated the two credit contracts. In the FE contract, the entrepreneurs' expected return is set as high as that from their alternative way of investment. That is, instead of participating with the FE contract, entrepreneurs can purchase capital goods using their own net worth $N^E\left(s^t\right)$. Here, the expected return to this project equals $R^E\left(s^{t+1}\right)N^E\left(s^t\right)$. Consequently, the FE contract between an FI and entrepreneurs is agreed only when the following inequality is expected to hold

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

$$\geq R^E\left(s^{t+1}|s^t\right)N^E\left(s^t\right) \text{ for } \forall s^{t+1}|s^t. \quad (29)$$

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 alternatively may invest on this asset. Consequently, investors profit from the investment to the loans to the FIs must equal the opportunity cost of lending. That is

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

$$\geq R\left(s^t\right)\left(Q\left(s^t\right)K\left(s^t\right)-N^F\left(s^t\right)-N^E\left(s^t\right)\right). \tag{30}$$

The FI maximizes its expected profit (27) by optimally choosing the variables $\overline{\omega}^F\left(s^{t+1}|s^t\right)$, $\overline{\omega}^E\left(s^{t+1}|s^t\right)$, $K\left(s^t\right)$, subject to the investors' participation constraint (30) and entrepreneurial participation constraint (29). Combining the first order conditions yields the following equation:

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

B Parameterization I

This appendix provides parameterization of the variables associated with household, wholesalers, capital goods producers, retailers, final goods producers, government and monetary authority. Following precedent studies including BGG and CMR, we choose conventional values for these parameters.

Parameters[5]

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
ξ	.75	Probability that Price cannot be adjusted
χ	.3	Utility weight on Leisure
κ	2.5	Adjustment Cost of Investment
γ_p	.5	Degree of Price Indexation
θ	.8	Autoregressive Parameter for Policy Rate
ρ_a	.85	Autoregressive Parameter for TFP
ϕ_π	1.5	Policy Weight on Inflation
ϕ_y	.0	Policy Weight on Output gap

[5]Figures are quarterly unless otherwise noted.

C Parameterization II

This appendix provides parameterization of the variables that are related to the credit contracts among investors, FIs and entrepreneurs. The values are all taken from HSU. In HSU, we choose them so that they are consistent with the equilibrium conditions and the observed U.S. data.

Calibrated Parameters[6]

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

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 FIs' lending 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.

[6]Figures are quarterly unless otherwise noted.

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(Table 1) Welfare comparison with the Ramsey rule

	n_F	n_E	σ_F	σ_E	TFP
Benchmark Policy	-2.38	-1.15	-1.21	-1.14	-2.48
Policy II (Weak)	-1.98 (+)	-1.17 (-)	-1.18 (+)	-1.19 (-)	-2.34 (+)
Policy II (Strong)	-1.76 (+)	-1.28 (-)	-1.17 (+)	-1.26 (-)	-2.31 (+)
Policy III (Weak)	-2.16 (+)	-1.17 (-)	-1.19 (+)	-1.19 (-)	-2.18 (+)
Policy III (Strong)	-2.03 (+)	-1.26 (-)	-1.18 (+)	-1.25 (-)	-2.19 (+)
Policy IV (Weak)	-2.14 (+)	-1.14 (+)	-1.20 (+)	-1.14 (0)	-2.91 (-)
Policy IV (Strong)	-1.93 (+)	-1.14 (+)	-1.19 (+)	-1.14 (0)	-3.53 (-)
CIFN (Weak)	-2.22 (+)	-1.14 (+)	-1.19 (+)	-1.15 (-)	-2.49 (-)
CIFN (Strong)	-1.23 (+)	-1.57 (-)	-1.46 (-)	-1.68 (-)	-2.55 (-)
CIEN (Weak)	-2.36 (+)	-1.11 (+)	-1.20 (+)	-1.14 (0)	-2.50 (-)
CIEN (Strong)	-2.26 (+)	-0.96 (+)	-1.27 (0)	-1.26 (-)	-2.63 (-)

Notes:

1. Each number represents the deviation of consumption in percent in a case in which a certain policy is implemented compared with that in a case in which the Ramsey policy is implemented.

2. Signs (+, −, 0) in parenthesis represent welfare improvement, deterioration, and no change compared with the benchmark policy, respectively.

3. Weak and strong policy in Policy II, III, and IV suggests that the coefficient on credit spreads is 0.5 and 1, respectively. Weak and strong capital injection suggests that capital is injected by 0.1% and 1% of steady state GDP.

4. The amplitude of shocks are 10% of steady state GDP (1.25% of steady state asset QK) for the net worth shocks, 10% of the standard deviation of idiosyncratic productivity of borrowing sectors for the riskiness shocks, and 10% of productivity for the TFP shock.

