Partial Deposit Insurance and Moral Hazard in Banking

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Abstract: Countries with deposit insurances differ significantly on how much protection their insurance provides. We study the optimal coverage limit in a model of deposit insurance with capital requirements and risk sensitive premia to prevent moral hazard. Depositors have incentives to monitor the bank's risk taking behavior, thus threatening banks with withdrawals of deposits if necessary. We find that either banking regulations or market discipline is insufficient to reduce bank's risk. In addition, our numerical example explains the differences in coverage cross countries which agree with empirical evidence. We show that low income countries provide more generous insurance protection than higher income countries.

Keywords: Depositor's monitoring; moral hazard; optimal coverage, partial deposit insurance.
JEL Classification: E65, G21, G28.

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1. Introduction

Countries differ significantly on the amount of protection their deposit insurance provides. Most developed countries have a smaller ratio of coverage limit per capita GDP than developing countries (Demirguc-Kunt and Kane, 2002). Coverage limits also vary over time. In the United States, the Federal Deposit Insurance Act of 2005 has increased the coverage limit for retirement accounts to \$250,000.[2] The legislation authorizing temporary increases in deposit insurance coverage of all accounts to \$250,000 through December 31, 2013 was in response to the unforeseen financial crises started in late 2007.

The purpose of this paper is to study the optimal level of coverage and shed light on the liquidity of deposit insurance. The theoretical model has incorporated capital requirements, risk-sensitive premium, and partial deposit insurance in a partial equilibrium model. The model discusses the interaction among risk-taking banks, ex-ante heterogeneous depositors, and a deposit insurer.

In the current crisis, banking regulations combined with the poor management and supervision, in part, have been responsible for the bank's improper leverages, lending and securitization. A bank failure could easily turn into a crisis when the financial institution is overly exposed to credit risks and when the government is least equipped to deal with those risks. While regulatory arbitrage and incomplete risk transfers increase the risk in the banking system, pricing of deposit insurance that subsidizes bank's improper investment decisions may also exacerbate risk taking.[3] In this paper, we study the effect of the well-designed deposit insurance to manage bank's moral hazard induced by unsophisticated regulations prior to a crisis.

Our paper is related to three strands of research, including work on market discipline against bank's risk taking behavior, work on prudent banking regulations against moral hazard, and work on determining the level of insurance coverage. We attempt to bring together these three strands by focusing on the role of optimal coverage limit in combating moral hazard and, further, reduce the chance of a banking failure.

The literature on market discipline focuses on how deposit insurance reduces depositors' incentives to monitor. Market discipline from depositors takes place by either demanding higher interest rates or by withdrawing deposits early. The goals of deposit insurance are to protect unsophisticated depositors, to smooth bank liquidity

[2] http://www.fdic.gov/consumers/consumer/news/special/specialRevised.pdf

[3] 25 financial institutions in 2008, 140 in 2009, and 15 up to date in 2010 have been assumed or purchased through the FDIC. "without substantial amounts of additional assessment revenue in the near future, current projections indicate that the fund balance will approach zero or even become negative" (Bair, 2009). The FDIC proposed an emergency premium that plans to charge a higher regular premium. However, these actions will worsen the procyclical of lending. Pennacchi (2005), Jarrow, Madan and Unal (2006) are examples.

services, and to prevent banking panics. However, over-expanded deposit insurance, which shifts the risk of potential banking failure mostly to taxpayers, will weaken market discipline and exacerbate moral hazard. Greenspan (2002) provided an annotation for the problem in the banking system:

> The market discipline to control risks that insured depositors would otherwise have imposed on banks and thrifts has been weakened. Relieved of that discipline, banks and thrifts naturally feel less inhibited from taking on more risk than they would otherwise assume.[4]

Empirical evidence supports Greenspan's statement. Using a panel of 61 countries, Demirguc-Kunt and Detragiache (2002) show countries with generous coverage limits have higher probabilities of banking crises. Demirguc-Kunt and Kane (2002) show that interest rates increase significantly with bank riskiness for those partially insured instruments. Demirguc-Kunt and Huizinga (2004) provide cross-country evidence about how deposit insurance makes depositors less sensitive to bank risks. Similarly, Martin (2006) shows a blanket deposit insurance guarantee financed by taxing depositors either induces moral hazard or cannot prevent bank panics. To summarize, the literature shows complete deposit insurance weakens market discipline and increases the chance of banking failures. Depositors and banks who are protected from the negative consequence of risk taking will not hesitate to engage in risky banking practices. Our emphasis on the effect of market discipline is to focus on whether the action of depositors who are credible excluded from insurance can successfully reduce bank's risk.

The loss of market discipline could be compensated by banking regulation and supervision (Demirguc-Kunt and Kane, 2002). The literature on prudent banking regulations emphasizes the role of capital requirement. Hellmann, Murdock, Stiglitz (2000) show capital requirement can reduce bank's risk, but the result is Pareto inefficient. Banks will hold no capital under a full deposit insurance scheme with moral hazard. Cooper and Ross (2002) conclude that bank runs can be eliminated without depositors' monitoring if the capital requirement is sufficiently large. In this paper, we show that with capital requirement, depositor's monitoring is crucial to prevent banking failures. Informational friction between depositors, the government, and the bank gives depositors the incentives to monitor.

