Revisiting the Valuation of Deposit Insurance

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Abstract

This paper proposes a framework for pricing deposit insurance in which we take the national depositor preference law of 1993, the issuance of reverse convertible bonds, and other factors into consideration. We argue that using the traditional option pricing models for valuing deposit insurance, based on the U.S. Banking Act of 1935, assume that all debts are of equal liquidation priority and hence result in mispricing insurance premiums. For considering the national depositor preference law and the reverse convertible bonds, our proposed model assumes that depositors and the Federal Deposit Insurance Corporation have first priority claims over residual assets in liquidation. We demonstrate that our proposed model can nest the traditional option pricing models for valuing deposit insurance on one hand. Additionally, on the other hand, our empirical results reveal that the traditional deposit insurance pricing models overestimate insurance premiums. Moreover, we show that the traditional models overestimate insurance premiums for larger banks more than they do for smaller banks in our study period.

Keywords: Deposit Insurance, Depositor Preference, Reverse Convertible Bonds

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1. Introduction

Deposit insurance is an important scheme that countries implement to stabilize the financial system. In the absence of deposit insurance, depositors rush to withdraw their funds from the bank because they predict the bank to fail during a bank crisis. An introduction of deposit insurance makes deposits equally risk-free across banks and withdrawals are unnecessary in a panic with bank failures. For the consideration of fair pricing, the Federal Deposit Insurance Corporation Improvement Act of 1991 (FDICIA) required the Federal Deposit Insurance Corporation (FDIC) to assess a risk-adjusted premium system. Since then, the deposit insurance premiums are priced according to risk.

While the risk-adjusted deposit insurance is more equitable and more efficient than the fixed-rate premiums, it has been that accurately quantifying the riskiness of each insured bank is difficult. Recent developments have further contributed to an increasing dissatisfaction with the pricing of deposit insurance. First, in 1993, the U.S. Congress passed the Omnibus Budget Reconciliation Act and adopted the national depositor preference.[2] Provisions of the legislation change the priority ordering of claims by domestic depositors and the FDIC in the resolution of insolvent banks. The law provides domestic depositors and the FDIC claims that are superior to those of foreign depositors and general creditors. By raising the priority, the FDIC may reduce costs in the resolution process that were estimated to be nearly $750 million over the 5 years after the law was enacted (Kaufman, 1997). Consequently, the FDIC could, in principle, charge lower deposit insurance premiums to financial institutions.

Moreover, deposit insurance premiums are unlikely to reflect the true cost of the government's guarantee because regulators face constraints that limit their ability to

[2] Before 1993, depositor preference laws were already effective in some states for state chartered banks. For example, Hirschhorn and Zervos (1990) report that at the end of 1987, 23 states had depositor preference laws for banks and eight states had them for thrift institutions.

discriminate between banks having different risks of failure (Stiglitz, 1993). Pennacchi (2010) claims that the reverse convertible bond (RCB), a bank issue subordinated debt that automatically converts to new shareholders' equity when the value of its original shareholders' equity declines, can eliminate the possibility of default so that reduce the mispricing of the catastrophic loss piece. After the global financial crisis of 2008-2009, the RCBs have become an important source of financing for banks. However, few studies have considered this factor in the pricing of deposit insurance.

In this article, we attempt to analyze the impact of the national depositor preference law and the RCBs on the pricing of deposit insurance. The model utilized in this paper is an application of the option pricing framework. Empirical estimation of risk and the premium of deposit insurance is tractable in our model when time series data on the bank's equity and debt are available.

As shown by Merton (1977), deposit insurance is identical to the price of a put option written on the underlying assets of banks with a strike price that is equal to its liabilities and a maturity that is equal to the length of time until the next audit. Thus, it allows for the application of Black–Scholes option pricing methods (e.g., Merton, 1978; Marcus and Shaked, 1984). The option pricing framework for the pricing of deposit insurance is testable. For example, Marcus and Shaked (1984) and Ronn and Verma (1986) empirically test the mispricing of insurance premiums using Merton’s (1977) model. Using a different approach, Duan (1994, 2000) develops a maximum likelihood method to estimate insurance premiums under the option pricing framework.

Buser et al. (1981), Ronn and Verma (1986), and Duan et al. (1992) argue that the FDIC may not close a bank even if the bank is insolvent by market standards. The FDIC might be willing to allow such banks to continue operations to avoid bankruptcy costs in the resolution process. They consider the capital forbearance policy of the FDIC by adjusting the exercise price of the option. Furthermore, Allen and Saunders (1993) model deposit insurance as a callable perpetual American put option with consideration of both self-closure rules and regulatory closure policies. Hwang et al. (2009) further modify Allen and Saunders's model by introducing bankruptcy costs.

Brockman and Turtle (2003) argue that corporate security is a path-dependent option and the presence of a barrier level results in the termination of the option. After the FDICIA of 1991, federal banking regulators were required to undertake prompt corrective action for critically undercapitalized banks. Therefore, the FDIC has the power to close a bank when it becomes insolvent before maturity and deposit insurance can be considered a barrier option. Episcopos (2008) and Hwang et al. (2009) consider a continuous default triggering boundary and apply a barrier option framework to the pricing of deposit insurance.

Acharya et al. (2010) and Lee et al. (2015) show the importance of joint bank failure risk in pricing deposit insurance. They suggest that the systematic risk cannot be diversified by pooling individual bank failure risk together. Therefore, the cost of the FDIC should be higher than that implied by actuarially fair premiums.[3]

However, these models assume that at the time of failure, holders of deposits are entitled to a prorated fraction of the asset values with all debt holders, implying that these models assume all debts are of equal liquidation priority (e.g., Ronn and Verma, 1986). The assumption of equal liquidation seniority in the theoretical models is reasonable before 1993 because the U.S. Banking Act of 1935 gave the same priority for a failed bank's residual assets to all depositors and other general creditors.

[3] Another framework for the pricing of deposit insurance is the reduced-form structure (e.g. Duffie et al., 2003). However, the primary focus of reduced-form models of default is not the determination of capital structure. Therefore, we do not focus our analysis on the reduced-form model.

However, after the national depositor preference law was enacted in 1993, this assumption seems unreasonable for the pricing of deposit insurance because the FDIC is given preference over foreign depositors and other creditors in liquidation.