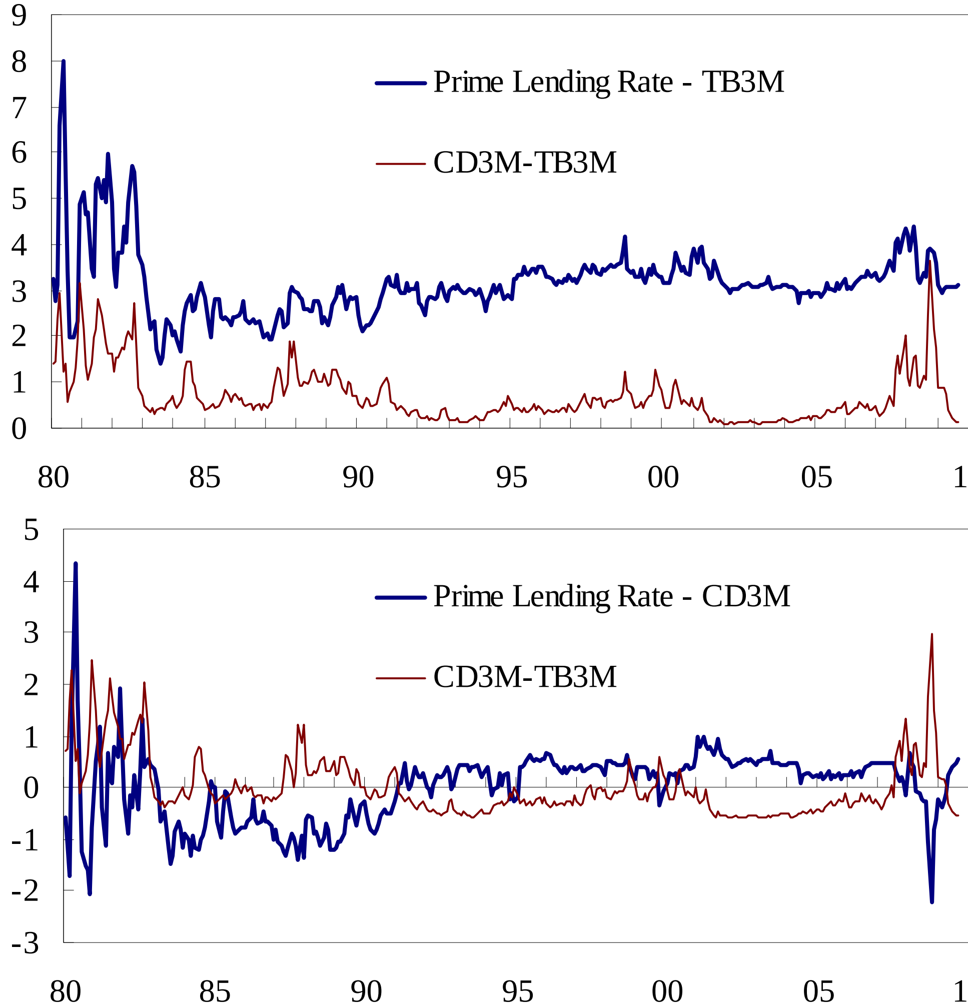

Figure 1: The upper panel shows the time paths of the spread between prime lending rate and treasury bill, and the spread between certificate of deposit (CD) and treasury bill. The lower panel shows the demeaned time paths of the spread between prime lending rate and CD, and the spread between CD and treasury bill.

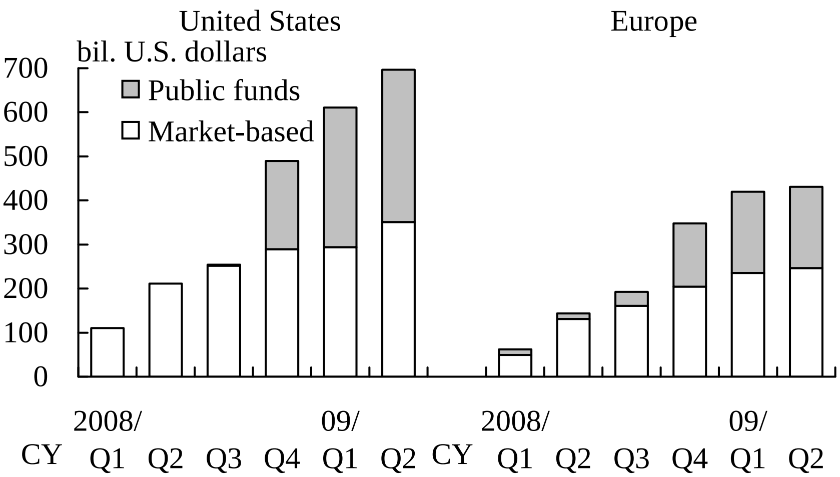

Figure 2: Capital Raised by Global Financial Institutions. Figures are accumulated using data from July 2007. The values are the sum of those of brokerage firms, insurance companies and GSEs, as well as banks. Financial institutions in the United States and Euro are the sum of 43 and 45 financial institutions, respectively.

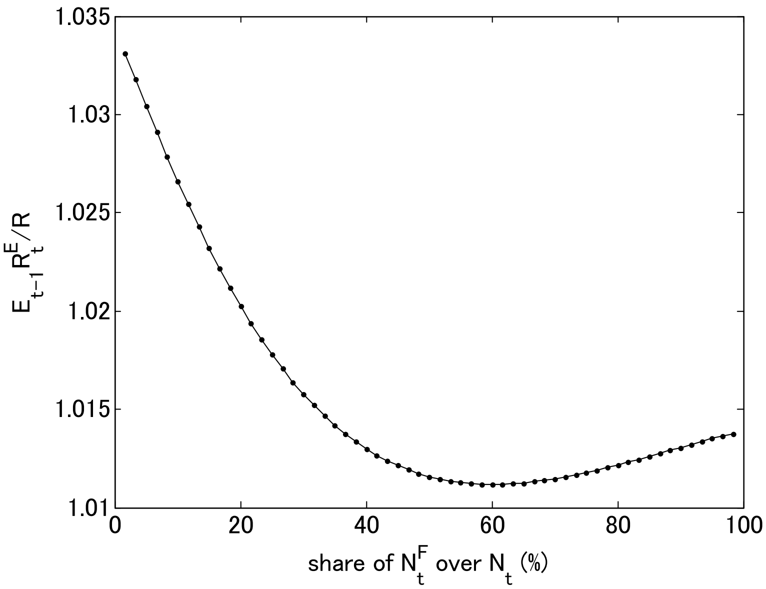

Figure 3. Effect of the net worth distribution on the external finance premium. μ^F, μ^E, σ^F and σ^E are calibrated to the US economy. The y-axis denotes the external finance premium and x-axis denotes the share of the FIs' net worth over the total net worth.