The literature on banking regulation also discusses how to use the risk-sensitive premium against moral hazard. Asymmetric information and regulation-induced conflict of interest make pricing deposit insurance difficult. Chan, Greenbaum, and Thakor (1992) conclude that fairly priced deposit insurance is not

[4] The Testimony of Chairman Alan Greenspan, Paragraph 7.

incentive compatible and will not solve the moral hazard in a one-period model. Under socially optimal deposit insurance, Giammarino, Lewis, and Sappington (1993) show that high quality banks face lower capital requirement. Bhattacharya, Boot, and Thakor (1998) survey the literature and summarize that cash-asset reserve requirements, risk-based capital requirement, risk-sensitive deposit insurance premium, and partial deposit insurance may all be effective in dealing with the moral hazard problem. Boyd, Chang, and Smith (2002) study how deposit insurance is priced and how government makes up the possible FDIC shortfalls. We use related ideas to understand the effectiveness of a risk-based premium. We find, however, most of the literature either assumes deposits are fully insured or excludes the chance of default of the insurer. In this study, we explain why a wide range of variation of coverage from unlimited guarantee to tight coverage limits could exist.[5] In an environment with capital requirements, bank's investment incentives, depositors' market discipline, and a chance of default of the insurer, we contribute to the existing literature by releasing the assumption of full insurance and providing a way to jointly determine the optimal risk-sensitive premium and the level of coverage.

Finally, our paper is related to a theoretical study of the optimal level of coverage of deposit insurance. Under the framework of global game, Manz (2009) finds that a higher level of insurance mitigates market failure but increases the chance of inefficiency. While the contribution of Manz's paper is to study the comparative statics of the optimal level of coverage, we make an effort to explain why countries have different coverage among the deposit insurance provided by using a simple model with heterogonous depositor, banks, and an insurer.

Some important conclusions are noteworthy. First, we show that optimal coverage encourages depositors' monitoring and withdrawals. Social welfare improvement can be reached through the implementation of partial deposit insurance when the gain from banks outweighs the losses from depositors. Second, risk-sensitive premium and market discipline are essential to reduce bank risk taking behavior. Third, the adjustment between the level of coverage and the premium guarantees long term liquidity of the deposit insurance funds and makes banks better off. Fourth, the numerical findings are consistent with the empirical evidence that shows differences in coverage between countries. Our numerical example indicates that low income countries are willing to provide greater insurance protection than higher income countries.

[5] Demirguc and Kane (2002) and Demirguc, Kane, and Laeven (2008) summarize that some poor countries provide generous coverage than the high-income countries and developed countries or relatively high-income countries tend to provide less protection For example, Central African Republic, Chad, and Peru set up the coverage limits that are far above the deposits saved by their citizens. Austria, Belgium, Germany, and the United Kingdom have a coverage limit which is equal to or even less than the GDP per capita.

The paper proceeds as follows. Section 2 is the theoretical model. Section 3 is a numerical example and followed by the conclusion in section 4.

2. The Model

Depositor's Monitoring

There is a continuum of ex-ante heterogeneous depositors with unit mass in the economy. With a fraction q, a depositor was born with higher endowments, D_1, and belongs to the group of the rich; otherwise, she has fewer endowments, D_2, and belongs to the poor group. $D_1 > D_2$ and we assume $q < 1\text{-}q$. The questions depositors confront are whether they will monitor the bank and whether they will withdraw early from the bank. At the beginning of each period, the FDIC announces the maximum coverage limit, $\overline{C}$, to the public. Depositors save at the bank and the bank chooses investment portfolios. Then, depositors decide whether to monitor the bank with the cost, d, to become informed.[6] Informed depositors who know the return on assets and the true failing probability, P_f, of the bank can withdraw early before the bank exhausts its resources in a simple one-shot game. Early withdrawal, however, is not free; the cost of early withdrawal is the interest depositors would have earned from saving. A simple assumption, $D_2 < rD_2 < \overline{C} < D_1 - d < rD_1$, reveals different actions taken by heterogeneous depositors.[7] r is the given deposit interest rate in a partial equilibrium setup, where r>1. Under the maximum coverage limit, rich depositors are partially uninsured even after paying monitoring cost. On the other hand, poor depositors will receive the full guarantee from insurance if the bank fails.

Figure 1 Depositors' Two-Step Decision

[6] Bank's historical financial statements are available for the public free of charge but the up-to-date information such as banking management, financial ratio and detailed off-balance-sheet activity can only be obtained from some financial company who gather those data thoughtfully for sale.

[7] The model does not discuss the possibility of a contagious run and the free rider problem. Each depositor's withdrawal is unobservable to the rest of depositors. Thus, no one can take advantage from the action taken by others. Of course, other equilibria result from the liquidity shock, informational shock, and sunspot could happen when releasing the constraint on interdependence among agencies. Then, the free rider problem and panic bank run equilibrium may occur.

