Liquidity Risk, Bank Competition, and Financial Stability

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Abstract

In this paper, we explore the banking market competition with the onset of a liquidity shock. Using a simple model of the spatial monopolistic competition, we show that banks hold lower level of liquid assets than the socially desirable level. On the other hand, when the liquidity requirement is imposed, banks are forced to increase liquid assets which have inferior returns than illiquid assets. This will lead banks to prefer funding to low-cost deposits from high-cost deposits. Our paper suggests that the liquidity regulation of Basel III Accord can be justified as a necessary tool in stabilizing the financial system but only at the expense of decline in both the depositor wealth and the social welfare.

Keywords: liquidity risk, interbank loan, financial stability, bank competition

Liquidity Risk, Bank Competition, and Financial Stability

I. Introduction

It is often claimed that the fragility of the interbank loan market elevated the adverse consequences of the 2007-2008 financial crisis. Although the interbank loan helps banks respond to a sudden liquidity shock and therefore enhances the investment efficiency, the result will be highly likely to be contagious to other if a bank with considerable fraction of interbank loans fails. For instance, Demirgüç-Kunt and Huizinga (2010) find that interbank loans deteriorate bank fragility. Iyer and Peydró (2011) further show that higher interbank exposure leads to large deposit withdrawals, which indicates that the interbank loan is one of the main sources in the contagious banking crisis. On the other hand, López-Espinosa, Moreno, Rubia, and Valderrama (2012) report that the interbank loans triggers the episodes of the systemic risk. This chain reaction increases the probability of the crisis on the whole banking system where all banks simultaneously suffer from the liquidity problem. Consequently, it is recently suggested that the liquidity requirements, imposing banks to maintain the liquidity at ordinary times, are necessary to stabilize the global financial system.

Forthcoming Basel III Accord introduces liquidity requirements to build a stable financial system. One measure of liquidity requirements is known as Liquidity Coverage Ratio (LCR). Banks should maintain sufficient amount of high quality liquid assets to meet the expected cash outflows in a short period of time. Although these liquidity requirements are anticipated to bring about benefits to the global financial system, the positive and negative effects of such liquidity requirements are yet to be closely examined in the academia.

This paper provides with thoughtful answers to the question by theoretically examining the relationship between liquidity, bank competition, and financial stability. We show that when banks are put in highly competitive markets, they bear the excessive liquidity risk compared to the socially desirable level. We also find that liquidity requirements may result in the relaxed competition among banks so that the wealth of depositors shrink. Therefore, the liquidity requirements of Basel III Accord can be justified as a necessary tool in stabilizing the financial system but only at the expense of decline in both the depositor wealth and the social welfare.

Our findings contribute to the extent of financial regulation literature in several ways. First, this paper enrich further discussion on the literature of liquidity risk and interbank loan market. There is an aggregate uncertainty on the liquidity shock in our model. In other words, the liquidity shock in two markets are not negatively correlated. In this setting, banks cannot insure themselves perfectly using interbank loan so they rationally choose the optimal level of liquidity to overcome the liquidity shock in their own interests. Moreover, the monopolistic competition in deposit market is considered in this paper, while most of papers in the contagious banking crisis literature assume the deposit market is competitive or the size of deposit is given. Since the deposit returns and the size of deposits thereafter are endogenously determined in our paper, the profitability of banks can be damanged when they attempt to collect more deposits. Thus, it is possible that banks may not fully obtain the deposits available when the cost of raising deposit is too high compared to their profits.

Second, besides the contribution to the literature on liquidity risk and interbank loan, this paper also contributes to the literature on the banking competition and the fragility of the banking system. Our results suggest that it may not be possible to achieve both the competition among banks and the financial stability. When liquidity requirements are introduced to make more robust financial system, the competition among banks are weakened. Moreover, it may be helpful for the economy to allow banks to gain such monopolistic rents to promote the investment efficiency.

Our work is also related to the existing studies on the industry orgainzation of banks. Especially, we provide a monopolistically competitive banking market based on the work of Chen and Riordan (2007). This setting is more advanced from the traditional spatial competition such as the circular model suggested in Salop (1979). To be specific, the competition among multiple firms is divided into the competition between two firms and it is hard to consider a new entry in the model of Salop (1979), while the model of Chen and Riordan (2007) overcomes such shortcomings.

The remainder of this paper is organized as follows. The next section reviews the literature on the liquidity risk and the contagious banking crisis. We also review the literature on the bank competition and the financial fragility. Section III presents a model on liquidity risk, bank competition, and financial stability. In Section IV, policy implications are provided. Finally, Section V concludes.

II. The Literature

A. Liquidity and Interbank Loan Market

There is a rich body of literature that theoretically models the interbank loan market and the consequent contagious banking crisis. For example, Allen and Gale (2000) show that the interbank deposit holdings, which prevent the regional liquidity shock, may result in the collapse of the whole banking system when a single bank faces an unexpected global liquidity shock. This is due to the the difficulties in coordinating among depositors with the existence of the interbank loans lead to the contagious banking crisis. In a line with Allen and Gale (2000), Dasgupta (2004) shows that a failure of a regional bank may have the contagious effect on another bank if there is liquidity insurance between two banks. In particular, it is assumed that there is a liquidity shock in a region and it is the origin of the panic. By the liquidity shock, some depositors withdraw their deposits and these behaviors are observed by the depositors who are in another region. Thus, it is possible that the liquidity shock spreads to other regions. Brusco and Castiglionesi (2007) argue that contagious banking crisis may arise even there is no exogenous liquidity shock due to the main characteristics of banks: limited liability and moral hazard. They find that interbank loan improves the efficiency of the financial system but the cost of excessive risk-taking is burden on depositors. They also claim that the bank capital is important to resolve the problems related to limited liability and moral hazard.

Diamond and Rajan (2005) show that even if depositors do not panic, it is possible to have a contagious banking crisis due to the underlying nature of the banks' assets. They explain that the human capital is required for banking industry, which in turns makes a bank's loan illiquid. Therefore, when depositors demand their deposits to consume early, banks should liquidate their projects lower than its fair value or restructure them. Once banks liquidate their long-term projects, the aggregate productivity of the economy decreases and a bank run occurs. Similarly, it is shown that the market price of a bank's illiquid assets is depressed as the bank liquidate it and that the lowered value let the other banks to suffer from the loss of their asset values in Cifuentes, Ferrucci, and Shin (2005). This adverse effect of illiquidity on the asset prices amplifies the liquidity shock and thus leads to the contagious banking crisis. They point out that liquidity requirements can be an effective way to prevent contagious crises.

Another explanation on the contagious banking crisis relies on the optimal contract theory. In this point of view, the lending banks chooses the optimized monitoring level for the borrowing banks. In some circumstances, the optimization leads to a socially sub-optimal decisions and there will be a banking crisis. For example, Huang and Ratnovski (2011) find that the borrowing banks may be liquidated if there exists a noisy public signal on the quality of the banks. To be specific, when the lending banks observe a negative signal from public information, it is optimal for them to liquidate the borrowing banks because they might lose their payoffs if they do not liquidate and the signal is correct. Freixas and Holthausen (2005) also discuss interbank market under asymmetric information. They focus on the role of interbank market as the tool to connect two regional banking markets. In their point of view, there is an information asymmetry between domestic banks and foreign banks. Therefore, the role of peer-monitoring is emphasized in their work.

