Bank Capital Regulation and Credit Supply

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<Abstract>

For the increase of the bank capital adequacy ratio, banks can meet this requirement either by issuing new equity or by reducing loan. With a simple model with banks, we try to show two things. (i) If a bank's decision is made for the benefit of the incumbent shareholders, it may reduce risky loan for the new capital regulation even though it can re-capitalize by selling new equity to the public. (ii) If all the banks do so, there happens net deposit withdrawal, which may cause a further shrinkage of credit supply. A simple heuristic calibration with Korean data shows that these results may hold in a reasonable parameter value range.

I. Introduction.

One of the common economic phenomenons in the Asian countries after the financial crises is the sharp decline in credit. (Alba, Bhattacharya, Claessens, Ghosh, and Hernandez (1999), Ding, Domaç, and Ferri (1999)) There are some empirical studies on the causes of the decline. Using survey data of commercial banks in Thailand, Ito and Pereira de Silva (1999) suggest that the decline was due to the contraction of credit supply of banks.

Behind the tightening of bank credit supply was the restructuring of banking sector of the crisis-stricken countries. For the restructuring of the banking sector, IMF demanded strict enforcement of capital regulation. Peek and Rosengren (1995) suggest empirical evidence about the link between the bank regulatory enforcement and the shrinkage of bank loan with U.S. data.

The issue of capital based regulation of bank has been widely studied after the Basle agreement in 1988. Gorton and Winton (1995), Calem and Rob (1996) and Blum (1999) are among them. However, most of the studies on the effect of capital regulation focused on the bank's risk taking. Furlong and Keely (1989) argues that tighter bank capital regulation reduces bank's risk-taking incentives. However, Calem and Rob (1996) and Blum (1999) show that increased capital regulation induces banks to take more risky assets and therefore, tighter capital regulation makes bank more prone to default.

The reason why banks become riskier is that when they cannot meet the regulation, they have an option to go bankrupt. Bad banks with low capital ratio have an incentive to invest in assets with high risk and return profile. If blessed, they can meet the capital requirement with high return and the increased capital can generate more investment as Cooke's ratio. But if not, they can simply exit. However, this type of response is plausible only for marginal banks.

In Asian countries, bad financial institutions were eliminated in the first stage of recovery from the crisis. But the credit contraction had been continued even after a couple of years. Together with restructuring, banks become less willing to make loan because of the tightened regulation. The tightening of the bank regulation was in the form of the increase of capital adequacy requirement. When the supervising authority increases the capital adequacy rate, bank has two options. It may either issue more equity or reduce risky assets.[1] When the owners of the bank decide what to do, they may prefer reduction of loan instead of equity issue because further equity issue would reduce their share.

In this paper, we try to suggest conditions under which this conjecture is true. If the enforcement of the capital adequacy requirement reduces the bank credit supply, the reduction

[1] Bank may leave the industry instead of meeting the requirement. But in this paper this option is ruled out.

of credit supply causes the financing difficulty of firms. Firms that are unable to borrow may go bankrupt, and their outstanding loans become non-performing. Then banks must decrease the loan payout further because of the loan loss reserve. In addition, workers laid off from the bankrupt firms have to withdraw their deposit and the withdrawal may reduce the bank's available resources and may cause a further shrinkage of loan. The purpose of the capital adequacy requirement is to reduce the risk of bank failure. However, the above-mentioned story may expedite the bank failure.

This paper suggests a simple dynamic model with consumer, firm and banks. Consumers use bank deposit to smooth their consumption. Initially, all firms borrow money for the fixed investment. After the installment of fixed capital, they still need working capital for production activity. Some firms, even though they were able to finance the cost of fixed capital, may fail to borrow enough working capital for various reasons. If they could borrow required working capital, they produce goods. If not, they go bankrupt. Bank accepts deposits from consumers and gives loans to firms to maximize the profit. Especially bank maximizes profit of the owner and is subject to regulation.

In this model we show that tightening of bank capital regulation may contribute credit crunch. If a bank's decision is made for the benefit of the incumbent shareholders, it may reduce risky loan for the new capital regulation even though it can re-capitalize by selling new equity to the public. If all the banks do so, there happens net deposit withdrawal, which may cause a further shrinkage of credit supply.

A simple heuristic calibration is done with Korean data. It shows that these results may hold in Korean economy.

This paper is organized as follows. In section II, model is presented. We define reference equilibrium in section III. The effects of the increase of bank capital are discussed in section IV. In section V, we perform a simple calibration with Korean data, and section VI concludes.