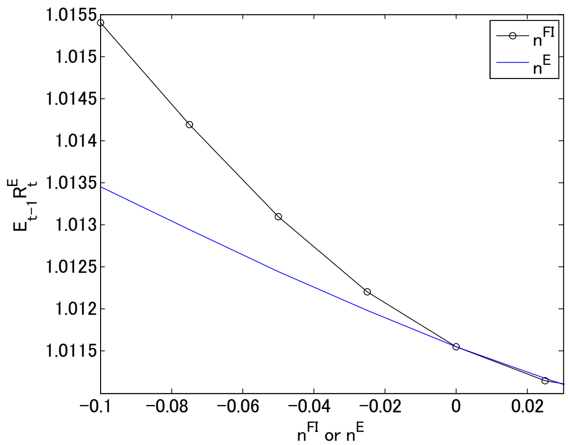

Figure 4: Change in the risk premium for marginal decrease in the net worth held by FIs and entrepreneurs.

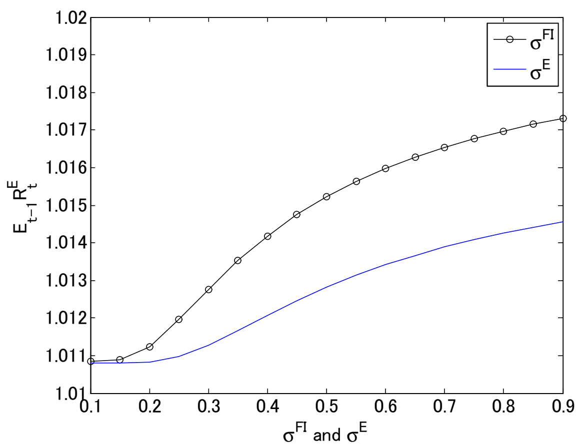

Figure 5: Changes in the risk premium for an increase in FI's riskiness and entrepreneur's riskiness.

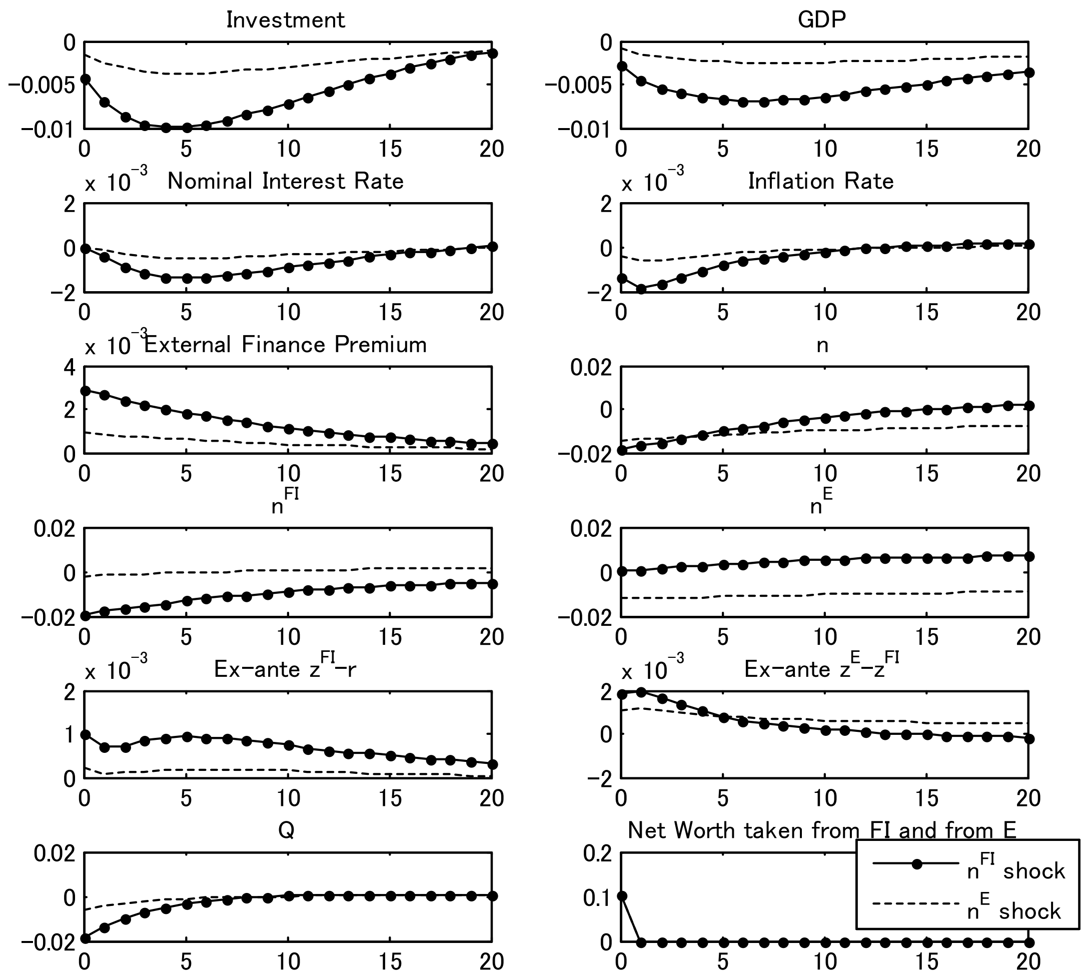

Figure 6: Impulse response to a temporary decline in net worth of the borrowing sectors.