National depositor preference entails four implications for the FDIC. First, it can reduce the FDIC's resolution costs for failed banks because it elevates the FDIC's priority for claims (Hirschhorn and Zervos, 1990). Second, foreign depositors or general creditors, who have been adversely affected by the law, are likely to take protective actions; they can improve their standing by collateralizing their claims. Therefore, such creditors' actions may partially offset the cost reductions of the FDIC achieved through the law (Marino and Bennett, 1999). Third, nondeposit creditors may be expected to intensify the monitoring of the banks. Thus, the law has increased the role of nondeposit creditors in providing market discipline (Kaufman, 1997). These actions may reduce the risk of banks and, by implication, the FDIC's resolution costs. Finally, the law has a greater effect on large banks because they rely proportionately more on funding through foreign deposits and other liabilities than smaller banks (Kaufman, 1997; Marino and Bennett, 1999).

By ignoring the national depositor preference law, the conventional pricing models of deposit insurance may overestimate assessment premiums and thus reducing its utility. For example, during 1996–2006, most banks were classified in the lowest risk category and were not charged deposit insurance premiums by the FDIC.[4] Because the conventional pricing models do not consider depositor preference, they, on average, overestimate the premiums of deposit insurance during that period.[5] According to Kaufman (1997) and Marino and Bennett (1999), the extent to which

[4] Refer to the FDIC website: https://www.fdic.gov/deposit/insurance/assessments/priorperiod.html.

[5] Another reason that most banks paid no deposit insurance is that the Deposit Insurance Fund reserves exceeded 1.25% of the insured deposits during 1996–2006. According to the Deposit Insurance Act of 1996, the FDIC is prohibited from charging insurance premiums to banks in the lowest risk category.

different types of banks are affected by the national depositor preference law is different. Therefore, risk-based premiums from the traditional models do not accurately reflect the risk of the insured bank. If depositor preference is not priced in the model, banks may skew their asset choice in response to the mispricing of deposit insurance.

Moreover, traditional models assume that the FDIC closes a bank if the market value of the bank's asset is lower than the total debt liabilities. However, when a bank issues RCBs, the bonds can be automatically converted to equity share when the bank's asset falls below a threshold. Therefore, the closure point of the bank should be adjusted when the RCBs are considered.

The proposed conceptual framework can be expressed in the closed form, which is an extension of Black–Scholes option pricing methods. In the proposed framework with depositor preference, at the time of failure, holders of deposits and the FDIC have first priority claims over residual assets after paying the administrative expenses of receivers. The FDIC is entitled to a prorated fraction of the asset values with all depositors. Next, with considering the issuance of RCBs, the closure point should be adjusted as the total debt liabilities other than RCBs at maturity. In addition, we further consider other factors such as the regulatory forbearance, bankruptcy costs, and direct assistance costs into account. Using the concept of Brockman and Turtle (2003), we can easily extend our pricing model to a barrier option framework.

Our deposit insurance model can be compared with that of Ronn and Verma (1986) through the use of the fairly-priced premium rate. Because of the new priority of the FDIC, the insurance premium under the Ronn and Verma (1986) model is always greater than that of the proposed model. The overestimates are particularly for banks with low deposit-to-debt ratios, low asset volatilities, and high asset-to-debt ratios. Under some conditions, the FDIC does not need to pay anything in the proposed model even if the bank is insolvent, suggesting that the national depositor preference law protect the FDIC from the risk of bank failure.

Furthermore, the practice of capital forbearance was criticized by Kane (1987) and Kaufman (1987) among others. They argued that capital forbearance encourages troubled banks to engage in excessive risk-taking. Our model shows that the issuance of RCBs can decrease the failure probabilities of the banks when the FDIC permitted the troubled banks to remain open. To prevent the RCBs convert to shareholders' equity, banks may restrain excessive risk-taking. However, the proposed model also reveals that the RCBs can decrease the deposit insurance premiums only when the issuance of RCBs is large. In other words, issuance of RCBs should large enough to cover the shortfall of the FDIC's potential loss in the insolvency of the bank.

Using a large sample, we calculate deposit insurance premiums in the Ronn and Verma (1986) model and our proposed model for 1,260 banks and 21,390 bank-quarter observations. A comparison of the estimated premiums between the two models reveals that, on average, the Ronn and Verma model overestimates deposit insurance premiums by five times during our sample period.[6] Moreover, the Ronn and Verma model tends to overestimate premiums for larger banks more than it does for smaller banks because these banks rely more on funding through foreign deposits and other debts. The results are consistent with those of previous studies, such as Hirschhorn and Zervos (1990) and Marino and Bennett (1999).

The remainder of the paper is organized as follows. Section 2 summarizes the analytical framework of the Ronn and Verma (1986) model to provide the necessary background for subsequent sections. Section 3 describes the development of the proposed model for accurately estimating deposit insurance premiums; the numerical

[6] Our estimations ignore the administrative expenses of the receiver. Therefore, the actual overestimation by the Ronn and Verma model may be lower than that reported.

results for the properties of deposit insurance identified in our model are also included in this section. Section 4 discusses our data set and the estimation methodology. Section 5 presents the empirical results. Section 6 provides the conclusions and implications.

2. Notation and the benchmark Ronn and Verma (1986) model

The following notation is employed:

$V =$ the unobserved post-insurance value of a bank's assets,

$B_1 =$ the value of total deposits,

$B_2 =$ the value of all debt liabilities other than total deposits,

$B_{RCB} =$ the value of reverse convertible bonds (RCBs),

$B = B_1 + B_2 =$ the value of total debt liabilities,

$B' = B - B_{RCB} =$ the value of all debt liabilities other than RCBs,

$T =$ time until the next audit of the bank's assets,

$\sigma_v =$ the instantaneous standard deviation of the rate of return on the value of the bank's assets,

$\delta =$ the percentage dividend yield of the assets,

$FV_t(x) =$ the future time t value of x.