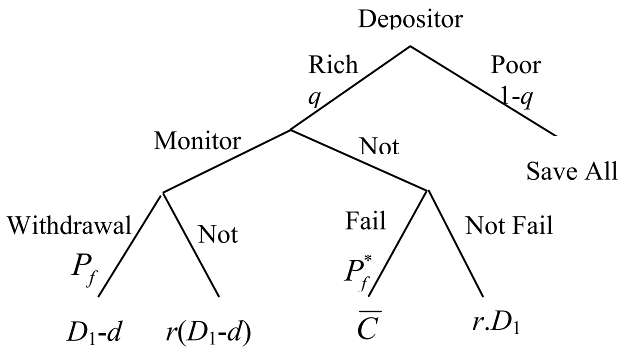

Figure 1 shows the depositor's decision of monitoring and withdrawal. If monitoring cost is moderate, informed depositors will then decide whether to withdraw depending on the chance of banking failure. Depositor's expected return if monitoring is $P_f(D_1\text{-}d)+(1\text{-}P_f)r(D_1\text{-}d)$. Otherwise, the expected return for uninformed depositor without an effort of monitoring is $P_f^*\overline{C}+(1-P_f^*)rD_1$. In such case, uninformed depositors observe only P_f^* that indicates an estimate of the bank's failing probability from the past experience. P_f^* may or may not truly reflect the chance of default of a bank. Uninformed depositors will receive up to the FDIC's maximum coverage and will lose the uninsured deposits when bank fails. From the discussion above, we know that if the initial endowment of the rich depositors is greater than D^*, where

$$D^* \equiv \frac{P_f^*\overline{C}+P_f d+(1-P_f)rd}{(1-r)P_f+rP_f^*},$$

monitoring the bank is incentive compatible; otherwise, depositors rather remain uninformed because monitoring is too expensive. The expected return of depositors is

$$ER_D = q\{\Pr(D_1>D^*)[P_f(D_1\text{-}d)+(1\text{-}P_f)r(D_1\text{-}d)] + \Pr(D_1<D^*)[P_f^*\overline{C}+(1\text{-}P_f^*)rD_1]\}+(1\text{-}q)rD_2 \quad (1).$$

The first term in equation (1) indicates the return for rich depositors, which includes the expected return with and without monitoring, and the second term is the return for the poor depositors.[8]

[8] Government deposit insurance guarantee could be unclear. The maximum coverage could be easily avoided and certain accounts could indirectly get full insurance (Pennacchi, 2006). The examples are allocating large deposits cross member banks within the same multi-bank holding company and shifting sweep account balances from money market mutual fund to the insured account. In this study, market discipline is enforced through incentives from exclusive creditors. The substitute subordinated debt holders could result in a stronger incentive to monitor.

One special case this study considers is the situation when government provides no deposit insurance. In the absence of a deposit insurer, the model simply goes back to the economy in which the bank provides deposit contracts that transform funds to those who have a profitable investment opportunity from those who have extra funds. Without the FDIC, depositor's self-protection seems necessary; even the poor depositors who were born with fewer endowments have incentives to monitor.

Banks' Gambling Behavior

Other than depositors, there is a continuum of identical banks with unit mass in the economy. At the beginning of each period, the FDIC announces the maximum level of coverage and collects the insurance risk premium, p, from banks. Banks are the only ones that have access to investment technology. A representative risk-neutral bank maximizes its expected return by choosing the combination between a risk-free asset with a certain return α, and a risky asset, I, with a random realized return, R. We assume the return of risky assets belongs to $N(\overline{R}, \sigma^2)$, where $1 < \alpha < \overline{R}$. Only the bank and informed depositors know the private information about the portfolio of risky assets and the realized returns afterwards. Moral hazard problem arises from bank's unobservable temptation to gamble. To reduce the inappropriate risk-sharing from banks to taxpayers, banks face a capital requirement constraint. An exogenous fraction k is the required capital per unit of deposit, and kD is shareholders' equity capital that has to match the minimum capital requirement. Capital requirements that force shareholders to put their own money at risk provide the motivation for the bank to take prudent action. But capital is costly. It comes with a cost, ρ, which is higher than the return of risk-free assets.[9] $\rho > \alpha$. The expected return of a profit-maximizing bank is

$$ER_B = \int_{\tilde{R}}^{\infty} \left\{ R \cdot I + \alpha\left[(1+k-p)ED - I\right] - (\rho k + r)ED \right\} f(R)dR - EW \qquad (2).$$

The first term in equation (2) is the net expected return on assets. ED is the expected deposits resulting from depositor's monitoring decision. The second term in equation (2), EW, is the potential early withdrawals from informed depositors if monitoring. The lower bound of the integral, $\tilde{R}$, represents bank's break-even point. When $R > \tilde{R}$, the bank will keep operating because its return on assets is enough to pay off all obligations for creditors and depositors. Otherwise, the bank fails.[10] The elements

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[9] Hellmann, Murdock, and Stiglitz (2002) have the similar assumption.

[10] A bank's true failing probability can be seen as the portion of insolvent banks assumed by the FDIC if there is more than one bank in the society.

inside the integral are the return from risky assets, RI, followed by the return of safety assets, $\alpha[(1+k-p)ED-I]$, and the cost to repay shareholders and depositors, $(\rho k+r)ED$.

