Optimal Policy Response to Systemic Bank Insolvency

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October 16, 2002

Abstract

In some cases of recent financial crises, most of the domestic banks or the banking sector as a whole becomes insolvent (*systemic bank insolvency*). We analyze the welfare effects of policy responses to the systemic bank insolvency by examining the Diamond-Dybvig type model. The source of inefficiency in banking crisis of our model is the premature liquidation of assets that is caused by fixed liability of banks, which is not changeable contingent on the state of bank asset.

We assume that the systemic bank insolvency is caused by an exogenous macroeconomic shock that destroys a part of bank asset. We analyze the consequences of different policy responses to the insolvency: (1) laissez faire, (2) deposit guarantee (without immediate recapitalization), (3) immediate recapitalization, and (4) control of inflation. We show that the policy of immediate recapitalization is optimal in our model. Our findings imply that the protracted recession (and the asset-price deflation) in Japan for over a decade may be caused by inappropriate policy response to the systemic bank insolvency.

JEL Classification: E5, E6, G2, H3.

Keywords: Financial crises, deposit guarantee, recapitalization.

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1 Introduction

In this paper, we analyze and compare the consequences of different policy responses to financial crises. In the recent theoretical research, there are considerably rich literatures on the mechanism how financial crises occur (Diamond and Dybvig [1983], Postlewaite and Vives [1987], and Allen and Gale [1998, 2000a, 2001]). But there are not so many theories that explain the difference of recovery paths from the crises in accordance with different policy responses. For example, Diamond and Dybvig (1983), Freixas, Parigi, and Rochet (1999), and Martin (2001) argue the policies to prevent bank runs, not to respond to systemic insolvency. Few authors like Diamond and Rajan (2002), and Bergoeing, et al. (2002) argue about ex post policy responses to financial crises.

Meanwhile, the world has experienced a sizable number of banking crises in the last twenty five years. Caprio and Klingebiel (1999) identified 113 systemic banking crises that have occurred in 93 countries since the late 1970s, and 50 borderline and smaller banking crises in 44 countries during that period. In these experiences, researchers have become to pay more attention to bank insolvency rather than to bank runs. Recent crisis episodes show that bank insolvency is the central problem that should be rectified and that a rush of bank runs or temporary shortage of liquidity is rather a symptom. Several stylized facts about the recovery paths from banking crises have been found by case studies and empirical researches of recent financial crises (See, for example, Claessens et al. [2001], Alexander et al. [1997], Caprio and Klingebiel [1996]).

Honohan and Klingebiel (2000) find that open-ended liquidity supports, regulatory forbearance and an unlimited depositor guarantee are all significant contributors to the fiscal cost of banking crisis (See also Leggett[1994] for forbearance policy). They also find that liquidity support significantly increases the output loss or delays the economic recovery (This result is confirmed by Bordo et al. [2001] who used a broader data set). On the other hand, Claessens et al. (2001) show that the liquidity support and depositor guarantee may be effective for recovery of corporate sector when they are implemented with the measures to restore solvency of banks (by disposing of nonperforming assets).

In short, these empirical analyses seem to indicate that open-ended liquidity support without resolving systemic insolvency may hinder economic recovery and magnify the fiscal cost.

The researchers emphasized on moral hazard or managerial or political distortions as the causes why liquidity supports tend to increase the output loss and fiscal cost. In this paper we neglect all these microeconomic distortions, and emphasize the excessive liquidation of premature assets made by banks that try to fulfill the commitment to repay when they are insolvent and do not have enough aggregate liquidity.

Among the recent financial crises around the world, Japan's case is quite peculiar. As Caprio and Klingebiel (1999) point out, the banking sector of Japan has fallen into the crisis at the beginning of the 1990s as a result of the burst of asset-price bubble, and the Japanese banks have stayed in the crisis situation for over a decade until today. The characteristics of recent Japanese economy are (a) continuation of low economic growth, (b) continuation of asset-price decline, i.e., asset-price deflation, (c) increase in the liquidity of bank assets and of corporate liability. Figure 1 shows the proportion of liquid assets and of loans and bills discounted in bank assets of all Japanese banks during the period of 1986-2002. The liquidity in bank asset surged in 1994 when the financial crisis was widely recognized for the first time, and it has continued to grow after the second crisis of 1997-1998.

Figure 1: Assets of All Banks in Japan

Figure 2 shows the liquid liability of non-financial corporations. Although liquid liability decreases over time, the liquidity has been consistently above the trend since mid-1990s.

Figure 2: Liquid Liability of Non-Financial Corporations

Our aim in this paper is to analyze the effects of different policy responses to bank insolvency, to find the optimal policy response, and eventually to construct a consistent explanation of the above features of Japan's protracted recession.

In order to analyze the banking crises, we use a variant of the Diamond-Dybvig model (Diamond and Dybvig [1983]). In our model, we do not describe how financial crises occur, but we just set that all banks become insolvent as a result of an unspecified macroeconomic shock (e.g., a burst of asset-price bubble, fall in currency exchange rate) that suddenly decrease the value of bank asset. Taking this *systemic bank insolvency* as given, we focus our analysis on welfare properties of the following policy responses: (1) laissez faire, (2) deposit guarantee, (3) immediate recapitalization, and (4) control of inflation.

If the government chooses no action (laissez faire) to systemic bank insolvency, all households would withdraw their deposits immediately since they know that bank assets are smaller than bank liabilities. In this case, all banks are run on, premature liquidation of all assets occurs, and welfare of households becomes worse.

If the government guarantees the depositors (but does not recapitalize banks immediately), the use of assets becomes inefficient. Since the government guarantees deposits, depositors do not run on banks. But banks are forced to partially liquidate their premature assets to meet the demand of withdrawals, since the government does not supply additional liquidity into the economy. Private agents rationally believe that in the future the government must recapitalize insolvent banks to fulfill the commitment to guarantee deposits. In this case as a result of inefficient liquidation of premature assets, the welfare of households becomes suboptimal, and the fiscal cost imposed on households in the future becomes large.

If the government immediately recapitalizes insolvent banks by issuing the government bonds, there are several tradeoffs for private agents. Since the government bonds provide the economy with additional liquidity, households can withdraw their deposits in full. But they must pay tax to redeem the government bonds in the future. Banks do not need to liquidate premature assets since they are given liquidity, i.e., the government bonds. Since assets can be used efficiently and the output can be maximized if the government recapitalizes banks appropriately, households can attain the optimal consumption in this case.

If the government can control the inflation rate immediately and accurately, it is easily shown that the optimality can be attained. But in the case where it takes time for the government to change the inflation rate, households run on banks before inflation occurs, anticipating that the real value of their deposit will be small due to the inflation. In this case, the outcome is similar to the case of laissez faire.

The rest of the paper is organized as follows. Section 2 describes the basic model. Section 3 analyzes the consequences of several policy options. Section 4 concludes.

2 Model

The economy consists of a continuum of households and of banks. The measure of each continuum is normalized to 1. The economy continues two periods with three dates: $t = 0, 1, 2$. There is one type of good (*consumer good*) in this economy that can be consumed by households.

2.1 Assets

There are two investment technologies in this economy. The following two assets represent these investment technologies.
(1) The short-term asset: one unit of the consumer good invested in the short-term asset at date t yields R_1 units at date $t+1$, for $t = 0, 1$. Although we will assume that $R_1 = 1$ for simplicity in Section 3, we describe our model for general values of R_1 in this section.
(2) The long-term asset: one unit of the consumer good invested in the long-term asset at date 0 produces R_2 units at date 2, where $R_2 > R_1$. It is assumed that partial liquidation of the long-term asset is available to banks. One unit of long-term asset yields xl units of consumer good at date 1 and $(1-l)R_2$ units at date 2, where the bank can choose the degree of liquidation $l \in [0, 1]$ at date 1.

We assume that the short-term asset is available to both households and banks, and the long-term asset is available only to banks. The parameters satisfy

$$x < 1 \leq R_1 \leq R_1^2 < R_2. \tag{1}$$

2.2 Households

Each household is endowed with E units of consumer goods at date 0 and nothing at subsequent dates. A household can either deposit E in bank account, or invest all of the endowment in short-term asset by itself. We analyze the case where expected payoff for households is larger when they make a deposit than when they hold their assets by themselves.