In his seminal deposit insurance pricing model, Merton (1977) assumes that banks issue only deposits (i.e., $B_2 = 0$). Ronn and Verma (1986) extend Merton's (1977) model by allowing all debt liabilities other than total deposits. Like Merton (1977), they assume that debt maturity (corresponding to the maturity of deposit insurance) is the length of time until the next audit of the bank's assets. Moreover, they assume that all pre-insurance debt is of equal seniority. Under this assumption, deposit holders receive the future value of their deposits $FV_T(B_1)$ if the bank is solvent (i.e., $V_T > B_1 + B_2$), or their proportional share of the terminal value of the bank's assets $V_T B_1 / (B_1 + B_2)$ otherwise. When the bank is insolvent, the FDIC pays the insured depositors the difference of $FV_T(B_1)$ and $V_T B_1 / (B_1 + B_2)$. Thus, the maturity value of deposit insurance is given as follows:

$$\max\left\{0, FV_T(B_1) - \frac{V_T B_1}{B_1 + B_2}\right\}. \quad (2)$$

Moreover, Ronn and Verma (1986) adopt the standard assumptions of the Black–Scholes option pricing model. Thus, the total dollar value of the deposit insurance premium (IP) can be derived by applying the expectation of Eq. (2) under the risk-neutral measure and discounting it using the risk-free rate as follows:

$$IP = B_1 N(-d_2) - e^{-\delta T} V \frac{B_1}{B} N(-d_1), \quad (3)$$

where *N(.)* denotes the cumulative probability distribution function for a variable with a standard normal distribution, $d_1 = \dfrac{\ln(V/B) - \delta T + \sigma_v^2 T / 2}{\sigma_v \sqrt{T}}$ and $d_2 = d_1 - \sigma_v \sqrt{T}$.

Dividing both sides of Eq. (3) by B_1,[7] we obtain the insurance premium per dollar of insured deposits (IPP_{RV}) as follows.

Ronn and Verma (1986) model

Under the Ronn and Verma (1986) model, the insurance premium per dollar (IPP) of insured deposits is expressed as follows:

$$IPP_{RV} = N(-d_2) - e^{-\delta T} \frac{V}{B} N(-d_1). \quad (4)$$

The total dollar value of the deposit insurance premium in the Ronn and Verma (1986) model is a fraction (B_1/B times) of that in the Merton (1977, Eq. (4)) model because all debts are of equal seniority and the FDIC provides guarantees (insurances)

[7] The total dollar value of the deposit insurance premium charged by the FDIC equals the assessment base multiplied by the assessment rate. Because the FDIC defines the assessment base as domestic deposits (with minor adjustments), the IPP of insured deposits should be divided by domestic deposits and not by total deposits B_1.

on only a portion of the debt liability (i.e., the deposits); thus, the insurance value in the Ronn and Verma (1986) model is B_1/B times that in the Merton (1977) model. Moreover, the *IPP* of insured deposits in the Ronn and Verma (1986) model is consequently identical to that in the Merton (1977, Eq. (6)) model; however, the Merton model does not consider the dividend yield of the assets.

3. Proposed deposit insurance pricing models

In this section, we develop deposit insurance pricing models under a standard option valuation method and a barrier option approach by incorporating several important factors that are not considered in the literature. To start with, we consider the effect of the national depositor preference law on deposit insurance valuation. Next, we extend the pricing models by considering RCB issuance and other factors, including the regulatory forbearance, bankruptcy costs, assistance costs, and the early closure policy. Finally, some crucial implications and properties of the proposed pricing models are discussed in this section.

3.1. Pricing deposit insurance using standard option valuation models

Previously, federal and state laws often set different priorities for payments of receivership claims allotted when a bank failed. However, the Omnibus Budget Reconciliation Act of 1993 includes provisions that establish a uniform order for distributing the assets of failed insured financial institutions. According to the national depositor preference law of 1993, depositors have first priority claims over residual assets, after paying the administrative expenses.[8] The law is intended to reduce the

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[8] According to the national depositor preference law (Section 3001 of the Omnibus Budget Reconciliation Act of 1993), "...amounts realized from the liquidation or other resolution of any insured depository institution by any receiver appointed for such institution shall be distributed to pay claims (other than secured claims to the extent of any such security) in the following order of priority:
(i) Administrative expenses of the receiver.
(ii) Any deposit liability of the institution.
(iii) Any other general or senior liability of the institution (which is not a liability described in clause

FDIC's resolution costs, thereby decreasing deposit insurance premiums.[9]

Similar to Merton (1977) and Ronn and Verma (1986), we regard deposit insurance as a European put option written by the FDIC. In other words, in the event of bank insolvency (i.e., $V_T < FV_T(B)$), depositors have first priority claims, and if the residual assets are not sufficient to cover the future value of deposits at the maturity date, the shortfall of the insured deposits would be paid by the FDIC. Thus, the FDIC's liability at maturity under the national depositor preference law is as follows:

$$\begin{cases} \max[\lambda(FV_T(B_1) - V_T), 0], & V_T < FV_T(B), \\ 0, & \text{otherwise}, \end{cases} \tag{5}$$

where λ is the ratio of insured deposits to total deposits (B_1).[10] A comparison of the payoff functions in Eqs. (2) and (5) highlights two major differences between our model and the Ronn and Verma (1986) model. First, in contrast to their model, we do not assume that all deposits are insured (i.e., λ may be equal to or less than 1 in our model). Second, consistent with the national depositor preference law, we allow depositors to have first priority claims over residual assets when a bank fails.

Eq. (5) illustrates that the FDIC's liability at maturity is significantly reduced under the national depositor preference law, particularly when the value of all debt liabilities other than total deposits (i.e., B_2) is high. Thus, the deposit insurance

(iv) or (v)).
(iv) Any obligation subordinated to depositors or general creditors (which is not an obligation described in clause (v)).
(v) Any obligation to shareholders or members arising as a result of their status as shareholders or members (including any depository institution holding company or any shareholder or creditor of such company)."

9 Conducting a different analysis, Osterberg (1996) and Osterberg and Thomson (1999) extend the single-period version of the capital asset pricing model to include depositor preference. They analyze the impact of depositor preference laws on the cost of debt capital. Davis (2015) discusses this issue from different points of view.

10 Merton (1977) and Ronn and Verma (1986) assume that all deposits are insured; however, this assumption does not consider that only domestic deposits are insured and that insurance coverage is capped (currently, at $250,000).

premiums should decrease correspondingly.