The informed depositors know ex ante the realization of bank's risky assets before a banking failure. If return on assets is large enough, the bank earns positive profits, and thus, there is no need to withdraw early. From equation (2), we know the bank's break-even condition holds when $RI+\alpha[(1+k-p)ED-I] = (\rho k+r)ED$. From there, we define

$$\tilde{R} \equiv \alpha-(1/I)[\alpha(1+k-p)-(\rho k+r)]ED \quad (3).$$

When prob($R>\tilde{R}$), depositors will not panic and withdrawal irrationally.

Meanwhile, the bank faces a credible threat from informed depositors to withdraw if the portfolio tends to be too risky. To guarantee that the informed depositors can successfully withdraw uninsured deposits before the bank runs out of resources, the condition, $q\ (D_1-d-\bar{C}) \leq R.I+\ \alpha[(1+k-p)ED-I]$, needs to hold. The amount of withdrawals on the left hand side must be less than the bank's gross return on investment on the right hand side. $\hat{R}$ is the lower bound of the random realized return that satisfies the feasibility constraint above. Before repaying the uninformed depositors and shareholders, gross payoffs of the bank must be sufficient for the informed depositor to withdraw. It implies that R should be greater than $\hat{R}$, where

$$\hat{R} \equiv \alpha-(1/I)[\alpha(1+k-p)ED-q.(D_1-d-\bar{C})] \quad (4).$$

Equation (5) is the expected withdrawal from depositors. Rich depositors who monitor the bank will withdraw the uninsured deposits when knowing the bank is going to fail at the probability $R<\tilde{R}$. Also, early withdrawal is feasible for depositors when $R>\hat{R}$. Combined with equation (3) and (4), we define the lower bound, $\hat{R}$, and the upper bound, $\tilde{R}$, to calculate the potential withdrawals from depositors.

$$EW = \int_{\hat{R}}^{\tilde{R}} q\Pr\left(D_1 > D^*\right).(D_1 - d - \bar{C})f(R)dR \quad (5).$$

Withdrawing the unprotected portion of deposits, $D_1-d-\bar{C}$, is the consequence of monitoring.[11] However, the adverse effect of the withdrawal could drive down a bank's franchise value. Lower franchise value implies unfavorable quality of collaterals which may increase the risk taking behavior of the bank.

The FDIC's Optimization

[11] At the time of an economic downturn or a panic, however, depositor would withdraw irrationally from the bank. In that case, the informed depositor who monitors the bank will withdraw totally, D_1-d, before the banking failure occurs.

The third player in the economy is the deposit insurer. The FDIC indemnifies depositors when banks are unable to meet their obligations and file for bankruptcy. The FDIC maximizes social welfare and subjects to its budget constraint. The objective function of the FDIC is the sum of the expected return from depositors and the bank as we specify in equation (1) and (2)

$$SW = ER_D + ER_B \tag{6}$$

When the bank's actions are not observable, the FDIC must design a compensation scheme to give banks incentives to take on the socially desirable actions. If the bank's portfolio is relatively risky, the greater the chance the bank may default and that places a heavier burden on the deposit insurance funds. Hence, the FDIC will charge a higher insurance premium for this financial intermediary. When the bank fails, the FDIC reimburses the depositors of the troubled bank up to the maximum coverage limit. Outflow of the insurance funds are highly tied to the amount of coverage, depositors' withdrawal decisions, and the risks of bank. The FDIC's budget constraint is

$$p.ED \geq \int_{-\infty}^{\tilde{R}} \left\{ q.\bar{C} + (1-q)rD_2 \right\} f(R)dR \tag{7}$$

The left hand side of the equation (7) is the Deposit Insurance Funds financed by collecting risk premium. The use of funds depends on the action of a bank and depositors, which is on the right hand side of the equation. When a bank files for bankruptcy, $R<\tilde{R}$, the FDIC repays rich depositors in the failing bank up to the maximum coverage and reimburses principal and interests to the poor.[12]

3. A Numerical Example

We solve the model numerically by considering the interdependence between players. The first loop control variable is the bank's failing probability, P_f, from $1 \cdot 10^{-3}$ to $5 \cdot 10^{-3}$ in a $1 \cdot 10^{-5}$ interval. At each P_f , the second loop counter variable $\bar{C}$ is initialized at \$80,000 at the start of the first pass through the loop, and automatically increments by \$1,000 each time through the loop to \$250,000. From the loops, we can jointly determine the optimization for both depositors and the bank. The process behind the model is that given a coverage limit, the greater the chance of withdrawal the lower the risky asset a bank is going to choose. The fewer risky assets a bank

[12] Without aggregate uncertainty, other aspects such as the solvency of the FDIC can be managed in a form of a tax or a subsidy from/to banks and depositors. In a general equilibrium model, Boyd et al.(2002) model deposit insurance finances through taxing depositors.

engages, the lower the possibility it will be insolvent if risky assets do not payoff and, hence, lower depositor's willingness to monitor and the chance of withdrawals. The optimal coverage results from the highest total return. Hence, the combination of *EW*, *I* and $\overline{C}$ in terms of a set of exogenous variables, $(D_1, D_2, q, d, \overline{R}, \sigma^2, P_f^*, \alpha, k, \rho, r)$, as the optimization in the model.[13] The details are in Appendix 1.

