

Capital Requirements and Financial Problems with the Macroeconomy

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Abstract

The 2008 financial crisis has revitalized policymakers to find an appropriate policy to respond to recurring financial problem. The purpose of this paper is to investigate the impacts of capital requirements in response to shocks and to find out how capital requirements work in reducing financial problems and stabilizing balance sheets. We consider a macroeconomic model with a banking sector that is allowed to borrow funds from the international and domestic markets. The results show that capital requirements are efficient in responding to financial problems. It increases the bank's net worth and reduces its leverage ratio. A less aggressive policy produces lower losses and stabilizes the variation of net worth and bank leverage. But a high degree of responsiveness is required if authorities aim to accelerate net worth accumulation and overcome a banking crisis. However, capital requirements are less effective in responding to technology shocks. Capital requirements cannot fully stabilize net worth and balance sheets.

Keywords: Capital Requirements, Financial Problems,
Macroeconomic Model

1. Introduction

The 2008 financial crisis has shown that macroeconomic stability does not guarantee banking sector stabilization. Sometimes the financial problem is not related to the policy interest rate, rather it depends on the banker behavior in making decisions on their balance sheets. A bank maximizes its profit by purchasing the assets and finances by borrowing from financial markets. However, many banks failed to internalize their balance sheets and made decisions based on the aggregate asset prices. This contributed the financial effects to the banking system and accumulated the systemic risk. After a subprime crisis, the devaluation in the assets has sharply deteriorated banks' balance sheets and net worth contraction. Thus, banks face high external finance premiums and induce to a reduction of investment and output. The impacts of financial problem become more severe and lead to a significant output loss. Moreover, it takes time for policymakers to overcome such a banking crisis.

The objective of this paper is to find out whether the regulatory instrument imposed by the Basel committee helps to mitigate the banking problem and improves banks' balance sheets. The capital requirement is introduced to regulate banks' behavior and to limit the impacts of the financial problem. To end this question, we use a standard open economy with the banking sector following Gertler and Karadi (2011). In this set up, it shows the capital inflows from the agency problem between domestic financial intermediaries and foreign investors. The leverage ratio can be determined within the model and it will fluctuate over the cycles. As a sequence, the amount of credit supply that the bank can extend from the external funds depends on endogenous bank capital (net worth). In the presence of adverse shocks, namely a technology shock and capital quality shock, a reduction in the bank capital leads to a self-enforcing financial accelerator mechanism. That is banks will reduce their domestic credit supply immediately in order to restore acceptable bank capital levels, thereby driving the asset prices down further.

Many papers investigate the potential benefit of capital requirement on the financial crisis, such as Meh et al. (2008), Angeloni et al. (2009),

Dib (2010), Chistensen et al. (2011), Gertler et al. (2012), and find that the potential gains of capital requirement reduce the impacts of the financial crisis. Meh et al. (2008), uses a standard dynamic stochastic general equilibrium (DSGE) model with the bank to examine the effects of bank capital and balance sheets on the economy. The paper finds that the bank's capital has a negative relation to the financial shock and helps stabilizing the financial crisis. The bank's capital shortage generates double impacts during the economy downturn during crisis. Angeloni et al. (2009), using a DSGE model with monetary policy reaches the similar conclusion. The key finding is that a strong countercyclical capital requirement improves economic losses when the economy is hit by the banking crisis. The gains of capital requirement in responding to technology shocks depend on the aggressive of the monetary policy. Dib (2010) analyzes the role of capital requirement in propagating the effects of shocks in real economy under financial frictions environment by using a DSGE model with an active role of banking sector, financial accelerators, and financial frictions in the capital market. The result shows that the financial frictions in the capital market amplify the effects of shocks on the economy and the capital requirement reduces real impacts of shocks by stabilizing macroeconomic variables. Chistensen et al. (2011), extends further by investigating the interaction between the monetary policy and countercyclical buffers. The study reveals that a strong interaction between the capital requirement and monetary policy are benefit. The countercyclical bank leverage regulation is more beneficial if bank's capital shock arises. Gertler et al.(2012) investigates the impacts of capital requirement whether it discourages the bank to issue short-term debts and encourages the bank to increase the net worth. The study finds that the capital requirement can stabilize the bank's balance sheets and the potential benefit is high when economy faces a financial crisis. This paper differs from the previous studies in two key aspects. First, the model is analyzed under a neoclassical perspective of a small open economy that the bank is allowed to borrow from an international financial market. Second, the model is calibrated based on the Thai economic parameters.

This paper is organized as follows. Section 2 briefly presents the baseline model description. Section 3 is the quantitative model analysis. The last section offers some conclusions and remarks.

2. The baseline model

The core framework is a small open economy neoclassical model. We modify this model with a financial sector based on Gertler and Karadi (2011) and Steffen (2011). A financial intermediary is allowed to borrow from two financial sources, namely domestic deposits and international financial markets. There are four types of agents in the economy: households, financial intermediaries, non-financial firms and capital producers. The capital producers' production is subject to the capital adjustment costs, otherwise the capital can change easily. The financial intermediaries are owned by domestic households and invest mainly by purchasing assets of non-financial domestic firms. An agency problem between financial intermediaries and lenders generates an endogenous borrowing constraint on the leverage ratio in the financial sector and introduces the financial accelerator mechanism following Bernanke et al. (1999). We also include a disturbance to the quantity of capital. With a financial frictions process, the shock induces a significant capital loss in the banking sector, which in turns increases a tightening credit and a significant downturn. The real activity of the economy depends on the financial contract, and the banks' balance sheets constraint limits domestic production. Next, we will characterize the basic ingredients of the model.

2.1 Households

Assuming that there is measure one continuum of identical households in the economy, each household engages in consumption, savings, and labor supply. A household saves by lending funds to competitive financial intermediaries.

Within each household, there is a fraction $(1 - f)$ of workers and a fraction f of bankers. Workers supply labor to non-financial firms and return the wage they earn to the household. Bankers manage financial intermediaries and contribute to the household's income by transferring their earnings back to the household. Within each household, there is perfect consumption insurance. Bankers face a finite horizon to insure that over time they will not accumulate capital until they can fund all investment projects from their own capital. In particular, bankers have probability $(1 - \varphi)$ to exit from the financial

sector, which is independent of history. The average survival time for the bankers to work in the financial sector is $1/(1 - \varphi)$ and leads to the amount $f(1 - \varphi)$ of bankers that exit the financial sector and become workers in each period. To keep a constant ratio of workers and bankers, a similar amount of workers moves to the financial sector. Bankers who exit finally transfer their retained earnings to their household. The new entry bankers will be provided with some start-up funds from their family which will be described later.