We assume there are two types of households, *early households*, who only consume the good at date 1, and *late households*, who only consumes at date 2. The type of each household is revealed at date 1, and all households are identical at date 0. The type of a household is private information that cannot be observed by banks or other households. Each household has a probability η of being an early household and it is assumed that the law of large number holds so that the proportion of early households in the population is η. Let c_1 (c_2) denote the consumption of an early (late) household at date 1 (date 2). The household's ex ante utility is

$$\eta U(c_1) + (1-\eta)U(c_2).$$

The utility function $U(\cdot)$ satisfies the usual neoclassical properties, $U'(c) > 0$, $U''(c) < 0$, and $\lim_{c\downarrow 0} U'(c) = \infty$. In the following, we assume for simplicity that

$$U(c) = \frac{c^{1-\theta}}{1-\theta},\ \theta > 1.$$

The assumption: $\theta > 1$ is necessary to guarantee that the liquidity insurance given by banks can be Pareto superior to the market allocation attained in the case where assets are directly owned by households and households can trade their assets and the goods in a competitive market (See von Thadden [1999], Diamond and Dybvig [1983]).

Possibility of Bank Run We focus our attention to the case where households make a deposit at date 0. Since late households can invest in short-term asset at date 1, they can pretend to be early households and withdraw their deposit at date 1, invest it in short-term asset, and consume the proceeds at date 2. Therefore, if households believe that all late households withdraw early, a bank run can occur as a result of self-fulfilling expectations even when banks have enough resources to meet their commitment to early households at date 1 and make an equal or greater payment to late households at date 2, as Diamond and Dybvig (1983) describe (Allen and Gale [2001] call this type *unnecessary bank runs*). Since our analysis focus on the effect of policy responses to financial crises, we ignore the self-fulfilling prophecies, which make the equilibrium path unnecessarily complicated. Thus following Allen and Gale (2001), we assume that in equilibrium late households wait until date 2 to withdraw from the bank as long as it is incentive-compatible to do so.

2.3 Systemic Bank Insolvency

We formalize a financial crisis as destruction of assets due to an exogenous macroeconomic shock at a time between date 0 and date 1. At date 0, households make a deposit of E in banks, and banks make investments (S, L) and commitments (W_1, W_2), where S is the amount invested in short-term asset, $L \equiv E - S$ is the long-term asset, W_1 is the amount to be repaid when a depositor withdraws at date 1, and W_2 is the amount to be repaid at date 2.

Assumption 1 *The commitments (W_1, W_2) and investments (S, L) are observable and verifiable for all agents in the economy.*

We assume the following for contractual technology of demand deposit:

Assumption 2 *A bank's commitment to repay W_1 is not renegotiable at date 1.*

This assumption implies that a bank must repay W_1 to all withdrawer at date 1 unless the bank runs out of asset, even if it becomes unable to repay W_2 at date 2 as a result of the repayment at date 1. The specific reason why banks cannot renegotiate the amount of repayment with depositors is out of the scope of this paper. One justification of Assumption 2 may be given by the agency problem that is thoroughly analyzed by Diamond and Rajan (2001).

After these investments (S, L) and commitments (W_1, W_2) are made, a macroeconomic shock hits the economy at, say, date $\frac{1}{2}$, and destroys the proportion $1 - \lambda$ of all banks' short-term assets and $1 - \mu$ of all banks' long-term assets where λ and μ are random variables that satisfy $(\lambda, \mu) \in [0, 1]^2$ and $(\lambda, \mu) \sim F(\lambda, \mu)$ where $F(\cdot, \cdot)$ is the joint distribution function over $[0, 1]^2$.

Assumption 3 *The random shock λ and μ are both observable but not verifiable. Thus agents cannot write a contract contingent on (λ, μ). When the government takes policy action at date 1, the action can be contingent on (λ, μ).*

Thus the short-term asset of a bank becomes $S' = \lambda S$, and the long-term asset becomes $L' = \lambda L$ at date 1 whereas banks cannot change the commitment W_t $(t = 1, 2)$ that is made at date 0. [1]

Note that the macroeconomic shock $(\lambda,\ \mu)$ is formalized as a convenience to create a situation where banks' deposit liability exceeds their asset (*systemic bank insolvency*). We formalize the macroeconomic shock that brings about insolvency of the banking system as a physical destruction of productive asset, although its counterpart in reality is a burst of asset-price bubble or a fall of currency exchange rate, which typically does not involve physical destruction of productive assets.[2]

2.4 Structure of the Game

At date 1, the government chooses one policy among the policy options that are specified in Section 3, given (W_1, W_2, S) and (λ, μ). Note that each bank can choose different values of (W_1, W_2, S), and the government can apply different policy to each bank contingent on

[1] If the bank insolvency is an idiosyncratic events, then banks can insure themselves by forming the deposit insurance. But the deposit insurance among banks is useless if the shock is macroeconomic and all banks become insolvent as in the model of this paper.

[2] We may regard our model as a variant of the model by Allen and Gale (1998) in which business cycle fluctuation is formalized as a random return on long-term asset. In their model, one unit of long-term asset generates R units of consumer goods where R is a random variable the realized value of which is common for all banks.

the values of (W_1, W_2, S) since these variables are observable and verifiable (Assumption 1).

We denote the government's choice of policy by P: $P = P(W_1, W_2, S, \lambda, \mu)$. The government's objective is to maximize the average utility of households, given $(W_1, W_2, S, \lambda, \mu)$. The government chooses $P(W_1, W_2, S, \lambda, \mu)$, anticipating banks' reaction (m, l) where m is the fraction of consumer goods generated from short-term asset that is to be reinvested in short-term asset, and l is the fraction of long-term asset that is to be liquidated prematurely at date 1. At date 1 after the government chooses the policy, banks choose (m, l). Thus a bank pays out $(1 - m)R_1\lambda S + xl\mu L$ units of consumer goods at date 1 to withdrawers. Banks' choice m (or l) is a mapping from $(W_1, W_2, S, \lambda, \mu, P)$ to a real number in $[0, 1]$. Thus

$$m = m(W_1, W_2, S, \lambda, \mu, P), \text{ and } l = l(W_1, W_2, S, \lambda, \mu, P).$$

Therefore, the bank's problem at date 0 is written as follows:

$$\max_{W_1, W_2, S} E[\eta U(c_1) + (1 - \eta)U(c_2)]$$

subject to

$$\begin{cases} P = P(W_1, W_2, S, \lambda, \mu), \\ m = m(W_1, W_2, S, \lambda, \mu, P), \\ l = l(W_1, W_2, S, \lambda, \mu, P). \end{cases}$$

The expectation $E[\cdot]$ is taken over λ and μ. As we will see in Section 3, the consumptions c_1 and c_2 are uniquely determined by the choice of (P, m, l).

Since all banks solve the same problem at date 0, the solution (W_1, W_2, S) should be identical for all banks. Thus we can focus our attention to the symmetric equilibrium where all banks choose the same values of (W_1, W_2, S) when we examine the policy response of the government at date 1.

Note that we have assumed time consistency in the government's choice of policy: The government cannot commit, before (λ, μ) is revealed, to any policy that is not optimal *ex post*. Under the assumption of time consistent government, we can compare the effect of different policy chosen at date 1 on the premise that $(W_1, W_2, S, \lambda, \mu)$ are all fixed and identical for all banks.

3 Policy Responses to Systemic Bank Insolvency

In sections 3.1 — 3.5, we compare the policy options at date 1 for fixed values of $(W_1, W_2, S, \lambda, \mu)$. In Section 3.6, we see the date 0 problem for banks, in which they determine (W_1, W_2, S) anticipating which policy to be chosen at date 1 by the government for each (λ, μ).