B. Banking Competition and Financial Fragility

The competition and the financial stability have been attracted the attentions from voluminous researchers. Allen and Gale (2004) state that there is a complex relationship between the competition and the financial stability. After examining the relationship under various settings, they conclude that the the relation is positive in some circumstances while it is reversed in others. For example, Nicoló, Bartholomew, Zaman, and Zephirin (2004) argue that the competition among banks increase the financial stability. They find that it is more likely to have a banking crisis when the banking industry is more concentrated. To be specific, they find the positive relation between the concentration ratio of top five banks in a jusrisdiction and the probability of the failure for these banks.

On the other hand, the empirical results of Berger, Klapper, and Turk-Ariss (2008) support the view that the banks with less competition are prone to avert risks. Using bank-level data from 23 countries, they find that the percentage of non-performing loans increases in the degree of market power such as Lerner index and Herfindahl index. Their analysis alleviates the endogeneity concern by using Generalized Method of Moments estimators with several instrumental variables.

The studies concerning the spatial competition among banks are relatively scarce. For example, Park and Pennacchi (2009) model not only the deposit competition but also the loan competition among banks using the circular model of Salop (1979). Their results suggest that loan market competition leads to the increase in loan interest rate while the deposit interest rate decreases.

III. The Model

A. Model Description

Consider an economy with two regional banking markets, denoted by market A and market B respectively (Figure 1). The number of spokes in each market is n and the number of banks in each market is identically $m < n$. Each bank is located at the tip of a spoke. The length of a spoke is equivalently k so that the distance from a bank to another bank is identically one.

Only banks can access the assets in this economy. There are two assets: the liquid asset and the illiquid asset. One unit of the liquid asset invested at $t = 0$ produces one unit of numeraire at $t = 1$. On the other hand, one unit of the illiquid asset invested at $t = 0$ produces $1 + r > 1$ unit of numeraire at $t = 2$. Assume $r > 2k$ to assure that illiquid assets are sufficiently productive. Illiquid assets can be liquidated at $t = 1$, but

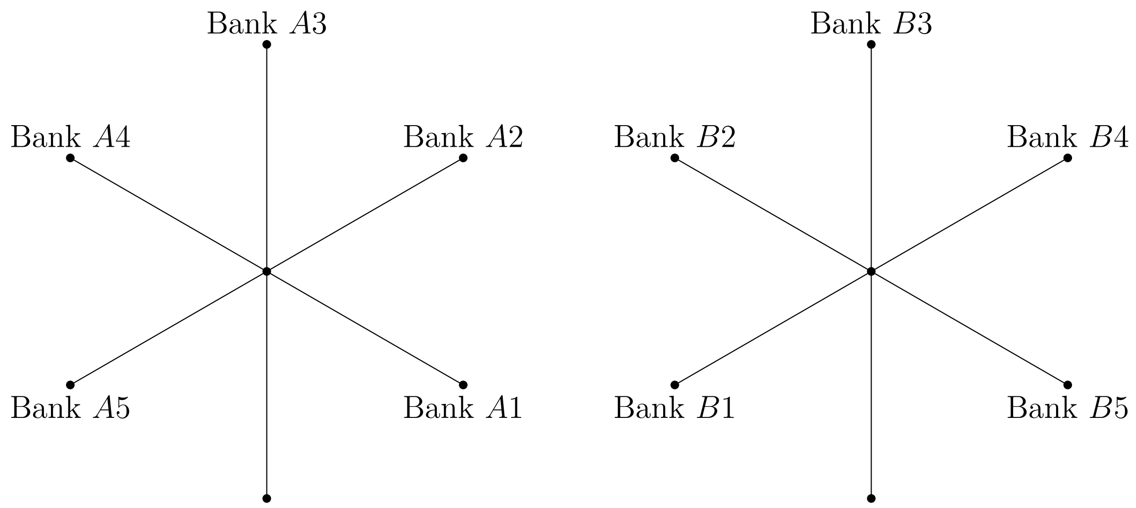

Figure 1. Two banking markets ($n = 6$ and $m = 5$).

This figure shows the market structure of the economy. There are two markets, called A and B. Each market has n spokes, and at the tip of a spoke, a bank is located. The total number of banks in a market is $m < n$. The distance from a bank to the center of a market is k. n unit of depositors are uniformly located in each market.

assume that the partial liquidation is not possible. Liquidating one unit of illiquid assets gives one unit of numeraire at $t = 1$. It is also possible to store liquid assets from $t = 1$ to $t = 2$. By storing one unit of liquid assets at time 1, a bank receives one unit of numeraire at time 2. Let the fraction of liquid asset of bank ij be ρ_{ij}. This can be interpreted as the liquidity of bank ij's total assets. A bank maximizes its expected payoff at $t = 2$.

For simplicity, assume that all banks have the identical endowment, i.e., equity, E at $t = 0$. Banks raise additional funds only in the form of deposits. At $t = 0$, bank ij announces its deposit rate of return d_{ij}. A deposit contract is long-term so that a bank which receives one unit of deposits from a depositor at $t = 0$ returns $1 + d_{ij}$ at $t = 2$ unless it defaults. However, each depositor has an option to withdraw her deposit early at $t = 1$. If a depositor withdraw her deposit at $t = 1$, then she only receives the principal. That is, the promised return for early withdrawal is fixed as one.

Deposits are perfectly insured by the third party, such as governments, central banks, or deposit insurance corporations. If a bank defaults, the deposit insurance scheme initiates and the government pays for its depositors.

n units of depositors are uniformly located in a market so that there are one unit of depositors in each spoke. Each depositor has one unit of endowment at $t = 0$. Following Diamond and Dybvig (1983), a depositor is either patient so that she maximizes her wealth at $t = 2$ or impatient so that she withdraw her deposit at $t = 1$ to consume at that time. The type of each depositor is revealed at $t = 1$ and the ex-ante probability that a depositor is impatient is w. At $t = 0$, a depositor chooses a bank to maximize her expected utility. Therefore, her maximization problem is

$$\max \; U = wu_i + (1 - w) \, u_p$$

where u_i is the utility of an impatient depositor and u_p is the utility of a patient depositor. Due to the deposit insurance, it is always better for a patient depositor to stay in her deposit contract until $t = 2$. Hence, there is no panic origniated from depositors and no bank run occurs in this economy.

To maximize her utility, a depositor chooses between her first-preferred bank and her second-preferred bank if they exist. The first-preferred bank of a depositor is on the spoke which the depositor is located at. The second-preferred bank is decided by nature with probability $1/ (n - 1)$. Therefore, it is possible for a depositor that her preferred banks do not exist. For example, a depositor located on spoke $m + 1$ does not have her first-preferred bank. Another depositor located on spoke $l < m$ certainly has her first-preferred bank but may not have her second-preferred bank if her second-preference is assigned to bank with index greater than m.

The utility of a patient depositor located at the distance $0 \leq y \leq k$ from bank ij is given as $u_p = 1 + d_{ij} - y \geq 1$ if she goes to bank ij at $t = 0$ to deposit. To simplify the problem, assume that an impatient depositor has no cost of travel and the consequent utility of an impatient depositor located at y from Bank ij is $u_i = 1$ regardless of her position. Assume also that depositors can store their endowment from time $t = 0, 1$ to time $t + 1$, but it returns only one unit of numeraire. Then, the deposits D_{ij} of bank ij for the given level of the deposit interest rate d_{ij} is derived in Appendix A.