Households maximize expected lifetime utility function by choosing a level of consumption (C_t), labor supply (H_t), and next period deposit level (D_{t+1}^H). The household preferences are given as follows:

$$\max E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \chi \frac{H_t^{1+\nu}}{1+\nu} \right] \quad (1)$$

with $\beta \in (0,1)$ denotes the subjective discount factor and $\sigma, \nu, \chi > 0$ represent the degree of risk aversion, the elasticity of labor supply and disutility weight, respectively.

The intermediaries' deposit is a one period deposit which pays a real gross return R_t^d from period $t - 1$ to t . In equilibrium, it is considered as a riskless asset. Let D_{t+1}^H be the total demand for deposits the household acquires, W_t be the real wage, and Π_t be the net payouts to the household from the ownership of both non-financial firms and financial intermediaries. The household budget constraint is given as follows:

$$C_t + D_{t+1}^H = W_t H_t + R_t^d D_t^H + \Pi_t \quad (2)$$

The household's correspondingly optimal conditions for consumption, labor supply, and saving are, respectively, given by

$$\Lambda_{t,t+1} = E_t \left[\frac{C_{t+1}^{-\sigma}}{C_t^{-\sigma}} \right] \quad (3)$$

$$\frac{\chi H_t^\nu}{C_t^{-\sigma}} = W_t \quad (4)$$

$$\beta E_t [\Lambda_{t,t+1} R_{t+1}^d] = 1 \quad (5)$$

where $\Lambda_{t,t+1}$ is the marginal rate of substitution of consumption between the period t and $t + 1$. Equation (4) sets the marginal rate of substitution between

consumption and leisure equal to the real wage. The last equation denotes the optimal savings decision which implies that the household smooths consumption over time.

2.2 Financial intermediaries

The financial intermediaries are owned by domestic households. Banks lend funds obtained from households and international financial markets to non-financial firms. Bankers act as specialists that assist in transferring funds from savers to investors. They engage in the maturity transformation by holding long term assets and fund these assets with short term liabilities. The financial intermediaries capture the entire banking sector including investment banks and commercial banks.

The representative financial intermediary j is separated into two subunits, a liabilities unit and operation unit. The liability unit obtains two sources of funding, namely depositors and foreign lenders, and then sells them as liabilities to the operation unit. The operation unit acts as a commercial bank and uses liabilities to expand its balance sheet by purchasing the assets.

The liability unit obtains deposits (D_{jt+1}^B) with an interest rate R_t^d and foreign debts (B_{jt}^*) with an interest rate R_t^* . Then they sell liabilities (L_{jt}) to an operation unit with an interest rate R_t^L . However, to obtain the foreign debts, bank faces a convex adjustment cost, $\frac{\tau_b}{2} \left(\frac{B_{jt}^*}{L_{jt}} - \vartheta \right)^2$. ϑ is a desire level of foreign debt to liabilities ratio. It costs to the liability unit if the structure of debt over the desired level. The purpose to introduce this friction is to wedge between a domestic interest rate and foreign interest rate.

The liability unit maximization problem is specified as follows:

$$\max_{D_{jt+1}^B, B_{jt+1}^*} E_t \sum_{i=0}^{\infty} \beta^i \Lambda_{t,t+i} (R_{t+1}^L L_{jt+1} - R_t^d D_{jt}^B - R_t^* B_{jt}^* - \frac{\tau_b}{2} \left(\frac{B_{jt}^*}{L_{jt}} - \vartheta \right)^2) \quad (6)$$

subject to the liabilities constraint given by

$$L_{jt+1} = D_{jt+1}^B + B_{jt+1}^* \quad (7)$$

The liability unit chooses optimal deposits to maximize their profit as follows:

$$(R_{t+1}^L - R_{t+1}^d) = -\tau_b \left(\frac{(B_{jt+1}^*)}{L_{jt+1}} - \vartheta \right) \left(\frac{(B_{jt+1}^*)}{(L_{jt+1})^2} \right) \quad (8)$$

The liability unit chooses optimal foreign debts to maximize their profit as follows:

$$(R_{t+1}^L - R_{t+1}^*) = \tau_b \left(\frac{(B_{jt+1}^*)}{L_{jt+1}} - \vartheta \right) \left(\frac{D_{jt+1}^B}{(L_{jt+1})^2} \right) \quad (9)$$

Dividing equation (8) by equation (9), we get the return to liabilities as follows:

$$R_{t+1}^L = R_{t+1}^d \left(\frac{D_{jt+1}^B}{L_{jt+1}} \right) + R_{t+1}^* \left(\frac{B_{jt+1}^*}{L_{jt+1}} \right) \quad (10)$$

Note that the return on liabilities is a sum average of the interest rates.

The operation unit maximizes the expected terminal values of net worth. Let N_{jt} be the amount of net worth that the intermediary j holds at the end of period t , L_{jt+1} be the liabilities composing of domestic deposits (D_{jt+1}^B) and the non-contingent debts (B_{jt+1}^*) that banks issue to international financial markets, Z_{jt} be the quantity of financial claims on non-financial firms that banks hold, and Q_t denotes the relative price of each claim. The relationship between assets and liabilities of balance sheet of financial intermediary j at time t is given by

$$Q_t Z_{jt} = N_{jt} + L_{jt+1} \quad (11)$$

The L_{jt+1} can be thought as the intermediary's debts and N_{jt} as its equity capital. The bank assets earn the stochastic return R_{t+1}^K over this period. Note that both R_{t+1}^K and R_{t+1}^L are determined endogenously.

Over time, the financial intermediary's net worth evolves as the difference between earnings on the assets and interest repayments on its liabilities, which is given by

$$\begin{aligned} N_{jt+1} &= R_{t+1}^K (Q_t Z_{jt}) - R_{t+1}^L (L_{jt+1}) \\ &= (R_{t+1}^K - R_{t+1}^L) Q_t Z_{jt} + R_{t+1}^L N_{jt} \end{aligned} \quad (12)$$

The growth of net worth above the riskless return is increasing in the total quantity of assets, $Q_t Z_{jt}$, and depends on the interest rate premium ($R_{t+1}^K - R_{t+1}^L$). When the bankers receive a payment on its assets, he repays to the lenders.

