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Article

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The Valuation of Deposit Insurance Premiums Based on a Specific Bank's Official Default Probability

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This study presents a formula for valuating a deposit insurance (DI) premium based on a specific official default probability. This formula can be used to flexibly determine the DI premium that reflects changes in economic circumstances. We provide a new estimation method to determine the implied asset risk based on the efficient frontier between asset value and asset risk. Doing so avoids the problem for estimating a bank's assets and asset risk using market equity data. Empirical evidence shows current DI premium assumes that banks have too high default rates. We suggest the DI premium should be lower for banks that fully obey the financial supervisory regulations. Doing so should incentivize these banks to decrease their likelihood of default by strictly implementing financial regulations, thus stabilizing financial environment. We also suggest a new dynamic method to help them determine reasonable DI premiums and maintain the target level of DIF reserves. (JEL: G12, G18, G21, G22, G28)

Keywords: deposit insurance; premium; default probability; financial supervision

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I. Introduction

A fair deposit insurance (DI) premium is important for financial supervisors and financial institutions because it contributes to the stability of the financial system. Merton (1977) was the first to derive a formula for pricing risk-based DI premiums. In the application of Merton's model, the value of the bank's assets and its asset risk are two important but unobserved parameters. Thus, they need to be estimated. However, this creates an incorrect DI premium and greatly restricts the application of Merton's model. Moreover, the fact that a bank must usually follow numerous strict financial regulations implies that its default probability should be expected to be below a specific level (hereafter defined as the official default probability) required by the financial supervisor. For these reasons, we present a new formula for the valuation of DI premiums based on an official default probability. In our model, it can avoid to estimate the bank's asset risk using equity market data. This greatly improves the model's applicability and the DI premium analyses. Our model can help bank supervisors determine a fair DI premium based on changes in economic conditions and based on a change in the target surplus level of the DI Corporation.

Given the official default probability, a bank is required to reduce its asset risk by adjusting its investments based on the current asset/debt level. From the financial viewpoint, banks which look for maximum profit should optimize their investments based on an efficient frontier between the bank's current asset/debt level and asset risk. Thus, the bank's asset risk should be bounded to a certain value (i.e., the maximum asset risk). This allows us to calculate the implied asset risk for a bank when valuating a fair DI premium. Moreover, we provide theory to discuss such a frontier to show the maximum asset risk given a specific official default probability.

To demonstrate the applicability of our model, we provide numerical examples using data from the Federal Deposit Insurance Corporation (FDIC). We present the results for a fair DI premium if the bank well obeys the financial regulations. We also show that the FDIC's current DI premium implies how large the bank's default probability is. The empirical evidence reveals that the current DI premium assumes that the bank has a high expected default rate. Moreover, we determine a reasonable DI premium for both before and after the 2007 financial crisis. Our results show that the mean values of DI premiums were 0.360bp, 25.114bp, and 0.583bp for the periods before, during, and after the crisis, respectively. In addition, based on our model, we propose a new dynamic method to help the DI Corporation determine a reasonable DI premium that reflects the change in its target surplus level.

The main contributions of this paper can be summarized as follows. First, we construct a valuation model for DI premiums based on a specific official default rate. It can reasonably determine the DI premium for banks that fully obey the financial supervisory regulations. To the best of our knowledge, our model is the first to valuate a DI premium considering such specifications. Second, we provide a new concept, the efficient frontier, for determining the implied asset risk and we propose a DI premium formula based on the efficient frontier. Doing so avoids the problem with the traditional DI valuation models, caused by estimating the bank's asset risk using market equity data. Third, we present sensitivity analyses to clarify the relationship of the DI premium to the asset/debt ratio. Fourth, we provide extensive discussion of how the application of our model helps DI institutions and policy makers determine an optimal DI premium based on changes in the economic situation and changes in the surplus levels of DI institutions. Finally, we discuss and offer suggestions for the current DI premium and the external audit system on the DI Corporation.

The remainder of the paper is organized as follows. In Section II, we discuss the bank regulations. In Section III, we present DI valuation formulas using Merton's model and our model. Section IV reports the results of our analysis of U.S. bank data from the FDIC. In Section V we discuss and offer suggestions for the current DI premium and the external audit system on the DI Corporation. Our conclusions are summarized in Section VI.

II. Discussion of capital requirements and financial regulations

Because banks play an important role in the economic development of a country, they are usually governed by numerous strict financial regulations. To avoid the insolvency risk for a bank, regulators usually concerned with bank's capital, because they believe that a high level of capital will reduce the probability of default. For example, the FDIC Implement Act (FDICIA) of 1991 required that banks should adopt risk-based capital requirement. Nowadays, the Basel Accords, suggested by the Basel Committee on Bank Supervision (BCBS), are a key regulation for calculating the risk-based capital requirement in many countries. Part of TARP (Troubled Asset Relief Program) of 2008-09 is the Capital Purchase Program, which was intended to encourage U.S. banks to build the capital needed to support the U.S. economy.[1] Currently, the FDIC implements the U.S. version of the international bank capital standards adopted by the Basel III Accords1 and the bank capital requirements under the Dodd-Frank act.

The functions of capital requirements and strict financial regulations have been addressed in many research studies. Many of these found that capital requirements and strict supervision are effective tools in reducing the bank's default risk, thereby contributing to the stability of the banking system (Barth, Caprio and Levine, 2004; Kopecky and VanHoose, 2006; Repullo and Suarez, 2013; Agoraki, Delis and Pasiouras, 2011; Čihák, Demirgüç-Kunt Pería and Cheraghlou, 2012; Tsai and Hung, 2013; Jin, Kanagaretnam, Lobo and Mathieu, 2013). Some studies have pointed to weaknesses in regulation and supervision as factors that led to the 2007 crisis (Levine, 2010). However, several studies found that the effect of capital requirements on risk-taking is ambiguous (Rochet, 1992; Besanko and Kanatas, 1996; Agoraki, Delis and Pasiouras, 2011). Barth, Caprio and Levine (2008) argue that capital requirements will not improve bank stability or efficiency.