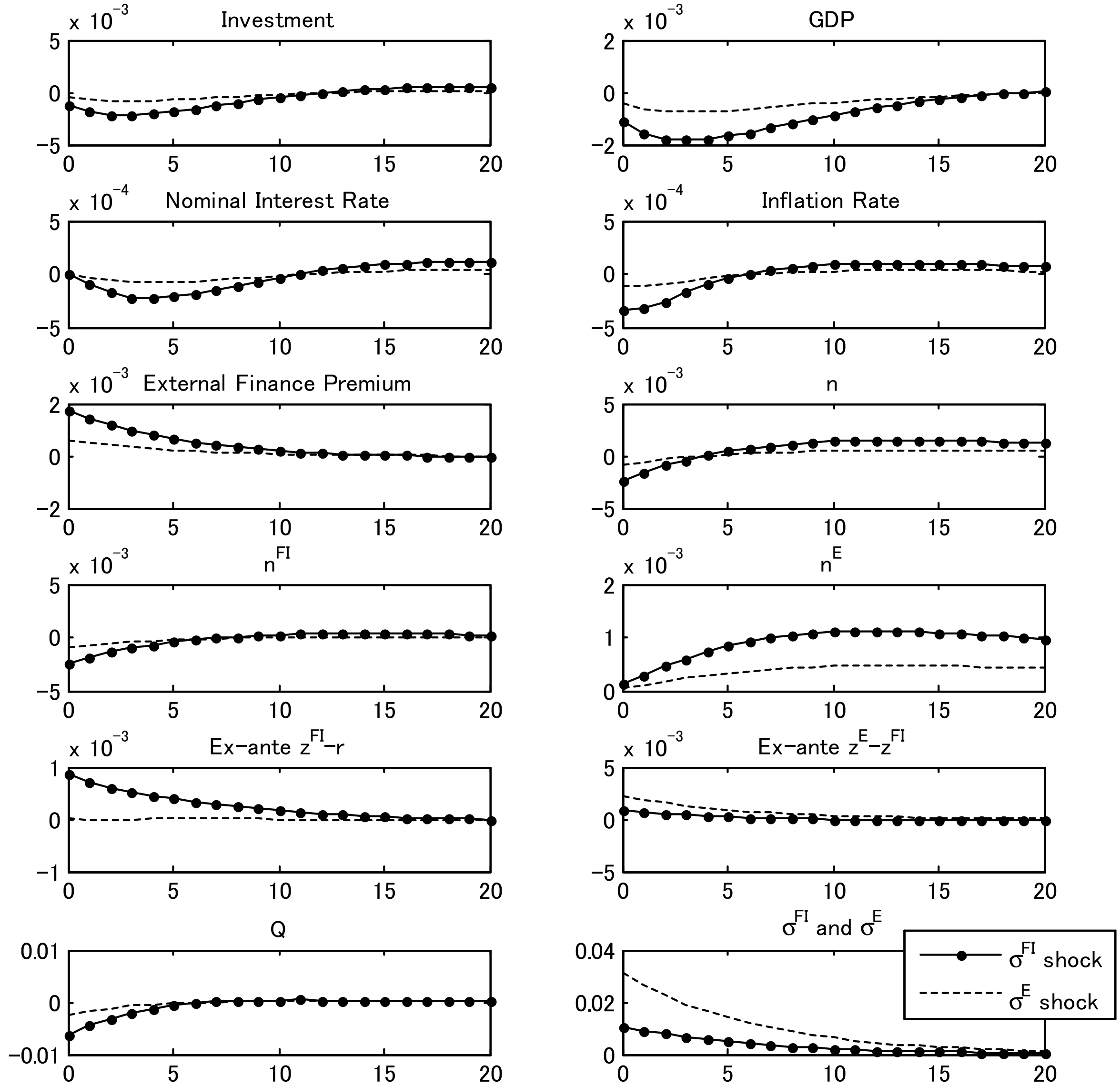

Figure 7: Impulse response to a temporary rise in riskiness.