Let $\beta^i \Lambda_{t,t+i}$ denote the stochastic discount factor that the banker, at t , applies to the earnings at $t + i$. In order to set an incentive for the financial intermediary to engage in financial intermediation, the risk adjusted interest rate premium must be positive at all times and given as follows:

$$E_{t+i} \beta^i \Lambda_{t,t+i} (R_{t+1+i}^K - R_{t+1+i}^L) \geq 0, i \geq 0 \tag{13}$$

The rational banker will not fund the assets if a discounted return less than the discounted borrowing cost. Under perfect capital markets, this relationship always holds at equality, the risk adjusted premium is zero. However, with imperfect capital markets, the premium must be positive due to limits on the bank’s ability to receive funds. As long as the incentive constraint always holds, the bankers keep building assets until they exit from the financial sector. The financial intermediary uses the household’s discount factor, since it is owned by the latter. This motivates the financial intermediary’s objective to maximize the terminal values of the net worth which can be carried over to the household at the end of its lifetime.

Formally, the bankers’ maximize the expected terminal wealth, given by

$$V_{jt} = \max_{(Z_{jt})} E_t \sum_{i=0}^{\infty} (1 - \varphi) \varphi^i \beta^{t+i} \Lambda_{t,t+i} (N_{jt+t+i}) \tag{14}$$

with $N_{jt+t+i} = (R_{t+1+i}^K - R_{t+1+i}^L) Q_{t+i} Z_{jt+i} + R_{t+1+i}^L N_{jt+i}$

Given a positive interest rate premium, $E_{t+i} \beta^i \Lambda_{t,t+i} (R_{t+1+i}^K - R_{t+1+i}^L)$, the financial intermediary wants to extend its assets indefinitely by borrowing additional funds from the financial markets. In so doing, we follow Gertler and Karadi (2011) by adopting a moral hazard problem between international investors and domestic banks motivates to limit the borrowing behavior of the bankers. Specifically, at the beginning of the period the banker has a possibility to divert the fraction λ_t of available funds from the project and transfers them back to the household that he or she is a member. The cost to the banker is that lenders can force the intermediary into bankruptcy and

recover the remaining fraction $(1 - \lambda_t)$ of assets. However, it is too costly for the lenders to recover the fraction of assets that banker had diverted.

The lender is willing to supply the funds into the banking system, if the following incentive constraint holds:

$$V_{jt} \geq \lambda_t Q_t Z_{jt} \tag{15}$$

Only if the value of the banker on the left is higher than the value to divert funds on the right, the lenders are insured that they will not going to be defrauded, and continually lend their capital to the domestic banks. The left is what bankers would lose if they divert the assets, whereas the right is the gain in doing so. With a profit maximization objective, the bankers will expand the assets up to the point that the incentive compatibility constraint is binding, and if the interest rate premium is always positive.

The solution of the bank operation maximization problem can be expressed in the following form:

$$V_{jt} = l_t Q_t Z_{jt} + n_t N_{jt} \tag{16}$$

with

$$\begin{aligned} l_t &= E_t \{ (1 - \varphi) \beta \Lambda_{t,t+1} (R_{t+1}^K - R_{t+1}^L) + \beta \Lambda_{t,t+1} \varphi x_{t,t+1} l_{t+1} \} \\ n_t &= E_t \{ (1 - \varphi) \beta \Lambda_{t,t+1} (R_{t+1}^L) + \beta \Lambda_{t,t+1} \varphi z_{t,t+1} n_{t+1} \} \end{aligned} \tag{17}$$

where $x_{t,t+1} = Q_{t+1} Z_{jt+1} / Q_t Z_{jt}$ is the gross growth rate of the assets from period t to $t + 1$, and $z_{t,t+1} = N_{jt+1} / N_{jt}$ is the gross growth rate of the net worth. The l_t denotes the expected marginal gains of having additional asset given the net worth being constant and n_t is the expected value of the bank of having additional unit of the net worth given the asset being constant. The value of l_t is related to the positive interest rate premium constraint. With the frictionless competitive capital markets, the bank will expand borrowing up to the point that the rate of return will adjust until l_t is zero. Thus, the agency problem that is introduced may put limits on this arbitrage.

If the incentive constraint is binding, it can be shown that the intermediary's assets are constrained by its net worth. The incentive constraint can be expressed as follows:

$$l_t Q_t Z_{jt} + n_t N_{jt} \geq \lambda_t Q_t Z_{jt} \quad (18)$$

Given a binding constraint, the asset holding by financial intermediaries can be expressed in the term of net worth position as follows:

$$Q_t Z_{jt} = \left(\frac{n_t}{\lambda_t - l_t} \right) N_{jt} \quad (19)$$

Given net worth N_{jt} being constant, an increase in asset quantity Z_{jt} would break this balance and raises an incentive for the banker to divert funds. Rearranging the previous equation yields the bank j 's leverage ratio as the relation of the asset over the net worth, given by

$$Q_t Z_{jt} = \phi_t N_{jt} \quad (20)$$

with

$$\phi_t = \frac{n_t}{\lambda_t - l_t}$$

where ϕ_t is the ratio of asset to capital, which refers to the individual financial intermediary's leverage ratio. This constraint limits bank's leverage ratio to the point where the banker has incentive to cheat exactly balanced by the cost. Hence, the agency problem leads to an endogenous constrained bank's balance sheets (the net worth) to acquire more assets.

The asset diverting process is increasing in the net worth and assets growths, but decreasing in the leverage ratio. We can think that the bank diverts the fraction of assets for a personal purpose (e.g. payout a large bonus), which can be written in the following from:

$$\lambda_t = \frac{n_t + \phi_t l_t}{\phi_t} \quad (21)$$

Given $N_{jt} > 0$, the constraint is binding only if $0 < l_t < \lambda_t$. In this instance, it is profitable for the banker to expand assets since l_t is greater than zero. The larger is l_t , the greater is the opportunity cost to the banker from being forced into bankruptcy. This is because of an increase in the asset growth and opportunity to divert assets to satisfy the banks maximization problem. If l_t rises above λ_t , the incentive constraint does not bind, the present value of the bank always exceeds the gain from diverting funds.

The net worth evolution can be rearranged in the following form:

$$N_{jt+1} = [(R_{t+1}^K - R_{t+1}^L)\phi_t + R_{t+1}^L]N_{jt} \quad (22)$$

Regarding to equation (20), the leverage ratio is specified by a non-firm-specific component. This allows us to obtain the aggregate demand for assets and the aggregate net worth of the financial system by summing over all individuals as follows:

$$Q_t Z_t = \phi_t N_t \quad (23)$$

with ϕ_t denotes the aggregate leverage ratio in the banking sector, Z_t is the aggregate demand for an asset quantity, and N_t is the aggregate net worth of the banking system.