In our study, we assumed that when strict financial regulations (i.e., capital requirements) are in place, the bank's default probability, determination of which is required by the financial supervisors, will decline to a specific level (i.e., the official default probability). For example, under the Basel Accords, whenever a bank sets its capital at the minimum level allowed by the regulations, the implied probability of default is 0.1% (Repullo and Suarez, 2004; Tasi and Chen, 2011). Thus, we assume that the official default probability is set at 0.1% for a bank conforming to the Basel Accords. The regulation influences the determination of the official default probability and in turn influences the DI premium. Clearly, strict financial regulation decreases the official default probability, and in turn, decreases the DI premium. In view of that, for banks that fully obey the financial supervisory regulations (e.g., the Basel Accords) and do an excellent job in keeping their risks low, we argue that their fair DI premium should be determined by an appropriate model incorporating the official default probability.

1. TARP, signed into law on Oct. 3, 2008 to address the subprime mortgage crisis, is a U.S. government program that purchases toxic assets and equity from financial institutions.

III. The models for DI premium

This section has two subsections. In Subsection A, we present Merton's model for the DI premium. Subsection B illustrates how we incorporate the official default probability in our new valuation formula for the DI premium.

A. The DI premium in Merton's model

Numerous researchers have investigated how Merton's valuation framework can be used to more precisely determine DI premiums (Ronn and Verma, 1986; Duan, Moreau and Sealey, 1992; Allen and Saunders, 1993; Duan and Yu, 1994; Shyu and Tsai, 1999a, b; Duan and Simonato, 2002; Lee, Lee and Yu, 2005; Chen, Ju, Mazumdar and Verma, 2006; Chuang, Lee, Lin and Yu, 2009). In Merton's model, a bank is bankrupt if the value of its assets falls below its debt level at the maturity date. Thus, the DI premium is the same as the initial value of a European put option, the strike price and underlying assets of which are respectively the values of the bank's deposits and total assets. The DI premium is expressed as follows (Merton, 1977):

$$IPP = N(d_2) - \eta N(d_1). \tag{1}$$

where

IPP is the DI premium of per-monetary-unit assuming only one auditing time (at the maturity date);

$N(\cdot)$ is the cumulative distribution function for a standard normal distribution;

$$d_1 = \frac{\ln\left(\eta^{-1}\right) - \frac{1}{2}\sigma^2 T}{\sigma\sqrt{T}}; \;\; d_2 = d_1 + \sigma\sqrt{T};$$

$\eta = \dfrac{V(0)}{B(0)}$ is the asset/debt ratio at the initial time;

$V(0)$ is the total asset value at the initial time;

$B(0)$ is the total value of the deposit at the initial time;

σ is the instantaneous standard deviation of a bank's asset return (i.e., asset risk); and

T is the auditing time which one can judge whether or not the bank is bankrupt; $T = 1$ year in general specification.

In the Merton's model, the bank's total assets and the asset risk both must be estimated. Some authors used simultaneous equations, using the bank's equities and the standard deviation of its equity returns, to determine these two parameters (Ronn and Verma, 1986; Giammarino, Schwarz and Zechner, 1989; Duan and Yu, 1994). However, the bank's stock price may be overly influenced by many factors, such as the reaction to the new information, market anomalies, and investor sentiment (De Bondt and Thaler 1985, 1987; Huang, 1998; Albert and Henderson, 1995; Chen and Sauer, 1997; Odean, 1998). This can lead to overestimation of the standard deviation of the bank's equity returns and then overestimation of bank's asset risk. Thus, the DI premium may be inaccurate when the equity returns are used to estimate the bank's asset risk. In addition, many banks are not traded in the equity market. Thus, these banks have no equity data for estimating its asset risk. For these reasons, the application of Merton's model is greatly restricted. We therefore present a new valuation model of the DI premium that does not require the use of equity data in the application.

B. A new DI premium valuation formula that takes account of the official default probability

We assume that the bank's supervisor assigns an official default probability p under the risk-neutral measure if the bank obeys the financial regulations (e.g, $p = 0.1\%$ if the Basel Accords are followed). If the forecasted default probability is larger than this value, the bank is required to reduce its default probability by making adjustments, such as increasing its equity or decreasing its investment in risky assets. Otherwise, the bank should be penalized severe penalties until the requirements are met.

When the bank's default probability is restricted up to the official default probability, the bank's asset risk should be bounded at the maximum asset risk. The following shows how to obtain the maximum asset risk given the official default probability. The formula for valuating a risk-based DI premium (e.g., equation (1)) shows that the premium should be smaller than bank's default probability, $N(d_2)$. Here we let $N(d_2) = p$, denoted as the official default probability under the risk-neutral measure,[2] and obtain the following:

$$d_2 = \frac{\ln \eta^{-1} + \frac{1}{2}\sigma^2 T}{\sigma\sqrt{T}} = N^{-1}(p), \tag{2}$$

where $N^{-1}(\cdot)$ is the inverse for cumulative normal probability.

Accordingly, we have:

$$\frac{1}{2}\sigma^2 T - \sigma\sqrt{T}N^{-1}(p) + \ln \eta^{-1} = 0. \tag{3}$$

Equation (3) shows a relationship between σ and η given the official default probability p under the risk-neutral measure.[3]

After solving equation (3), we derive the bank's maximum asset risk as follows:

$$\sigma\sqrt{T} = N^{-1}(p) \pm \sqrt{\left(N^{-1}(p)\right)^2 - 2\ln \eta^{-1}}. \tag{4}$$

Because the official default probability based on the financial supervisory policy is usually set at a small value, we can obtain $N^{-1}(p) \leq 0$. In addition, because $\sigma\sqrt{T} > 0$, we have:

$$\sigma\sqrt{T} = N^{-1}(p) + \sqrt{\left(N^{-1}(p)\right)^2 + 2\ln \eta}. \tag{5}$$

Equation (5) shows that the bank's maximum asset risk can be determined based on the bank's current asset/debt ratio and the official

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2. Since we focus on the valuation on DI, we derive the model under the risk-neutral measure.

3. If the default probability p is given under Physical measure, $\ln \eta^{-1}$ can be replaced by $\ln \eta^{-1} + \int_0^T (\mu(t) - r(t))\,dt$ in equation (3) for obtaining the relationship between σ and η, where $\mu(t)$ is the return of bank asset.

default probability. For example, if the asset/debt ratio is $\eta = 1.1442$ and $p = 0.1\%$, the maximum asset risk, $\sigma\sqrt{T}$, is 4.33%. The bank must reduce its investment in risky assets if its asset risk is larger than 4.33%. Otherwise, the bank can be punished.