II. Model

The economy consists of one commodity and four types of agents. The only commodity is to be consumed or invested. Four agents are consumer/worker, firm, bank, and the government. Since we are interested in the behavior of bank, we use some assumptions to make the behavior of consumer and firm as simple as possible.

The economy lasts for three periods. At the first period (t=0), each consumer is endowed with a unit of consumption good. Consumers deposit all of the their endowments in the bank and bank lends its fund to firms. Firms are established with loan from bank. However, the

production does not take place until t=1[2]. At the beginning of period one (t=1), the bank supervisory authority may announce new capital adequacy rate. In that case equity market opens at the beginning of period one so that the bank may sell new shares. At later periods (t=1,2), production takes place and consumer consumes some part of their income/wealth. At time t=2, all liabilities are to be liquidated and all assets are compensated.

There exist a continuum of consumers/workers of mass 1. Since they are assumed to have the same utility function, and receive equal unit of endowment, they are identical at t=0. However, after the employment contract is made, some of them may become unemployed as some firms go bankrupt. Consumers/workers have two sources of income. One is the endowment of consumption good given at t=0, and the other is wage income. They supply one unit of labor to the firm, and receive wage, *w*. Each consumer/worker enters an employment contract with one of a continuum of firms and this contract is binding for two periods. Since the contract is written before the realization of shocks, the wage rate is the same for all workers. We assume the workers and firms are randomly matched. After the contracts are signed, indices for consumers/workers and firms can be used interchangeably.

Consumers' utility function is given as follows,

$$u(c_1) + \beta u(c_2), \tag{1}$$

where c_1 (c_2) is the consumption at t=1 (t=2), and β is the discount rate.[3]

There exist a continuum of entrepreneurs with mass one. At t=0, they must build the factory which costs B_0. They borrow the start-up cost from bank as a long-term loan. They pay interest at t=1, but both principal and interest at the end of t=2. Each entrepreneur hires one worker for production. Because of a rigidity of labor market, firm and worker enter an employment contract for a predetermined wage level. Even though the contract lasts for two periods, worker is laid-off in case the firm is not able to finance the working capital. However, if the firm succeeds in financing next period, the worker is reinstated.

During the period t=0, after the contract is written, each entrepreneur makes his/her effort which affects the level of output afterward.

In addition to the start-up cost (B_0), firm needs working capital of amount B_1 to operate at t=1. If a firm is able to finance, it produces output *y*, and pays out wage and interest. We assume

[2] The first period is introduced only for the setup of the production. It can be regarded as the beginning of the first period in two-period model.

[3] We may assume that consumer consumes at t=0, and he/she save the rest of the endowment. Since the consumer's saving decision is not our interest, we assume it away.

that the profit, if any, is consumed by the entrepreneur.[4] If a firm fails to finance the working capital, the firm cannot produce any output, the worker employed in this firm is laid-off, and the loan is not performed. Even though the firm is suspended from the production process at t=1, it can still produce at t=2 if it succeeds in financing the required working capital. Working capital (B_1) is borrowed as a short-term loan, which is to be redeemed both interest and principal at the end of each period.

The level of output of a firm is determined by the amount of effort of the entrepreneur, overall economic condition and individual shock. But it is assumed that we cannot decompose the effects into those of individual factors.

The behavior of the bank is as follows. There is only one (representative) bank. It is owned by a banker who pays all the original capital(*K*). We assume that the banker puts all of his/her wealth to establish the bank. When the authority increases the capital adequacy rate, and the bank needs to increase the capital, the bank has to sell the shares to the public. The capital rate is defined as the ratio of capital(*K*) and risk-weighted sum of bank assets. In this model loan to the firm has risk-weight of 1 and government bond 0.

We assume that the banker is the manager of the bank and maximizes his/her own profit. The profit accrued to the banker is consumed. As in the case of entrepreneurs, the utility function of the banker is the sum of the consumption each period.

At time t=0, the bank accepts the consumer deposit which is summed to 1. The bank has 1+*K* to be invested to maximize profit. It may either lend to firms or buy government bond that pays fixed interest (r_f). The lending rate is given by r_l and deposit rate by r_d.[5] We assume that the lending rate (r_l) is expected to be greater than r_d.[6]

During the period, the bank collects information about the entrepreneurs (effort). It is denoted by *x,* which can be interpreted as a credit rating of each firm. The value of x lies between 0 and 1. It reflects the possibility that a firm produces output. Since there are entrepreneurs of mass 1, there is a continuum of firms with the same credit-rating *x*. Even after the realization of the first period output level, the bank keeps the same credit rating for each firm. This is the same as assuming that the bank knows the effort level of each firm and regards the deviation from the credit rating as individual shock.