We can derive an equation of motion for the net worth of the banking system, by first recognizing that it is the sum of the net worth of existing bankers (N_{et}) and the net worth of entering bankers (N_{nt}). It can be expressed as the follows:

$$N_t = N_{et} + N_{nt} \quad (24)$$

Since the fraction φ of the bankers at period $t - 1$ survive until period t , the net worth of existing bankers is given by

$$N_{et} = \varphi[(R_t^K - R_t^L)\phi_{t-1} + R_t^L]N_{t-1} \quad (25)$$

It can be observed that the main source of variation in N_{et} will be fluctuations in the ex post return on the asset R_t^K . In addition, the net worth (N_{et}) is increasing in the leverage ratio (ϕ_t). The entering bankers receive a transfer from their family as a start up value, which is equal to fraction $\omega/(1 - \varphi)$ of value of assets $(1 - \varphi)Q_{t-1}Z_{t-1}$ that exited bankers had transferred out in their final operating period. Thus, in the aggregate level, a fraction of new entering bankers can be written as

$$N_{nt} = \frac{\omega}{(1 - \varphi)}(1 - \varphi)Q_{t-1}Z_{t-1} = \omega Q_{t-1}Z_{t-1} \quad (26)$$

Combining equation (25) and equation (26), once yields the following equation of motion for net worth:

$$N_t = \varphi[(R_t^K - R_t^L)\phi_{t-1} + R_t^L]N_{t-1} + \omega Q_{t-1}Z_{t-1} \quad (27)$$

Note that ω helps pinning down the steady state of leverage ratio QZ/N .

2.3 Non-financial firms

Next, we turn to the production and investment sides of the economy. There are competitive non-financial firms engaged in the production of a single tradable retail good which serves as a numeraire. Producers combine capital and labor into the Cobb-Douglas production function to produce a final consumption good, which is given by

$$Y_t = A_t (\xi_t K_t)^\alpha H_t^{1-\alpha}, 0 < \alpha < 1 \quad (28)$$

where K_t is the capital stock and H_t denotes the labor input. The total factor productivity and the capital quality shocks are assumed to follow an AR(1) process as follows:

$$\ln(A_t) = \rho_A \ln(A_{t-1}) + \varepsilon_{A,t} \quad (29)$$

$$\ln(\xi_t) = \rho_\xi \ln(\xi_{t-1}) + \varepsilon_{\xi,t} \quad (30)$$

with $E_t(A_t) = 1$ and $\varepsilon_{A,t} \sim i.i.d.N(0, \sigma_A^2)$, $E_t(\xi_t) = 1$ and $\varepsilon_{\xi,t} \sim i.i.d.N(0, \sigma_\xi^2)$.

Following Gertler and Karadi (2011), the capital quality shock ξ_t provides an exogenous source of variation in the capital value. In the context of the model, it corresponds to economic depreciation of capital so that $(\xi_t K_t)$ is an effective capital quantity at period t . The capital quality shock causes the devaluation of bank's capital and deteriorates the balance sheet. Thus, banks face a financial distress condition and eventually the crisis.

When outputs are available to the firms at the end of the period, the wage bill ($W_t H_t$) will be paid to the households. Firms have options to sell depreciated capital $(1 - \delta)K_t$ to the capital producers at the unitary price of Q_t and the new capital stock K_{t+1} is purchased for production in subsequent period. The firms finance its capital acquisition each period by borrowing funds from the financial intermediaries. To acquire the funds to purchase capital, firms issue claims Z_{jt} which is equal to the number of units of capital K_{t+1} , and price each claim at a unit price of capital Q_t . The relationship between the value of capital acquired and the value of claims against capital is given by

$$Q_t Z_{jt} = Q_t K_{t+1} \quad (31)$$

This condition equates the price of a unit of capital to the price of financial claim. The arising equity contract between the financial intermediary and the non-financial firm yields the gross interest rate R_t^K . This implies that firms will pay $R_t^K(Q_t Z_{jt-1})$, a zero profit condition in the non-financial sector, to the bank. Assuming that there is frictionless between this contracts which is an underlying assumption, the intermediaries have perfect information about the firms and have no problem enforcing payoffs. Thus, firms offer a perfectly state-contingent debt to financial intermediaries, best interpreted as firms' equity. However, since banks suffer from the agency problem in financial markets, physical capital purchases are indirectly affected through this constraint. Within the model, only financial intermediary faces capital constraints to obtain funds and, these constraints affect the supply of funds available to non-financial firms. The required rate of return on capital eventually rises.

A firm profit maximization problem yields the following optimal conditions for factors demand:

$$(1 - \alpha) \frac{Y_t}{H_t} = W_t \tag{32}$$

$$E_t R_{t+1}^K = \frac{E_t \left\{ \hat{\xi}_{t+1} \left[\alpha \frac{Y_{t+1}}{(\hat{\xi}_{t+1} K_{t+1})} + (1 - \delta) Q_{t+1} \right] \right\}}{Q_t} \tag{33}$$

The labor demand equation (32) shows that the marginal productivity of labor equal to the wage rate. The capital demand depends on the marginal productivity of capital and capital gains.

2.4 Capital producers

The capital producers are set along with Bernanke et al. (1999) to determine the variation in the endogenous price of capital. In addition, the capital adjustment costs are added into the small open economy models to reduce the investment volatility.

There is a competitive sector of identical capital producers which is owned by the households. At the end of period t , a competitive capital

producer buys depreciated capital from firms at price Q_t and quantities of capital stock $(1 - \delta)(\xi_t K_t)$. The investment amount I_t yields the gross newly built capital $\Phi(I_t/K_t)K_t$. Only net investment is subject to quadratic adjustment costs, which is governed by a function $\Phi(I_t/K_t)$ with, the steady state $\Phi(\delta) = \delta$. The capital producers combine a quantity of capital and new investment, I_t , with a linear technology to get capital K_{t+1} . Then they sell the newly produced capital stock K_{t+1} to non-financial firms with a competitive price Q_t per unit of capital.

The capital producers profit maximization problem is given by

$$\text{Max}_{\{I_t, K_{t+1}\}} E_t \sum_{i=0}^{\infty} \beta^i \Lambda_{t,t+i} [Q_{t+i} K_{t+1+i} - (1 - \delta) Q_{t+i} (\xi_{t+i} K_{t+i}) - I_{t+i}] \quad (34)$$

subject to the law of motion of the capital stock

$$K_{t+1} = (1 - \delta)(\xi_t K_t) + \Phi\left(\frac{I_t}{K_t}\right)K_t \quad (35)$$

$$\text{with } \Phi\left(\frac{I_t}{K_t}\right) = \left[\frac{I_t}{K_t} - \frac{\tau_K}{2} \left(\frac{I_t}{K_t} - \delta \right)^2 \right]$$

The capital producers choose an optimal level of investment to maximize profit yields the Tobin Q equation as follows:

$$Q_t = \left[1 - \tau_K \left(\frac{I_t}{K_t} - \delta \right) \right]^{-1} \quad (36)$$

The capital producers choose an optimal capital stocks to maximize profit yields the investment demand equation as follows:

$$I_{t+1} = \Phi\left(\frac{I_{t+1}}{K_{t+1}}\right)(K_{t+1}) \left[1 - \tau_K \left(\frac{I_{t+1}}{K_{t+1}} - \delta \right) \right]^{-1} \quad (37)$$

where $\tau_K > 0$ is the degree of capital adjustment costs. The meaning of asset price equation is that capital producers sell capital at price equal to adjustment cost.