One can use equation (5) to create a function for the maximum asset risk and the asset/debt ratio given the official default probability. From the financial theory viewpoint, the expected risk premium on an investment should be proportional to the risk, and therefore the greater the asset risk the greater the expected return. Given the asset/debt ratio, the bank can modify the return and the risk in its asset portfolio by adjusting the amount of its investment in risky assets. The more the bank has invested in risky assets, the larger its return of asset portfolio and the larger its risk of asset portfolio.

Assuming the bank's goal is to maximize profit, an efficient frontier is therefore defined as the function (i.e., equation (5)) for the implied asset risk and asset/debt ratio given the official default probability. If the asset risk based on the asset/debt ratio is below the efficient frontier, the bank's investments are not efficient because they do not achieve the goal of maximizing the bank's profit. On the contrary, if the asset risk based on the asset/debt ratio is above the efficient frontier, the bank is violating the regulation requirement for the official default probability. Thus, if a rational bank manager wants to both maximize profit and meet the financial supervision regulations, (s)he should locate the optimal asset allocation for the current asset/debt ratio and its asset risk on the efficient frontier under the risk-neutral measure.

Figure 1 shows the positive relationship between the bank's current asset/debt ratio and its implied asset risk according to equation (5), given the different official default probabilities. The figure reveals that if the bank raises its asset/debt ratio, its investment risk for risky assets consequently increases. Moreover, the efficient frontier is a concave function with positive slope, representing the correspondence between the implied asset risk and the asset/debt ratio. Under the same asset/debt ratio, the efficient frontier moves up when the official default probability increases. In other words, the implied asset risk increases as the official default probability become larger. This implies that when the government relaxes the restriction of the official default probability, the bank can invest more in risky assets in pursuit of greater returns to maximize its profit.

Still assuming that the bank manager is looking for maximum profit given the official default probability p, the investment portfolio based

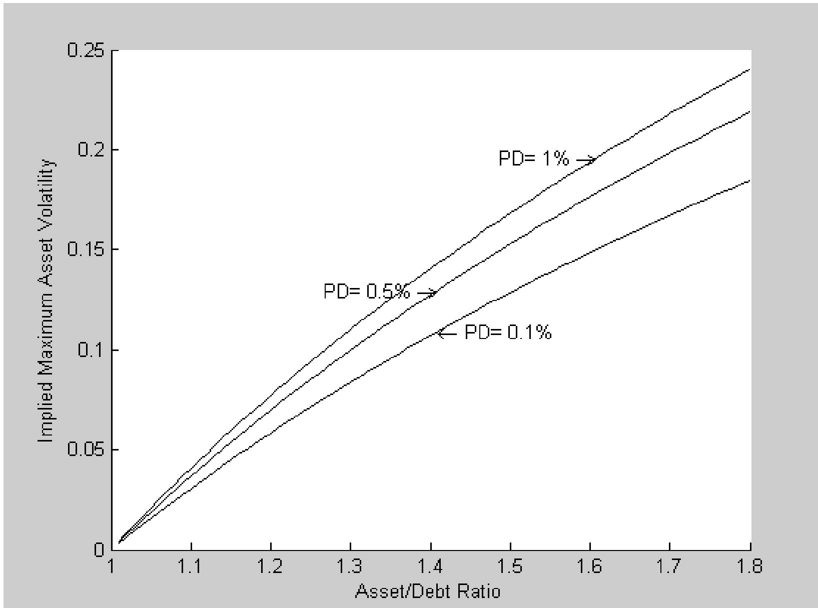

FIGURE 1.— Effect of different official default probabilities on the efficient frontier

Note: PD represents the official default probability under risk-neutral measure. The implied maximum asset volatility is obtained from equation (5).

on the implied asset risk and asset/debt ratio η should be located on the efficient frontier. Then using equation (5), we have

$$\begin{aligned} d_1 &= d_2 - \sigma\sqrt{T} \\ &= -\sqrt{\left(N^{-1}(p)\right)^2 + 2\ln\eta}. \end{aligned} \tag{6}$$

Therefore, the relationship for the DI premium and η given p can be expressed as:

$$IPP_p = p - \eta N\left(-\sqrt{\left(N^{-1}(p)\right)^2 + 2\ln\eta}\right), \tag{7}$$

where IPP_p is the DI premium of per-monetary-unit for the given official default probability p.

In equation (7), a pricing formula for the DI premium is obtained if the bank's investments are on the efficient frontier. If the bank's investments are below the efficient frontier, the DI premium should be less than the value calculated by this formula. When the bank satisfies the requirement of the official default probability, equation (7) gives the calculation of the maximum DI premium that the bank should pay. In financial theory it is usually assumed that banks look for maximum profit. Thus, the DI Corporation can treat equation (7) as a closed-form formula for valuating a DI premium for a bank that meets its goal of maximizing profit and satisfies the restriction of the official default probability. According to this formula, banks that obey the financial regulations should find that their DI premium (IPP_p) should be less than the official default probability (p), as noted above.

It is worth mentioning that the asset risk $\sigma\sqrt{T}$ need not be estimated when using equation (7) to calculate the IPP_p. As mentioned above, the implied asset risk is determined by equation (5) given the official default probability. Our model for valuating a DI premium should be easier to apply and more accurate than Merton's model, because it avoids the problem caused by the inaccurate estimation of the asset risk when using market equity data. Note that in equation (7), p is regulated by the financial supervisor. Thus, it is an exogenous variable. Accordingly, the DI premium depends mainly on the current asset/debt ratio η.

The slope for the DI the premium on the current asset/debt ratio is:

$$\frac{\partial IPP_p}{\partial \eta} = -N\left(-\sqrt{\xi}\right) + n\left(-\sqrt{\xi}\right)\left(\sqrt{\xi}\right)^{-1}, \tag{8}$$

where $\xi = \left(N^{-1}(p)\right)^2 + 2\ln\eta$; and $n(\cdot)$ is the probability density function for a standard normal distribution. The first term on the right side of equation (8) is a negative value and the second term is a positive value. Thus, one cannot judge whether the effect of the change in η on IPP_p is positive or negative. Therefore, we present figure 2 to show the relationship between IPP_p and η.