3.1 Optimal Allocation

The values of $(W_1, W_2, S, \lambda, \mu)$ are all revealed at date 1. The optimal allocation is defined as (m, l) that maximizes the average utility of household, given the resource constraints only. Thus the optimal allocation is the solution to the following problem:

$$\text{(PO)} \quad \max_{m,l} \eta U(c_1) + (1-\eta)U(c_2)$$

subject to

$$\begin{cases} \eta c_1 \leq (1-m)\lambda R_1 S + xl\mu L, \\ (1-\eta)c_2 \leq (1-l)R_2\mu L + m\lambda R_1^2 S, \\ L = E - S \\ m \geq 0 \\ l \geq 0. \end{cases}$$

If the solution satisfies $l \geq 0$ and $m = 0$, the first order condition is

$$U'(c_1) - \frac{R_2}{x}U'(c_2) \geq 0, \tag{2}$$

where $c_1 = \frac{1}{\eta}(\lambda R_1 S + xl\mu L)$ and $c_2 = \frac{1-l}{1-\eta}R_2\mu L$. If the solution satisfies $m \geq 0$ and $l = 0$, the first order condition is

$$U'(c_1) - R_1 U'(c_2) \leq 0, \tag{3}$$

where $c_1 = \frac{1-m}{\eta}\lambda R_1 S$ and $c_2 = \frac{1}{1-\eta}(m\lambda R_1^2 S + \mu R_2 L)$. Since $U(c) = \frac{c^{1-\theta}-1}{1-\theta}$, the first order conditions (2) and (3) imply that the solution (l, m) to (PO) satisfies that $l > 0$

and $m = 0$ if (λ, μ) falls in Region I, that $l = m = 0$ if (λ, μ) falls in Region II, and that $l = 0$ and $m > 0$ if (λ, μ) falls in Region III, where Regions I, II, and III are defined as follows.

$$\begin{aligned}
\text{Region I } &= \left\{ (\lambda, \mu) |\ (\lambda, \mu) \in [0,1]^2, \mu > \left(\tfrac{R_2}{x}\right)^{\frac{1}{\theta}} \tfrac{(1-\eta)R_1 S}{\eta R_2 L} \lambda \right\}, \\
\text{Region II} &= \left\{ (\lambda, \mu) |\ (\lambda, \mu) \in [0,1]^2, \mu \leq \left(\tfrac{R_2}{x}\right)^{\frac{1}{\theta}} \tfrac{(1-\eta)R_1 S}{\eta R_2 L} \lambda, \text{ and } \mu \geq R_1^{\frac{1}{\theta}} \tfrac{(1-\eta)R_1 S}{\eta R_2 L} \lambda \right\}, \\
\text{Region III} &= \left\{ (\lambda, \mu) |\ (\lambda, \mu) \in [0,1]^2, \mu < R_1^{\frac{1}{\theta}} \tfrac{(1-\eta)R_1 S}{\eta R_2 L} \lambda \right\}.
\end{aligned}$$

These regions I, II, and III are shown in Figure 3.

Figure 3: Optimal Allocation

If $(\lambda, \mu) \in$ Region I, the optimal consumptions c_t $(t = 1, 2)$ and l are uniquely determined by (2) in equality. If $(\lambda, \mu) \in$ Region II, the optimal consumptions c_t $(t = 1, 2)$ are uniquely determined by $l = m = 0$. If $(\lambda, \mu) \in$ Region III, the optimal consumptions c_t $(t = 1, 2)$ and m are uniquely determined by (3) in equality.

In problem (PO), we implicitly assume that the social planner observes the type of each household and assigns c_1 (c_2) to an early (late) household. Since the type of a household is private information, we should impose a restriction that the government cannot observe types of households. In this case, the consumption allocation must satisfy the following incentive compatibility constraint to prevent late households from mimicking early households:

$$R_1 c_1 \leq c_2.$$

When we add this constraint to (PO), this constraint becomes redundant only if $R_1 \leq 1$. Therefore in this section we assume for simplicity of analysis that

$$R_1 = 1. \tag{4}$$

If $R_1 = 1$, the solution to (PO) always satisfies the incentive compatibility constraint $(c_2 \geq R_1 c_1 = c_1)$ that the government faces when it chooses policy action. Before moving on to other policies, we examine two policy options that are excluded from available options in this paper: Deposit Cut and Monetary Easing.

Deposit Cut Deposit cut forced by the government is the most straightforward policy to realize the optimal allocation. If the government can order arbitrary change of repayments (W_1 and W_2) at date 1, then the optimal allocation is obviously attained. In some episodes of banking crises, the governments coercively cut the deposit liability of banks without causing major macroeconomic impacts (Baer and Klingebiel [1995]). But those episodes show that deposit cut in which the government order overrides private contracts and property rights can be implemented only when the country falls into the emergency situation: for example, the occupation by foreign army (Japan 1946) or the great depression (the United States 1933). Since it seems plausible to assume that deposit cut policy incurs prohibitively high political costs, we exclude deposit cut from the available policy options in this paper.

Monetary Easing Since inefficiency in our model is caused by early liquidation of long-term asset, liquidity provision by monetary policy seems effective to mitigate the inefficiency. But careful consideration shows that the monetary policy is ineffective in our model. Monetary easing can be defined as the following policy: The government supplies "cash" to banks at date 1 in exchange for the banks' commitment to repay the prespecified amount of "cash" at date 2. "Cash" is something exchangeable with consumer good. Suppose that early households withdraw $W_1 = W_c + W_m$ from banks at date 1, where W_c is consumer goods and W_m is cash. Since in monetary policy the government does not impose any tax on early households, all early households try to convert all amount of cash (W_m) to consumer goods. As long as the aggregate supply of consumer goods at date 1 ($(1-m)\lambda R_1 S + xl\mu L$) is less than ηW_1, the price of consumer good in terms of cash is bid up to infinity and the cash becomes worthless. Thus the monetary easing cannot prevent early liquidation of long-term asset.

This analysis is based on the implicit assumption that deposit contracts are made in terms of consumer good. If we allow deposit contract be nominal, the monetary authority may control the price level to induce the optimal allocation. We analyze this case in Section 3.5.

3.2 Laissez Faire

If the government does not take any policy action to the systemic bank insolvency, all banks are run on at date 1 for small λ and μ. It is shown as follows.

At date 1, the values of $(W_1, W_2, S, \lambda, \mu)$ are revealed. We assumed that late households wait to withdraw if and only if it is incentive compatible to do so. Thus bank run occur iff c_2 satisfies $c_2 < R_1 c_1 = c_1$ where c_2 is what a late household can get by waiting to withdraw until date 2. The condition for occurrence of bank runs is thus rewritten as $\min\{W_2, c_2(l,m)\} < \min\{W_1, (1-m)\lambda S + xl\mu L\}$ where $(l, m, c_2(l,m))$ is determined by

$$\text{(PLF)} \quad \max_{m,l} \ \eta U(\min\{W_1, (1-m)\lambda S + xl\mu L\}) + (1-\eta)U(c_2(l,m))$$

subject to

$$\begin{cases} \eta W_1 \leq (1-m)\lambda S + xl\mu L, \text{ or } \ l = 1-m = 1, \\ c_2(l,m) \equiv m\lambda S + (1-l)R_2\mu L. \end{cases} \tag{5}$$

If $\min\{W_2, c_2(l,m)\} < \min\{W_1, (1-m)\lambda S + xl\mu L\}$, late households try to withdraw W_1 at date 1, invest it in short-term asset, and consume W_1 at date 2. That all late households run on banks in this case is guaranteed by Assumption 2 and the technological constraint that premature liquidation of long-term asset generates some amount of consumer goods at date 1.

Assuming that W_2 is sufficiently large, we can rewrite the condition for bank runs as

$$\lambda \geq \frac{\eta W_1}{R_1 S} \ \text{and} \ \ \mu < \frac{R_1 W_1 - \lambda R_1^2 S}{R_2 L} \tag{6}$$

or

$$\lambda \leq \frac{\eta W_1}{R_1 S} \ \text{and} \ \ \mu < \frac{(1-\eta)R_1 W_1 + \eta \frac{R_2}{x} W_1 - \frac{R_2}{x}\lambda R_1 S}{R_2 L}, \tag{7}$$

where $R_1 = 1$. We define a region $BR(W_1, S)$ in $[0,1]^2$ by

$$BR(W_1, S) = \{(\lambda, \mu) | \ \lambda \text{ and } \mu \text{ satisfy conditions (6)and (7).}\} \tag{8}$$

Region $BR(W_1, S)$ for fixed values of W_1 and S is shown in Figure 4.