2.5 Closing the model

Finally, the exogenous processes for a foreign interest rate and its shock need to be specified. Assuming that a foreign interest rate depends on a last-period foreign interest rate and its shock, which is given by

$$R_t^* = \rho_R R_{t-1}^* + \varepsilon_{R^*,t} \quad (38)$$

The market clearing conditions for a small open economy are given by

$$Y_t = C_t + I_t$$

$$D_{t+1}^H = D_{t+1}^B$$

$$L_{jt+1} = D_{jt+1}^B + B_{jt+1}^*$$

3. The model analysis

3.1 Calibration

Table 1 lists the choice of parameter values for the baseline model. Eleven parameters govern the steady state and six parameters govern the dynamics. We start a discussion about the conventional parameters. We set a discount factor as an annual gross real interest rate $\beta = 0.9926$, implying that an annual realized interest rate is 3%. This parameter can be computed as $((1.03)^{-0.25} = 0.9926)$. The degree of risk aversion is assumed to be $\sigma = 0.2$ which is, consistent with the evidence of low sensitivity of expected consumption growth to real interest rates. ν is assumed to be 3.0303, implying that the elasticity of labor supply is high. χ is set to be 1, implying that there is no scaling disutility of labor supply. The probability of banks surviving into the next period is set to be $\varphi = 0.979$ which is close to 1. This implies that banks are difficult to be bankruptcy. The fraction of households transferring to new entry bankers is set to be $\omega = 0.005$ meaning that only a small amount of the assets will be transferred into the banking system at the beginning of the period. The capital income share is assumed to be $\alpha = 0.35$ implying that domestic firms are labor intensive in production. The depreciation rate of capital can be derived from the average annual depreciation rate of capital stock of the year 1970 to 2012 based on 1988 prices, the National Economics and Social Development Board. The average annual depreciation rate is 4.17% which is $\delta = (0.042/4) = 0.0105$ per quarter.

The technology shock persistence is set to be $\rho_A = 0.80$. It implies that about 80% of technology improvement from the last period affects the production in the current period. According to Gertler and Karadi (2011), the initial decline in capital quality shocks is fixed at five percent and the

autoregressive factor is $\rho_{\xi} = 0.66$. Absent any changes in investment, the shocks generate roughly a ten percent decline in effective capital stocks. That is the source of financial crisis is a decline in asset values as opposed to the physical capital destruction. The foreign interest rate shock persistence is set to be $\rho_{\omega} = 0.80$. It implies that about 80% of foreign interest rate from the last period affects the current interest rate.

Table 1 Parameters

Household	Value Assigned	Description
β	0.9926	Discount factor
σ	0.20	Degree of relative risk aversion
ν	3.0303	The elasticity of labor supply
χ	1	Disutility weight
Financial intermediary		
φ	0.979	Probability of banker survival
τ	0.0042	Portfolio adjustment cost
ϑ	1	Desire level of debt ratio
ω	0.005	Fraction of new entry transfer
Non-financial firm		
α	0.35	Share of capital income
δ	0.0105	Capital depreciation rate
τ_K	0.028	Capital adjustment cost
Dynamic parameters		
ρ_A	0.80	Persistence of technology shock
ρ_{ξ}	0.66	Persistence of capital quality shock
ρ_{ω}	0.80	Persistence of foreign interest shock
ρ_{τ}	(-5,5)	Degree of responsiveness
κ_y	0.5	Preference over output
κ_{τ}	0.1	Preference over policy change

3.2 Experiment

The experiment is set to a downturn economy with a negative technology shock by one percent of standard deviation and a negative capital quality shock by five percent of standard deviation. The first order Taylor approximation is used in approximation process. The model is simulated by using Dynare. The impulse response function shown in a percentage change of decimal point and timing is used with quarterly data.

A negative shock of technology by one percent standard deviation with autoregressive factor 0.80 dampens significantly the domestic economy, the output and input demands drop sharply. This leads weakens the bank's balance sheet. Specifically, the leverage rises immediately, while the net worth and capital to assets ratio significant decline as shown in the Figure 1.

The initial technology shock induces a sharp contraction of outputs by 0.01 percent. A drop in productions induces a reduction of labor and investment demands, so the return to capital declines. The nominal wage decreases about 0.01 percent. A reduction in the nominal wage leads further a decline in household consumption about 0.015 percent point. As the return to capital declines, the household optimal savings decision by increasing a deposit into the bank. In the financial sector, a reduction in spreads leads to a reduction of liabilities demanded by the bank because the banks have a high borrowing cost and less expected profits. Therefore, the net worth drops dramatically, whereas the leverage and the asset rise immediately. It induces a significant drops capital to assets ratio. The high leverage of the bank incorporating with low capital of the bank leads to a high risk and the bank's balance sheet weakening. Thus, the banking sector will face a financial distress condition and, if they borrow external funds, they will face high external financial costs. The second effect loop will start when banks face a distress condition and a high external finance premium. Finally, the impacts on both financial activity and real activity become more severe because of a sharp contraction in the aggregate output and investment.