The positive relationship between IPP_p and η shown in figure 2 means that if the bank asset/debt ratio η rises, the DI premium IPP_p also increases. This result seems to contradict the general concept that the bank pays a lower DI premium if its asset/debt ratio increases. However, this traditional concept is correct only if the asset risk is assumed to be

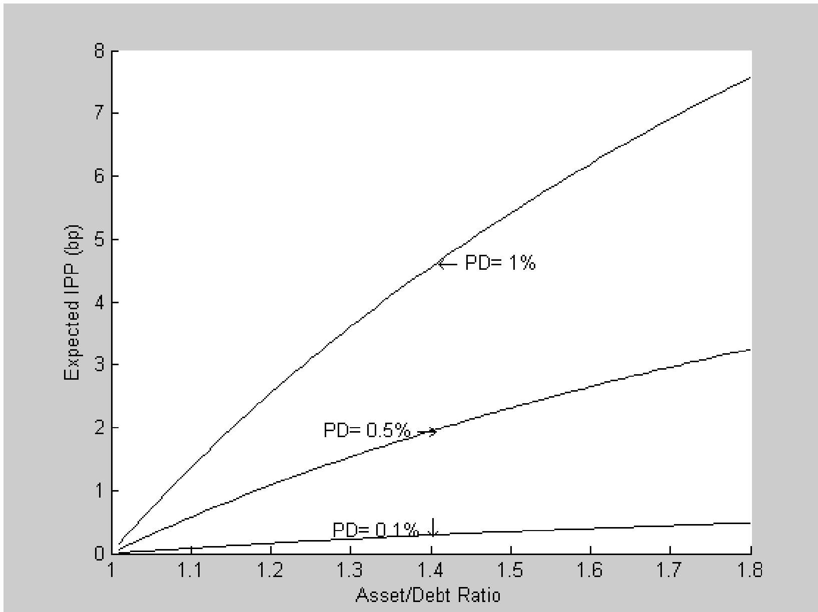

FIGURE 2.— The relationship between the expected deposit insurance premium and asset/debt ratio for different official default probabilities

Note: The expected *IPP* is obtained by equation (10). PD represents the official default probability under risk-neutral measure set by the financial supervisory policy.

a fixed value in the analyses of DI premium. In our model, this result is not surprising, because a larger asset/debt ratio implies that the bank has more enough capacity to withstand the greater risk given a specific value for the official default probability, as shown in figure 1. Thus, the bank manager invests in more risky assets to maximize profit. However, doing so can also increase the probability of bank failure, which would result in DI premium increases. In addition, the curve of the relationship between IPP_p and η moves up as the official default probability increases. According to this view, if the government loosens the restriction causing an increase of the official default probability, the bank will increase its risky investments to maximize profit. This in turn will lead the increases of the DI premium to protect the depositors against losses.

IV. Application of the model

This section has three subsections. In Subsection A, we introduce the data. Subsection B shows the numerical results for DI premium when banks well obey the financial regulations. In Subsection C, we suggest a minimum positive surplus (hereafter MPS) method for determining the DI premium based on our model.

A. The data

We use yearly data obtained from the FDIC to illustrate the application of our model. These data include the banks' assets, debts, and deposits, recorded on their balance sheets reported on December 31 of each year. The sample period is from December 1999 to December 2017, covering 19 years. We selected the data based on the following criteria: 1. the bank's asset/debt ratio is greater than one; 2. the debt is greater than zero; and 3. the deposits are greater than zero. After data cleansing, there were 152,677 sample banks. Table 1 presents summary data for the banks' assets, debts, and deposits.

B. The numerical results of DI premium considering the official default probability

As shown in equation (7), the value of a DI premium given the official default probability can be determined only from the asset/debt ratio. From the investment viewpoint, the bank's initial total asset value represents how the funds in the portfolio are allocated between risky and risk-free assets at the time the portfolio is established. Based on the recently enacted accounting rules (i.e., the International Financial Reporting Standards, IFRS), if the assets can be traded in the market, the bank needs to disclose their market value. If the assets are not to be traded, the bank needs to disclose its estimate of their fair market value. From this viewpoint, the book value of the assets shown in the accounting report (e.g., the balance sheet) reasonably represents the current investment values of both the risky and risk-free assets. We calculated the asset/debt ratio from this book value.

In table 2, we summarize the estimated DI premiums IPP_p for each bank in each year, calculated from our model, given p = 0.1%. For example, in 1999, the mean, standard deviation, minimum, median, and maximum values of the IPP_p were 0.109 basis points (hereafter denoted

TABLE 1. Summary of basic bank information on our sample

	Asset Value	Debt Value	Deposit Value
Mean	1,536,438	1,374,357	1,088,770
Std	28,675,972	25,858,189	20,198,054
Max	2,140,778,000	1,928,932,000	1,534,907,000
Median	130,151	116,137	107,635
Min	551	12	1
Data Num.	152,677	152,677	152,677

Note: This table gives data of bank's balance sheet obtained from FDIC. The sample period was from 1999 to 2017. The balance sheet is reported in Dec. 31 for each year. The "mean", "Std", "Max", "Median", "Min" and "Data Num" denote the mean, the standard deviation, maximum value, median value, minimum value and data number of the sample. The second to forth columns give statistic summaries for the banks' assets, debts and deposit values respectively during the sample period (Dollar amounts in thousands).

as bp; 1bp = 0.01%), 0.125bp, 0.017bp, 0.085bp, and 3.064bp, respectively.

From April 1, 2011 to June 30, 2016, the DI premium required by the FDIC ranged from 2.5bp to 45bp. Under this DI premium regulation, a bank's assessment base is about equal to its total domestic deposits. Nowadays, the DI premium required by the FDIC ranges from 1.5bp to 40bp. However, under the requirements for the current DI premiums, the FDIC redefines a bank's assessment base as its average consolidated total assets minus its average tangible equity. Because with our model the DI premium is calculated using the bank's assessment of its deposits, we compare our results with the FDIC-required DI premium that was effective April 1, 2011 - June 30, 2016. Table 2 shows that the mean value of IPP_p given $p = 0.1\%$ is lower than 2.5bp for all years. Even if we focus on the maximum DI premiums for all 19 years, they are higher than 2.5bp for only eight of these years (1999, 2000, 2005, 2007, 2008, 2009, 2015, and 2017). DI premiums calculated from our model are much smaller than the lower-bound DI premium of 2.5bp required by the FDIC. This implies that the FDIC's current DI premium could be too high for banks that fully adhere to the strict financial supervisory regulations.