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[4] The utility function of entrepreneurs is simply the sum of the level of consumption at time 1 and 2. Since the entrepreneurs consume the residual profit, the functional form is not a great matter.

[5] Since we are analyzing the economy with credit market either in excess supply or excess demand, we assume that interest rates are fixed. We are assuming the following economy. The government issues bond with fixed rate of return. Only the bank can buy the bond. Since the operation cost of the bank is null, the deposit rate is same as the return from the government bond. And the borrowing-lending rates spread is fixed.

[6] Since the lending rate is fixed, the only risk of the loan is the possibility of default.

The level of output of a firm with credit rating x is as follows,

$$y_t(x) = \begin{cases} y & with \quad probability \quad (1-A)+Ax \\ 0 & " \qquad\quad " \qquad\quad A-Ax \end{cases}. \tag{2}$$

In this setup, a firm with credit rating 1 never defaults and one with 0 does not always default. We assume the productions of period 1 and 2 are independent. A firm which defaults at t=1 may not at t=2, and one which succeeds in paying the debt at t=1 still has some probability of default at t=2. That is, a firm with the same credit rating has the same probability of default at t=2 regardless of whether it defaults at t=1 or not.

The macroeconomic condition of the economy is denoted by the probability parameter A that lies between 0 and 1. The greater A is, the larger the probability of successful production is for all firms.

At the beginning of period t=1, the bank decides how much to lent to firms and how much to buy government bond. When the authority changes the capital adequacy rate, it changes the portfolio according to the new regulation.

At the end of period 1, bank receives the interest from the asset. Since the output of each firm is subject to a shock, some firms may fail to pay the interest. Then the loan becomes bad and appropriate reserve must be placed.[7] Workers employed in those unlucky firms are not paid even though they are put into the production.[8] The bank may face the withdrawal of deposit from the workers who became unemployed or unpaid during the period.

There may be some possibility of false report of a firm. Even though the realized output of a firm y, the firm may report the bank that it did not get enough output. The firm has an incentive to do so because, due to the serial independence of the output probability, the default in period 1 does not affect the bank's lending decision in period 2. We simply assume the myopia of the firm and they reveal their production honestly since we want to keep the firms' behavior simple. We assume another myopia about workers. We assume that the workers are ignorant of the firms or entrepreneurs they are working for.

At the beginning of period 2, the bank reshuffles the portfolio again. At the end of the period, the bank receives all the principal and interest and returns the deposit with interest.

The government does two things: supplying the government bond, and determining the capital adequacy rate of bank.

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[7] We assume that loan loss reserve can be held in the form of risk-free asset, which is government bond in this model.

[8] There are two types of unpaid workers: one whose firm fails to finance the working capital and the other whose firm are bit by a bad productivity shock. Even though the exact employment statuses are different, we call them both 'unemployed' without differentiating them.

(1) Optimizations of consumers and entrepreneurs

Consumer maximizes the lifetime utility (1) subject to the following budget constraint,

$$c_1 + \frac{c_2}{1+r_d} = 1 + r_d + wI_1 + \frac{w}{1+r_d} I_2,$$

where I_1 and I_2 are indices for the employment status of period 1 and 2.

For the simplicity, we assume that the time preference of the consumer is equal to the inverse of the gross deposit rate, i.e. $\beta(1+r_d) = 1$. Since the time preference is fully compensated by the deposit interest rate, consumer smoothes his/her consumption completely, i.e. $c_1 = c_2$ holds *ex ante*. Of course, the *ex post* level of the second period consumption (c_2) depends on the realization of shock, and is not the same as c_1.

In this model the only uncertainty the consumer faces is the possibility of layoff.[9] Since the consumption takes place at the end of each period, the employment status at t=1 is known. The solutions are different according to the period 1 status.

Let *p* denote the possibility that the employed at t=1 become unemployed at t=2 and *q* the possibility the unemployed become employed. Because of the completely smooth consumption, the consumptions of the worker employed (paid) at t=1 become,

$$c_1^1 = E(c_2^1) = \frac{(1+r_d+w)(1+r_d)}{2+r_d} + (1-p)\frac{w}{2+r_d}, \tag{3}$$

where subscript denotes the period of consumption and superscript employment status. The employed are denoted by 1 and unemployed by 0. Depending on the magnitude of consumption (c_1^1) and wage (*w*), they withdraw some of their deposit or make new deposit.

The consumptions of the unpaid workers at t=1 are,

$$c_1^0 = E(c_2^0) = \frac{(1+r_d)^2 + qw}{2+r_d} \tag{3'}$$

Since they do not have current income, they have to retrieve this amount from their deposit.

[9] Exactly speaking, it is the possibility of being unpaid. Because of the employment contract written at the beginning of period 0, all workers are employed.