Next, because of the 2008–2009 global financial crisis, RCBs have become an important source of financing for banks (Flannery, 2002; 2009). For example, Lloyds Banking Group issued £7.5 billion in RCBs in November 2009 (Hilscher and Raviv, 2014). These hybrid securities pay coupons that are similar to normal bonds but are automatically converted to ordinary shares when the equity ratio falls below a predetermined threshold. Serving as contingent capital, RCBs reduced leverage ratios and helped in alleviating the bankruptcy risk of banks during the financial crisis. Therefore, the closure point of the FDIC and deposit insurance premiums would be reduced when RCB issuance is considered. In other words, a bank is insolvent when its asset value is less than the total debt liabilities other than RCBs at maturity, $V_T < FV_T(B')$.

In addition, under practical market standards, the FDIC closes a bank if its asset value is lower than the maturity value of the total debt liabilities. However, because of regulatory forbearance for stabilizing the financial system or avoiding the bankruptcy costs inherent to bank closures, the FDIC does not always close a bank when it is insolvent according to market standards. As suggested by Kane (1986), Ronn and Verma (1986), and Duan et al. (1992), we adjust the exercise price of the option by a value ρ, where $0 < \rho < 1$, to consider the effects of closure forbearance. When both regulatory forbearance and RCBs are considered, the FDIC would close a bank when its asset value at maturity is lower than the future value of the total debt liabilities other than RCBs multiplied by the regulatory forbearance, $V_T < \rho FV_T(B')$.

Besides, the FDIC must consider bankruptcy costs in its closure rules for financial institutions (Buser et al., 1981; Allen and Saunders, 1993; Hwang et al., 2009). If k is the percentage recovery rate (thus $1-k$ is the bankruptcy cost) of a failed bank, then $0<k<1$. In the event of insolvency at the maturity date *T*, we assume that the bank's residual asset value after paying the administrative expenses equals its asset value at maturity (before the resolution of the bank) multiplied by the recovery rate, kV_T. Depositors have first priority claims over kV_T and the shortfall is paid by the FDIC.

Finally, as discussed by Ronn and Verma (1986), when the asset value of a bank ranges between the regulatory forbearance level ($\rho FV_T(B')$) and the standard market bankruptcy level ($FV_T(B')$), the FDIC is likely to provide direct assistance (e.g., an infusion of funds) to the bank. The FDIC's Failures and Assistance Transactions Report of 2017 records 592 assistance transactions from 1934 to 2017 that cost the FDIC \$1.87 billion[11]. Thus, the FDIC's direct assistance costs are not negligible and should be incorporated into deposit insurance pricing models. To include assistance costs in our model, we assume that when the asset value of banks at maturity (V_T) ranges between $\rho FV_T(B')$ and $FV_T(B')$, the FDIC infuses funds to make the value equal to $\lambda FV_T(B_1)$, if $V_T < \lambda FV_T(B_1)$.

With the setup as described above, the FDIC's liability at maturity with consideration of all of the aforementioned factors is as follows:

$$\begin{cases} \max\left[\lambda\left(FV_T(B_1)-kV_T\right),0\right], & \rho FV_T(B')>V_T, \\ \max\left[\lambda FV_T(B_1)-V_T,0\right], & \rho FV_T(B')\le V_T<FV_T(B'), \\ 0, & \text{otherwise.} \end{cases} \tag{6}$$

The deposit insurance pricing formula corresponding to Eq. (6) is stated in Model 1.

Model 1

When the national depositor preference law, RCB issuance, regulatory forbearance, bankruptcy costs, and direct assistance costs are considered, the pricing formula of

[11] Available from the FDIC's Historical Statistics on Banking website: http://www2.fdic.gov/hsob/.

the IPP of insured deposits is as follows:

$$IPP_1 = IPP_{WC} + IPP_{AC}, \tag{7}$$

$$IPP_{WC} = N(-d_4) - e^{-\delta T}\frac{kV}{B_1}N(-d_3),$$

$$IPP_{AC} = \begin{cases} \left[N(-d_6) - N(-d_8)\right] - e^{-\delta T}\dfrac{V}{\lambda B_1}\left[N(-d_5) - N(-d_7)\right], & \text{if } \rho B' < \lambda B_1, \\ 0, & \text{otherwise,} \end{cases}$$

where $d_3 = \dfrac{\ln(V/A) - \delta T + \sigma_v^2 T/2}{\sigma_v\sqrt{T}}$, $d_4 = d_3 - \sigma_v\sqrt{T}$ *, and* $A = \min\left(B_1/k, \rho B'\right)$.

$$d_5 = \frac{\ln(V/(\lambda B_1)) - \delta T + \sigma_v^2 T/2}{\sigma_v\sqrt{T}}, \quad d_6 = d_5 - \sigma_v\sqrt{T},$$

$$d_7 = \frac{\ln(V/(\rho B')) - \delta T + \sigma_v^2 T/2}{\sigma_v\sqrt{T}}, \quad \textit{and} \quad d_8 = d_7 - \sigma_v\sqrt{T}.$$

Proof: See Appendix 1.

A. The effect of the national depositor preference law for the pricing of deposit insurance

To focus on the national depositor preference law, we first exclude RCB issuance and other factors in our proposed model.

Special Case I

Without RCB issuance, regulatory forbearance, bankruptcy costs, and direct assistance costs, the IPP of insured deposits equals:

$$IPP_1 = N(-d_{10}) - e^{-\delta T}\frac{V}{B_1}N(-d_9), \tag{8}$$

where $d_9 = \dfrac{\ln(V/B_1) - \delta T + \sigma_v^2 T/2}{\sigma_v\sqrt{T}}$ *and* $d_{10} = d_9 - \sigma_v\sqrt{T}$.

Proof: When the direct assistance from the FDIC is not considered, the IPP_{AC} of Eq. (7) equals zero. Then, the pricing formula of insured deposits in Model 1 degenerates to Eq. (8) by setting $B_{RCB} = 0$, $\rho = 1$, and $k = 1$. Q.E.D.