Figure 1 A Negative Technology Shock

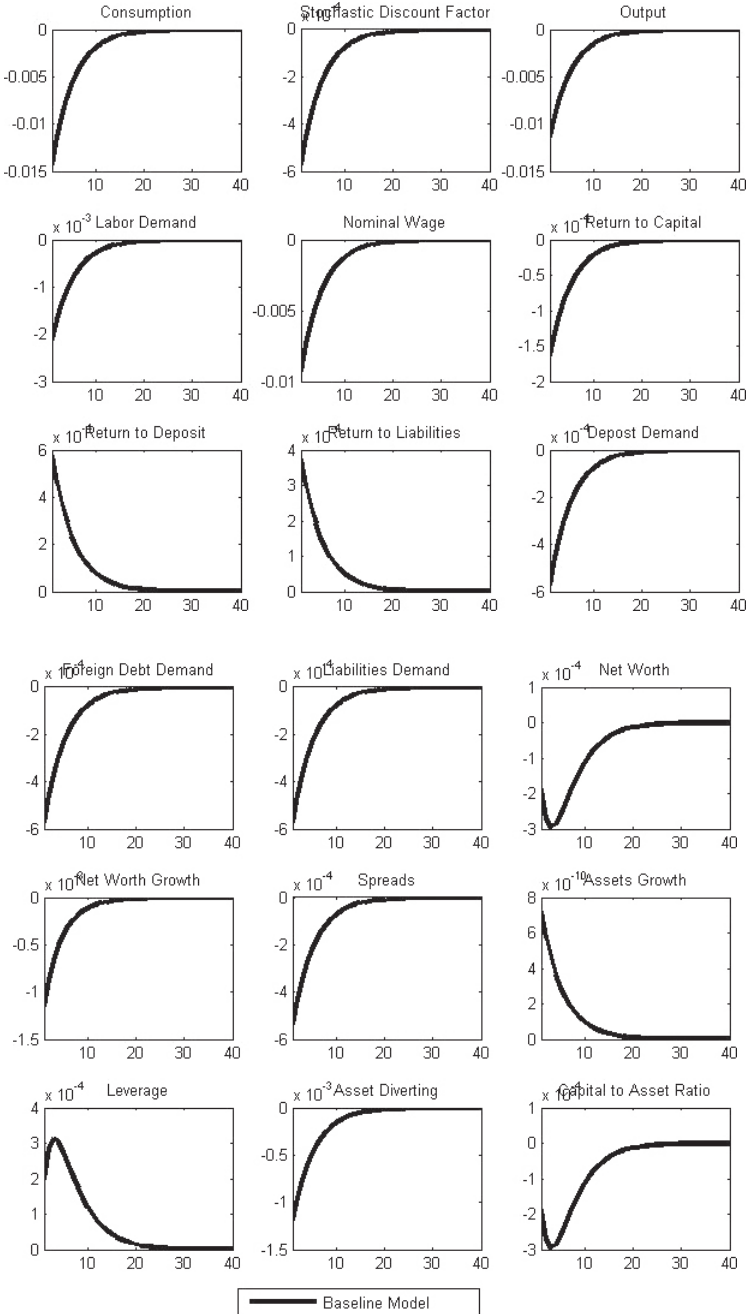
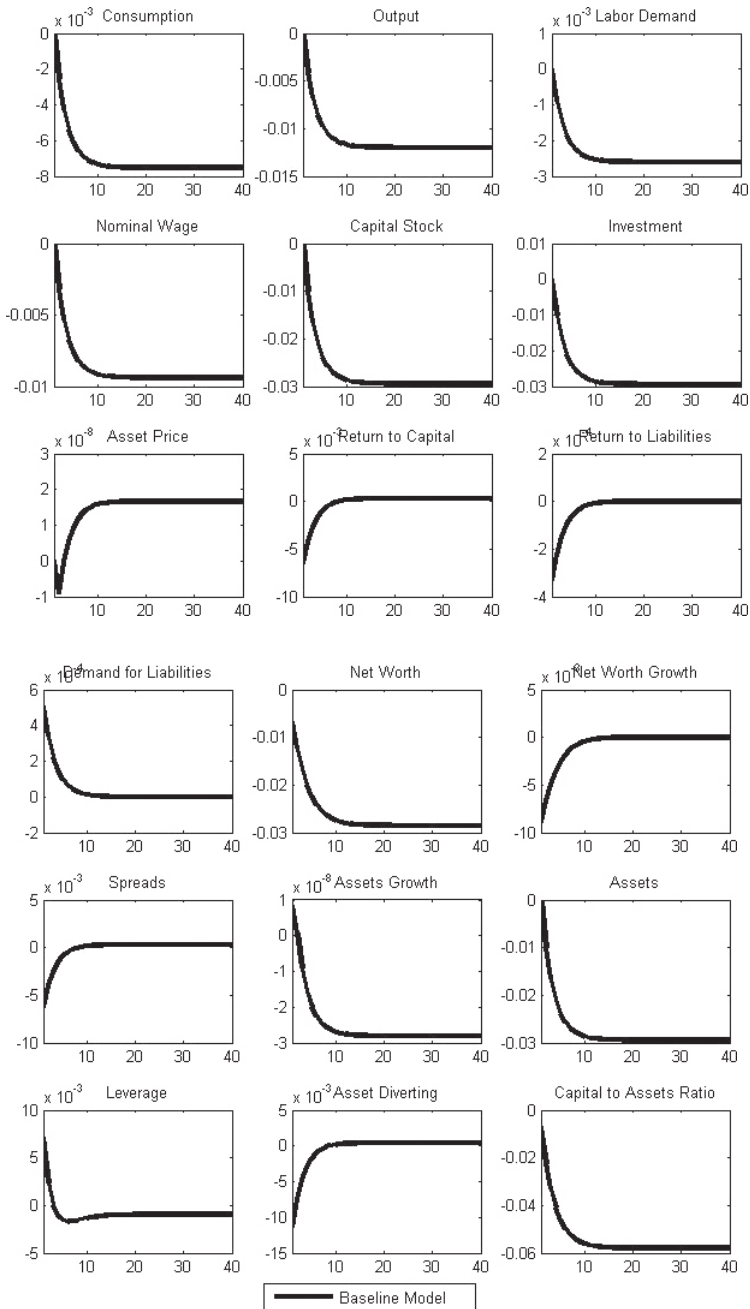


Figure 2 A Negative Capital Quality Shock



A negative capital quality shock by one percent of standard deviation with autoregressive factor 0.66 induces a sharp contraction of the effective capital quantity. It leads further to a significant drop in the aggregate output and investment immediately. The shock contracts outputs by about 0.01 percent, while the capital stock and investment demand drop by 0.03 percent. A reduction in outputs induces a decline in the labor demand and nominal wage. A significant drop in investment demand induces a decline in the return to capital and asset price. A reduction in the effective capital quantity leads to a further contraction in the net worth and capital to assets ratio. A decline in capital induces a high leverage of the bank and a drop in spreads and assets. It leads to a further decrease further in profits and net worth. So the banks face balance sheet constraint and the financial problem arises. This is a rough way to introduce a banking crisis into the model. The second impacts become more severe when banks have a balance sheet constraint and high leverage. This amplifies the effects of financial problem to the economy.

3.3 Capital requirement

Within this framework, there are two motives of the capital requirement that aim to encourage banks to increase the quality and quantity of capital and to discourage them to extend more risky assets. As asset prices affect the borrowing constraints and balance sheet, there exists a pecuniary externality that banks do not properly internalize when they make decisions on their balance sheet structure. The participants take asset prices as given and since the asset price is determined by an aggregate level. In the aggregate level, their joint behavior determines asset prices and, by implication, the extent of balance sheet effect and the degree of financial fragility in the economy. In particular, they induce banks to raise too much debt, such as to purchase excessively short maturity assets and thus the banks take excessive risk. In this sense, financial fragility is uninternalized by the product of external finance made by individual institutions.