Although there is no bank-run, there exists a liquidity shock at $t = 1$ due to impatient depositors. Once their types are revealed at $t = 2$, they withdraw their deposits from banks to consume early. The proportion of impatient depositors in a market is either $w - x > 0$ or $w + x < 1$ with equal probability 1/2. By assuming $w + x < 1$, there exists at least some patient depositors in the market in any case. The liquidity shock in each market is determined independently. Hence, there exists aggregate uncertainty on the size of required liquidity.

Let $s = (\widetilde{w_A}, \widetilde{w_B})$ be the state of the economy at $t = 1$ where $\widetilde{w_A}$ is the proportion of impatient depositors in market A and $\widetilde{w_B}$ is the proportion of impatient depositors in market B. There are four states: $s_{LL} = (w - x, w - x)$, $s_{HL} = (w + x, w - x)$, $s_{LH} = (w - x, w + x)$, and $s_{HH} = (w + x, w + x)$.

To hedge the liquidity shock, bank Aj and bank Bj agree on an interbank loan. For example, if bank Aj is insolvent while bank Bj is solvent at $t = 1$, bank Bj provides some liquidity to bank Aj. In return, bank Aj instead of bank Bj pays for the portion of depositors of bank Aj equivalent to the amount of liquidity provided at $t = 2$. Since we assume that all banks in a market suffer from the same liquidity shock, there is no room for banks in a market help each other. Thus, the focus of our model is on international or multimarket interbank loans not on domestic or local interbank loans.

Summarizing up, the time line of the model is given as Fig. 2.

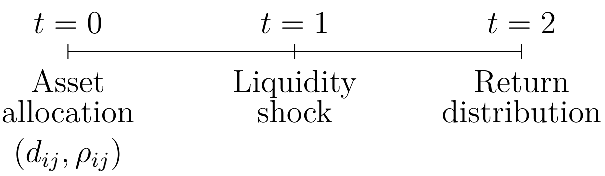

Figure 2. The Time Line of the Model

This figure shows the time line of the model. At $t = 0$, bank ij raises deposits by promising the deposit return d_{ij}. At the same time, bank ij invests $1 - \rho_{ij}$ portion of its budget in the illiquid asset which yields $1 + r$ at $t = 2$ and ρ_{ij} portion in the liquid asset which yields one at time $t = 1$. At $t = 1$, some depositors withdraw since it is revealed they are impatient. The withdrawal causes liquidity shock and banks may overcome it by their own strengths, or with the help of interbank loan. If a bank survives until $t = 2$, its return on the illiquid asset is realized and its depositors are paid off.

B. Social Planner's Optimization

Before we describe the banks' choice under the liquidity risk, we find the socially optimal choice by analyzing a social planner's optimization problem. Assume that there is a social planner who decides $d_{ij} = d^0$ and $\rho_{ij} = \rho^0$ instead of banks. The social planner maximizes the expected social welfare at $t = 2$. That is, the social planner solves the following problem:

$$\max_{\{d^0,\rho^0\}} \; S^0 = \sum_{i,j} E\left[R_{ij}\right] \tag{1}$$

where R_{ij} is the production of bank ij.

Since the social planner does not concern about the distribution, she maximizes the deposits of banks. Therefore, her choice on the deposit interest rate is

$$d^0 \geq 2k \tag{2}$$

to assure that all depositors in the economy are served by banks. In other words, the competition of banks reaches its peak under the control of the social planner. In that case, the deposits of a bank are

$$D^0 = \frac{2n - m - 1}{n - 1} \tag{3}$$

The optimal liquidity level chosen by the social planner cannot be any other value of the followings:

$$\rho^0 = \begin{cases} \frac{(w-x)D^0}{D^0+E} \\ \frac{wD^0}{D^0+E} \\ \frac{(w+x)D^0}{D^0+E} \end{cases} \tag{4}$$

We refer them as low liquidity, medium liquidity, and high liquidity, respectively. Figure 3 shows the possible states in the economy.

Suppose that the deposit of a bank is D^0 and the social planner chooses low liquidity. Then, bank Aj can satisfy the demand of early withdrawal at $t = 1$ if $\widetilde{w}_A = w - x$. However, it should liquidate its illiquid assets at $t = 1$ if $\widetilde{w}_A = w + x$ because bank Bj cannot provide an interbank loan. Therefore,

$$R_{Aj} = \begin{cases} \left[1 + r\left(1 - w + x\right)\right] D^0 + \left(1 + r\right) E & \text{if} \quad s = s_{LL}, s_{LH} \\ D^0 + E & \text{if} \quad s = s_{HL}, s_{HH} \end{cases} \tag{5}$$

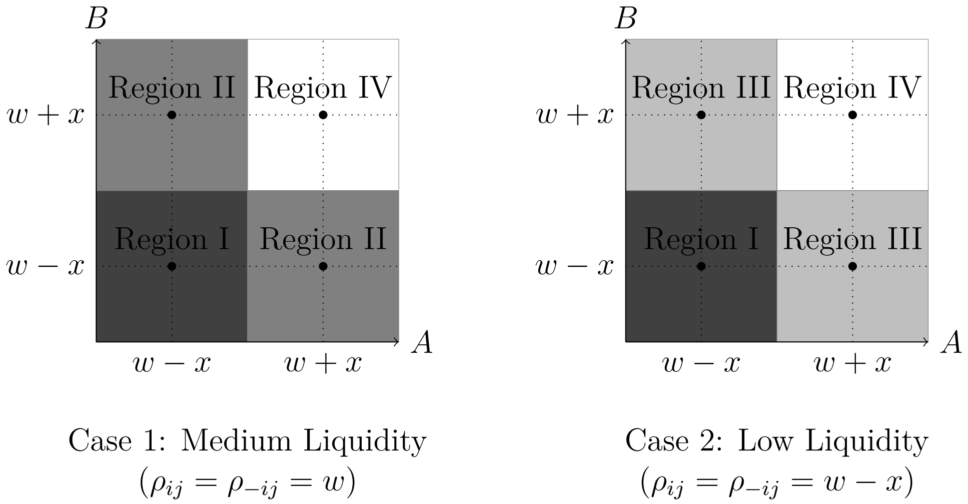

Figure 3. The Possible States in the Economy.

This figure shows the possible states in the economy. The left-sided graph is the case where $\rho_{ij} = w$ and the right-sided graph is the case where $\rho_{ij} = w - x$. The case where $\rho_{ij} = w + x$ is not shown in this figure. Each point symbolizes a possible state in this economy. For example, the point $(w - x, w + x)$ is the state where the fraction of impatient depositors in Market A is $w - x$ and the fraction of impatient depostors in Market B is $w + x$. At this point, Bank Aj can relieve Bank Bj's liquidity problem by offering the interbank loan of size x if their choice ρ_{ij} at Time 1 is w. Region I (darkgray) is the region where both Bank Aj and Bj survive in their own strengths at Time 2. Region II (gray) is the region where both banks survives with interbank loan. Region III (lightgray) is the region where one of them only survives. In Region IV (non-shaded), i.e., when the liquidity shock is given as $(w + x, w + x)$ but $\rho_{ij} = \rho_{-ij} < w + x$, both banks default at Time 2.