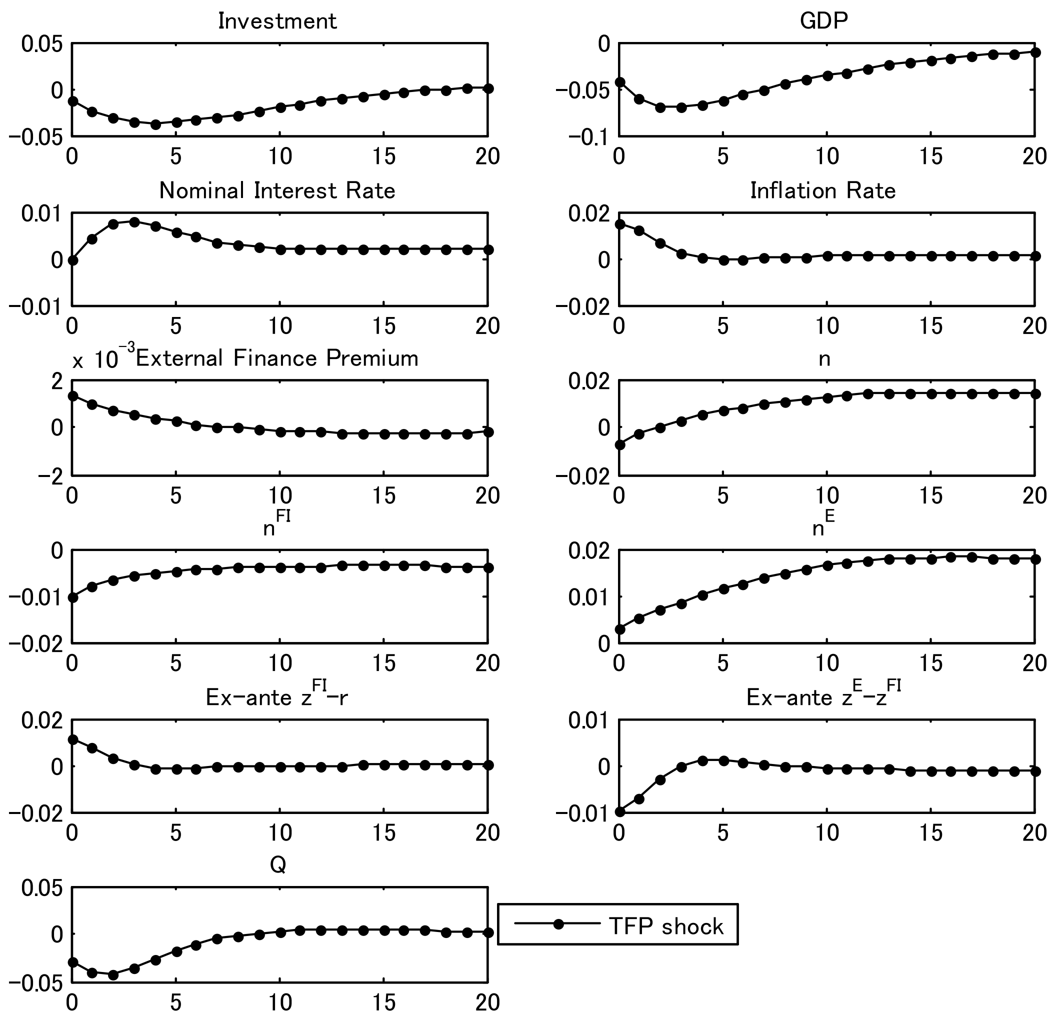

Figure 8: Impulse response to an adverse technology shock

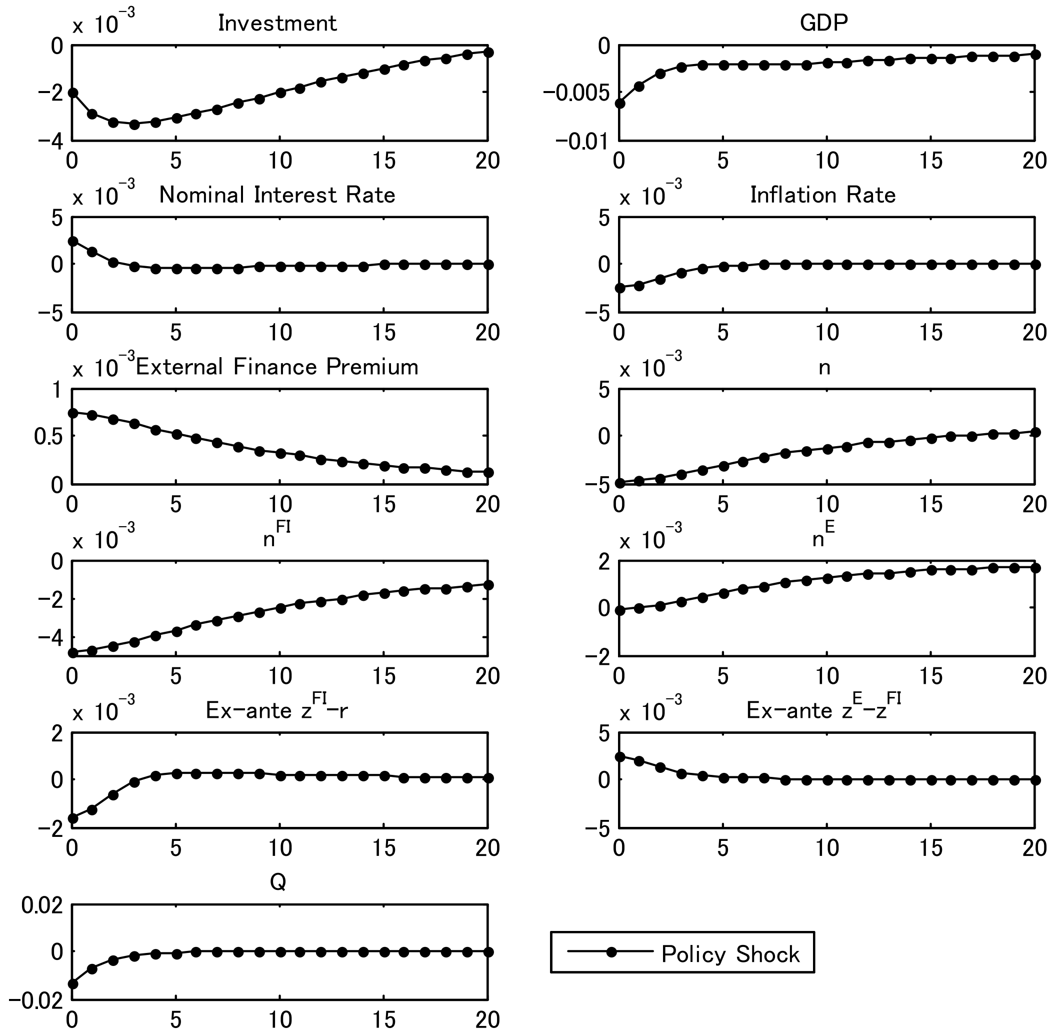

Figure 9: Impulse response to a temporary increase in the policy rate.