Moreover, using our model one can flexibly adjust the official default probability when calculating the DI premium. Table 3 shows the IPP_p estimates for each year based on the different official default probabilities. The means of these estimates are 1.808bp, 2.518bp, 4.386bp, 42.631bp, 44.670bp, and 49.613bp for the official default

TABLE 2. The summary of estimated DI premiums given 0.1% official default probability

	Estimated $IPP_{0.1\%}$				
Year	Mean	Std	Min	Median	Max
1999	0.109	0.125	0.017	0.085	3.064
2000	0.112	0.124	0.017	0.088	2.831
2001	0.110	0.120	0.010	0.088	2.482
2002	0.110	0.111	0.009	0.090	2.051
2003	0.112	0.120	0.004	0.090	2.421
2004	0.115	0.129	0.024	0.091	2.451
2005	0.118	0.137	0.015	0.091	2.897
2006	0.123	0.144	0.031	0.093	2.249
2007	0.127	0.146	0.010	0.095	2.758
2008	0.114	0.117	0.001	0.092	2.790
2009	0.108	0.110	0.000	0.091	2.516
2010	0.107	0.101	0.001	0.092	2.130
2011	0.109	0.091	0.003	0.097	2.131
2012	0.111	0.100	0.000	0.098	2.163
2013	0.110	0.110	0.003	0.096	2.329
2014	0.115	0.110	0.004	0.100	2.344
2015	0.115	0.110	0.013	0.100	2.561
2016	0.116	0.115	0.011	0.100	2.403
2017	0.117	0.117	0.016	0.101	2.613

Note: This table shows the estimated IPP_p given p = 0.1% in each year. The second to fifth columns show the mean, standard deviation, the minimum value, the median value, and the maximum value for estimated IPP_p s.

probabilities of 1%, 1.3%, 2%, 10%, 10.3%, and 11%, respectively. Because the FDIC's DI premium ranges from 2.5bp to 45bp, our results reveal that the banks' official default probability is assumed to range from 1.3% to 10.3%. Such high default probabilities are unreasonable. Several studies have shown that banks obeying the financial regulations hold capital well in excess of the minimum required by the regulations; their probabilities of default are less than 0.1%.[4] Historical data show that banks' default probabilities tend to be quite low in many countries. As for U.S. banks, the FDIC data show that from 1999 to 2017 the bank default rate ranged from 0% to 2.05% and the average was only 0.40%.[5]

4. In fact, banks normally hold capital well in excess of this minimum regulatory amount (Jokipii and Milne, 2008, 2011; Stolz and Wedow, 2011). As a result, their default probabilities may be lower than 0.1%.

5. See table 4.

TABLE 3. Mean of the estimated DI premiums based on different official default probabilities

	Official Default Probability					
Year	$p = 1\%$	$p = 1.3\%$	$p = 2\%$	$p = 10\%$	$p = 10.3\%$	$p = 11\%$
1999	1.728	2.407	4.191	40.683	42.627	47.341
2000	1.777	2.475	4.309	41.814	43.812	48.654
2001	1.755	2.445	4.257	41.335	43.310	48.100
2002	1.757	2.447	4.264	41.519	43.507	48.327
2003	1.778	2.476	4.312	41.880	43.882	48.736
2004	1.820	2.535	4.412	42.726	44.765	49.707
2005	1.868	2.601	4.525	43.644	45.721	50.754
2006	1.952	2.717	4.725	45.419	47.575	52.798
2007	2.006	2.791	4.853	46.580	48.788	54.136
2008	1.818	2.532	4.410	42.842	44.889	49.853
2009	1.724	2.402	4.186	40.845	42.804	47.554
2010	1.710	2.383	4.154	40.633	42.584	47.317
2011	1.747	2.435	4.246	41.629	43.630	48.485
2012	1.774	2.472	4.309	42.155	44.179	49.089
2013	1.757	2.448	4.267	41.657	43.656	48.503
2014	1.830	2.550	4.443	43.332	45.409	50.446
2015	1.841	2.564	4.469	43.593	45.683	50.750
2016	1.841	2.564	4.467	43.527	45.613	50.669
2017	1.870	2.605	4.538	44.177	46.292	51.421
Mean	1.808	2.518	4.386	42.631	44.670	49.613

Note: This table shows the mean of the estimated IPP_p s, calculated by equation (10), with the bp unit (0.01%) in each year. p denotes the official default probability under the risk-neutral measure.

For Italian banks in 2007, the average estimate of the default probability was 0.02% with a maximum of 0.1% (De Lisa, Zedda, Vallascas, Campolongo and Marchesi, 2011). Thus, the DI premium should not be calculated using too high a default probability.

In view of the above discussion, we suggest that the DI premium should be reduced for banks that fully obey the financial supervisory regulations and do an excellent job in keeping their risks low. The restriction of the official default probability has to be considered in a DI valuation model if one wants to obtain a reasonable DI premium for these banks. Doing so incentivizes them to decrease their likelihood of default by strictly implementing the Basel Accords and strengthening their internal controls.

C. The MPS method for determining the DI premium based on our model

Since the FDIC must make sure that adequate funds are available to protect insured depositors in the event of a bank failure, we suggest that they can use the MPS method to determine a reasonable DI premium based on changes in the financial environment. We define the DI surplus as the difference between the bank's total DI premium income and total loss given default. The estimated loss for defaulted banks was obtained from the FDIC report. In the following expressions of the estimated loss, the premium income and the DI surplus, the dollar amounts are in thousands. Table 4 gives the information on defaulted banks reported by the FDIC for each year from 1999 to 2017. Across the 19 years, the total number of defaulted banks was 581. The accumulated estimated loss until 2017 was $75,802,641. For each year, we calculated the default ratio, that is, the total number of banks divided by the number of defaulted banks. As shown in the table, the maximum default rate was 2.05% in 2010. The maximum loss was $26,957,643 in 2009.

The total premium income was obtained by summing each bank's individual DI premiums, calculated by multiplying its deposit value by its corresponding implied *IPP*. Using the MPS method, we define a critical official default probability such that the DI surplus is the lowest positive value (almost break-even). The implied *IPP* is calculated based on the critical official default probability and our formula. Table 5 shows that the reasonable critical official default probability should be set to 2.29% for the entire sample based on the MPS method. Accordingly, for all 19 years, the mean of the implied IPP_p is 5.233bp, the total premium income is $75,804,937, the expected loss is $75,802,641, and the DI surplus is $2,295.56. If the IPP_p determined by the critical official default probability, the DI surplus should be almost break-even. Accordingly, the FDIC can ensure DI funds adequately cover the losses caused by bank failures.