Eq. (8) shows that the IPP is irrelevant to the ratio of insured deposits to total deposits, λ, when RCB issuance and other factors do not take into account. In addition, debt liabilities other than total deposits are crucial for the pricing of deposit insurance. We assume that if a bank has no debt liabilities other than total deposits, the national depositor preference law should have no effect on the IPP of insured deposits. This is confirmed by comparing our result with that of Ronn and Verma (1986); in this case, substituting $B = B_1$ into Eq. (8) yields Eq. (4).[12]

To identify the effects of the national depositor preference law on deposit insurance premiums, we conduct numerical simulations to examine Model 1. The parameters are set with the following values: the asset to debt ratio, V/B, is 1.1096, the standard deviation of the rate of return on the value of the bank's assets, σ_v, is 0.0494, and the dividend rate of the assets, δ, is 0. All of these inputs are estimated from the sampled U.S. banks.[13] The time to maturity, *T*, is 1, which is adopted from Ronn and Verma (1986). These input parameters are used throughout this paper.

In Fig. 1, we examine the relationship between deposit insurance premiums and the ratio of total deposits to debt. According to Fig. 1, other parameters being equal, the deposit insurance premium under the proposed model, IPP_1, is always less than or equal to that under the Ronn and Verma (1986) model, IPP_{RV}. IPP_{RV} is not affected by the ratio of total deposits to debt because the insolvency risk of a bank is irrelevant to the ratio. However, even though the insolvency risk of a bank is unchanged, depositors and the FDIC's risk is reduced by raising the priority of their claims under a depositor preference scheme. Therefore, we identify a positive relationship between IPP_1 and the ratio of total deposits to debt, which reveals that depositors and the FDIC's risk

[12] When $B = B_1$, our pricing formula for the IPP of insured deposits is also identical to that of Merton (1977).

[13] The estimation of these parameters is discussed in Section 4/Section 5.

increases with this ratio.

The differences between the deposit insurance premium of our model and that of the Ronn and Verma (1986) model increase at a lower ratio of total deposits to debt, which implies that the Ronn and Verma model overestimates the premium, especially when the deposits to debt ratio is low. This result is confirmed in Fig. 2, which indicates a positive relationship between the IPP_1 to IPP_{RV} ratio and the ratio of total deposits to debt.

Fig. 3 (Fig. 5) shows how deposit insurance premiums vary according to a bank's asset volatility (total assets to debt ratio). Similar to the Ronn and Verma (1986) model, our model charges higher deposit insurance premiums to a bank with higher asset volatility (lower assets to debt ratio). However, the premium is significantly reduced after considering the national depositor preference law. Fig. 4 (Fig. 6) presents a positive (negative) relationship between the IPP_1 to IPP_{RV} ratio and the bank's asset volatility (total assets to debt ratio), indicating that the Ronn and Verma (1986) model produces overestimates, particularly for banks with low asset volatilities (high asset-to-debt ratios).

In summary, the simulation results reveal that deposit insurance premiums are inadequate and prone to overestimation if the national deposit preference law is not considered. In addition, the overestimates for the Merton (1977) and Ronn and Verma (1986) models are severe, particularly for banks with relatively low deposits-to-debt ratios, low asset volatilities, and high asset-to-debt ratios. The results indicate that depositors of those banks are well protected by raising the priority of claims when banks are insolvent.

B. The effect of RCB issuance, regulatory forbearance, and bankruptcy costs for the pricing of deposit insurance

To focus on the effect of RCB issuance and other factors on the IPP under the national depositor preference law, we exclude the factor of the FDIC's direct assistance in the proposed model.

Special Case II

Without direct assistance costs, the IPP of insured deposits is expressed as follows:

$$IPP_1 = N(-d_4) - e^{-\delta T}\frac{kV}{B_1}N(-d_3), \tag{9}$$

where $d_3 = \dfrac{\ln(V/A) - \delta T + \sigma_v^2 T/2}{\sigma_v\sqrt{T}}$, $d_4 = d_3 - \sigma_v\sqrt{T}$ *, and* $A = \min\left(B_1/k, \rho B'\right)$.

Proof: When the direct assistance from the FDIC is not considered, the IPP_{AC} of Eq. (7) equals zero. Then, the pricing formula of insured deposits in Model 1 degenerates to Eq. (9). Q.E.D.

From Eq. (9), we can observe that the moneyness of deposit insurance (i.e., V/A) is determined by many factors, including B_1, k, ρ, and B'. For example, when the percentage recovery rate (k) is lower, the deposit insurance becomes more in the money and, thus, insurance premiums become more expensive. Moreover, when there is no bankruptcy cost ($k=1$), regulatory forbearance ($\rho=1$), or RCB issuance ($B' = B$), Eq. (9) degenerates to Eq. (8).

In comparison with the Ronn and Verma (1986) model, the additional factors considered in our model may decrease or increase the deposit insurance premium. For example, although the national depositor preference law may reduce the insurance premium, the bankruptcy costs increase it. The overall effect of these factors is complicated and requires a detailed numerical analysis. However, under certain circumstances, the deposit insurance premium under the Ronn and Verma (1986) model is always greater than that under the proposed model. We state the result in Proposition 1.

Proposition 1

If the recovery rate (k) *is greater than the ratio of total deposits to total debt liabilities (i.e.,* B_1 / B*), then the deposit insurance premium under the Ronn and Verma (1986) model is always greater than that under the proposed model.*

Proof: Under special case II, the payoff function (Eq. (2)) of the Ronn and Verma (1986) model is always greater than that (Eq. (6)) of the proposed model when $k > B_1 / B$. Moreover, the probability of bank closure under the Ronn and Verma (1986) model is also greater than that under the proposed model. Therefore, the deposit insurance premium under the Ronn and Verma (1986) model is greater than that under the proposed model. Q.E.D.

In Fig. 7, we illustrate how the deposit insurance premium varies according to regulatory forbearance. We consider three scenarios of *k*—(i) $k = 0.99 \times B_1/B$; (ii) $k = B_1/B$; and (iii) $k = 1.01 \times B_1/B$, where B_1/B is 0.8346, which is estimated from the sampled U.S. banks in Section 4/Section 5. A shift from (i) to (iii) indicates an increase in the recovery rate (or a decrease in the bankruptcy cost).