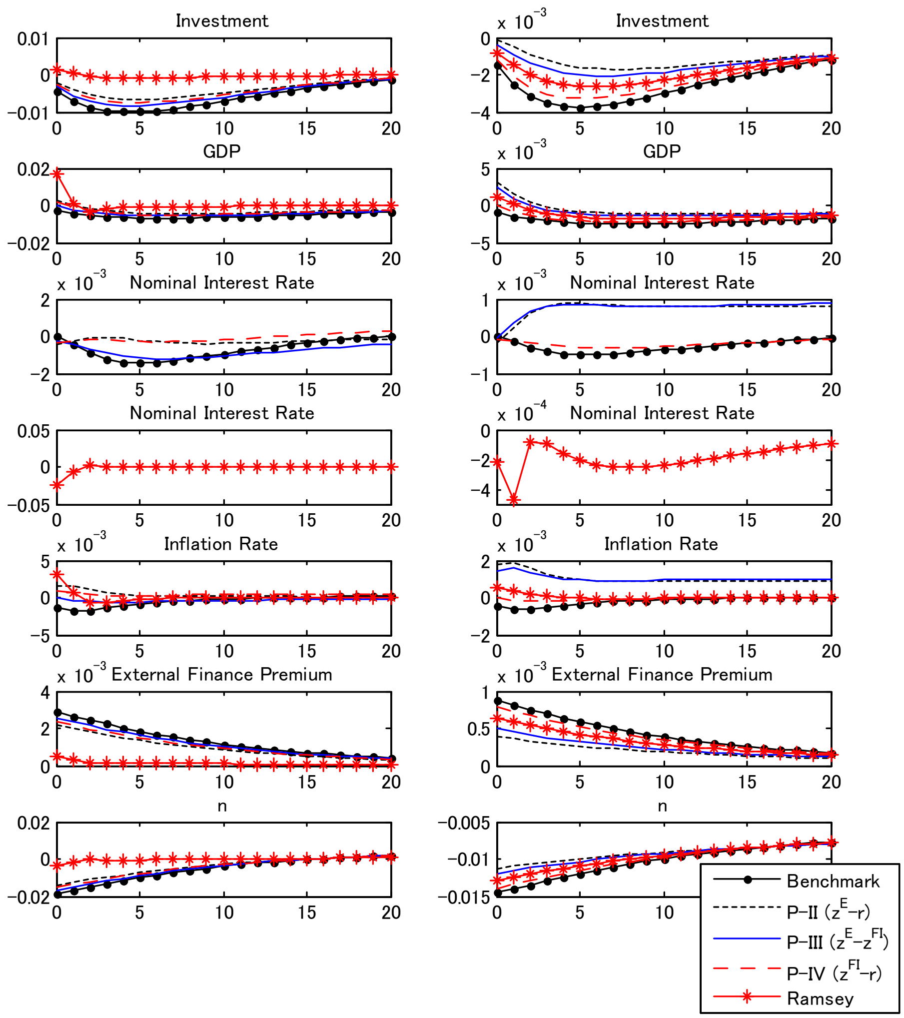

Figure 10: Impulse response to a one-shot decline in net worth under different policy rules. Left and right panels represent responses to shocks to FIs and entrepreneuris, respectively.

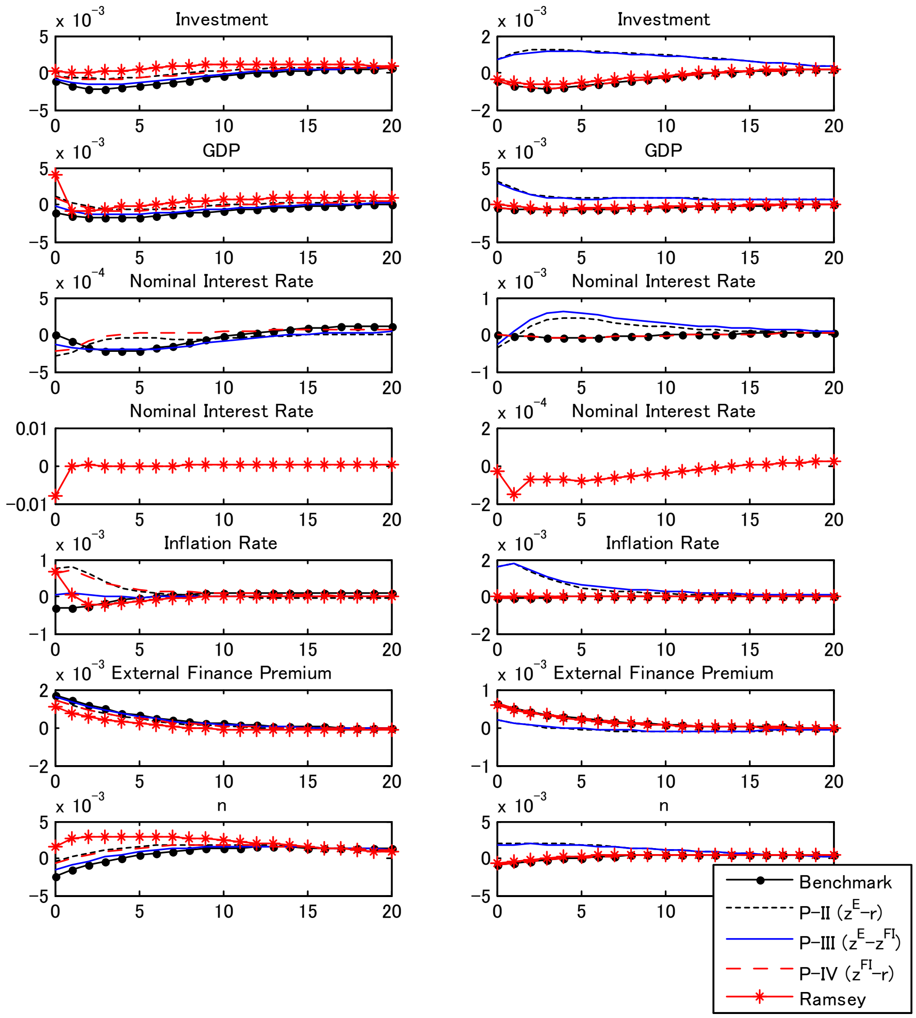

Figure 11: Impulse response to a rise in riskiness under different policy rules. Left and right panels represent responses to riskiness shocks to FIs and entrepreneuris, respectively.