Figure 4: Region of Bank Runs (Case of Laissez Faire)

Therefore, the consumption allocation in the case of laissez faire is summarized as follows: If $(\lambda, \mu) \in BR(W_1, S)$, bank runs occur and each household consumes $\lambda S + \mu x L$ units of consumer goods[3] ; Otherwise early households consume W_1, and late households consume $\min\{c_2(l,m), W_2\}$ where $c_2(l,m)$ is the solution to (PLF).[4]

If bank runs occur, banks are forced to liquidate all asset. Therefore $(l,m) = (1,0)$ if $(\lambda, \mu) \in BR(W_1, S)$. Comparing Figures 3 and 4, it is easily shown that laissez faire policy cannot realize the optimal allocation for given (W_1, W_2, S) without measure-zero coincidence in which (λ, μ) happens to satisfy either (2) or (3) in equality with $c_1 = W_1$ and $c_2 = c_2(l,m)$.

3.3 Deposit Guarantee

In order to prevent bank runs, the government can declare unlimited guarantee of depositors. We assume that to initiate this policy incurs the social cost C_D that is a dead weight loss for the economy. Since banks are insolvent if λ and μ are small, the government must use fiscal expenditure to fulfill the commitment of deposit guarantee. In order to contrast with recapitalization policy in Section 3.4, we assume the following for this deposit guarantee policy.

Assumption 4 *When the government implements the deposit guarantee policy, it restricts itself to use public money only after banks run out of all assets.*

To subsidize individual banks or the deposit insurance company in order to guarantee depositors is politically controversial in reality. This assumption formalize this political difficulty in a simple form (We will assume in Section 3.4 that the government can subsidize banks before they run out of asset if the government pays higher political cost). The government must collect tax to cover the fiscal cost of deposit guarantee. We assume the following for the government ability of tax collection:

[3]We assume as Allen and Gale (1998) that all proceeds of liquidation of bank asset are equally divided by all depositors at date 1 when bank runs occur.

[4]We assume for simplicity that if late households wait until date 2, all remaining proceeds of bank assets are equally devided by remaining depositors at date 2.

Assumption 5 *Although the government does not observe type of each household, it can collect tax from household contingent on the timing of its withdrawal. The government can impose tax* (T_{11}, T_{12}, T_2) *where an early withdrawing household must pay* T_{11} *at date 1 and* T_{12} *at date 2, and a late withdrawing household must pay* T_2 *at date 2.*

Note that an early withdrawing household must save $\frac{T_{12}}{R_1} = T_{12}$ and invest it in short-term asset at date 1 in order to pay tax T_{12} at date 2. Given $(W_1, W_2, S, \lambda, \mu)$, the government problem is written as follows:

$$\text{(PDG)} \max_{l,m,T_{11},T_{12},T_2,F_1,F_2} \eta U(W_1 - T_{11} - T_{12}) + (1-\eta)U(W_2 - T_2)$$

subject to

$$\begin{cases} \begin{cases} \eta W_1 = \lambda S + x\mu L + F_1 \text{ and } l = 1 - m = 1, & \text{if } \lambda S + x\mu L < \eta W_1, \\ \eta W_1 = (1-m)\lambda S + l x\mu L, & \text{otherwise,} \end{cases} \\ \eta T_{11} \geq F_1, \\ (1-\eta)W_2 = m\lambda S + (1-l)R_2\mu L + F_2, \\ \eta T_{12} + (1-\eta)T_2 \geq F_2, \\ \eta T_{11} + \eta T_{12} + (1-\eta)T_2 \geq F_1 + F_2 + C_D, \\ W_1 - T_{11} - T_{12} \leq W_2 - T_2. \end{cases} \tag{9}$$

The last constraint of (9) is the incentive compatibility constraint to prevent bank runs. As long as this constraint is satisfied, early households withdraw at date 1, and late households withdraw at date 2. This fact justifies the other constraints in (9). Define $F(\lambda, \mu)$, $F^*(\lambda, \mu)$, $F^{**}(\lambda, \mu)$, and $F^{***}(\lambda, \mu)$ by

$$\begin{aligned} F(\lambda, \mu) &= \begin{cases} F^*(\lambda, \mu) & \text{if } \lambda \geq \frac{\eta W_1}{S}, \\ F^{**}(\lambda, \mu) & \text{if } \lambda \leq \frac{\eta W_1}{S} \text{ and } \lambda S + \mu x L \geq \eta W_1, \\ F^{***}(\lambda, \mu) & \text{if } \lambda S + \mu x L \leq \eta W_1. \end{cases} \\ F^*(\lambda, \mu) &\equiv (1-\eta)W_2 - R_2\mu L + \eta W_1 - \lambda S + C_D, \\ F^{**}(\lambda, \mu) &\equiv (1-\eta)W_2 - R_2\mu L + \tfrac{R_2}{x}(\eta W_1 - \lambda S) + C_D, \\ F^{***}(\lambda, \mu) &\equiv (1-\eta)W_2 - x\mu L + \eta W_1 - \lambda S + C_D. \end{aligned} \tag{10}$$

Problem (PDG) can be simplified to

$$\text{(PDG')} \max_{T_{11},T_{12},T_2} \eta U(W_1 - T_{11} - T_{12}) + (1-\eta)U(W_2 - T_2)$$

subject to

$$\begin{cases} \eta T_{11} + \eta T_{12} + (1-\eta) T_2 \geq F(\lambda, \mu), \\ T_{11} \geq \max\{0, \eta W_1 - \lambda S - x\mu L\}, \\ W_1 - T_{11} - T_{12} \leq W_2 - T_2. \end{cases} \tag{11}$$

We can specify when this policy attains the optimal allocation. In order to simplify the comparison, we assume $C_D = 0$ for now. If $\lambda < \frac{\eta W_1}{S}$, banks must liquidate long-term asset prematurely at date 1, and the degree of liquidation l is uniquely determined by $l = \min\left\{\frac{\eta W_1 - \lambda S}{x\mu L},\ 1\right\}$. Given (W_1, W_2, S), the value of l cannot be optimal without measure-zero coincidence in which (λ, μ) satisfies equation (2) in equality for $l = \frac{\eta W_1 - \lambda S}{x\mu L}$. Therefore, if $\lambda < \frac{\eta W_1}{S}$, inefficient liquidation of long-term asset occurs almost always, and thus the government cannot attain the optimal by choosing any values for (T_{11}, T_{12}, T_2).

If $\lambda \geq \frac{\eta W_1}{S}$, no inefficient liquidation of long-term asset occurs. In this case it is easily shown that the government can attain the optimal consumption by appropriately choosing (T_{11}, T_{12}, T_2) if the optimal value of l equals 0. The incentive compatibility constraint is automatically satisfied by the optimal consumption since $R_1 = 1$. Therefore, we have shown the following proposition for the optimality of deposit guarantee policy.

Proposition 1 *If $C_D = 0$, the deposit guarantee policy can attain the optimal only when (λ, μ) satisfies $\lambda \geq \frac{\eta W_1}{S}$ and $\mu \leq \left(\frac{R_2}{x}\right)^{\frac{1}{\theta}} \frac{(1-\eta) R_1 S}{\eta R_2 L} \lambda$.*

See Figure 5 for the region where the deposit guarantee policy can attain the optimal.

Figure 5: Region of Optimality (Case of Deposit Guarantee)

3.4 Recapitalization

In the previous subsection, we made a restriction that the government does not give subsidy to banks unless they run out of all assets. We assume that the government can subsidize or recapitalize banks before they run out of asset if it pays higher political cost than in the case of deposit guarantee policy. Thus we assume that to initiate the recapitalization policy incurs social cost C_R, where $C_R \geq C_D$.