Hence, the expected social welfare with low liquidity is

$$S^0_{\text{low}} = 2m\left[\left\{1 + \frac{r}{2}(1 - w + x)\right\}D^0 + \left(1 + \frac{r}{2}\right)E\right] \tag{6}$$

Suppose that the social planner chooses medium liquidity. Then, bank Aj can survive by itself at $t = 1$ if $\widetilde{w}_A = w - x$. Also, it can avoid liquidating its illiquid assets if $s = s_{HL}$ because bank Bj can provide an interbank loan in this case. Still, it should liquidate xcD^0 units of its illiquid assets if $s = s_{HH}$. Therefore,

$$R_{Aj} = \begin{cases} [1 + r(1 - w)]D^0 + (1 + r)E & \text{if} \quad s = s_{LL}, s_{LH}, s_{HL} \\ D^0 + E & \text{if} \quad s = s_{HH} \end{cases} \tag{7}$$

and

$$S^0_{\text{med}} = 2m\left[\left\{1 + \frac{3r}{4}(1 - w)\right\}D^0 + \left(1 + \frac{3r}{4}\right)E\right] \tag{8}$$

Suppose that the social planner chooses high liquidity. Then, bank Aj can survive by itself in any state. Therefore,

$$R_{Aj} = \left[1 + r\left(1 - w - x\right)\right] D^0 + \left(1 + r\right) E \tag{9}$$

The expected social welfare with high liquidity is

$$S^0_{\text{high}} = 2m\left[\left\{1 + r\left(1 - w - x\right)\right\} D^0 + \left(1 + r\right) E\right] \tag{10}$$

Comparing the expected social welfare in each case, the optimal choice of liquidity ρ^0 depends on the volatility of the liquidity shock x.

Lemma 1. *The social planner's choice of deposit interest rate is $d_{ij} = d^0 = 2k$, and the liquidity level is*

$$\rho_{ij} = \rho^0 = \begin{cases} \frac{(w-x)D^0}{D^0+E} & \text{if } \frac{(1-w)D^0+E}{2D^0} < x \leq 1 - w \\ \frac{wD^0}{D^0+E} & \text{if } \frac{(1-w)D^0+E}{4D^0} < x \leq \frac{(1-w)D^0+E}{2D^0} \\ \frac{(w+x)D^0}{D^0+E} & \text{if } 0 < x \leq \frac{(1-w)D^0+E}{4D^0} \end{cases}$$

If the volatility of the liquidity shock x is relatively small, the potential cost of producing more liquidity can be compensated by the production of illiquid assets. Therefore, the social planner has the incentive to choose high liquidity. On contrary, if the volatility of the liquidity shock x is relatively significant, the cost of producing more liquidity is higher than the payoffs from illiquid assets. Thus, the social planner will conclude that it is better to choose low liquidity in such circumstance.

D. The Average Liquidity under Competition

Since it is complex to find the equilibrium where banks choose both d_{ij} and ρ_{ij} simultaneously, we first describe the equilibrium where banks only choose the optimal level of ρ_{ij} by themselves at $t = 1$ under the given deposit return $0 < \bar{d} \leq 2k$.

At $t = 0$, bank ij solves the following optimization problem:

$$\max_{\rho_{ij}} \; E\left[\pi_{ij}\right] \tag{11}$$

where π_{ij} is the profits of bank ij.

Let the consenquent deposits of bank ij from the given deposit interest rate $\bar{d}$ be $D_{ij} = \bar{D}$. Suppose that bank Aj believes $\rho_{Bj} = (w - x)\,\bar{D}/\left(\bar{D} + E\right)$. Then, bank Aj has no incentive to choose $\rho_{Aj} = w\bar{D}/\left(\bar{D} + E\right)$. If $\rho_{Aj} = (w - x)\,\bar{D}/\left(\bar{D} + E\right)$, then bank Aj survives by itself if $\widetilde{w}_A = w - x$. If $\widetilde{w}_A = w + x$, No interbank loan can be expected from bank Bj and bank Aj will liquidate its illiquid assets. Therefore,

$$\pi_{Aj} = \begin{cases} \left(r - \bar{d}\right)(1 - w + x)\,\bar{D} + (1 + r)\,E & \text{if} \quad s = s_{LL}, s_{LH} \\ -\bar{d}\,(1 - w - x)\,\bar{D} + E & \text{if} \quad s = s_{HL}, s_{HH} \end{cases} \tag{12}$$

The expected profits are

$$E\left[\pi_{Aj}\right] = \left[\frac{r}{2}\,(1 - w + x) - \bar{d}\,(1 - w)\right]\bar{D} + \left(1 + \frac{r}{2}\right)E \tag{13}$$

If $\rho_{Aj} = (w + x)\,\bar{D}/\left(\bar{D} + E\right)$ under the belief $\rho_{Bj} = (w - x)\,\bar{D}/\left(\bar{D} + E\right)$, then bank Aj can survive by itself in any case. Furthermore, bank Aj can reduce the costs of deposits by providing an interbank loan of value $2x\bar{D}$ to bank Bj if $s = s_{LH}$. Therefore,

$$\pi_{Aj} = \begin{cases} \left[r\,(1 - w - x) - \bar{d}\,(1 - w + x)\right]\bar{D} + (1 + r)\,E & \text{if} \quad s = s_{LL} \\ \left(r - \bar{d}\right)(1 - w - x)\,\bar{D} + (1 + r)\,E & \text{if} \quad s = s_{LH}, s_{HL}, s_{HH} \end{cases} \tag{14}$$

The expected profits are

$$E\left[\pi_{Aj}\right] = \left[r\,(1 - w - x) - \bar{d}\left(1 - w - \frac{x}{2}\right)\right]\bar{D} + (1 + r)\,E \tag{15}$$

Comparing the expected profits in two cases, bank Aj's choice of liquidity level under the belief $\rho_{Bj} = (w - x)\,\bar{D}/\left(\bar{D} + E\right)$ is

$$\rho_{Aj} = \begin{cases} \frac{(w-x)\bar{D}}{\bar{D}+E} & \text{if} \quad \frac{(1-w)+E/\bar{D}}{3-\bar{d}/r} < x \leq 1 - w \\ \frac{(w+x)\bar{D}}{\bar{D}+E} & \text{if} \quad 0 < x \leq \frac{(1-w)+E/\bar{D}}{3-\bar{d}/r} \end{cases} \tag{16}$$

Suppose that Bank Aj believes $\rho_{Bj} = w\bar{D}/\left(\bar{D} + E\right)$. If $\rho_{Aj} = w\bar{D}/\left(\bar{D} + E\right)$, then bank Aj can expect an interbank loan of size $x\bar{D}$ from bank Bj in case of $s = s_{HL}$. Also, bank Aj will provide an interbank loan of equal size to bank Bj if $s = s_{LH}$. However, both banks will have to liquidate their illiquid assets in case of $s = s_{HH}$. Therefore,

$$\pi_{Aj} = \begin{cases} \left[r\,(1 - w) - \bar{d}\,(1 - w + x)\right]\bar{D} + (1 + r)\,E & \text{if} \quad s = s_{LL} \\ \left(r - \bar{d}\right)(1 - w)\,\bar{D} + (1 + r)\,E & \text{if} \quad s = s_{LH}, s_{HL} \\ -\bar{d}\,(1 - w - x)\,\bar{D} + E & \text{if} \quad s = s_{HH} \end{cases} \tag{17}$$

The expected profits are

$$E\left[\pi_{Aj}\right]=\left(\frac{3r}{4}-\frac{\bar{d}}{2}\right)(1-w)\,\bar{D}+\left(1+\frac{3r}{4}\right)E \tag{18}$$