Three implications are derived from Fig. 7. First, the deposit insurance premium of the proposed model, IPP_1, increases monotonically with the increase in the regulatory forbearance for cases (i) and (ii). By contrast, although IPP_1 increases monotonically with the regulatory forbearance, it is fixed after the regulatory forbearance is greater than 0.99 for case (iii). Recall from Eq. (9) that the regulatory forbearance does not affect IPP_1 when ρ is greater than $B_1/(kB')$. This result implies that regulatory forbearance is not always effective in decreasing deposit insurance premiums.

Second, IPP_1 decreases with the recovery rate, *k*, indicating that a bank with lower bankruptcy costs is charged lower deposit insurance premiums. This result is consistent with those of Allen and Saunders (1993) and Hwang et al. (2009). Third, IPP_1 is always lower than or equal to IPP_{RV} for cases (ii) and (iii), in which k is greater than or equal to the ratio of total deposits to debt, which is consistent with Proposition 1. Moreover, for case (i), IPP_1 may be greater than IPP_{RV} when the regulatory forbearance is high. These results imply that IPP_1 is not always lower than IPP_{RV} when we consider bankruptcy costs and regulatory forbearance into the model.

Fig. 8 presents the relationship between IPP_1 and RCB issuance. In addition, we set regulatory forbearance as $\rho = 0.97$, which is adopted from Ronn and Verma (1986), Duan et al. (1992), and Hovakimian and Kane (2000). We expect that RCBs help in alleviating the insolvency risk of banks and therefore reduce the IPPs. Surprisingly, according to Fig. 8, RCB issuance can reduce deposit insurance premiums when RCB issuance is high but has no effect when RCB issuance is low. Moreover, RCB issuance that reduces deposit insurance premiums is less effective for banks with higher recovery rates (or lower bankruptcy costs).

Although RCB issuance clearly can reduce leverage ratios and facilitate alleviating the bankruptcy risk of banks, its effectiveness in reducing deposit insurance premiums requires investigation. Because RCB issuance can reduce the failure probabilities of banks, it is expected that it can also reduce deposit insurance premiums; however, our derivations suggest that this is not always the case. Using the valuation model of Eq. (7), in Proposition 2, we identify the conditions in which effective RCB issuance can reduce deposit insurance premiums.

Proposition 2

The effects of RCB issuance on deposit insurance premiums depend on the following conditions:

(1) If $B_1 \le k\rho B'$, *then* $\frac{\partial IPP_1}{\partial B_{RCB}} = -\frac{\partial IPP_1}{\partial B'} = 0$. *In other words, other parameters being*

equal, RCB issuance does not change deposit insurance premiums when $B_1 \le k\rho B'$.

(2) If $B_1 > k\rho B'$, *then* $\frac{\partial IPP_1}{\partial B_{RCB}} = -\frac{\partial IPP_1}{\partial B'} < 0$. *In other words, other parameters being equal, RCB issuance decreases deposit insurance premiums when* $B_1 > k\rho B'$.

Proof: See Appendix 2.

Typically, RCB issuance facilitates reducing deposit insurance premiums. For example, when the bankruptcy cost is high (i.e., k is low) or regulatory forbearance is low (i.e., ρ is low), issuing RCBs (to replace other debts) can decrease bank failure probabilities and, thus, reduce deposit insurance premiums. The results reveal that although capital forbearance and bankruptcy costs were criticized that they encourage troubled banks to engage in excess risk-taking, the RCBs issuance can offset some of the problem.

Moreover, when there is no bankruptcy cost (i.e., $k = 1$) and no regulatory forbearance (i.e., $\rho = 1$), RCB issuance does not always lower the insurance premiums, which is confirmed by substituting $k = 1$ and $\rho = 1$ into condition (1) of Proposition 2. In this case, the pricing formula of insured deposits in Model 1 degenerates to Eq. (8) and is irrelevant to the RCB issuance.

C. The effect of direct assistance costs for the pricing of deposit insurance

To examine how direct assistance costs affect deposit insurance premiums, we simulate IPP_1 and IPP_{AC} and vary their values according to the ratio of total deposits to debt under different insured deposit to total deposit ratios, λ. For simplicity, we set the recovery rate as k = 1 and RCB issuance rate as *RCBs* = 0, which are consistent with those of previous studies, such as Ronn and Verma (1986).

Fig. 9 indicates a positive relationship between IPP_{AC} and the ratio of total deposits to debt when $\rho B < \lambda B_1$. Moreover, IPP_1 and IPP_{AC} are lower when the ratio of total deposits to debt is lower because when the asset value of the bank at maturity (V_T) ranges between $\rho FV_T(B')$ and $FV_T(B')$, the bank has not become insolvent. In this case, depositors and other debt holders do not liquidate the bank's assets, and therefore, the FDIC can infuse fewer funds to the bank. This result implies that banks with lower insured deposits are charged lower deposit insurance premiums.

3.2. Pricing deposit insurance using the barrier option approach

In this section, we apply a down-and-out put option approach that allows for an early bank closure (i.e., before the next audit date) by the FDIC for deposit insurance pricing. This is a practical setup because the FDIC has the right to close a bank before the next audit, if the bank's asset value reaches the regulatory closure point. Specifically, we assume that the closure policy implies that the FDIC closes a bank whenever its asset value reaches the low barrier (H_t), which is expressed as $H_t = \rho B' e^{rt}$. This assumption explicitly considers the future value of all debt liabilities other than RCBs ($B' e^{rt}$) and regulatory forbearance (ρ). If the asset value of a bank does not reach the barrier, then at the maturity date, the FDIC has no liability when $V_T > FV_T(B')$; alternatively, the FDIC issues $\max\left[\lambda FV_T(B_1) - V_T, 0\right]$ to the bank to stabilize the financial system when $\rho FV_T(B') < V_T < FV_T(B')$. By contrast, if the asset value reaches the barrier sometime during the life of the option, the FDIC closes the financially distressed bank and provides a payment of $\max\left[\lambda(FV_\tau(B_1) - kH_\tau), 0\right]$ to the insured depositors at time τ, where τ is the first passage time for the asset value to reach the barrier level. Thus, the FDIC's liability can be expressed as follows:

$$\begin{cases} \max\left[\lambda FV_T(B_1) - V_T, 0\right], & \text{if } V_t > H_t, \ \forall t \in [0, T], \\ \max\left[\lambda(FV_\tau(B_1) - kH_\tau), 0\right], & \text{otherwise.} \end{cases} \tag{10}$$

Because the payoff function illustrated as Eq. (10) has two parts, the analytic pricing formula of the deposit insurance premiums also contains two parts: The first corresponds with assistance costs and the second relates to early closure costs. The mathematical techniques required for the derivations of the barrier option pricing formula are found in many textbooks (e.g., Harrison, 1985; Musiela and Rutkowski, 1997). After some derivations, we obtain a closed-form solution for deposit insurance premiums, which is stated in Model 2.