The optimization problem of entrepreneur is very simple. They borrow B_0 from the bank at t=0, and make some effort for the production during the period. At period 1, they try to borrow an additional working capital (B_1) from the bank. The entrepreneur who is not able to finance it, he/she cannot do anything other than waiting for next period. Entrepreneurs who borrow the working capital can participate in production. The actual output level of each firm depends on the realization of shocks as in (2). Firms with positive output pay wage, service the debt, and realize positive profit.[10] The other firms with zero profit inform their workers and the bank that they cannot pay wage and interest. Even though they produce nothing in period 1, they still keep the factory and wait for the next period.

The behavior at period 2 is the same as at t=1 except that the firms have to pay the long term principal (B_0) at the end of the period. We assume that the scrap value of each firm is B_0. Therefore, firms whose period 2 output is not big enough to redeem the debt use the scrap value to pay the principal of long-term debt.[11]

(2) Bank profit maximization

The bank behavior at t=0 is simple. It receives 1 unit of deposit from consumers. Since each firm has to borrow B_0 at t=0, loan demand is B_0. Since the bank does not have any information about entrepreneurs, it gives loan of B_0 to all firms, and buys $1-\rho+K-B_0$ of government bond. It keeps ρ in cash as reserve requirement for deposit.

At the beginning of period t=1, the bank reshuffles the portfolio. Since B_0 is lent as a long-term loan, it has $1-\rho+K-B_0$ of bond to be reshuffled. Some of them will be on loan to the firms. Different from the loan decision at t=0, bank has some information on entrepreneurs, which is credit rating *x*. Expected profit from an additional short-term loan (B_1) to a firm with rating x is $p(x)r_l(B_0+B_1)-(1-p(x))B_1$, where $p(x)$ is the probability that this firm realizes positive output, i.e., $(1-A)+Ax$. Since the banker is assumed to be risk-neutral, he/she will simply maximize expected profit, lending to all firms with *x* greater than $p(\underline{x})r_l(B_0+B_1)-(1-p(\underline{x}))B_1=r_fB_1$.

Since we do not assume any cost for operating a bank, we can safely assume that the deposit rate and risk free rate are equal. All the more, we may assume they are zero without loss of generality, i.e., $r_d=r_f=0$. We also assume that the reserve requirement rate (ρ) is zero.

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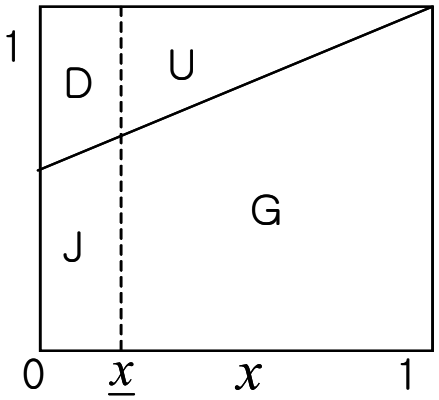
[10] We assume the output of lucky firms (y), is big enough, i.e. $y>w+r_lB_0+(1+r_l)B_1$.

[11] For this reason, the bank does not need to put loan loss reserve for long-term debt.

Since we have firms of mass one, they can be represented by a square as in <Figure 1>. All firms with credit rating (x) greater than $\underline{x}$ would succeed in borrowing the required working capital. Among those firms, firms that belong to area G realize positive output, the rest of the firms (U) zero output. Then the profit of the bank is,

<Figure 1>



$$\pi = (1-\underline{x})\left(\frac{2-A(1-\underline{x})}{2}\right) r(B_0 + B_1) - \frac{A}{2}(1-\underline{x})^2 B_1 ,$$

where r is the lending rate. We suppressed the subscript for the interest rates because deposit rate and risk-free rate are assumed to be 0. The first term is the interest received from the good firms and the second the loss from the bad firms.

At the beginning of period t=2, the bank does the same thing as in period 1. Since the realized output level at period 1 does not affect the expected output of period 2, the bank does not have any incentive to reshuffle the loan portfolio.

III. Reference equilibrium

In this section, we define an equilibrium that will be compared with a new equilibrium. It is an allocation that maximizes each agent's utility given the fixed interest rate. We think of an equilibrium that is similar to the steady state. Even though this model has only three periods, it can be similar to the steady state when we extend to model to infinite time setup. This equilibrium will be compared to the dynamics of the model when the authority changes the capital regulation for banks.

Given capital adequacy rate (k), suppose the following five conditions hold.