If $\rho_{Aj}=(w-x)\,\bar{D}/\left(\bar{D}+E\right)$, then bank Aj is sustainable if $\widetilde{w}_A=w-x$. In this case, any interbank loan is not feasible because the surplus in bank Bj's liquid assets are not sufficient to cover the deficit of bank Aj even if $s=s_{HL}$. Therefore,

$$\pi_{Aj}=\begin{cases}\left(r-\bar{d}\right)(1-w+x)\,\bar{D}+(1+r)\,E & \text{if} \quad s=s_{LL},s_{LH}\\ -\bar{d}\,(1-w-x)\,\bar{D}+E & \text{if} \quad s=s_{HL},s_{HH}\end{cases} \tag{19}$$

The expected profits are again

$$E\left[\pi_{Aj}\right]=\left[\frac{r}{2}(1-w+x)-\bar{d}\,(1-w)\right]\bar{D}+\left(1+\frac{r}{2}\right)E \tag{20}$$

If $\rho_{Aj}=(w+x)\,\bar{D}/\left(\bar{D}+E\right)$, then bank Aj can be stand-alone in any case. Moreover, the profits of bank Aj increases in case of $s=s_{LH}$ since it will provide an interbank loan of size $x\bar{D}$ to bank Bj.

$$\pi_{Aj}=\begin{cases}\left[r\,(1-w-x)-\bar{d}\,(1-w+x)\right]\bar{D}+(1+r)\,E & \text{if} \quad s=s_{LL}\\ \left[r\,(1-w-x)-\bar{d}\,(1-w)\right]\bar{D}+(1+r)\,E & \text{if} \quad s=s_{LH}\\ \left(r-\bar{d}\right)(1-w-x)\,\bar{D}+(1+r)\,E & \text{if} \quad s=s_{HL},s_{HH}\end{cases} \tag{21}$$

The expected profits of bank Aj are

$$E\left[\pi_{Aj}\right]=\left[r\,(1-w-x)-\bar{d}\left(1-w-\frac{x}{4}\right)\right]\bar{D}+(1+r)\,E \tag{22}$$

Comparing the expected profits in three cases, the choice of bank Aj on its liquidity level under the belief $\rho_{Bj}=w\bar{D}/\left(\bar{D}+E\right)$ is

$$\rho_{Aj}=\begin{cases}\frac{(w-x)\bar{D}}{\bar{D}+E} & \text{if} \quad \frac{\left(1+2\bar{d}/r\right)(1-w)+E/\bar{D}}{2}<x\leq 1-w\\ \frac{w\bar{D}}{\bar{D}+E} & \text{if} \quad \frac{\left(1-2\bar{d}/r\right)(1-w)+E/\bar{D}}{4-\bar{d}/r}<x\leq\frac{\left(1+2\bar{d}/r\right)(1-w)+E/\bar{D}}{2}\\ \frac{(w+x)\bar{D}}{\bar{D}+E} & \text{if} \quad 0<x\leq\frac{\left(1-2\bar{d}/r\right)(1-w)+E/\bar{D}}{4-\bar{d}/r}\end{cases} \tag{23}$$

Suppose that bank Aj believes that $\rho_{Bj}=(w+x)\,\bar{D}/\left(\bar{D}+E\right)$. Then, bank Aj will not choose $\rho_{Aj}=w\bar{D}/\left(\bar{D}+E\right)$ since this strategy is strictly dominated by $\rho_{Aj}=(w-x)\,\bar{D}/\left(\bar{D}+E\right)$. This is because bank Aj will survive by itself if $s=s_{LH}$ or

$s = s_{LL}$, need to borrow an interbank loan if $s = s_{HL}$, and liquidate its illiquid assets if $s = s_{HH}$ in both strategies. If bank Aj chooses $\rho_{Aj} = (w + x)\,\bar{D}/\left(\bar{D} + E\right)$, then both banks can withstand liquidity shock in any case. Therefore,

$$\pi_{Aj} = \begin{cases} \left[r\,(1-w-x) - \bar{d}\,(1-w+x)\right]\bar{D} + (1+r)\,E & \text{if} \quad s = s_{LL}, s_{LH} \\ \left(r - \bar{d}\right)(1-w-x)\,\bar{D} + (1+r)\,E & \text{if} \quad s = s_{HL}, s_{HH} \end{cases} \tag{24}$$

The expected profits of bank Aj are

$$E\left[\pi_{Aj}\right] = \left[r\,(1-w-x) - \bar{d}\,(1-w)\right]\bar{D} + (1+r)\,E \tag{25}$$

If bank Aj chooses $\rho_{Aj} = (w - x)\,\bar{D}/\left(\bar{D} + E\right)$, then it can survive by itself in case of $\widetilde{w}_A = w - x$. However, it can only avoid the liquidation of its illiquid assets in case of $s = s_{HL}$ with the interbank loan of $x\bar{D}$ from bank Bj. Therefore,

$$\pi_{Aj} = \begin{cases} \left(r - \bar{d}\right)(1-w+x)\,\bar{D} + (1+r)\,E & \text{if} \quad s = s_{LL}, s_{LH}, s_{HL} \\ -\bar{d}\,(1-w-x)\,\bar{D} + E & \text{if} \quad s = s_{HH} \end{cases} \tag{26}$$

The expected profits of bank Aj are

$$E\left[\pi_{Aj}\right] = \left[\frac{3r}{4}(1-w+x) - \bar{d}\left(1 - w + \frac{x}{2}\right)\right]\bar{D} + \left(1 + \frac{3r}{4}\right)E \tag{27}$$

Comparing the expected profits in two cases, the choice of bank Aj on its liquidity level under the belief $\rho_{Bj} = (w + x)\,\bar{D}/\left(\bar{D} + E\right)$ is given as the following.

$$\rho_{Aj} = \begin{cases} \frac{(w-x)\bar{D}}{\bar{D}+E} & \text{if} \quad \frac{(1-w)+E/\bar{D}}{7-2\bar{d}/r} < x \le 1 - w \\ \frac{(w+x)\bar{D}}{\bar{D}+E} & \text{if} \quad 0 < x \le \frac{(1-w)+E/\bar{D}}{7-2\bar{d}/r} \end{cases} \tag{28}$$

The results can be summarized as the following lemma.

Lemma 2. *For given $d_{ij} = \bar{d}$ where $0 < \bar{d} \le 2k$, the average liquidity level $\rho^* = \frac{\rho_{Aj}+\rho_{Bj}}{2}$ chosen by bank Aj and Bj are given as the function of the volatility in the liquidity shock x.*

$$\rho^* = \begin{cases} \frac{(w-x)\bar{D}}{\bar{D}+E} & \text{if} \quad \frac{(1-w)+E/\bar{D}}{3-\bar{d}/r} < x \le 1 - w \\ \frac{w\bar{D}}{\bar{D}+E} & \text{if} \quad \frac{(1-w)+E/\bar{D}}{7-2\bar{d}/r} < x \le \frac{(1-w)+E/\bar{D}}{3-\bar{d}/r} \\ \frac{(w+x)\bar{D}}{\bar{D}+E} & \text{if} \quad 0 < x \le \frac{(1-w)+E/\bar{D}}{7-2\bar{d}/r} \end{cases}$$

From lemma 1 and lemma 2, the following proposition can be found.