Our model can be used to determine the critical official default probability given various financial environments. In table 5, we give the analyses for the critical official default probability and IPP_p for the sub-periods of the subprime mortgage crisis. We divide the sample period into three sub-periods: Before Crisis, During Crisis, and After Crisis. Before Crisis is defined as the period from 1999 to 2007 (9 years); During Crisis is defined as the period from 2008 to 2010 (3 years); After Crisis is defined as the period from 2011 to 2017 (7 years).

TABLE 4. Statistics for defaulted U.S. banks from 1999 to 2017

Year	Estimated Loss in 2017	Number of Defaulted Banks	Number of Total Banks	Calculated Defaulted Rate
1999	590,861	8	10,208	0.08%
2000	32,538	7	9,886	0.07%
2001	292,465	4	9,607	0.04%
2002	415,314	11	9,351	0.12%
2003	62,646	3	9,175	0.03%
2004	3,917	4	8,974	0.04%
2005	0	0	8,831	0.00%
2006	0	0	8,676	0.00%
2007	161,851	3	8,531	0.04%
2008	18,160,993	30	8,296	0.36%
2009	26,957,643	148	7,996	1.85%
2010	16,359,499	157	7,645	2.05%
2011	6,617,073	92	7,349	1.25%
2012	2,461,603	51	7,079	0.72%
2013	1,247,973	24	6,807	0.35%
2014	392,245	18	6,507	0.28%
2015	866,542	8	6,181	0.13%
2016	47,114	5	5,909	0.08%
2017	1,132,364	8	5,669	0.14%
Sum	75,802,641	581	152,677	Mean=0.402%

Note: The sample period was from 1999 to 2017, 19 years total. The second to fourth columns give the estimated losses in 2017 (dollar amounts in thousands) due to the bank was bankrupt, the number of defaulted banks (including failures and assistance transactions), and the number of total banks in each year. These data were directly obtained from the FDIC. The fifth column shows the default rate, calculated by dividing the third column by the fourth column.

As shown in table 5, in the sub-period Before Crisis, the critical official default probability was 0.27%, the mean value of IPP_p was 0.360bp, the total premium income was \$1,560,083, the total estimated loss was \$1,559,592, and the DI surplus was \$491.13. However, in the During Crisis sub-period, the critical official default probability sharply increased because of the sharp increase in the total estimated loss for the defaulted banks. During this period, because the total estimated loss was \$61,478,135, the critical official default probability was 7.07%. Accordingly, the mean value of IPP_p was 25.114bp, the total premium income was \$61,478,812, and the DI surplus was \$677.14. The critical official default probability can decline if the problems of a financial crisis are resolved. In the sub-period After Crisis, the critical official default probability was 0.40%, the mean value of IPP_p was 0.583bp, the

TABLE 5. Analyses of the minimum official default probability with respect to the 2007 financial crisis

Period	Official Default Probability	Mean of *IPP*	Total Premium Income	Total Estimated Loss	Surplus
All sample	2.29%	5.233	75,804,937	75,802,641	2,295.56
Before Crisis	0.27%	0.360	1,560,083	1,559,592	491.13
During Crisis	7.07%	25.114	61,478,812	61,478,135	677.14
After Crisis	0.40%	0.583	12,765,110	12,764,914	196.00

Note: The first column shows the period. Before Crisis is defined as the period from 1999 to 2007, 9 years total; During Crisis is defined as the period from 2008 to 2010, 3 years total; After Crisis is defined as the period from 2011 to 2017, 7 years total. The second column shows the critical official default probability, defined as the IPP_p critical value under the assumption that the FDIC's surplus is the minimum positive value (i.e., the MPS method). The third to fifth columns show the total premium income, the total estimated losses, and the FDIC's surplus (dollar amounts in thousands). For each bank, the DI premium is calculated by multiplying its deposit value by its corresponding IPP_p, using our formula based on the critical official default probability. The FDIC's total premium income is the sum of the individual banks' DI premiums. The total estimated losses for the defaulted banks were obtained from the FDIC report, as shown in table 2. The surplus is the difference between the total premium income and the estimated loss.

total premium income was $12,765,110, the expected loss was $12,764,914, and the DI surplus was $196.

V. Discussion and suggestions

To ensure DI funds adequately cover the losses caused by bank failures, it has usually been suggested, especially after the subprime mortgage crisis, to increase the DI premium. However, our argument differs from this suggestion. We argue that the bank's DI premium is overestimated because the bank's expected default probability is assumed too high. We support the following discussions related with our arguments.

Use of a high expected default probability to determine the DI premium, can be observed in many countries. A high DI premium may be caused by two main reasons: designating a reserve ratio for the Deposit Insurance Fund and raising the DI premium to cover high auditing costs. For the first reason, numerous countries set a target ratio (i.e., the Designated Reserve Ratio, DRR)[6] for the Deposit Insurance

6. DRR is the reserve ratio of a bank's exposure to insured deposits. The Dodd-Frank

Fund (DIF) at the fixed ratio for insured deposits, because the DI Corporation's funds come mainly from the DI premiums collected and supported by the government. Financial supervisors believe that ensuring an adequate DIF is likely to help them stabilize the financial environment, because financial institutions expect to be bailed out if they are on the brink of failure. Thus, a higher DI premium is used to rapidly accumulate sufficient funds to cover the large bank's losses caused by the failure or systemic collapse. For the second reason, financial supervisors believe that a strict financial monitor, including both internal and external auditing mechanisms, is important for reducing possible default risks. The DI Corporation usually plays an important role in external audits. It is believed that when DI premiums are high, the DI Corporation can increase the quality of its external audits.

However, we support some arguments for the above two reasons. As for the first reason involving the DIF reserves, we provide the following opinions: First, it is impossible to obtain sufficient DIF reserve funds from DI premiums in a short period of time. Second, a higher DI premium reduces the bank's available fund and thus decreases the bank's revenues. Third, it is unfair to banks currently participating in the DI system because they must pay a higher DI premium for burdening the possible default losses for other banks, possibly participating in the DI system in future. Fourth, when a government guarantees the DIF, the insolvency risk is likely to be shifted from the troubled banks to the deposit insurance agent, then to the government, and finally to the taxpayers. In view of the above reasons, there seem to be problems no matter whether the DIF reserve is funded from DI premiums or by the government.