For policymakers, if we impose Pigouvian taxes or regulation to an individual institution to realize the externality that he contributes to the financial system. As a result, the decentralized market equilibrium is efficient and makes everybody in the economy better off. A number of papers have

emphasized this externality to introduce the impact of regulation, taxation and subsidies to the banks' balance sheets which finally reward the net worth. (Diamond and Rajan (2009) Korinek (2011) and Jean and Korinek (2013)).

In this model, the capital requirement is a regulatory policy imposed to the bank's balance sheet to reduce the financial externality and systemic risk, but rewards the net worth. An increase in the total net worth (equity) to the total asset ratio implies an increase in the capital requirement. In particular, we suppose that the government subsidizes banks τ_t^s per unit of net worth. The subsidy is financed by a tax on an increment of total liabilities. As regulators impose the capital requirement, the flow of funds constraint for the bank is now given by

$$N_{t+1} = R_{t+1}^K(Q_t Z_t) - (1 + \tau_t^s)R_{t+1}^L L_{t+1} \quad (39)$$

The net worth evolution becomes:

$$N_{t+1} = (R_{t+1}^K - (1 + \tau_t^s)R_{t+1}^L)Q_t Z_t + (1 + \tau_t^s)R_{t+1}^L N_t \quad (40)$$

with

$$l_t = E_t \{ (1 - \varphi)\beta\Lambda_{t,t+1}(R_{t+1}^K - (1 + \tau_t^s)R_{t+1}^L) + \beta\Lambda_{t,t+1}\varphi x_{t+1} l_{t+1} \}$$

$$n_t = E_t \{ (1 - \varphi)\beta\Lambda_{t,t+1}((1 + \tau_t^s)R_{t+1}^L) + \beta\Lambda_{t,t+1}\varphi z_{t+1} n_{t+1} \}$$

The capital requirement is set in responding to the capital requirement in the steady state and the deviation from the aggregate credit level as follows:

$$\tau_t^s = \tau_{ss} + \rho_\tau \ln\left(\frac{Q_t Z_t}{Q Z_{ss}}\right) \quad (41)$$

where the parameter τ_{ss} denotes the steady state of capital requirement. $Q_t Z_t$ denotes aggregate of credit and $Q Z_{ss}$ is the steady state level of aggregate credit. The parameter $\rho_\tau \in (-5, 5)$ is the degree of responsiveness of capital requirement.

The performance of capital requirement can be determined by the economic loss. The loss function depends on unconditional variance of output and the term of policy change as follows:

$$L_{cap} = \kappa_y \sigma_y^2 + \kappa_\tau \sigma_{\Delta\tau}^2 \quad (42)$$

where σ_y^2 is the asymptotic unconditional variances of output and $\sigma_{\Delta\tau}^2$ is the variances of the capital requirement changes, respectively. κ_y is a weight of policymakers' preference on variances of output and κ_τ denotes a weight of policymakers on variances of capital requirement changes. The least value of loss function is the best policy performance.

A negative technology shock induces a contraction in the net worth and weakens the balance sheet. It leads further to a financial distress condition and a significant drop in investment. Introducing capital requirement in responding to the asset growth deviating from its steady state affects directly the bank's balance sheet. An increase in capital requirement by one percent of its steady state level with the lower degree of responsiveness ($\rho_\tau = 1.5$) to the asset growth induces an increase in the leverage ratio and asset growth. The capital requirement increases the costs to the financial intermediaries for additional external funds, therefore the spreads decline. This reduces further the demand for liabilities. The capital requirement accelerates the net worth growth which induces later an improvement of net worth and balance sheet. In addition, the capital requirement reduces the banker's incentive to divert more assets for their personal purposes. However, the capital requirement does not affect real activities. The impacts of the technology shock on output, investment, and consumption as well as inputs demand remain unchanged from the baseline model.

The negative capital quality shock affects the economy through a reduction of effective capital quantity and therefore output and investment contract sharply. A reduction in values of capital and assets leads to a deterioration of the bank's balance sheets. Banks face a higher external finance premium and thus increase lending rates. This induces firms to cut back all investment projects. The balance sheet constraint and high leverage amplify the impacts of financial problem on the economy. Introducing the capital requirement with more aggressiveness ($\rho_\tau = 3.5$) in response to the asset growth that deviates from its steady state level is the most effective policy. The capital requirement changes the bank behavior. That is, it reduces bank leverage by 0.1 percent and leads to a drop in asset growth. It increases the spreads by over 0.05 percent. It increases the bank net worth by about 0.05 percent and improves the bank's capital to assets ratio. Finally, it strengthens the bank's balance sheet and reduces the financial distress condition.