Proposition 1. *For a typical monopolistic competitive banking market with deposit return* $0 < d_{ij} = \bar{d} \leq 2k$*, the average liquidity level is not greater than the socially desirable liquidity level. That is,* $\rho^* \leq \rho^0$*. Furthermore, there exists the region where the average liquidity level is strictly less than the socially desirable level. That is,* $\{x \mid \rho^* < \rho^0\} \neq \emptyset$*.*

Proof. It is sufficient to show that $7 - 2\bar{d}/r > 4$ and $3 - \bar{d}/r > 2$ which are true for all $0 < \bar{d} \leq 2k < r$. □

Intuitively, banks choose their liquidity level lower than the socially desirable level. In other words, banks take the excessive liquidity risk. This structural problem results from the fact that banks are the agents on the behalf of depositors, and that banks may have benefits from borrowing the interbank loan.

The result that banks optimally choose lower liquidity when their deposit returns are given reminds the wisdom saying that the monopolistic rents or the charter value of banks and the financial stability are closely related. When banks are forced to distribute the larger portion of wealth to depositors, i.e., when $\bar{d}$ is higher, they take more liquidity risks, i.e., ρ^* is lesser compared to the socially optimal decision. More and more banks face the competitiveness in the deposit market, they run their business aggressively to leave money in their pockets.

E. The Competition under Liquidity Regulation

Now we describe the equilibrium where banks choose the deposit return d_{ij} given that the social planner chooses $\rho_{ij} = \bar{\rho}$ where $\bar{\rho}$ is either $(w - x) D_{ij} / (D_{ij} + E)$, $wD_{ij} / (D_{ij} + E)$, or $(w + x) D_{ij} / (D_{ij} + E)$.

Suppose that the liquidity regulation is given as low level. That is, $\bar{\rho} = (w - x) D_{ij} / (D_{ij} + E)$. From the previous section, the expected profits of bank Aj if both bank Aj and Bj choose low level of liquidity are

$$E[\pi_{Aj}] = \left[\frac{r}{2}(1 - w + x) - d_{Aj}(1 - w)\right] D_{Aj} + \left(1 + \frac{r}{2}\right) E \tag{29}$$

The first order condition with respect to d_{Aj} is

$$-\left(1-w\right)D_{Aj}+\left[\frac{r}{2}\left(1-w+x\right)-d_{Aj}\left(1-w\right)\right]\frac{\partial D_{Aj}}{\partial d_{Aj}}=0 \tag{30}$$

If $d_{Aj}=2k$, then bank Aj should have no incentive to deviate from the choice. That is,

$$-\left(1-w\right)D_{Aj}+\left[\frac{r}{2}\left(1-w+x\right)-d_{Aj}\left(1-w\right)\right]\frac{\partial D_{Aj}}{\partial d_{Aj}}\geq 0 \tag{31}$$

for $d_{Aj}=2k$. Here,

$$D_{Aj}=\frac{2n-m-1}{n-1} \tag{32}$$

and

$$\frac{\partial D_{Aj}}{\partial d_{Aj}}=\frac{2n-m-1}{2k\left(n-1\right)} \tag{33}$$

Solving for k gives

$$k\leq\frac{\left(1-w+x\right)r}{8\left(1-w\right)} \tag{34}$$

If $k<d_{Aj}<2k$, then the deposits and the derivative of deposits are given as

$$D_{Aj}=\frac{\left(n-m\right)d_{Aj}+\left(m-1\right)k}{k\left(n-1\right)} \tag{35}$$

and

$$\frac{\partial D_{Aj}}{\partial d_{Aj}}=\frac{2n-m-1}{2k\left(n-1\right)} \tag{36}$$

Solving the first order condition for d_{Aj} gives

$$k<d_{Aj}=\frac{r\left(1-w+x\right)\left(2n-m-1\right)-4k\left(1-w\right)\left(m-1\right)}{2\left(1-w\right)\left(4n-3m-1\right)}<2k \tag{37}$$

This solution is feasible if and only if

$$\frac{\left(1-w+x\right)r}{8\left(1-w\right)}<k<\frac{\left(1-w+x\right)\left(2n-m-1\right)r}{2\left(1-w\right)\left(4n-m-3\right)} \tag{38}$$

If $d_{Aj}=k$, then the deposits of bank Aj are $D_{Aj}=1$. Also,

$$\frac{\partial D_{Aj}}{\partial d_{Aj}}=\frac{2n-m-1}{2k\left(n-1\right)} \tag{39}$$

for a slight increase in d_{Aj} while

$$\frac{\partial D_{Aj}}{\partial d_{Aj}}=\frac{1}{k} \tag{40}$$

for a slight decrease in d_{Aj}. For $d_{Aj} = k$ to be an equilibrium, there should be no deviation. That is,

$$-\left(1-w\right)+\left[\frac{r}{2}\left(1-w+x\right)-k\left(1-w\right)\right]\frac{2n-m-1}{2k\left(n-1\right)}\leq 0 \tag{41}$$

and

$$-\left(1-w\right)+\left[\frac{r}{2}\left(1-w+x\right)-k\left(1-w\right)\right]\frac{1}{k}\geq 0 \tag{42}$$

Solving two inequalities for k gives

$$\frac{\left(1-w+x\right)\left(2n-m-1\right)r}{2\left(1-w\right)\left(4n-m-3\right)}\leq k\leq\frac{\left(1-w+x\right)r}{4\left(1-w\right)} \tag{43}$$

If $0 < d_{Aj} < k$, then the deposits of bank Aj are $D_{Aj} = d_{Aj}/k$. Naturally, $\partial D_{Aj}/\partial d_{Aj} = 1/k$. The first order condition is satisfied if and only if

$$d_{Aj}=\frac{r\left(1-w+x\right)}{4\left(1-w\right)} \tag{44}$$

This is feasible if and only if

$$\frac{\left(1-w+x\right)r}{4\left(1-w\right)}<k<\frac{r}{2} \tag{45}$$

Therefore, under the liquidity regulation of $\bar{\rho} = \left(w-x\right)D_{ij}/\left(D_{ij}+E\right)$, the deposit interest rate chosen by bank Aj is given as

$$d_{Aj}=\begin{cases} 2k & \text{if} \quad k\leq\frac{(1-w+x)r}{8(1-w)} \\ \frac{r(1-w+x)(2n-m-1)-4k(1-w)(m-1)}{2(1-w)(4n-3m-1)} & \text{if} \quad \frac{(1-w+x)r}{8(1-w)}<k<\frac{(1-w+x)(2n-m-1)r}{2(1-w)(4n-m-3)} \\ k & \text{if} \quad \frac{(1-w+x)(2n-m-1)r}{2(1-w)(4n-m-3)}\leq k\leq\frac{(1-w+x)r}{4(1-w)} \\ \frac{r(1-w+x)}{4(1-w)} & \text{if} \quad \frac{(1-w+x)r}{4(1-w)}<k<\frac{r}{2} \end{cases} \tag{46}$$

Suppose that the liquidity regulation is given as $\bar{\rho} = wD_{Aj}/\left(D_{Aj}+E\right)$. The expected profits of bank Aj if both bank Aj and Bj choose the medium liquidity is

$$E\left[\pi_{Aj}\right]=\left(\frac{3r}{4}-\frac{d_{Aj}}{2}\right)\left(1-w\right)D_{Aj}+\left(1+\frac{3r}{4}\right)E \tag{47}$$

The first order condition is

$$\left[-\frac{1}{2}D_{Aj}+\left(\frac{3r}{4}-\frac{d_{Aj}}{2}\right)\frac{\partial D_{Aj}}{\partial d_{Aj}}\right]\left(1-w\right)=0 \tag{48}$$