Thus, to avoid the plight of an insufficient DIF, we provide two suggestions. First, the DI Corporation should consider multiple capital sources for funding an adequate DIF. For example, the DIF reserve can be funded by issuing a special bond for investors. This method has been implemented in some countries, such as Japan, Korea and Singapore.[7] With such a bond the payoff is related to the probability of the bank defaulting. It is similar to the idea behind catastrophe bonds or collateralized debt obligation (CDOs). Clearly, if there is no bank

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act establishes a minimum DRR of 1.35%. The FDIC's Board adopted a set of progressively lower assessment rates (i.e., *IPP*s) when the reserve ratios exceed 2.0% and 2.5%.

7. Retrieved from http://www.cdic.gov.tw/public/Attachment/0849263471.pdf.

default, the investor who buys such bond earns the interest paid by the DI premium. However, if the bank defaults before the bond fully matures, the investors are likely to suffer losses, because they must cover them. Using catastrophe bonds or CDOs can not only increase the number of capital sources, thereby greatly decreasing the financial burden on the DI Corporation and the government, but it also transfers the risk of targeting DIF reserves to investors outside the banking industry, thereby improving the stability of the banks.

Second, the FDIC can dynamically adjust the DI premium according to the level of the DIF reserves, because a bank's default decreases its DIF reserves. More specifically, the FDIC can set a minimum official default probability to determine the IPP_p for each bank if the DIF reserves are sufficient in the current year. However, if the DIF reserves fall below the target for the DRR in that year, the FDIC can consider resetting the official default probability to adjust the IPP_p for each bank for the next year. Our model can help the FDIC achieve this objective.

We show below how our model can be used to make the dynamic adjustment. To begin with, we assume the FDIC has enough DIF reserves in advance. The current DIF reserves equal the DIF reserves in the previous year plus the cumulative DI surplus. We assume FDIC uses the dynamic MPS method to determine the *IPP*. If the cumulative DI surplus for the current year is greater than zero, we let the critical official default probability be 0.1%. If the cumulative DI surplus is less than zero in the current year, we use our model to estimate a new critical official default probability that can cover the current negative cumulative DI surplus based on the bank's data (i.e., assets, liabilities, and deposits) in the current year. Then, we use this new official default probability to calculate the next year's DI premium for each bank. Thus, if FDIC adopts the dynamic MPS method, it can help them determine the reasonable DI premium and maintain the target level of DIF reserves.

Table 6 gives a statistical summary for the IPP_p calculated using the dynamic MPS method. Table 7 gives the calculated results for the critical official default probability, DI premium income, loss, and the cumulative DI surplus for each year. For example, in 1999, the critical official default probability was 0.1%. As shown in table 6, the IPP_p mean, standard deviation, minimum value, median value, and maximum value are 0.109bp, 0.125bp, 0.017bp, 0.085bp, and 3.064bp, respectively. Accordingly, table 7 shows that the total DI premium income in 1999 was $34,999. However, the estimated loss in this year

TABLE 6. Summary of estimated DI premiums using the dynamic MPS method

Year	Official Default Probability	Estimated *IPP*				
		Mean	Std	Min	Median	Max
1999	0.10%	0.109	0.125	0.017	0.085	3.064
2000	1.10%	2.003	1.984	0.303	1.601	41.228
2001	0.10%	0.110	0.120	0.010	0.088	2.482
2002	0.40%	0.569	0.545	0.049	0.465	9.818
2003	0.60%	0.944	0.944	0.034	0.765	18.110
2004	0.10%	0.115	0.129	0.024	0.091	2.451
2005	0.10%	0.118	0.137	0.015	0.091	2.897
2006	0.10%	0.123	0.144	0.031	0.093	2.249
2007	0.10%	0.127	0.146	0.010	0.095	2.758
2008	0.10%	0.114	0.117	0.001	0.092	2.790
2009	7.30%	25.196	18.315	0.017	21.973	341.578
2010	7.50%	26.085	17.766	0.257	23.192	318.176
2011	5.30%	16.051	10.291	0.461	14.498	208.649
2012	2.40%	5.479	4.120	0.017	4.895	81.936
2013	1.10%	1.981	1.747	0.063	1.743	35.045
2014	0.70%	1.174	1.033	0.044	1.028	20.986
2015	0.30%	0.422	0.383	0.046	0.368	8.715
2016	0.40%	0.596	0.557	0.059	0.517	11.359
2017	0.10%	0.117	0.117	0.016	0.101	2.613

Note: The second column shows the critical official default probability using the dynamic MPS method. The IPP_p is calculated by the determined critical official default probability and our formula. The third to sixth columns show the mean, standard deviation, minimum value, median value, and maximum value for the estimated IPP_p for each year.

was \$590,861 and the cumulative DI surplus was \$–555,862. Thus, we use the MPS method to reset the critical official default probability and recalculate the IPP_p to cover this negative cumulative DI surplus. Accordingly, in 2000, the critical official default probability was 1.10%. Then we recalculated the IPP_p for each bank based on this new critical official default probability. Accordingly, the total DI premium income becomes \$703,353. This income covers the negative cumulative DI surplus of \$–555,862 in 1999. However, the loss was \$32,538 in 2000. Thus, the cumulative DI surplus was \$114,953. Since the cumulative DI surplus is a positive value, again for 2001 the FDIC could reset the critical official default probability to 0.1%.

Our model can be applied to effectively reflect changes in the financial situation. For example, from 2004 to 2007, because the default rates were relatively low, the critical official default probability can be set to the minimum level (i.e., 0.1%). However, from 2009 to 2012, the

TABLE 7. Summary for DI premium using the dynamic MPS model

Year	Official Default Probability	Mean of *IPP* (bp)	Total Premium Income	Total Estimated Loss	Cumulative Surplus
1999	0.10%	0.109	34,999	590,861	–555,862
2000	1.10%	2.003	703,353	32,538	114,953
2001	0.10%	0.110	43,081	292,465	–134,431
2002	0.40%	0.569	245,350	415,314	–304,396
2003	0.60%	0.944	425,456	62,646	58,414
2004	0.10%	0.115	60,035	3,917	114,532
2005	0.10%	0.118	65,194	0	179,726
2006	0.10%	0.123	72,584	0	252,311
2007	0.10%	0.127	77,974	161,851	168,434
2008	0.10%	0.114	76,960	18,160,993	–17,915,599
2009	7.30%	25.196	22,410,962	26,957,643	–22,462,281
2010	7.50%	26.085	24,574,008	16,359,499	–14,247,772
2011	5.30%	16.051	15,890,607	6,617,073	–4,974,237
2012	2.40%	5.479	5,647,402	2,461,603	–1,788,439
2013	1.10%	1.981	2,113,113	1,247,973	–923,299
2014	0.70%	1.174	1,254,959	392,245	–60,585
2015	0.30%	0.422	465,648	866,542	–461,480
2016	0.40%	0.596	689,974	47,114	181,380
2017	0.10%	0.117	139,738	1,132,364	–811,246