Equilibrium Result

Table 1 shows the equilibrium results. One can see that the cost of promoting the partially covered insurance is high. It requires the FDIC to establish a fairly low coverage to encourage depositor's monitoring. The partial coverage could be beneficial in preventing a financial crisis which results from moral hazard and credit risks. Partial coverage could also be a good device to avoid unlimited implicit guarantee when a crisis unfolds. However, the confidence of the public is the first sign of a crisis trigger. We should note that a low coverage may jump start depositor's irrational withdrawals and cause a panic or a contagious bank run.

Table 1 Equilibrium Result

Insurance	SW	$\overline{C}$	p	ER_D	EW	ER_B	P_f	I
Full	44061	-----	0.0018	40488	-----	3573.3	0.0017	7188.3
Partial	44058	\$80,000	0.0017	40482	8.2258	3576.6	0.0018	7255
No	44041	-----	-----	40433	120.3225	3607.5	0.0030	7993.4

Note: Table 1 illustrates the equilibrium result from a numerical example in corresponding system. *SW* is social welfare including the expected return from depositors and bank; $\overline{C}$ is the optimal coverage; p is the risk premium; ER_D is the expected return to depositors; *EW* is expected withdrawals; ER_B is the expected return to banks; P_f shows the failing probability, and *I* is risky assets.

Comparing the equilibrium results in a partial insurance to the ones under full insurance, we note that depositors are better off under full insurance, but banks are better off under partial insurance. When the gains of depositors outweigh the losses of banks, full insurance has the highest social welfare. The results also reflect certain adverse effects of monitoring. The threat of depositors' monitoring and intention to withdraw can reduce bank's risk ex ante. But depositor's ex post withdrawals reduce the franchise value of a bank and, thus, stimulate bank's incentives to gamble. The net

[13] The parameter values in a benchmark are as follows: D_1 = \$125,000, D_2 = \$30,000, q = 0.1, d = 50, P_f^* = 0.01, $\overline{R}$ = 1.2, σ = 0.17, α = 1.1, ρ = 1.12, r = 1.025, and k = 0.04. Since small depositors represent a relatively large portion of total savers, we assume 90 percent of the depositors are fully covered by insurance. For a bank to be within the range of adequately capitalized, the required capital ratio is around 4% to 8%.

worth of a bank is the collateral from shareholders that would be lost if the bank fails. The lower the collateral, the higher the chance a bank is going to gamble. Hence, risky assets the bank holds, 7255, under partial insurance are slightly higher than under full insurance.

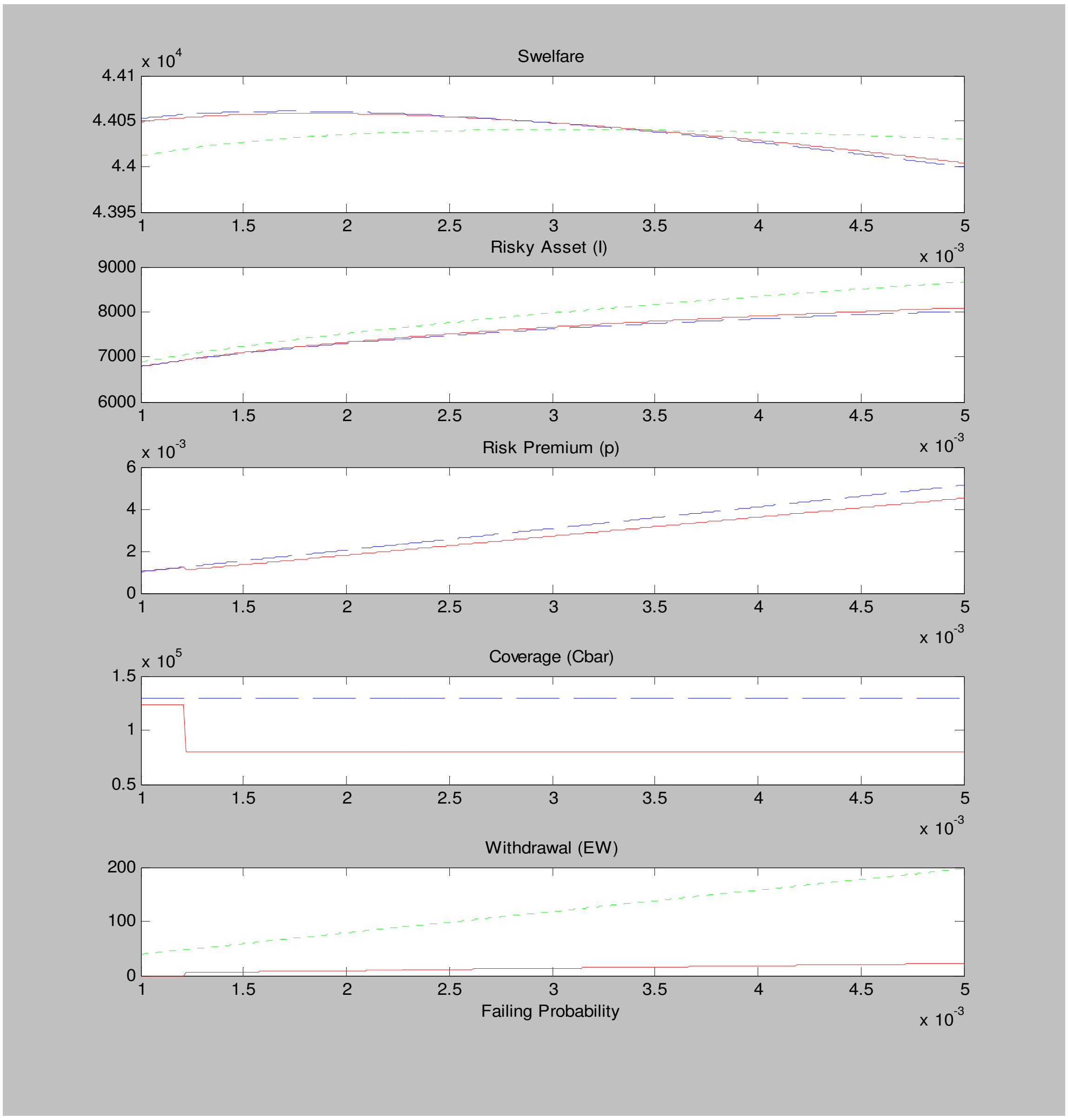
This numerical example illustrates another important point: without banking regulations, deposit insurance, and government intervention, market discipline is insufficient to manage bank risk taking behavior. Depositors who frequently monitor and supervise have the lowest welfare at 40,433, among all insurance schemes. Without deposit insurer, banks engaging in risky activities create higher expected return. But potential profit accompanies with greatest risk of default at 0.3 percent. Losses from depositors outweigh the gain from banks; therefore, the system with only market discipline has lowest social welfare.