For $d_{Aj} = 2k$ to be an equilibrium, there should be no deviation.

$$-\frac{2n-m-1}{2(n-1)} + \left(\frac{3r}{4} - k\right)\frac{2n-m-1}{k(n-1)} \geq 0 \tag{49}$$

Solving for k gives

$$k \leq \frac{3r}{8} \tag{50}$$

Solving the first order condition under the restriction $k < d_{Aj} < 2k$ gives

$$d_{Aj} = \frac{3(2n-m-1)r - 4(m-1)k}{2(4n-3m-1)} \tag{51}$$

where

$$\frac{3r}{8} < k < \frac{3(2n-m-1)r}{2(4n-m-3)} \tag{52}$$

For $d_{Aj} = k$ to be an equilibrium, there should be no deviation in both upward and downward directions.

$$-\frac{1}{2} + \left(\frac{3r}{4} - \frac{k}{2}\right)\frac{2n-m-1}{2k(n-1)} \leq 0 \tag{53}$$

and

$$-\frac{1}{2} + \left(\frac{3r}{4} - \frac{k}{2}\right)\frac{1}{k} \geq 0 \tag{54}$$

Solving for k gives

$$\frac{3(2n-m-1)r}{2(4n-m-3)} \leq k \leq \frac{3r}{4} \tag{55}$$

Finally, solving the first order condition under the restriction $0 < d_{Aj} < k$ gives

$$d_{Aj} = \frac{3r}{4} \tag{56}$$

where

$$\frac{3r}{4} < k < \frac{r}{2} \tag{57}$$

As a result, the deposit interest rate chosen by bank Aj under the liquidity regulation of $\bar{\rho} = wD_{ij}/(D_{ij}+E)$ is given as

$$d_{Aj} = \begin{cases} 2k & \text{if} \quad k \leq \frac{3r}{8} \\ \frac{3(2n-m-1)r-4(m-1)k}{2(4n-3m-1)} & \text{if} \quad \frac{3r}{8} < k < \frac{3(2n-m-1)r}{2(4n-m-3)} \\ k & \text{if} \quad \frac{3(2n-m-1)r}{2(4n-m-3)} \leq k \leq \frac{3r}{4} \\ \frac{3r}{4} & \text{if} \quad \frac{3r}{4} < k < \frac{r}{2} \end{cases} \tag{58}$$

Suppose that the liquidity regulation is given as $\bar{\rho} = (w + x) D_{Aj} / (D_{Aj} + E)$. The expected profits of bank Aj if both bank Aj and Bj choose high liquidity is

$$E[\pi_{Aj}] = [r(1 - w - x) - d_{Aj}(1 - w)] D_{Aj} + (1 + r) E \tag{59}$$

The first order condition is

$$-(1 - w) D_{Aj} + [r(1 - w - x) - d_{Aj}(1 - w)] \frac{\partial D_{Aj}}{\partial d_{Aj}} = 0 \tag{60}$$

Similarly, the deposit interest rate chosen by bank Aj under the liquidity regulation of $\bar{\rho} = (w + x) D_{ij} / (D_{ij} + E)$ is given as

$$d_{Aj} = \begin{cases} 2k & \text{if} \quad k \le \frac{(1-w-x)r}{4(1-w)} \\ \frac{(1-w-x)(2n-m-1)r-2(1-w)(m-1)k}{(1-w)(4n-3m-1)} & \text{if} \quad \frac{(1-w-x)r}{4(1-w)} < k < \frac{(1-w-x)(2n-m-1)r}{(1-w)(4n-m-3)} \\ k & \text{if} \quad \frac{(1-w-x)(2n-m-1)r}{(1-w)(4n-m-3)} \le k \le \frac{(1-w-x)r}{2(1-w)} \\ \frac{(1-w-x)r}{2(1-w)} & \text{if} \quad \frac{(1-w-x)r}{2(1-w)} < k < \frac{r}{2} \end{cases} \tag{61}$$

Lemma 3. *For the given liquidity level $\rho_{ij} = \bar{\rho}$, the deposit return $d_{ij} = d^*$ chosen by bank ij is given as the followings:*

1. *Low liquidity $\bar{\rho} = (w - x) D_{ij} / (D_{ij} + E)$:*

$$d^* = \begin{cases} 2k & \text{if} \quad k \le \frac{(1-w+x)r}{8(1-w)} \\ \frac{r(1-w+x)(2n-m-1)-4k(1-w)(m-1)}{2(1-w)(4n-3m-1)} & \text{if} \quad \frac{(1-w+x)r}{8(1-w)} < k < \frac{(1-w+x)(2n-m-1)r}{2(1-w)(4n-m-3)} \\ k & \text{if} \quad \frac{(1-w+x)(2n-m-1)r}{2(1-w)(4n-m-3)} \le k \le \frac{(1-w+x)r}{4(1-w)} \\ \frac{r(1-w+x)}{4(1-w)} & \text{if} \quad \frac{(1-w+x)r}{4(1-w)} < k < \frac{r}{2} \end{cases}$$

2. *Medium liquidity $\bar{\rho} = wD_{ij} / (D_{ij} + E)$:*

$$d^* = \begin{cases} 2k & \text{if} \quad k \le \frac{3r}{8} \\ \frac{3(2n-m-1)r-4(m-1)k}{2(4n-3m-1)} & \text{if} \quad \frac{3r}{8} < k < \frac{3(2n-m-1)r}{2(4n-m-3)} \\ k & \text{if} \quad \frac{3(2n-m-1)r}{2(4n-m-3)} \le k \le \frac{3r}{4} \\ \frac{3r}{4} & \text{if} \quad \frac{3r}{4} < k < \frac{r}{2} \end{cases}$$

3. *High liquidity $\bar{\rho} = (w + x) D_{ij} / (D_{ij} + E)$:*

$$d^* = \begin{cases} 2k & \text{if} \quad k \le \frac{(1-w-x)r}{4(1-w)} \\ \frac{(1-w-x)(2n-m-1)r-2(1-w)(m-1)k}{(1-w)(4n-3m-1)} & \text{if} \quad \frac{(1-w-x)r}{4(1-w)} < k < \frac{(1-w-x)(2n-m-1)r}{(1-w)(4n-m-3)} \\ k & \text{if} \quad \frac{(1-w-x)(2n-m-1)r}{(1-w)(4n-m-3)} \le k \le \frac{(1-w-x)r}{2(1-w)} \\ \frac{(1-w-x)r}{2(1-w)} & \text{if} \quad \frac{(1-w-x)r}{2(1-w)} < k < \frac{r}{2} \end{cases}$$

From lemma 1 and lemma 3, the following proposition is derived.

Proposition 2. *Under a liquidity requirement with the liquidity level $\rho_{ij} = \bar{\rho}$, the average deposit interest rate is not greater than the socially desirable deposit interest rate. That is, $d^* \leq d^0$. Furthermore, there exists the region where the average deposit interest rate is strictly less than the socially desirable level. That is, $\{k \mid d^* < d^0\} \neq \emptyset$.*

We find that the competition is reduced when banks are required to maintain more liquidity. When the given liquidity level is high, the profits of banks become smaller since their investment in the long-run illiquid assets decreases. The reduction in the illiquid assets weakens the profitability of banks. Hence, banks compensate themselves by promising little deposit returns to the depositors. It may result in the decrease in bank competition and the decrease in the social welfare.