Model 2

When the national depositor preference law, regulatory forbearance, bankruptcy costs, RCB issuance, assistance costs, and the early closure policy are considered, the IPP of insured deposits equals

$$IPP_2 = IPP'_{WC} + IPP'_{AC}, \tag{11}$$

$$IPP'_{WC} = \max\left(1 - k\rho B'/B_1, 0\right)\left[N(-d_{11}) + XN(d_{14})\right],$$

$$IPP'_{AC} = \begin{cases} \left[N(d_{11}) - N(d_{12})\right] + X\left[N(d_{13}) - N(d_{14})\right] - \dfrac{V}{\lambda B_1} e^{-\delta T}\left\{N(d_{11}^*)\right. \\ \qquad \left. - N(d_{12}^*) + X^*\left[N(d_{13}^*) - N(d_{14}^*)\right]\right\}, & \text{if } \rho B' < \lambda B_1, \\ 0, & \text{otherwise,} \end{cases}$$

where

$$d_{11} = \frac{\ln\left(V/(\rho B')\right) + \hat{\mu}T}{\sigma_v\sqrt{T}}, \qquad d_{11}^* = d_{11} + \sigma_v\sqrt{T},$$

$$d_{12} = \frac{\ln\left(V/(\lambda B_1)\right) + \hat{\mu}T}{\sigma_v\sqrt{T}}, \qquad d_{12}^* = d_{12} + \sigma_v\sqrt{T},$$

$$d_{13} = \frac{\ln\left((\rho B')^2/(V\lambda B_1)\right) + \hat{\mu}T}{\sigma_v\sqrt{T}}, \qquad d_{13}^* = d_{13} + \sigma_v\sqrt{T},$$

$$d_{14} = \frac{\ln\left((\rho B')/V\right) + \hat{\mu}T}{\sigma_v \sqrt{T}}, \qquad d_{14}^{*} = d_{14} + \sigma_v \sqrt{T},$$

$$\hat{\mu} = -\delta - \frac{1}{2}\sigma_v^2, \quad \hat{\mu}^{*} = -\delta + \frac{1}{2}\sigma_v^2, \quad X = \left(\frac{\rho B'}{V}\right)^{\frac{2\hat{\mu}}{\sigma_v^2}}, \quad X^{*} = \left(\frac{\rho B'}{V}\right)^{\frac{2\hat{\mu}^{*}}{\sigma_v^2}}.$$

Proof: See Appendix 3.

Because of the national depositor preference law, the early closure policy could substantially reduce the FDIC's costs at the expense of all debt holders other than depositors. For example, when the ratio of total deposits to the value of all debt liabilities other than RCBs (B_1 / B') is lower, the FDIC's future liability is also lower. Under some circumstances, the FDIC is not required to make any payments even if the bank is insolvent. We state the result in Proposition 3.

Proposition 3

Under Model 2, if $B_1 \leq k\rho B'$*, then the liability of the FDIC is zero when the bank is bankrupt.*

Proof: The FDIC's liability is zero when $B_1 \leq k\rho B'$ is substituted into Eq. (11).

Q.E.D.

To examine how an early closure policy affects deposit insurance premiums, we identify IPP_2 and IPP'_{AC} and change them according to the ratio of total deposits to debt. Fig. 10 depicts a positive relationship between IPP_2 and the ratio of total deposits to debt when $B_1 > k\rho B'$, implying that an early closure policy could reduce the FDIC's cost at a lower ratio of total deposits to debt. When $B_1 \leq k\rho B'$, the FDIC cost is zero because the FDIC's claim of residual assets can cover the insured deposits when the bank is insolvent. The result is consistent with Proposition 3.

4. Estimation methodology and data

4.1. Estimation method

In the proposed model, many unobserved variables should be estimated. For simplicity and without loss of generality, in Section 4/Section 5, we plan to focus our empirical analysis on the impact of the national deposit preference law, i.e. Eq. (8), so that the Ronn and Verma (1986) estimation procedure can be used. In the context of our models, two unobservable variables—the bank's asset value V and asset volatility σ_v—must be estimated. Ronn and Verma (1986) suggest a two-equation system to identify these two unknown variables. The first equation is acquired by representing bank equity as a call option on the bank's asset value with a strike price equal to the debt maturity value. Therefore, according to the assumption of the Black and Sholes (1973) option pricing model, the equity value of bank E can be expressed as follows:

$$E = VN(d) - BN(d - \sigma_v \sqrt{T}), \tag{15}$$

where $d = \dfrac{\ln(V/B) + \sigma_v^2 T/2}{\sigma_v \sqrt{T}}$, and T is assumed to be 1 year, following Merton's (1977) assumption that the debt maturity time is equal to the time of the next audit.

Applying Ito's lemma to Eq. (15), we identify that the following second equation holds:

$$\sigma_E = VN(d)\sigma_v / E, \tag{16}$$

where σ_E is the instantaneous standard deviation of the return on E. Because the market value of equity is observable and equity volatility can be estimated, Eqs. (15) and (16) are used for solving for the two unknown variables, V and σ_v. With the modified closure condition discussed in Section 3.2, Ronn and Verma (1986) adjust the exercise price of the option in Eq. (15); therefore, the option in Eq. (15) has an exercise value of ρB.