We may consider that the government subsidizes banks by issuing the government bonds and giving the government bonds to the banks. We make a crucial assumption:

Assumption 6 *Households accept the government bonds as liquidity. Banks can repay deposits in the form of the government bonds.*

Thus the recapitalization policy in our paper means that the government produces and supplies additional liquidity (i.e., the government bonds) to prevent excessive liquidation of long-term asset. Given $(W_1, W_2, S, \lambda, \mu)$, the government implements recapitalization policy by solving the following problem:

$$\text{(PR)} \quad \max_{l,m,T_{11},T_{12},T_2,B} \eta U(W_1 - T_{11} - T_{12}) + (1-\eta)U(c_2 - T_2)$$

subject to

$$\begin{cases} \eta W_1 = (1-m)\lambda S + lx\mu L + B, \\ \eta(W_1 - T_{11} - T_{12}) \leq (1-m)\lambda S + lx\mu L, \\ (1-\eta)c_2(l,m) = m\lambda S + (1-l)R_2\mu L, \\ c_2 = \min\{W_2, c_2(l,m)\}, \\ \eta T_{11} + \eta T_{12} + (1-\eta)T_2 \geq B + C_R, \\ W_1 - T_{11} - T_{12} \leq c_2 - T_2. \end{cases} \tag{12}$$

The essential difference between problems (PDG) and (PR) is that in (PR) the government can determine B, the subsidy for recapitalization of banks[5], *before* the value of (l, m) is fixed whereas in (PDG) the government must determine F_1 and F_2 only after (l, m) is determined by banks' obligation to repay (Assumption 2). Therefore, the government can set B as a function of (l, m).

In the case where $C_R = 0$ and W_2 is sufficiently large, problem (PR) can be degenerated to (PO) by setting $B = B(l,m) = \eta W_1 - (1-m)\lambda S - lx\mu L$, $\eta T_{11} + \eta T_{12} = B$, and $T_2 = 0$. Thus the optimal value of (l, m) is attained by recapitalization policy. We have shown the following:

Proposition 2 *If $C_R = 0$, the recapitalization policy can always attain the optimal.*

This result appears to be quite different from Diamond and Rajan (2002) who claim that recapitalization of failing banks during a financial crisis may worsen the crisis. Diamond

[5] We assume the subsidy B can take a negative value. In this case B is interpreted as tax on banks.

and Rajan seem to use the term "recapitalization" to represent the policy that transfers liquidity to an insolvent bank from the other banks. Thus in their model, the amount of aggregate liquidity does not increase at date 1, and therefore bank bailouts result in more inefficient liquidation of long-term assets. Therefore, "recapitalization" in Diamond and Rajan (2002) is similar policy as deposit guarantee without creation of additional aggregate liquidity, just like the policy in our Section 3.3.

In (PR) of our model however, the government can create aggregate liquidity when it recapitalizes insolvent banks by issuing the government bonds, which are accepted as liquidity by early households at date 1. Thus in our model, recapitalization attains the optimal allocation, while deposit guarantee (without recapitalization) results in inefficient liquidation of long-term asset.

We need to emphasize, however, that increase in aggregate liquidity alone is not sufficient to obtain the optimal. Let us compare recapitalization policy and monetary easing by the central bank. The increase of money supply by the central bank may increase the amount of aggregate liquidity but it does not rectify insolvency of banks since the central bank gives them cash only in exchange for their assets. The premature liquidation occurs because banks have too much obligation to repay at date 1. Thus monetary easing cannot prevent premature liquidation that is caused by bank insolvency, unless banks are given *de facto* subsidy by the central bank operation. Supply of aggregate liquidity and filling the gap of insolvency are both necessary to prevent inefficient asset liquidation.

3.5 Inflation

Inflation may be one of the policy options that can be used to address bank insolvency. In our simplified model, it is difficult to formalize inflation in self-consistent way. Instead of modeling the mechanism that generates inflation, we simply assume that the government can control inflation rates (π_t) at date $t = 1, 2$ by unspecified monetary policy which incur social cost of C_M. Crucial point is that the government can change the inflation rate without affecting the real value of bank asset. In this case, the government problem becomes

$$\text{(PI)} \quad \max_{l,m,\pi_1,\pi_2} \eta U\left(\frac{W_1}{\pi_1}\right) + (1-\eta)U\left(\frac{W_2}{\pi_2}\right)$$

subject to

$$\begin{cases} \eta \frac{W_1}{\pi_1} \leq (1-m)\lambda S + lx\mu L, \\ (1-\eta)\frac{W_2}{\pi_2} \leq m\lambda S + (1-l)R_2\mu L - C_M, \\ \frac{W_1}{\pi_1} \leq \frac{W_2}{\pi_2}. \end{cases} \tag{13}$$

This problem is identical to (PO) if the cost $C_M = 0$ and the government can freely control both π_1 and π_2. But if it takes time to change inflation rate, the consequence becomes different. Suppose that the government cannot generate inflation at date 1: $\pi_1 = 1$, while it can change π_2 freely. In this case, problem (PI) become identical to (PLF) if we assume W_2 is sufficiently large. Therefore, we have shown the following:

Proposition 3 *If $C_M = 0$, and if the government can freely change π_1 and π_2, inflation policy attains the optimal. If π_1 is fixed at 1 and the government can change π_2 only, the outcome of inflation policy is identical to that of laissez faire.*

3.6 Optimal Policy Response

Welfare Effect We have analyzed welfare effects of different policies in Sections 3.1 — 3.5. If political cost is zero: i.e., $C_D = C_R = C_M = 0$, the optimal policy response at date 1 is clear. The recapitalization of insolvent banks by issuing the government bonds is the optimal policy. Controlling the inflation rate is also optimal if the government or the central bank can immediately and accurately change the inflation rate of date 1. If $C_D = C_R \geq 0$, it is obvious that for any given (λ, μ), the recapitalization at date 1 is superior to the deposit guarantee.

Fiscal Cost Honohan and Klingebiel (2000) found that liquidity provision and deposit guarantee tend to increase the fiscal cost. This is confirmed in our model by comparing deposit guarantee policy and recapitalization policy. In order to compare the fiscal costs of policy actions, we need to measure the costs in the same condition. Thus we use $B + (1-\eta)(W_2 - c_2(l,m)) + C_R$ as the fiscal cost of recapitalization policy instead of

$B + C_R$, since the cost $(1-\eta)(W_2 - c_2(l,m))$ is directly borne by late households in (PR) while this cost is once borne by the government and is transferred to households by taxation in (PDG). The fiscal cost of deposit guarantee is $F_1 + F_2 + C_D$. Let us assume $C_D = C_R = 0$ for simplicity. It is easily confirmed that the fiscal costs defined above is rewritten as $\eta W_1 + (1-\eta)W_2 - \lambda S - \{lx + (1-l)R_2\}\mu L$, where l is chosen in response to deposit guarantee policy or recapitalization policy. The value of l may be larger or smaller in the case of deposit guarantee than in the case of recapitalization. So do the fiscal costs. But we can easily confirm the following:

Proposition 4 *Suppose that $C_D = C_R = 0$. If $\lambda < \frac{\eta W_1}{S}$ and the optimal consumption c_1 satisfies $c_1 < W_1$, the value of l and the fiscal cost are larger in the case of deposit guarantee than in the case of recapitalization.*

Banks' Problem at Date 0 If the values of (C_D, C_R, C_M) are fixed, the optimal policy response that maximizes $\eta U(c_1) + (1-\eta)U(c_2)$ is uniquely determined for each $(W_1, W_2, S, \lambda, \mu)$. Thus we can define a function $P(W_1, W_2, S, \lambda, \mu)$ which maps $(W_1, W_2, S, \lambda, \mu)$ to the optimal policy. If we make restriction that the inflation rate at date 1 is not changeable ($\pi_1 = 1$), the optimal policy is chosen from the following set:

$$P(W_1, W_2, S, \lambda, \mu) \in \{\text{Laissez Faire, Deposit Guarantee, Recapitalization}\}$$

Banks determine (W_1, W_2, S) at date 0 by solving the following problem:

$$\text{(P)} \quad \max_{W_1, W_2, S} E[\eta U(c_1) + (1-\eta)U(c_2)]$$

subject to

$$\begin{cases} P = P(W_1, W_2, S, \lambda, \mu), \\ m = m(W_1, W_2, S, \lambda, \mu, P), \\ l = l(W_1, W_2, S, \lambda, \mu, P), \\ c_1 = (1-m)\lambda S + lx\mu L, \\ c_2 = m\lambda S + (1-l)R_2\mu L. \end{cases}$$

Note that the solution to (P) can be the equilibrium only if the government can choose the different policy to each bank that is contingent on the bank's choice of (W_1, W_2, S). If not, it is easily shown as follows that a bank has an incentive to deviate from the solution to (P). For example, suppose that the government chooses the policy that is contingent on $(\overline{W_1}, \overline{W_2}, \overline{S})$, the social average of (W_1, W_2, S). In this case a bank can make its own depositors better off by setting W_1 at arbitrarily large value, because W_1 is guaranteed and the tax contingent on $\overline{W_1}$ is limited when the government chooses deposit guarantee or recapitalization.