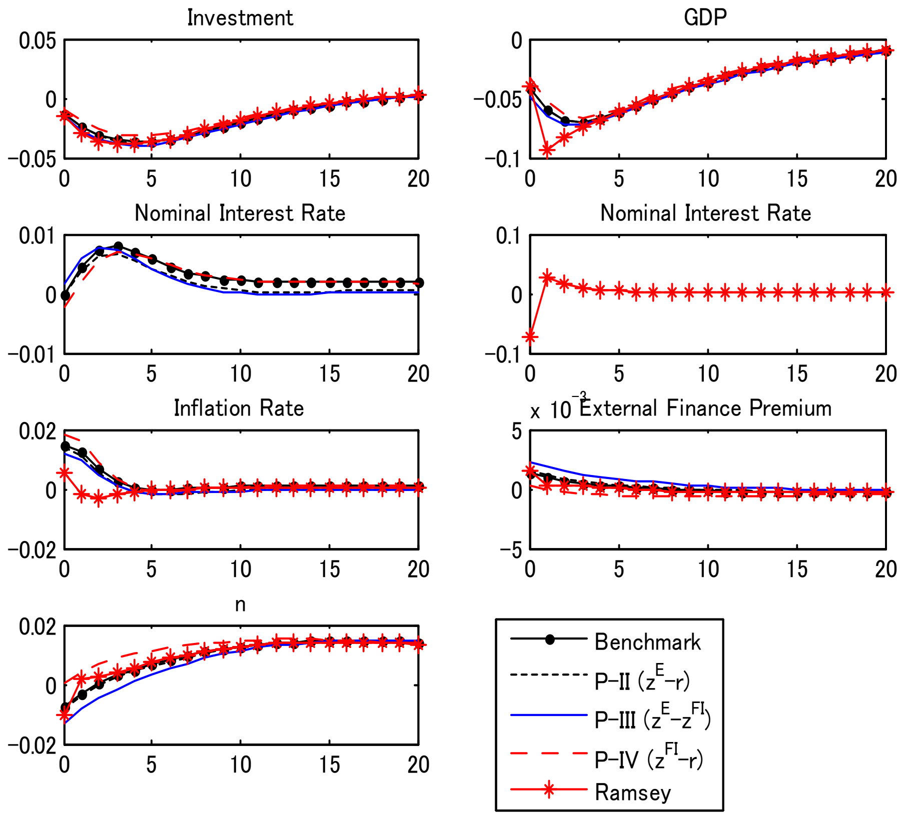

Figure 12: Impulse response to an adverse technology shock under different policy rules.

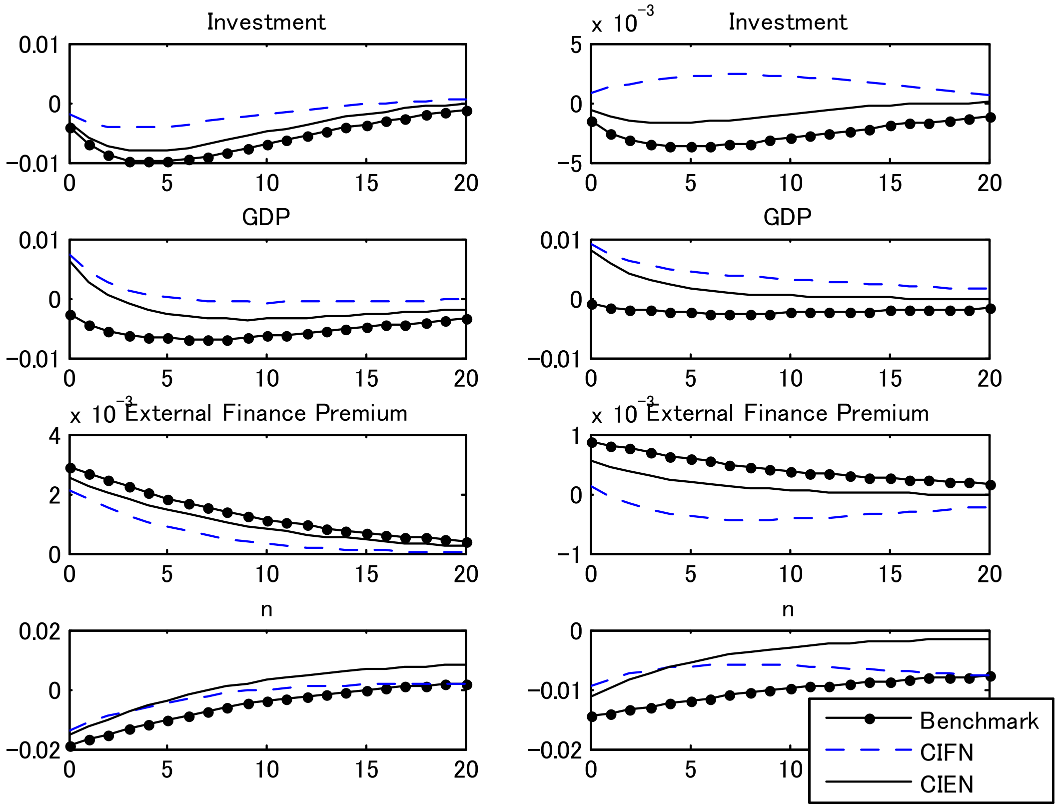

Figure 13: Impulse response to a one-shot decline in net worth under capital injection policy. Left and right panels represent responses to shocks to FIs and entrepreneuris, respectively.