IV. Policy Implications

A. Liquidity Requirements

The results in the model suggested in the previous section suggest that liquidity requrements can be effective regulatory devices. Recently, Basel III Accord is scheduled to be introduced by 2018. The main purpose of Basel III Accord is to strengthen the global financial stability by increasing bank liquidity. Among various principles, the newly introduced liquidity requirements are gaining attentions. Basel III Accord states that banks have to maintain the high-quality liquid assets to cover its expected cash outflows. This principle is known as the Liquidity Coverage Ratio (LCR). According to Basel Commitee on Banking Supervision, LCR is defined as

$$\text{LCR} = \frac{\text{High Quality Liquid Asset}}{\text{Net Expected Liquidity Outflows}} \geq 100\%$$

The denominator of LCR is determined by the characteristic of a bank's funding source. Although our model consider only small depositors, bank deposit is commonly categorized into two groups: retail deposit and wholesale deposit. Retail deposit is small in amount, mostly from households, and requires a low interest rate. Wholesale deposit is large, usually from corporations and other financial institutions, and requires a high interest rate. However, retail depositors hardly withdraw their deposits while wholesale depositors quickly react on an emergency. Although our model does not distinguish retail deposit from wholesale deposit explicitly, we can consider the depositors near to banks in our model as retail depositors because they require low deposit returns, and the depositors near the center as wholesale depositors because they require high deposit returns.

A bank may respond to LCR in two ways: decreasing the denominator or increasing the numerator. Consider a bank which would like to decrease the denominator. Then, this bank may rely more on retail deposit since the run-off rate of retail deposit is smaller compared to wholesale deposit. Therefore, the wholesale depositors are not served and the social welfare may decline. On contrary, consider a bank which would like to respond to LCR by increasing the numerator. This bank increases the portion of liquid assets while decreases the portion of illiquid assets. Since the illiquid assets are more profitable than liquid assets generally, the return on asset of the bank is negatively affected by LCR. Then, the bank cannot avoid the reduction in deposit returns to preserve their profitability. Thus, both the depositor wealth and the social welfare decline. In any case, the regulatory purpose of LCR is not fully attained. Banks under the liquidity requirement may cope with liquidity shock better, but they probably avoid the competition to keep their profitability. This is the potential cost of Basel III Accord.

B. Globalization and Large Multi-Market Banks

We do not include the large multi-market banks (LMB) in our model. Some research suggests that LMB may have benefits in avoiding a regional liquidity shock than small regional banks (For example, Cetorelli & Goldberg, 2012). However, our model suggests that the interbank loan is more efficient than merged banks in some circumstances. It is possible that LMB cannot avoid the contagious banking crisis which originates from a market, while a small bank can avoid it by limiting the interbank loan supply (Region III in Figure 3). Thus, it partially explains why LMBs and small regional banks are mixed in banking industry.

Moreover, the disadvantage of LMBs becomes graver when the liquidity shocks in regional markets are correlated. In our model, the liquidity shocks in two markets are independent. This setup is more advanced from the previous work where the liquidity shocks in two regions are negatively correlated so that banks can perfectly insure each other. However, the globalization leads to the correlated shocks. In recent years, the economy in a small region is not separated from the global economy. For example, the decline of the growth in China not only affects the consumption of Chinese people, but also the production in other nations such as Korea and Japan. Therefore, it is possible that two markets have the simultaneous liquidity shocks which cannot be insured by interbank loans even. If depositors perceive that two markets are positively correlated, then bank panics in a market will be susceptible to the liquidity shock in another market. Although we simply allow the state where both markets suffer from the liquidity shock of high level, it will be necessary to consider the correlation among the liquidity shocks for the futher exploration.

V. Conclusion

In this paper, we provide a theoretical framework which relates the bank competition and liquidity. By suggesting a simple model of the spatial competition among banks, we show that banks under monopolistic competition reduce their liquidity compared to the socially desirable level. On contrary, liquidity requirements lead to weak competition among banks compared to the socially desirable level. This results from the banks' choice to maintain their profitability under restrictions.

Our results suggest that the liquidity requirements in Basel III Accord can be an efficient method to sustain the financial system but these regulations may harm the depositors' welfare and the social welfare even further. If banks adapt to the liquidity requirements by allocating more assets on liquid assets, they cannot promise high returns on depositors so their competition is weakened. On the other hand, if banks tend to stabilize their funding source by promising high returns, they cannot invest much in liquid assets. It is necessary for the planners in banking system to consider not only the benefits of the liquidity requirements, the stabilization of financial system, but also the potential cost of the liquidity requirements suggested in this paper.

Appendix

Deposits Derivation

Following Chen and Riordan (2007), deposits D_{ij} of bank ij at time 0 is derived. While Chen and Riordan (2007) assume a monopolistically competitive market, we also include the case where the market is monopolistic. Consider the individual rationality constraint of a depositor located at the center of a market:

$$w + (1 - w)(1 + d_{ij} - k) \geq 1 \tag{62}$$

That is,

$$d_{ij} \geq k \tag{63}$$

Suppose that (63) does hold for bank ij and another bank, say bank il. Then, two banks compete with each other to attract depositors between them. In other words, the market is monopolistically competitive. There are two kinds of depositors who are relevant to bank ij: depositors who prefer bank ij where her two perferred banks are available, and depositors who prefer bank ij where her other preferred bank is not available.

Consider a depositor who prefers bank ij and when her other preferred bank is also available. Let the distance from her to bank ij be y. She is indifferent between two banks if and only if

$$w + (1 - w)(1 + d_{ij} - y) = w + (1 - w)[1 + d_{il} - (2k - y)] \tag{64}$$

Rearranging gives

$$y = k + \frac{d_{ij} - d_{il}}{2} \tag{65}$$

The conditional probability that she prefers bank il when she prefers bank ij is $1/(n-1)$. The number of depositors on a unit length of spoke is $n/(nk) = 1/k$. Therefore, the number of depositors served by bank ij is

$$\frac{1}{k(n-1)} \sum_{l \neq j}^{m} \max \left[\min \left(k + \frac{d_{ij} - d_{il}}{2}, 2k \right), 0 \right] \tag{66}$$

Consider a depositor who prefers bank ij when her other preferred bank is not available. She prefers Bank ij than doing nothing if her individual rationality constraint is satisfied. Therefore, a depositor is indifferent between going to bank ij and doing nothing if and only if

$$w + (1 - w)(1 + d_{ij} - y) = 1 \tag{67}$$

Rearranging gives

$$y = d_{ij} \tag{68}$$

The number of such depositors is

$$\frac{n - m}{k(n-1)} \max\left[\min(d_{ij}, 2k), 0\right] \tag{69}$$

If (63) does not hold, then it is impossible for two banks to compete. Hence, the market is now monopolistic. In that case, the deposit of bank ij is

$$\frac{1}{k} \max\left[\min(d_{ij}, 2k), 0\right] \tag{70}$$

In summary, the deposits for bank i is given by

$$D_{ij} = \begin{cases} \frac{1}{k(n-1)} \sum_{l \neq j}^{m} \max\left[\min\left(k + \frac{d_{ij} - d_{il}}{2}, 2k\right), 0\right] & \\ + \frac{n-m}{k(n-1)} \max\left[\min(d_{ij}, 2k), 0\right] & \text{if} \quad d_{ij} \geq k \\ \frac{1}{k} \max\left[\min(d_{ij}, 2k), 0\right] & \text{if} \quad d_{ij} < k \end{cases} \tag{71}$$

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