4 Conclusion

When the banking system falls into the situation of systemic insolvency, different policy responses have quite different welfare effects. (1) Laissez faire policy may brings about bank runs and inefficient liquidation of long-term asset. (2) Deposit guarantee without immediate recapitalization results in excessive liquidation of long-term asset, suboptimal consumption, and larger fiscal cost than in the case of recapitalization. (3) Immediate recapitalization by the government bond issuance can attain the optimal. (4) Control of the inflation rate generates the same outcome as laissez faire if the government cannot change the inflation rate immediately and accurately.

These results are quite consistent with the stylized facts of recent financial crises that we refer to in Section 1. Although open-ended liquidity support and blanket depositor guarantee are distinguished in empirical research (Honohan and Klingebiel [2000], Claessens et al [2001]), both tools serve for orderly deposit withdrawals. Therefore that the liquidity support without resolving systemic insolvency prolongs the crisis can be interpreted as that the deposit guarantee without recapitalization decreases the total welfare in our model.

Let us examine the 1990s of the Japanese economy in our theoretical framework.[6] Although Japan experienced a full-scaled crush of asset-price bubble at the beginning of the 1990s, the government began to recapitalize major banks only since 1998, while the

[6] We can easily generalize this three-period model into a multi-period model preserving the intuition so that the basic implication of the model can be applied to the decade-long recession of the Japanese economy.

government had insisted during the 1990s that they would never allow the occurrence of any bank closure. This attitude of the Japanese government can be interpreted as employing the policy of deposit guarantee without recapitalization. The observations in the Japanese economy seem consistent with the prediction of the model: low production, increase in liquidity of bank assets, and remarkable increase in (potential) fiscal cost of bank bailouts.

Another characteristic of the Japanese economy, i.e., the continuous decline of asset-prices seem to be consistent with the model too. In our model, the productivity of long-term asset falls from R_2 to $(1-l)R_2$ as a result of deposit guarantee without recapitalization. Since we do not explicitly formulate the asset market in the model, we cannot directly conclude that asset-price decline is caused by this productivity decline of long-term asset. But since it seems plausible to interpret asset-price fall as productivity decline of the asset in reality, we can argue that our model provides a possible explanation for the continuous decline of asset prices in Japan.[7]

In summary, our model implies that Japan's prolonged recession since the beginning of the 1990s may have been caused by inappropriate policy response to systemic bank insolvency: deposit guarantee[8] with "too little and too late" recapitalization.

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[7]Several authors incorporate the Diamond-Dybvig banking model with asset market. See Allen and Gale (2000b, 2001), Diamond (1997), and von Thadden (1999).

[8]Although Japan established the deposit insurance system in the 1970s, that guarantees up to 10 million yen for one depositor, there have been a tacit understanding that the government never let any bank close and thus deposits are guaranteed unlimitedly. Since 1995, the government declared explicitly that it guarantees all deposits unlimitedly for the time being. This unlimited deposit guarantee is scheduled to continue until 2005.