It is worth pointing out that this model provides an alternate way to derive the optimal risk premium. We suggest the risk premium around 17 to 18 cents per hundred dollars which is located in the range set up by the Risk-Based Assessment System.[14] This result emphasizes the important insight that banking regulations such as capital requirement and risk premium are essential to reduce the level of risk banks involve. The failing probability of a bank is relatively lower, 0.17% under full insurance and 0.18% under partial system, when proper baking regulation is in place.

Welfare varies across different deposit insurance systems. As in Figure 2, when the failing probability is low, as low as 0.1%, full insurance dominates partial coverage and the economy without insurance. A fair amount of risk premium can successfully manage the bank risk-taking behavior. However, when the bank increases the amount of risky assets to the point where failing probability locates in the range 0.3% ~ 0.35%, there is indifferent among three insurance systems. To make market discipline more incentive compatible, the FDIC announces a low coverage. When failing probability moves to the other end of the scale, the economy without insurance has the highest welfare. But high expected returns come with the highest chance of default.

Figure 2 Equilibrium Results

[14] Depending on the Risk-Based Assessment System from the FDIC, the FDIC charges premium rate from 5 to 43 cents per hundred dollars.



Note: The green dotted line represents the economy with no deposit insurance; the blue dashed line shows the full insurance; the red solid line is the partial coverage system. Figure 2(a), (b), (c), (d), and (e) results for welfare, risky asset, risk premium, coverage, and withdrawals, respectively.

Cross Country Difference

The heterogeneity of the coverage may vary from a generous guarantee to a very stringent limit. Demirguc-Kunt and Kane (2002) found that relatively poor countries such as Central African Republic, Chad, and Peru set up generous coverage limits while relatively high-income countries, Austria, Belgium, Germany, and the United Kingdom, tend to provide less protection. Table 2 illustrates the difference of the optimal coverage limit across countries calculated in this model.

The result of this numerical example is consistent with the empirical evidence that countries with deposit insurances differ significantly on how much protection they provide. Comparing developing countries and emerging markets, generally speaking, personal wealth and income of developed countries is much higher. Panel (a) and (b) in Table 2 mimic the case of developed countries and represent the wealth inequality in the economy, and panel (c) shows the situation of developing countries. When the initial endowment is higher, panel (a), a country tends to provide a moderate coverage, \$80,000. Therefore, depositors' early withdrawals increase to 23.39 from 8.23 in the benchmark listed in Table 1. In contrast, the authority provides insurance close to full protection in the economy with lower personal wealth and income. The optimal coverage is \$99,000 in panel (c) which is very close to the endowment of the rich at \$100,000. Since most of the depositors, no matter rich or poor, are under full deposit protection in the case of (c), it is not surprising that the optimal withdrawals drop to zero.

In addition, Table 2 lists the optimal coverage ratio, coverage over per capita GDP, calculated from the numerical example. Empirically, Garcia (1999) surveys the ratio of deposit coverage to per capita GDP in 68 countries. The average ratio is around 6.2 in Africa and is followed by 4 in Asia, 3.4 in Middle East, 3.2 in Western Hemisphere, and the lowest being 1.6 in Europe. The coverage ratio in our study varies from 1.03 to 2.68. The optimal coverage ratio for a relatively wealthy country is 1.702 in panel (a) which is lower than the one in the emerging economy, 2.6727, in panel (c). Compared to Garcia's survey, the numerical example demonstrates that both developing and developed countries tend to provide generous coverage. One possible explanation could be the society may not appropriately internalizing the externality resulted from the insurance policy. Too-big–to–fail is one of the examples that show market imperfection and externality.