(i) $1 + K = B_0 + (1-\underline{x})B_1$

(ii) $k = \dfrac{K}{B_0 + (1-\underline{x})B_1}$

(iii) $\pi = (1-\underline{x})\left(\dfrac{2-A(1-\underline{x})}{2}\right) r(B_0 + B_1) - \dfrac{A}{2}(1-\underline{x})^2 B_1 \geq 0$

(iv) $c_1^1 < w$ and $(1-\underline{x})\left(1 - \dfrac{A}{2}(1-\underline{x})\right)(w - c_1^1) = [\underline{x} + \dfrac{A}{2}(1-\underline{x})^2]c_1^0$

(v) $p = \frac{A}{2}(1-\underline{x})$ and $q = \frac{\frac{A}{2}(1-\underline{x})^2\left(1-\frac{A}{2}(1-\underline{x})\right)}{\underline{x}+\frac{A}{2}(1-\underline{x})^2}$

Equilibrium dynamics

In this equilibrium, we are assuming that the bank gives B_0 to all firms at period 0, and gives B_1 of short-term loan to firms with credit rating higher than $\underline{x}$ at period 1. The amount of loan to firms is $B_0 + (1-\underline{x})B_1$. It buys government bond with the rest of the fund $1+K-B_0-(1-\underline{x})B_1$. Condition (i) states that the bank has enough funds for this portfolio. We may assume an inequality that left hand side is greater. However, for the comparison with new equilibrium we impose equality, which means the bank do not hold any government bond at the reference equilibrium. By condition (ii), the bank is exactly satisfying the capital requirement. Condition (iii) is the profit of the bank and we are assuming that the bank realizes positive profit.

At the end of period 1, consumers who are not paid would withdraw their deposits for consumption. The amount of withdrawal of individual unpaid consumer is equal to c_1^0 as given in equation (3'). Consumers who are paid may or may not withdraw their deposit. If the first inequality in condition (iii) holds, their wage income is more than enough for the consumption (c_1^1). We assume they deposit the rest ($w - c_1^1$) into the bank. The second equality in condition (iii) shows the amount of withdrawal of the unpaid is equal to that of new deposit of the paid workers. There is no net change in total amount of bank deposit.

Consumers form the expected probabilities *p* and *q*. Probability *p* denotes the possibility that the paid worker at t=1 become unpaid at t=2. Those who are paid in period 1 belong to the area G in <Figure 1>. Because of the serial independence of the shock, they may fall in the area U next period. This conditional probability is $\frac{A}{2}(1-\underline{x})$. Probability *q* is the possibility the unpaid in period 1 become paid next period. In <Figure 1>, the unpaid workers are the ones who belong to area D+J+U. Among them, those who work for the firm with credit rating greater than $\underline{x}$ may fall in the area G in period 2. With some calculation we can show this conditional probability is

$$\frac{\frac{A}{2}(1-\underline{x})^2\left(1-\frac{A}{2}(1-\underline{x})\right)}{\underline{x}+\frac{A}{2}(1-\underline{x})^2}.$$

Condition (v) above shows that consumers form correct probability.[12] Therefore the economy is in equilibrium

At the beginning of period 2, the bank has the same amount of fund to be reshuffled by the condition (iv). The bank uses the same credit ratings as in period 1, and the bank gives loan to the same firms as in the previous period. At the end of the second period, the same proportion of firms is unable to liquidate the bank loan by the law of large number.

In this equilibrium, the bank portfolio at t=1 and t=2 are the same and expected consumption level at t=2 is the same as that of t=1. In addition, unemployment (unpaid) rate, and the rate of bad loan are the same in both periods. This is why we call it *similar* to the steady state

Consumption levels are as given in equation (3) or (3') according to the employment status in period 1. Realized consumption at t=2 is different from that of t=1 depending on their employment status at t=2. Entrepreneurs' (expected) profit is the realized output minus wage and interest payment. The banker's profit at t=1 is as in condition (iii).

IV. Dynamic effect of the increase of capital adequacy rate

If we use a multi-period model, we may analyze the effect by increasing the capital adequacy rate at a certain period to figure out the effect of the tightened capital regulation. Unfortunately, it is not possible in our setup because we have only three periods. Instead, we want to find equilibrium when government announces higher capital adequacy rate (k') in period 1, and it will be compared with the reference equilibrium in previous section.

When the banker faces the new regulation, he/she has four options: (i) exit the industry, (ii) recoup the additional capital from retained earning or other wealth, (iii) issue new equity to the public, (iv) reduce the risky asset. As mentioned above, we assume the first two options are not to be considered.