Note: The second and third columns show the critical official default probability and the mean value of *IPP*, as shown in table 6. The fourth to sixth columns show the total premium income, the total estimated losses, and the FDIC's surplus (dollar amounts in thousands). For the calculation of total DI premium income, see table 5. As for the value of total estimated loss, see the second column in table 4. The cumulative DI surplus equals the cumulative DI surplus in the previous year plus the DI premium income minus the estimated loss in the current year.

estimated loss in the previous year was quite large due to the financial crisis. Thus, when determining the IPP_p for each bank during this period, the critical official default probability can be set to a higher value: 7.30% for 2009, 7.50% for 2010, 5.30% for 2011, and 2.40% for 2012. Accordingly, the mean IPP_p s for 2009, 2010, 2011 and 2012 are 25.196bp, 26.085bp, 16.051bp, and 5.479bp, respectively. Table 6 shows that although the largest negative cumulative surplus occurred in 2009, the dynamically adjusted IPP_p leads to the cumulative surplus gradually increases form year to year, and in 2016 it is again positive. Therefore, the critical official default probability for 2017 can be reset to 0.1% and the mean IPP_p declines to 0.117bp. According to our estimates for the critical official default probability, the FDIC can adjust it in such a way as to achieve and maintain the target DI surplus level.

For the auditing costs, we argue that it is unreasonable to raise the DI premium to cover auditing costs, because these costs are different than insurance fees. Audit costs should be treated as servicing fees, like a corporation's costs for performing an audit that is certified by a certified public accountant. No bank should bear the burden of paying for a default caused by other banks. Each bank should have its own auditing costs, and how much it should be charged depends on how much time the DI Corporation spends auditing it.

Currently, to reduce the likelihood of default in advance, many countries conduct standard external audits at fixed intervals (e.g., once or twice a year). A higher monitoring frequency for the DI Corporation is necessary and useful for reducing the bank's default probability, but it is likely to lead to high audit costs for banks with good credit quality and could harm the efficiency of the bank's operations. A suitable way to solve this problem is to construct a risk-based audit rating system. The frequency and type of audit to be conducted depend on the bank's risk grading indicator. Employing such a system can make the audit more effective and thereby uncover problems in a timely fashion, thus minimizing losses resulting from a bank going bankrupt. Also, it is important to identify troubled financial institutions at an early stage and to effect prompt corrective action.

The other advantage of doing risk-based audit rating system is that the DI risk-shift problem is minimized, because no bank must incur any part of the auditing costs resulting from the actions of other banks with bad credit ratings. Furthermore, the risk-taking incentive is likely to be reduced, and the incentive for better internal supervision strengthened, because good financial supervision and risk management is likely to decrease the frequency of, and thereby greatly reduce the costs of, audits to the banks.

A high DI premium can lead to the following problems. First, it creates a high cost of capital for the bank, resulting in an increase in loan rates, which in turn shrinks its investments. Some previous studies also prove that a high DI premium is likely to reduce the bank's competitiveness and retard its overall economic growth (see, Pennacchi, 1999). Second, a higher DI premium affects the willingness of banks to take moral hazard risks. Cooper and Ross (2002) found that having full deposit insurance does not give depositors adequate incentive to monitor bank's investment and encourages banks to invest in excessively risky projects. Accordingly, we argue that the DI

Corporation should charge a fair DI premium calculated from a reasonable model. Charging banks a fair DI premium and a fair auditing fee can be expected to increase their incentive to rigorously implement the financial supervisory rules and meet the internal control requirements for reducing their credit risk.

VI. Conclusion

In this paper we have proposed a new concept for valuating DI premiums. To the best of our knowledge, ours is the first model for valuating a DI premium that takes account of the official default probability and provides a new method for calculating DI premiums without estimating asset risk by market equity data. Thus, the estimates obtained by our method should be more accurate than those obtained by the traditional method, because the specification in our model is more reasonable, and errors in estimating the asset risk can be avoided.

Through a numerical example using data from the FDIC, we show that the average DI premium was only 0.114bp from 1999 to 2017, given the bank's official default probability of 0.1%. Based on the results of our model, it shows that the DI premium currently required by the FDIC is determined under the assumption that the official default probability ranges from 1.3% to 10.3%. Using our MPS method, the reasonable official default probability and the implied IPP_p should be respectively 2.29% and 5.233bp for all samples. Moreover, our model can be used to flexibly determine the IPP_p given multiple financial environments. We show that the average implied IPP_p s are 0.360bp, 25.114bp, and 0.583bp for the periods before (1999 to 2007), during (2008 to 2010), and after (2011 to 2017) the 2007 financial crisis, respectively.

It has usually been suggested that after sub-prime mortgage crises the DI premium should be increased to ensure an adequate DIF and cover the high audit costs to improve the quality of the DI Corporation's external auditing. To maintain a sufficient DIF reserve, we suggest that the FDIC consider multiple capital sources for funding an adequate DIF. In addition, the FDIC can use the MPS method to dynamically adjust the *IPP* for achieving and maintaining the target DI surplus level. As for the auditing fees, we suggest that they be charged at auditing time, the amount determined by the bank's credit risk.

Most banks obey the financial regulations to avoid the likelihood of default. These banks increase their internal control mechanisms and implement the financial regulations (i.e., Basel Accords), but doing so may increase their management costs. Charging banks a fair DI premium and a fair auditing fee can be expected to increase their incentives to rigorously implement the financial supervisory rules and meet the internal control requirements for reducing their credit risk, thereby decreasing their DI premium and their auditing costs. Financial supervisors should project a positive attitude to encourage these banks to continue such behavior. However, charging a higher DI premium to banks with good credit quality is likely to be counterproductive in terms of such behavior. Therefore, we suggest that banks with good credit quality strengthen their incentives to continue aiming for lower DI premiums. Our model supports a practical and reasonable theory on how to implement this suggestion.

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