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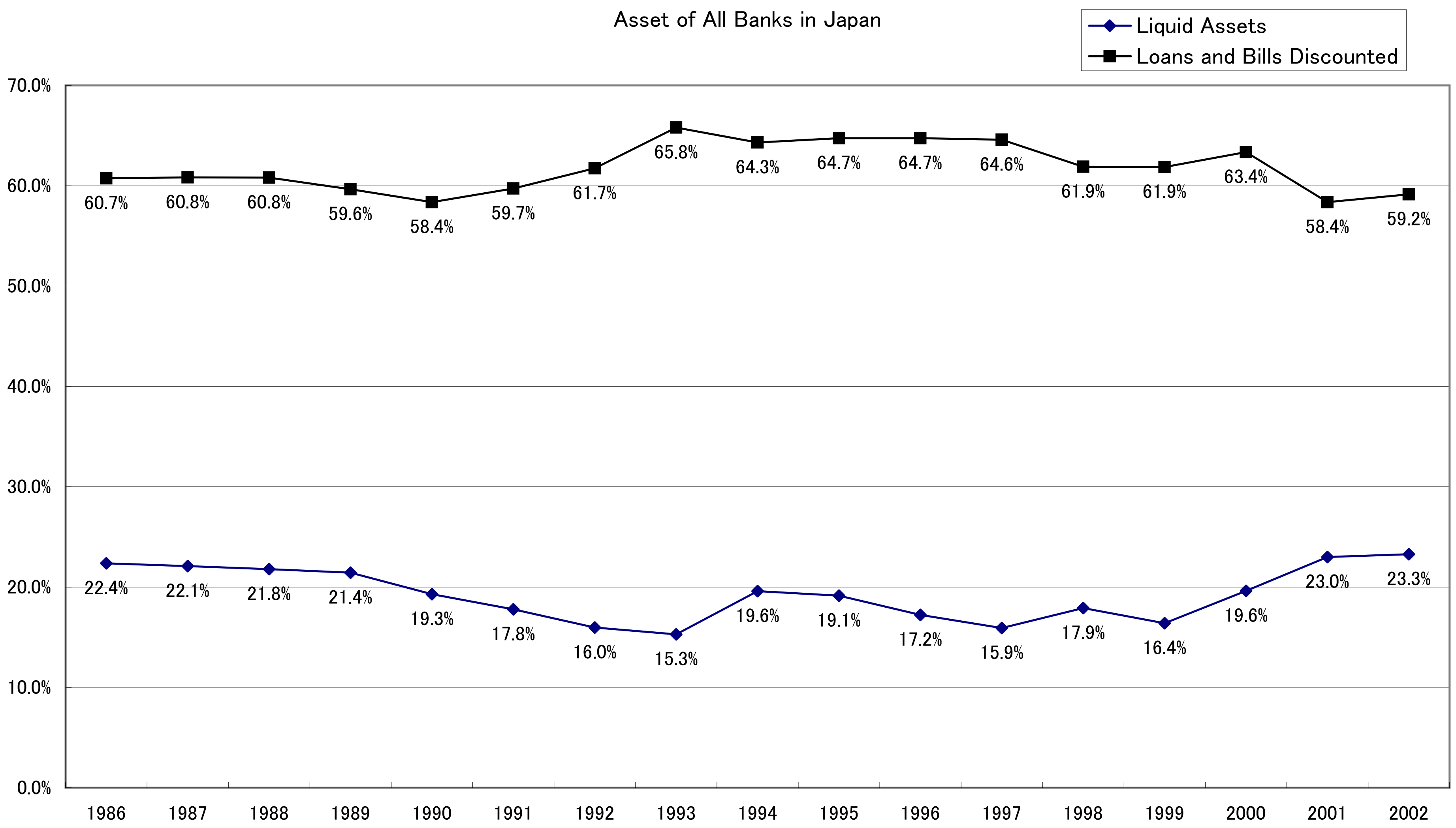
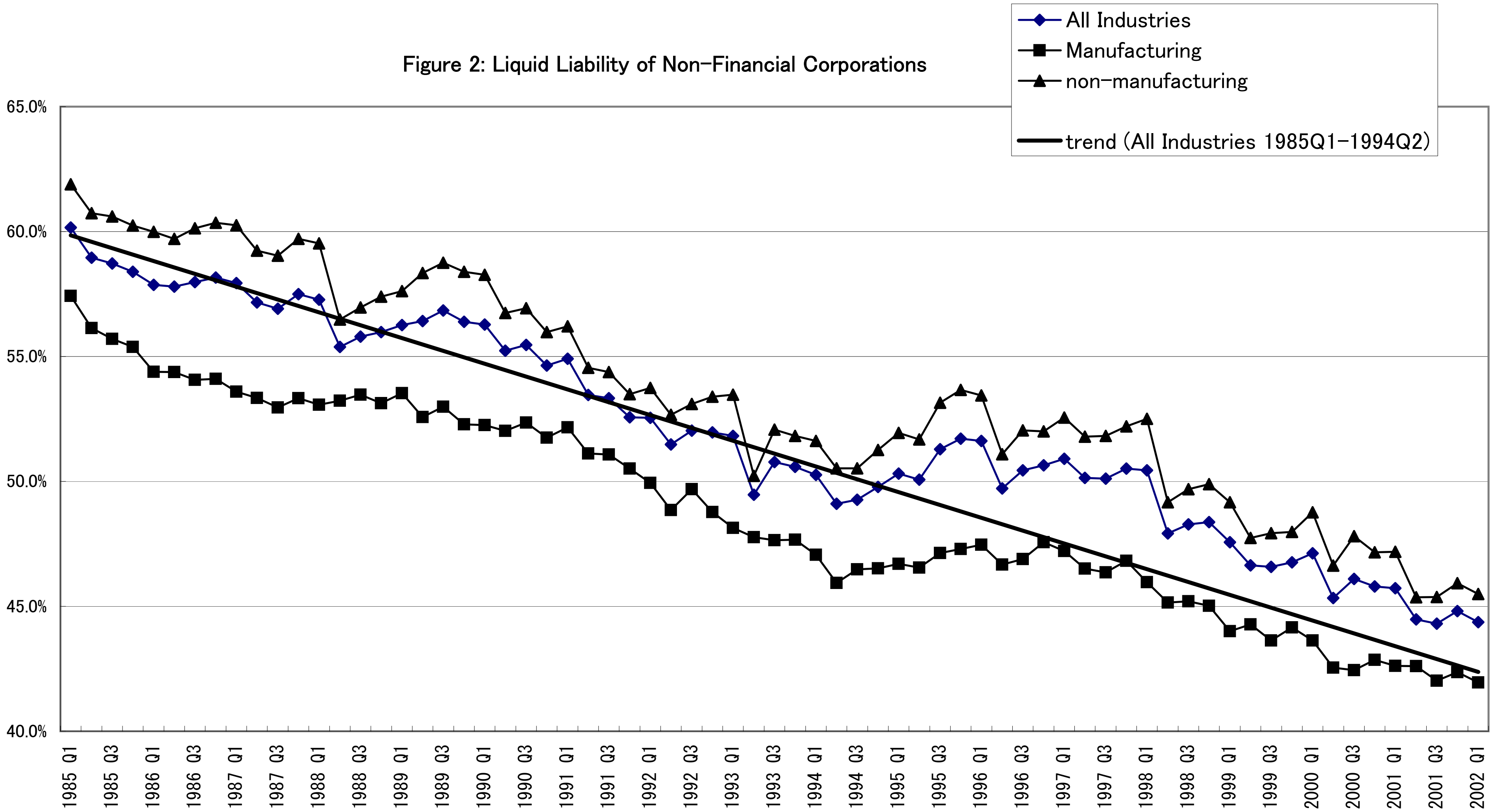
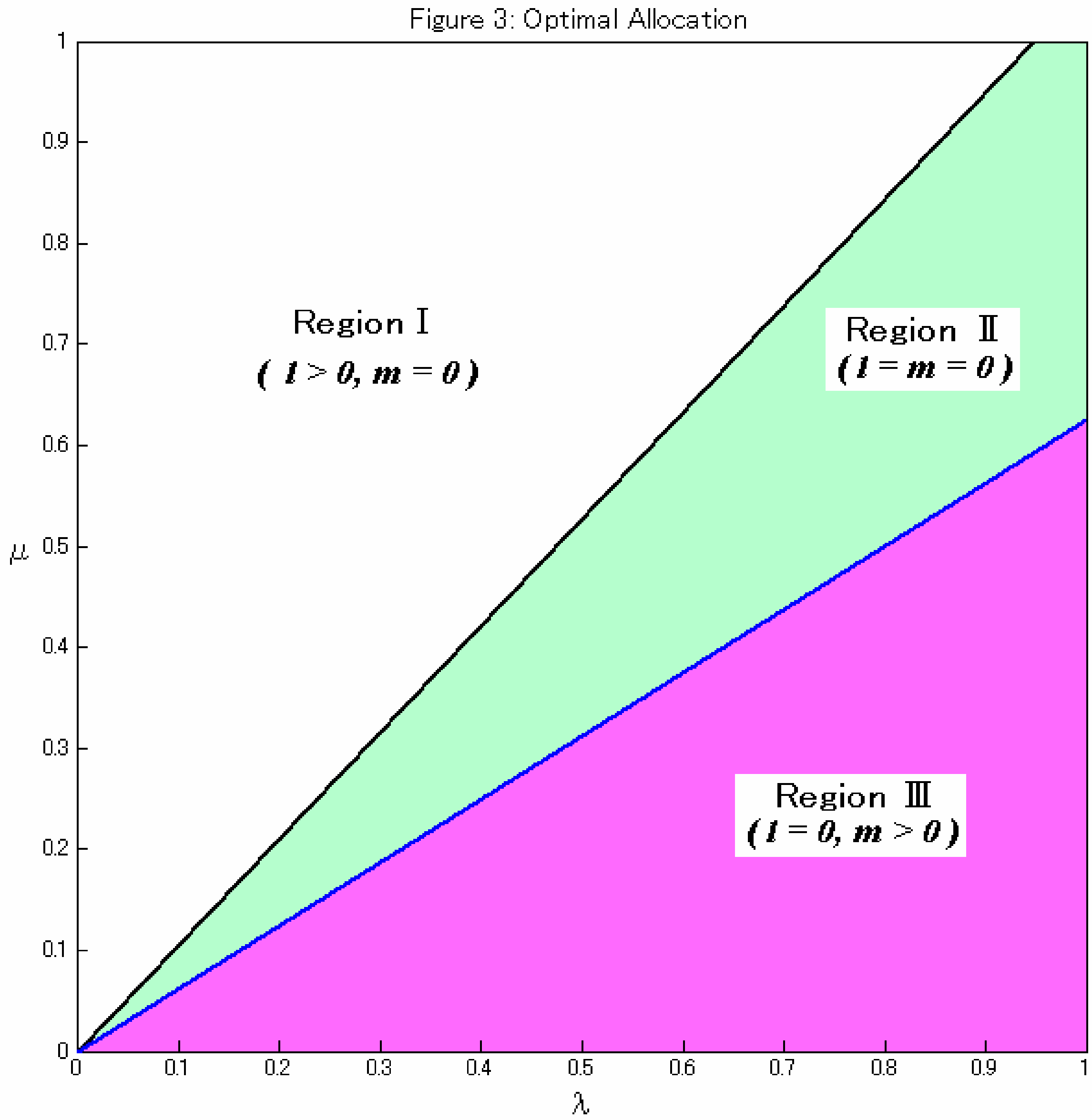


Note: Liquid Assets consist of (1) Cash and Due from Banks, (2) Call Loans, (3) Receivables under Resale agreements, (4) Bills Bought, (5) Monetary Claims Bought, (6) Trading Assets, (7) Trading Account Securities, (8) Money Held in Trust, (9) Government Bonds, (10) Local Government Bonds, and (11) Corporate Bonds.
Source: Bank of Japan

Figure 2: Liquid Liability of Non-Financial Corporations



Source: Financial Statements Statistics of Corporations by Industry (Houjin Kigyou Toukei), Ministry of Finance
Note1: Q1:January-March quarter, Q2: April-June quarter, Q3: July-September quarter, Q4: October-December quarter
Note2: liquid liability = bills and accounts payable + short-term borrowings + short-term allowance + bonds