For higher capital rate, he/she has to decide whether to issue new equities or to reduce the risky asset. In the view of the incumbent shareholders, issuing new equities means losing the

[12] In fact, a worker who belongs to a firm in the area D or J has no probability of being paid next period. However, thanks to the ignorance of the workers we assume, the unpaid workers are unable to tell whether his/her firm failed to finance the working capital or it was hit by a bad shock.

share and reducing the asset gives less profit. Both way gives less dividend to them. But the rates of decreases may not be equal. When they recapitalize by issuing new equity to the public, their share will reduced, and the dividend will decrease proportionally. However, when they reduce the risky loan, they could cut the most risky ones among the outstanding loans. So the profit may be reduced less proportionally. Therefore the incumbent shareholders would prefer the loan reduction. Theorem 1 below finds conditions for this argument is true.

[Theorem 1] *If the decision of the bank is made by the incumbent owners, the incumbent owners prefer reducing the risky loan to issuing the new equity to the public when they face higher capital requirement if one of the following conditions holds:*

(1) B_0 *=0, i.e., bank does not have any long-term loan.*

(2) $$1+\phi < \frac{A\eta^2[1+r(b+1)]}{2r(b+1)bk^2 + Ab^2k^2[1+r(b+1)]}, \quad (4)$$

where $1+\phi = \frac{k'}{k}$, $b = \frac{B_0}{B_1}$ and $\eta = \frac{K}{B_1}$.

[Proof in the Appendix]

If the firms never default or if the bank is completely ignorant of the firm, it is indifferent whether to issue new equity or to reduce the risky asset. However, in the actual world or in this model, the bank has some information - credit rating - about the possibility of default of the firms. This is from one of the bank role, which is monitoring investments.

When the bank decides to issue new equity, the incumbent shareholders lose the profit by the ratio of the current to the new capital adequacy rate. When the bank decides to reduce the amount of the risky loan, it has to cut the loan by the same proportion. But it will cut the loan to the firms with low credit rating, which actually has higher chance of default. In the latter case, the rate of the profit decreases is less than the decrease of profit share of the incumbent shareholders.

However, the above result does not hold unilaterally. When the bank has some outstanding long-term loan to a firm, rejecting the additional loan request of the firm for the working capital means that the bank gives up the receipt of the interest from the outstanding loan. Therefore reducing the risky loan is not always profitable for the banker. However, when the bank does not have any long-term outstanding loan as in condition (1) above, the asymmetry mentioned above applies straightforwardly.

Condition (2) states that even though the bank has some outstanding long-term loan, the banker is still profitable if the authority does not increase the capital adequacy rate too much.

The criterion depends on the interest rate, the ratio of long-term outstanding loan to short-term loan, the ratio of bank capital to short-term loan, and the interest rate.

The winning edge of loan reduction comes from cutting the bad loan. This effect diminishes as the credit rating of the firm in the lower limit ($\underline{x}$) becomes high. If the government increases the capital rate dramatically, the bank has to cut the loan by a comparable amount. It will move the limiting firm ($\underline{x}$) further above, so the relative edge becomes negligible, and the loan reduction does not guarantee comparative edge.

But the right hand side of condition (2) becomes lager when *A* or η is big. If A is big, the probability line in <Figure 1> is steep, and the effect from cutting bad loan is large. The parameter *A* can be interpreted as an indicator of the economic condition. Bigger *A* might mean bad condition. So Theorem 1 is true when the economic state is in recession. When η is big, it means the bank could lend small amount of working capital to many firms, meaning low $\underline{x}$, and the effect from cutting bad loan is large. This effect is small when the *k* in the reference case is large because the lower limit firm ($\underline{x}$) is already high enough.

The right hand side of condition (2) is small when *b* is large. Large *b* means relatively big long-term debt compared to the short-term one. When the bank has much long-term loan, the loss of interest from the loan by refusing to lend working capital to that firm dominates the effect from cutting bad loan.

Theorem 1 shows the conditions for the bank to reduce loan to firms for the increase of the capital adequacy rate. Theorem 2 below states the condition that further loan contraction occurs.

[Theorem 2] *If the bank meets higher capital adequacy rate by reducing risky loan,*

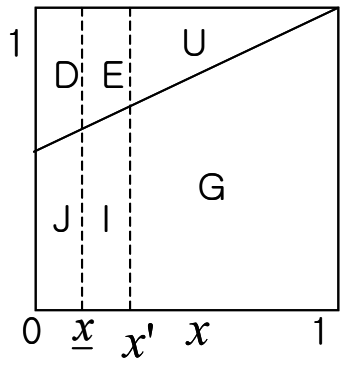
(i) there is a net deposit withdrawal.