Table 2 Equilibrium Results of Cross-Country Difference

	SW	$\bar{C}$	p	ER_D	EW	ER_B	P_f	I	C ratio
(a) D_1=\$200,000	52430	\$80,000	0.0015	48169	23.393	4261.0	0.0020	8730.5	1.7021
(b) q=0.5	86437	\$80,000	0.0014	79409	44.725	7028.7	0.0020	14446	1.0323
(c) D_1=\$100,000	41269	\$99,000	0.0018	37922	0	3348	0.0018	6747.4	2.6757

Note: Panel (a) increases the endowment of the rich to 200,000 from 125,000 and panel (c), on the other hand, reduces the endowment of the rich to 100,000. Panel (b), assumes that 50 percent of depositors belong to the rich and the other half of depositors are the poor.

Next, we examine the effect of monitoring cost in Table 3. When monitoring cost gradually decreases from \$500 to \$5, there is a welfare increase in the partially covered insurance. When monitor is costly, panel (a), monitoring bank's risk taking behavior is not incentive compatible for depositors. Therefore, the best strategy the FDIC provides is a protection up to \$124,000. When monitoring cost is cheaper, depositors are much more willing to engage in monitoring so that the FDIC reduces the level of coverage since market discipline dominates. Interestingly, the higher cost reduces depositor's incentives to monitor, but the protection from the coverage provides the compensation to depositors if bank fails. As a result, only a slight welfare difference of the partial coverage system can be observed when evaluate the variation of monitoring cost.

Table 3 Equilibrium Result when Varying Monitoring Cost

	SW	$\bar{C}$	p	ER_D	EW	ER_B	P_f	I
(a) d=500	44058	\$124,000	0.0018	40483	0	3574.3	0.0018	7203.5
(b) d=5	44063	\$80,000	0.0017	40486	8.2341	3577.1	0.0018	7255.9

Note: Panel (a) considers the case when monitoring cost is relatively costly and Panel (b) studies the case when monitoring is relatively low comparing to the benchmark, d=50.

Finally, this paper addresses the effect of the past failing probability in Table 4. Under the partially-covered insurance system, depositors update their information set and learn from the past experience. When P_f^* is relatively low, the opportunity cost of monitoring is high. From the past information, the banking industry is healthy as the chance of a bank failure is low. Therefore, depositors will not engage in monitoring, and the optimal withdrawal is down to zero. When P_f^* is high, depositors are relatively prudential and pay attention on banking management. Hence, the efficient banking regulation involves a lower level of coverage.

Table 4 Equilibrium Result when Varying Past Failing Probability

	SW	$\bar{C}$	p	ER_D	EW	ER_B	P_f	I
(a) P_f^* = 0.003	44061	\$124,000	0.0018	40486	0	3574.3	0.0018	7203.5
(b) P_f^* =0.05	44058	\$80,000	0.0017	40482	8.2258	3576.6	0.0018	7255

Note: We consider the cases with a lower past failing probability in Panel (a) and a higher failing probability in Panel (b).

4. Conclusion

Analyzing the coverage-determination process has practical importance in two major areas. The first is for the countries that have adopted a well-established deposit insurance system for a long period of time. The optimal coverage limit in this study provides the possibility to resolve the moral hazard in banking system and, further, prevents the risk-oriented bank run by reinforcing the market discipline. More importantly, for the countries that have the implicit deposit insurance, our model provides a theoretical foundation to support the introduction of a proper system which protects the small depositors and also reduces economic instability.

The design of a proper deposit insurance scheme is brought back to discussion when the economy has experienced the worst financial turbulence since the Great Depression. A bank failure could easily turn into a crisis when the financial institutions are overly exposed to credit risks and when the government is least equipped to deal with those risks. Therefore, revision of current banking regulations and the deposit insurance scheme are essential. This research focuses on the joint determination of optimal coverage limit and optimal risk premium within a partial equilibrium model in an effort to tackle the moral hazard problem. The model also incorporates banking regulation of capital requirements and market discipline from depositor's monitoring in a partial equilibrium model, which includes risk-taking banks, ex-ante heterogeneous depositors, and an insurance company providing deposit insurance.

We find optimal level of coverage encourages depositor's monitoring and improves social welfare. When the partial coverage limit is in place, banks are better off by balancing between the deposit premia and the depositor's monitoring and withdrawals. The adjustment between the level of coverage and the premium provide some flexibility on long term liquidity of the Deposit Insurance Funds in the FDIC. This issue becomes extremely important when financial crisis requires tremendous credit and liquidity support from the FDIC.

This study provides an explanation of cross-county difference on how much protection their deposit insurance would provide. First, the numerical example shows that the economy with higher income provides moderate coverage. On the other hand, low income economy provides greater protection on insurance. Second, we shed light on income inequality. An economy with fairly high income inequality adopted a relatively generous coverage to protect small depositors and prevent panic and runs. Third, we find that when an economy is health for a long time with low probability of default, depositors pay less attention to monitoring banks. Thus, the best strategy of the FDIC is to provide a higher coverage to prevent banking instability. Last, using the coverage per capita GPD as an indicator, the ratios from the empirical evidence summarized by Garcia (1999) are higher than the ones we suggest in the study. This may reflect that countries may not appropriately internalize the externality generated from the insurance policy.