Parameters:

R_1=1, R_2=2, x=0.7, θ =2, η =1/2, S=5, L=4, W_1=8

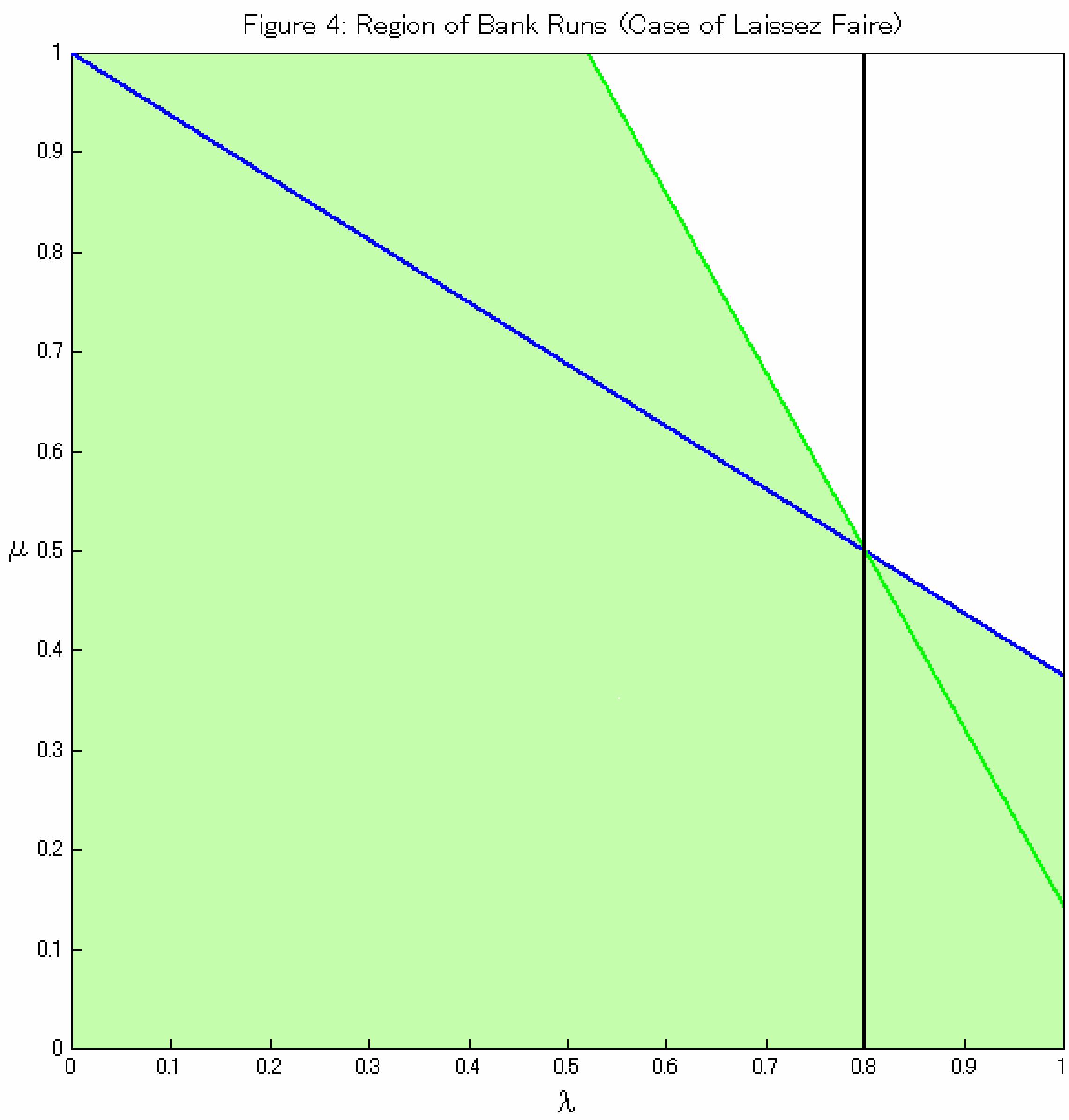


Figure 4: Region of Bank Runs (Case of Laissez Faire)
μ
λ
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

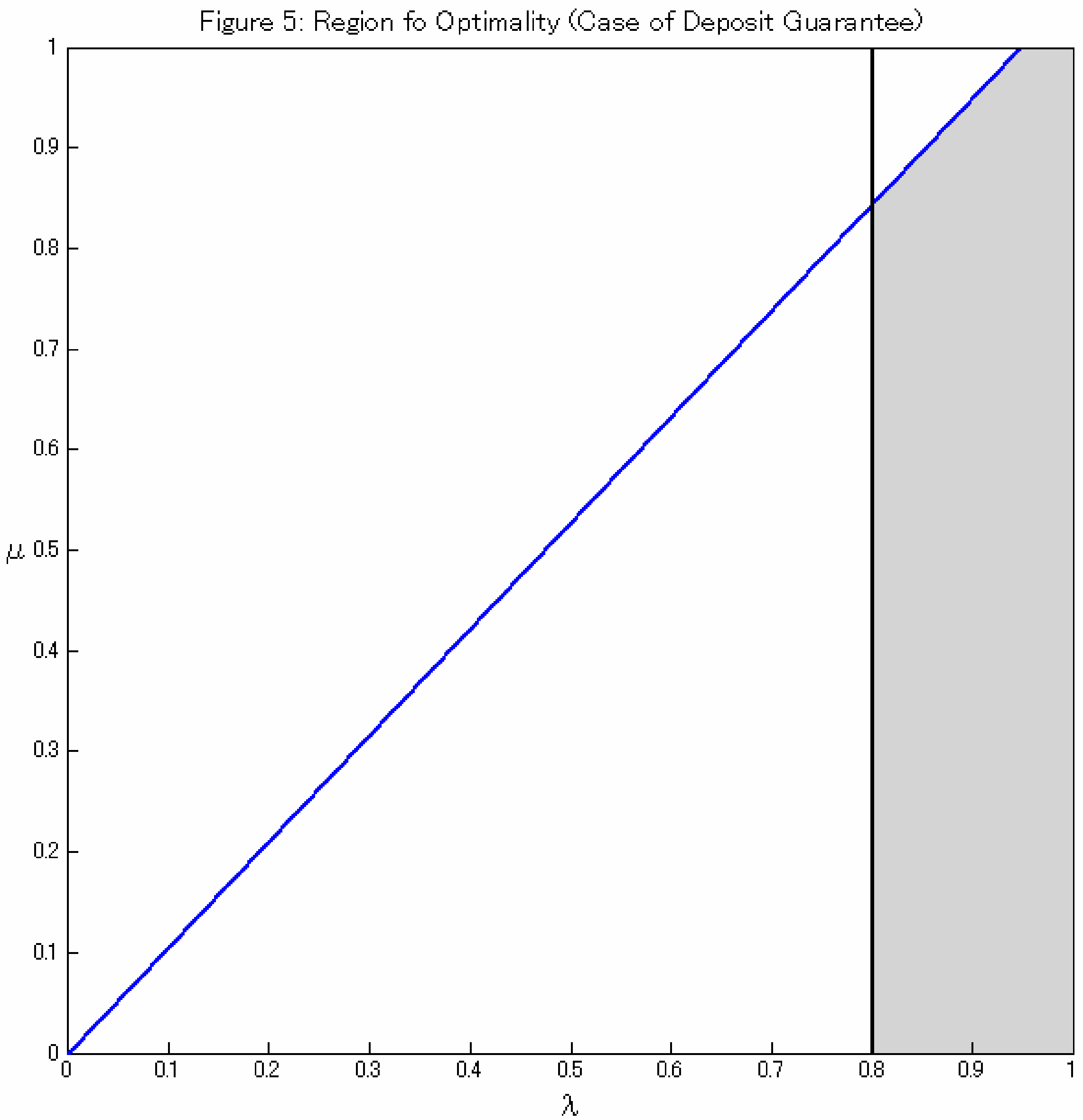


Figure 5: Region fo Optimality (Case of Deposit Guarantee)
μ
λ
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1