(ii) If the following inequality holds, further loan contraction is plausible.

$$\frac{B_1}{w} < \frac{1}{2(1+R_d)(x'-\underline{x})}\Big[2\{(x'-\underline{x})+(p-p')+(q\underline{x}-q'x')+(p'x'-p\underline{x})\} + A\{(x'-\underline{x})(x'+\underline{x}-2)-(p-p')+(q-q')+2(p\underline{x}-p'x'+q'x'-q\underline{x}) + (p'x'^2-p\underline{x}^2-q'x'^2+q\underline{x}^2)\}\Big] \quad (5)$$

To meet the higher capital regulation, the bank has to reduce the risky loan. Let's denote by *x'* the lowest level of *x* among the firms which receives loan under the new regulation. Then the total risky loan of the bank becomes $B_0+(1-x')B_1$. We choose x' so that it satisfies $\frac{K}{B_0+(1-x')B_1}=k'$. Since $k'>k$, $x'>\underline{x}$ must be true.

<Figure 2>



The proof of (i) is easily understood if we use figure. <Figure 2> shows the distribution of successful and unsuccessful firms in both equilibriums. In reference equilibrium, the mass of the paid worker is I+G, while it is G in new equilibrium under tighter regulation. The unpaid workers are in the area of J+D+E+U in reference equilibrium, but in the new equilibrium there are more unpaid workers who are in the area I.

As we mentioned above, after the period 1, there will be new deposit of $w-c_1^1$ from the paid workers, while withdrawal of c_1^0 from unpaid workers. Compared to the reference equilibrium, there are less workers making deposit, but more withdrawing it. Therefore net deposit withdrawal must be bigger in new equilibrium. Since we assume net deposit in the reference equilibrium is equal to 0 by condition (iii), there will be positive net deposit withdrawal when the government impose higher capital adequacy rate to the bank.

For (ii), we compare the net deposit withdrawal and the increase in government bond holding. After the period 1, there will be new deposit of $w-c_1^1$ from the paid workers, while withdrawal of c_1^0 from unpaid workers. In reference equilibrium, the mass of the paid workers is $(1-\underline{x})\left(1-\frac{A}{2}(1-\underline{x})\right)$, while that of the unpaid is $\underline{x}+\frac{A}{2}(1-\underline{x})^2$. The net deposit withdrawal is

$$\Delta=[\underline{x}+\frac{A}{2}(1-\underline{x})^2]c_1^0-(1-\underline{x})\left(1-\frac{A}{2}(1-\underline{x})\right)(w-c_1^1)$$

By condition (iii) for the reference equilibrium, net deposit is equal to 0. Plugging the exact amount of consumption in equation (3) and (3), we have,

$$\Delta=\frac{\left(2\underline{x}+A(1-\underline{x})^2\right)\left[R_d^2+(1-q)w\right]-(1-\underline{x})\left(2-A(1-\underline{x})\right)\left[pw-R_d^2\right]}{2(1+R_d)}.$$

For the amount of net deposit, we can simply replace the probabilities (p and q) and lower limit firm ($\underline{x}$) by p' and q' and x', respectively. We have,

$$\Delta'=\frac{\left(2x'+A(1-x')^2\right)\left[R_d^2+(1-q')w\right]-(1-x')\left(2-A(1-x')\right)\left[p'w-R_d^2\right]}{2(1+R_d)}.$$

This net deposit withdrawal must be compared to increased government bond holding. The increased government bond comes from the reduced loan, which is equal to $(x'-\underline{x})B_1$. If the net deposit withdrawal is greater than this amount, the bank has to reduce the loan to the bank to meet the request of the withdrawal. If this is the case, continuing loan contraction is plausible.

Since we assume $\Delta = 0$, $(x'-\underline{x})B_1$ will be compared with $\Delta'-\Delta$.[13] Using the above equations for Δ and Δ', we have

$$\Delta'-\Delta = \frac{w}{2(1+R_d)}\Big[2\{(x'-\underline{x})+(p-p')+(q\underline{x}-q'x')+(p'x'-p\underline{x})\} + A\{(x'-\underline{x})(x'+\underline{x}-2)-(p-p')+(q-q')+2(p\underline{x}-p'x'+q'x'-q\underline{x}) + (p'x'^2-p\underline{x}^2-q'x'^2+q\underline{x}^2)\}\Big].$$

Therefore if the condition stated in (ii) holds, the bank would face bigger amount of deposit withdrawal than the government holding, and it has to reduce the loan to meet the withdrawal request.

V. Calibration

Both results in the previous section hold under certain conditions that are stated in inequality conditions. It is uncertain whether they are meaningful in real world. In this section we calibrate the model and see if the conditions hold.