There are some possible directions for further study. There are more than one angles to study the current crisis, but among all causes the systemic risk could easily spillover and could turn a banking failure into a financial crisis has blamed the most. Hence, the model will be more sophisticated if we consider not only the idiosyncratic risk from either depositor's liquidity preference shock or from bank's inappropriate investment decision but also the aggregate uncertainty.

This research determines the optimal coverage, but the timing and frequency to adjust the coverage limits are beyond the scope of the study. Time inconsistency of implementing a new coverage may impact efficiency and effectiveness of the policy. An ex ante efficient policy may not be efficient ex post if the delay of government response is big enough to generate panics in financial markets. Panics and unstable banking could exacerbate the financial situation and cause real economy problems. Frequency of adjusting the coverage limit may affect the credibility of the authority and may further affect people's expectation. In current financial crisis, the FDIC increased the coverage limit temporarily to $250,000 from $100,000 on Oct, 2008. Then, later on the FDIC extended the deadline to Dec, 2013 on May, 2009. It could form an expectation of a permanent blanket guarantee of deposit insurance that increases the chance of future banking failures.

Also, one way to foster market discipline and boost the monitoring and supervision from the side of depositors is to introduce co-insurance.[15] Co-insurance would require depositors to share the pre-specified potential losses regardless of the size of their deposits. Required contractually at the beginning of the period, the coinsurance system seems to reinforce depositors' market discipline. Determination of the optimal share for depositors and influence of the coinsurance against the potential moral hazard are worth further investigation.

[15] According to Demirguc-Kunt and Huizinga (2004), relatively fewer countries such as Chile, Colombia, Poland and the United Kingdom have adopted co-insurance system.

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Appendix 1 Mapping procedure

We solve the model by considering the interdependence among those three players and examining how they react to behavior of others. Given the parameters determined by the bank, I and P_f, and the policy parameters announced by the FDIC, p and $\bar{C}$, we calculate the expected return for depositors, which is a function of P_f, $\bar{C}$, and the set of exogenous variables. Given depositor's reaction, ED and EW, we find the expected return of a bank, which is a function of EW, D^*, $\bar{C}$, and the set of exogenous variables. By doing so, we make sure the combination of EW and I will be the optimal choice for both depositors and bank. To find out how the optimal policy will locate, we run possible coverage limits from \$80,000 to \$250,000 dollars in a one-thousand interval and see which coverage will generate the highest total expected return[16]. Given the coverage with the highest total return, we claim the combination of EW, I and $\bar{C}$ as the optimization in the model.

The first loop control variable is the bank's failing probability, P_f, from $1 \cdot 10^{-3}$ to $5 \cdot 10^{-3}$ in a $1 \cdot 10^{-5}$ interval. At each P_f, the second loop counter variable $\bar{C}$ is initialized at \$80,000 at the start of the first pass through the loop and automatically increments by \$1,000 each time through the loop to \$250,000. Endogenous variables among three players listed in the front and followed by other exogenous variables in the model.

1. Depositor's maximization
   - Depositor's decision depends on D^*. If $D_1 > D^*$, prob(monitor) =1, otherwise prob(monitor)=0
   - $D^* = f(P_f, \bar{C}, P_F^*, d, r)$
   - $ED = f(D^*, D_1, D_2, q, d)$
   - $EW = f(P_f, I, \bar{C}, D^*, exog(D_1, q, d, P_F^*, r))$
   - From the FDIC's budget constraint, premium is $p = f(P_f, \bar{C}, ED, D_1, D_2, q) = f(P_f, \bar{C}, D_1, D_2, q, d, P_F^*, r)$
   - $DER = f(P_f, \bar{C}, D^*, D_1, D_2, q, d, P_F^*, r) = f(P_f, \bar{C}, exog(D_1, D_2, q, d, P_F^*, r))$

2. Bank's maximization
   - Under the same loops, depositor's monitoring is always between 0 and 1. Therefore, we have two possible results for ED given other exogenous variables. Also, we know P_f has one to one mapping for $\tilde{R}$.
   - A bank is breakeven if the realization of the random gamble return $R = \tilde{R}$. When a bank's payoff is less than its obligation, this bank is insolvent and fails. $P_f = prob(R < \tilde{R})$.

[16] The difference between a full coverage and a partial coverage is through two defined thresholds. If the coverage is less than (D_1-d), we report the result as partial coverage; otherwise, we report the result as full when the coverage is greater than $r(D_1$-$d)$.

- The two-step mapping from $\tilde{R}$ to gamble assets I. First, given the first loop control variable P_f, we compute the inverse of the normal CDF from $P_f = prob(R < \tilde{R})$
- Second, from the bank's maximizing function, we define $\tilde{R} \equiv \alpha - (1/I)[\alpha(1+k-p) - (\rho k + r)]ED$
- Hence, $I = f(D^*, \overline{C}, exog(D_1, D_2, q, d, \alpha, k, r, \rho))$
- $ER = f(D^*, EW, \overline{C}, I, exog(D_1, D_2, q, d, \overline{R}, \sigma^2, P_F^*, \alpha, k, \rho, r))$

3. The FDIC's maximization
   - Under the same loop iteration, we sum the expected return from depositor and from the bank.
   - At the point maximizing the sum of expected returns determines the optimal coverage of the FDIC, so as *DER*, *ED*, *EW* for depositor, *ER*, *I*, P_f for a bank, and *p* for the FDIC.