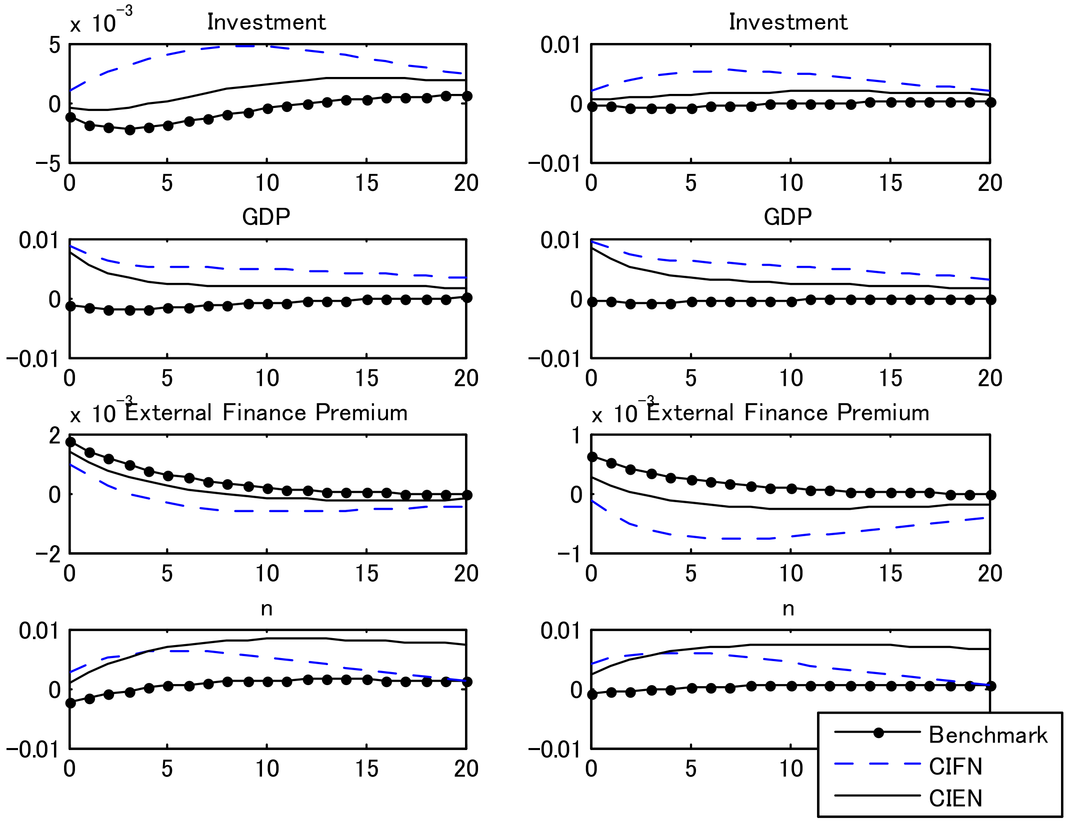

Figure 14: Impulse response to a rise in riskiness under capital injection. Left and right panels represent responses to riskiness shocks to FIs and entrepreneuris, respectively.

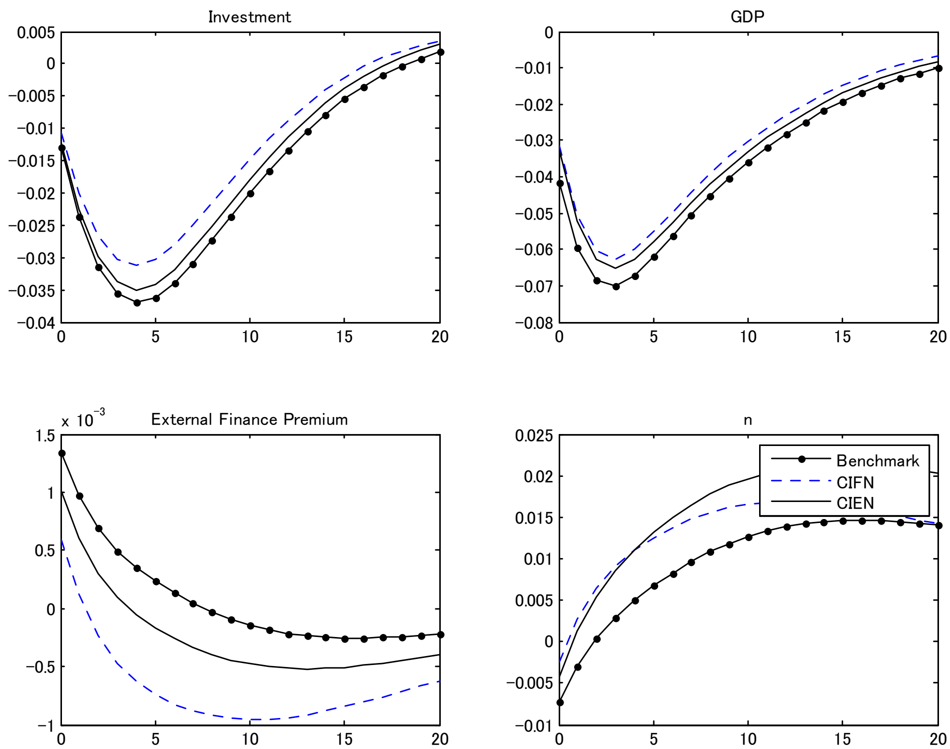

Figure 15: Impulse response to a decline in the productivity