Figure 3 Capital Requirement and Technology Shock

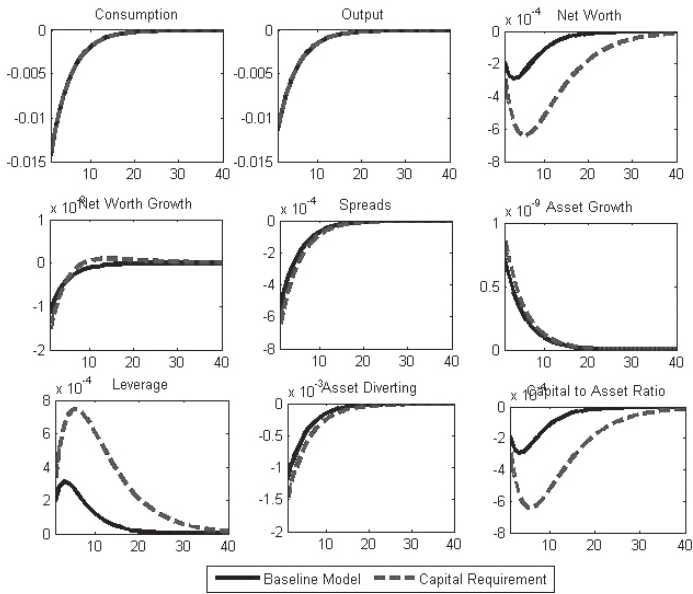
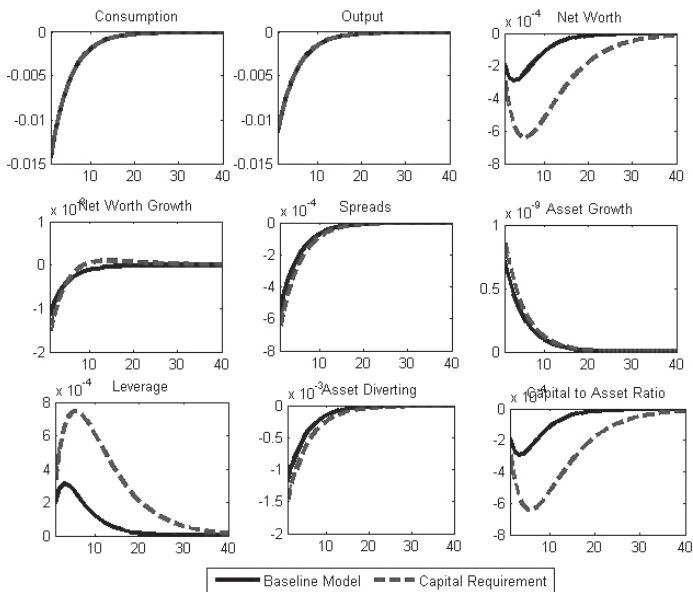
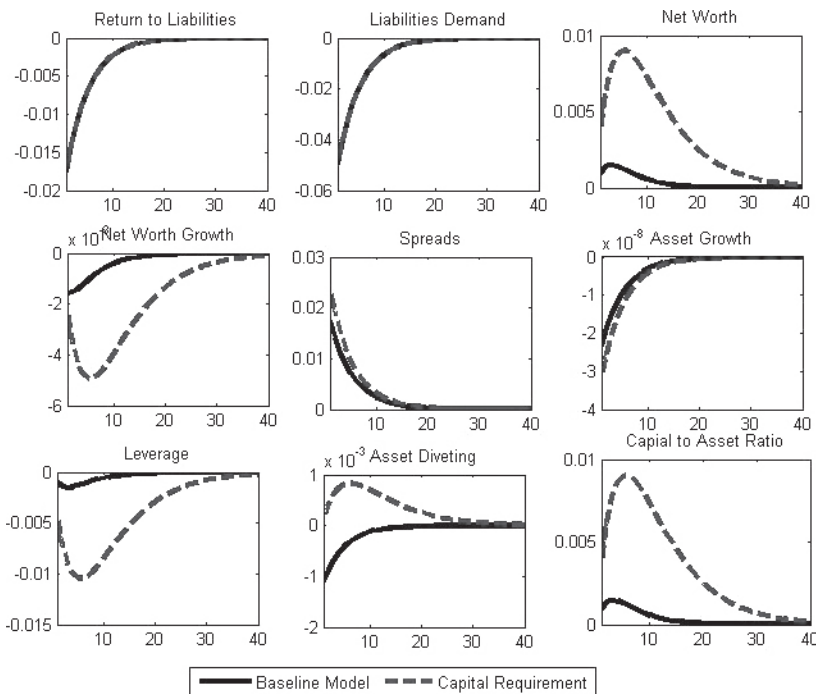


Figure 4 Capital Requirement and Capital Quality Shock



The negative foreign interest rate shock by five percent induces a contraction in the liabilities demand because a drop in the return to liabilities. It leads further a reduction in the asset growth and leverage. A reduction in the asset growth and leverage induce a decline in the net worth growth and deteriorate the bank's balance sheet. Banks further face a high external finance premium and thus increase the lending rates. This leads firms to cut back an investment. Introducing a capital requirement with more aggressiveness ($\rho_{\tau} = 5$) in response to the asset growth is beneficial to the banks. The capital requirement stabilizes the bank's leverage. That is, it increases the bank's net worth by 0.01 percent and the spreads rises over 0.02 percent. Finally, an aggressive capital requirement rewards the capital to asset ratio. Thus, the banks' capital rises and reduces financial distress condition. In addition, we find that the capital requirement regulation affects to the bankers' behavior and their balance sheets.

Figure 5 Capital Requirement and Foreign Interest Shock



The performance of the policy can be determined by the ability of the policy in stabilizing the bank balance sheet. To achieve this objective, we vary the policy choice against asset growth and find the degree of responsiveness that can stabilize the value of loss function and balance sheet variables. The financial problem induces a high variation of net worth and leverage ratio.

Table 2 The Impact of Capital Requirement

Shock	Capital requirement $\kappa_y = 0.5, \kappa_\tau = 0.1$ $L_{cap} = \kappa_y \sigma_y^2 + \kappa_\tau \sigma_{\Delta\tau}^2$				
	Loss	σ_y^2	$\sigma_{\Delta\tau}^2$	σ_{NW}^2	σ_ϕ^2
Technology shock $\rho_\tau \in (0, 5)$	0.0040	0.0080	0.000	0.0086	0.000
Capital quality shock $\rho_\tau \in (0.5, 2.5)$	0.0026	0.0052	0.0002	4.4106	0.0003
Foreign interest shock $\rho_\tau \in (5)$	0.0000	0.0000	0.0000	0.0000	0.0000

Source: Author's Calculation

The variances of output, policy changes, net worth and leverage ratio, respectively, are shown in Table 2. Specifically, the capital requirement is less effective in response to the technology shock because varying the policy parameter does not reduce the loss function and variance of net worth. However, the response of capital requirement to the financial shock is more efficient. That is, less degree of responsiveness of capital requirement ($\rho_\tau = 0.5$) to the asset growth generates the minimum values of loss function. Also, it helps stabilizing the bank balance sheet and generates the minimum variance of net worth and leverage ratio.

4. Conclusion and remarks

The objective of this paper is to investigate the impact of capital requirement in response to the shocks, which dampens down the economy. Also, we aim to find how it improves the bank's balance sheet. A negative shock of technology has a significant negative effect on the domestic economy, particularly, a drop in the output and input demand sharply. This leads to the

bank balance sheet weakening. The leverage rises immediately, while the net worth and capital to assets ratio significantly decline. Hence, banks face a financial distress condition. A negative capital quality shock induces a sharp contraction of the effective capital quantity. It decreases an aggregate output and investment immediately. The significant drop in investment demand induces a decline in the return to capital and asset price. A reduction in an effective capital quantity leads to a further contraction in the net worth and capital to asset ratio. A decline in capital induces a high leverage of the bank incorporating with a drop in spreads and assets. It leads to a decrease further in profits and net worth. So banks face balance sheet constraint and the financial problem arises. The capital requirement is efficient in response to the financial problem. It increases the bank net worth and reduces the leverage ratio. Finally, a less aggressive policy generates the minimum loss and stabilizes variation of net worth and bank leverage. A high degree of responsiveness is required if authorities aim to accelerate a net worth accumulation and overcomes the banking crisis. However, the capital requirement is less effective in response to the technology shock, so the capital requirement cannot stabilize net worth and balance sheet in this case.

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