For the calibration of the model we have to determine the values of model parameters. We choose them so that the model could replicate some characteristics of Korean banking industry. Most of data are collected in the website of Financial Supervisory Service (http://www.FSS.or.kr). For capital ratio (*k*), we use 0.08, which is suggested guideline by the BIS. For the lower limit of firm's credit rating ($\underline{x}$) that are successful in financing the short-term working capital, credit ratings of firms are collected. Among the 991 firms that were rated from 1999 to 2003, 13.5 percent of firms are below CCC. We assume that the bank must be reluctant to give loan to firms with credit rating CCC. Based on this proportion, we set it to 0.1, which means 10 percent of firms are rejected in their loan application. For the parameter *A*, we use the percentage of non-performing loan (NPL). The percentage of NPLs in 2001 through 2004 was about 2~3. But it dropped to 1.7 ~ 1.9 in 2005. We use 2 percent to be matched by the

[13] If we do not use the assumption $\Delta = 0$, the condition is stated as a function of the absolute levels of w and B_1. So it is hard to be used in calibration in next section.

model. In our model, the ratio of NPL is $\frac{U}{U+G}$ in <Figure 1>. When A is 0.0625, the ratio becomes 0.02. For the interest rate (r), we assume 0.05. Since it is lending rate when deposit rate is 0, it must be matched with interest margin of the bank. For $\eta = \frac{K}{B_1}$, we use data for bank capital and loan for equipment. When we calculate the ratios in 2001 ~ 2005, it is in the interval between 0.289 and 0.387. We use 0.323, which is the mean value. For the ratio of long-term loan to short-term loan (b) we use data for loan by use. When we calculate the ratio of loan for equipment to loan for working capital from 2001 to 2005, it lies in the range of 0.118 to 0.149.

When we calculate the value of the right-hand side of equation (4) in Theorem 1, it is 51.61. It must be compared to the ratio of the two capital ratios. Since we never expect any huge increase of the capital ratio to 50 times of 0.08, we can safely regard that the condition is satisfied. Therefore the Theorem 1 would hold for Korean banking industry.

For Theorem 2, when we calculate the right-hand side of equation (5), it is 0.518. If the ratio of short-term working capital to wage is less than half, the increase of capital adequacy rate may cause further contraction of bank loan. However, the ratio of working-capital to wage is not easy to be estimated. When we use the total amount of loan for working capital by general banks and compensation of employees collected from the National Income table, the ratio is about 0.32 ~ 0.37 in 2001 through 2004. Admitting this calculation is very rough, we may carefully guess that the equation (5) holds and Theorem 2 may apply for Korean economy.

VI. Conclusion and policy implication

With simple dynamic model with bank, we try to show that the increase in bank capital adequacy rate may cause credit contraction. If a bank's decision is made by incumbent shareholders, the shareholders have an incentive to meet the higher capital rate by reducing risky loan even though they can re-capitalize by selling new equity to the public. If all the banks do so, there happens net deposit withdrawal from the bank, which may cause a further shrinkage of credit supply for the economy.

These results hold under certain conditions. With parameter values retrieved based on some characteristics of Korean economy, we show that those conditions are met, meaning that the results may be applied to the Korean economy.

If this is true, the enforcement of bank regulation has to be imposed with caution. Especially when the economy is in a bad state, the increased bank capital adequacy rate may cause credit crunch.

Appendix

Proof of Theorem 1

References

Alba, Bhattacharya, Claessens, Ghosh, and Hernandez(1999), "The Role of Macroeconomic and Financial Sector Linkages in East Asia's Financial Crises," in *Financial Crises: Contagion and Market Volatility*, ed. by Pierre-Richard Agenor, Marcus Miller, David Vines and Axel Weber, Cambridge University Press.

Calem and Rob(1996), "The Impact of Capital-Based Regulation on Bank Risk-Taking: A Dynamic Model," Working Paper, Board of Governors of the Federal Reserve System.

Ding, Domaç, and Ferri(1999), "Is There a Credit Crunch in East Asia?," Working Paper, World Bank

Furlong and Keely(1989), "Capital Regulation and Bank Risk-Taking: A Note," *Journal of Banking and Finance* Vol. 13, pp. 883-891.

Gorton and Winton(1995), "Bank Capital Regulation in General Equilibrium," NBER Working Paper 5244.

Ito and Pereira de Silva(1999), "The Credit Crunch in Thailand during the 1997-98 Crisis,"Working Paper, World Bank.

Blum(1999), "Do capital adequacy requirements reduce risks in banking?," *Journal of Banking and Finance* Vol. 23, pp. 755-771.

Peek and Rosengren(1995), "Bank regulation and the credit crunch," *Journal of Banking and Finance* Vol. 19, pp. 679-692.