4.2. Data

Our point estimates of deposit insurance require data on balance sheets and the market value of stock prices. Data on the balance sheet items, including total debt (*B*) and the number of shares outstanding, are collected from the Compustat Industrial Quarterly database. Market data on the stock prices are acquired from the Center for Research in Security Prices Daily Return files. The market value of a bank's equity (*E*) is calculated as the stock prices multiplied by the number of shares outstanding. The equity volatility (σ_E) is the standard deviation of the return on *E*. Using the observed values of the data, the market value of a bank's assets (*V*) and asset volatilities (σ_v) are determined simultaneously using Ronn and Verma's (1986) method. Our data comprises information on U.S. commercial banks during 1993–2014. To enhance the estimation efficiency of equity volatilities, we stipulate that banks must have at least 6 weeks of data within a particular bank quarter. Moreover, to prevent outliers from affecting the range of the data set, we exclude 0.5% of the outlying observations from asset volatilities. The complete data set includes 1,260 commercial banks and 21,390 bank-quarter observations over 21 years.

5. Analysis of the empirical results

Table 1 presents the basic summary statistics for the sample data. The market value of a bank's asset ranges between \$20 million–\$950 billion. The average asset value of our sample banks is \$5.5 billion, whereas the median value is a much lower value, nearly exceeding \$851 million. Therefore, the sample is skewed toward larger banks. Asset volatilities display a wide variation within the sample, but cluster between 0.03 (25th percentile) to 0.05 (75th percentile). Given our interest in debt and deposit levels, we report summary statistics for the asset to debt ratio as well as the proportion of deposits to debt for banks within our sample. The asset to debt ratio varies narrowly between 1.06 (25th percentile) to 1.15 (75th percentile), with a similar mean and median values of approximately 1.1. Correspondingly, the mean and median of deposit-to-debt ratios are 0.84 and 0.87, respectively. Based on Merton's (1974) model, we estimate the distance to default ($(V - B)/(V\sigma_v)$) for the measurement of the default probability. Although there are some exceptions, most of the banks exhibit a positive distance to default, and the sample mean and median of distance to default are greater than 2. Consistent with the extant literature (e.g., Hovakimian and Kane, 2000; Lee et al., 2015), except for the deposit to debt ratio, the distribution of the sample variables tends to be skewed to the right in the U.S. markets.

Based on the aforementioned inputs, Table 1 lists the summary statistics for the IPP of insured deposits determined using the Ronn and Verma (1986) model in Eq. (4) and our model in Eq. (8). The mean of deposit insurance premiums is 33.22 bps in the Ronn and Verma model, which is much higher than that in the proposed model, 6.65 bps. The IPPs of insured deposits from both models are skewed to the right. The medians in both models are substantially lower than the means, implying that the IPP values for most of the banks in the U.S. markets are low and those for only a few banks are relatively high. These results are similar to those found in the literature, such as Marcus and Shaked (1984), Ronn and Verma (1986), Hovakimian and Kane (2000), and Lee et al. (2015). Moreover, more than half of the banks do not have to pay premiums and 75% of the banks' IPPs are lower than 0.01 bps in our model, whereas only 2.75% of the banks in the Ronn and Verma model do not pay premiums. The results in our model are close to the FDIC's report from the fact that approximately 95% of all banks did not pay premiums during 1996–2006.[14]

(Table 1)

Table 2 presents the mean of the estimated IPPs and the FDIC official

[14] Refer to the FDIC website: https://www.fdic.gov/deposit/insurance/assessments/priorperiod.html.

assessment rates for each year in 1993–2014. The average values of IPP_{RV} and IPP_1 fluctuate across years from 2.59 and 0.03 in 2005 to 172.46 and 31.97 in 2009. The average values of IPP in our model is much smaller than that in the Ronn and Verma model for each sample year. The ratios of $\mathrm{IPP_1/IPP_{RV}}$ vary between 0.01 in 2005 and 0.47 in 1993 and all of the ratios are smaller than one, which is consistent with Proposition 1; that is, the Ronn and Verma model always overestimates IPPs under the national depositor preference law. On average, the IPP in the Ronn and Verma model is five times greater than that in our model during the sample period.

(Table 2)

In Table 3, we establish five portfolios according to banks' assets and report the average IPPs, deposit to debt ratios, asset to debt ratios, asset volatilities, distances to default, and $\mathrm{IPP_1/IPP_{RV}}$ ratios for each portfolio. Panel A of Table 3 presents the results for the entire sample period (1993–2004). The IPP_{RV} and IPP_1 decrease with an increase in bank size. Although the asset to debt ratio (the asset volatility) does not increase (decrease) with asset value, the distance to default increases monotonically with the banks' asset value, suggesting that the FDIC assesses banks' insolvency risks based on its capitalization level and supervisory rating and tends to charge lower deposit insurance premiums to large banks with low insolvency risks. Moreover, according to the analysis in Section 3, under our model, the deposit insurance premiums are affected by not only the distance to default ratios but also the deposit to debt ratios. Compared with smaller banks, larger banks tend to have lower deposit-to-debt ratios because they rely proportionately more on funding through foreign deposits, federal funds, and RCBs. Therefore, low deposit-to-debt ratios for large banks lower their IPP_1 because they considered by the FDIC to have a lower risk than smaller banks. The IPP_1/IPP_{RV} ratio decreases monotonically with banks' asset value. In other words, the Ronn and Verma model is likely to overestimate the

IPPs, particularly for large banks, under the national depositor preference law.

(Table 3)

In Panels B–E of Table 3, we divide the sample into four subperiods based on the FDIC official assessment periods and establish five portfolios according to banks' assets for each subperiod. For these four subperiods, the IPP_{RV} and IPP_1 are the lowest (highest) during 1996–2006 (2007–2010), which coincides with the FDIC's report that the lowest (highest) official rates, 0–27 bps (5–77.5 bps), were recorded during 1996–2007 (2007–2010). The IPP_1/IPP_{RV} ratios of the largest group, *P5*, for all subperiods are lower than 0.1, suggesting that the average IPP of the largest group under the Ronn and Verma model is 10 times (or more) greater than that under our model for each subperiod.

In Table 4, we divide our sample into three groups based on banks' assets and then establish three subgroups based on the distance to default for each group. Within each subgroup, three portfolios are formed on the basis of the ranked deposit to debt ratio. A total of 27 portfolios are formed based on the three factors and the average values of IPPs are obtained for each portfolio. Consistent with the results in Table 3, Table 4 shows that IPPs decrease monotonically with an increase in bank size after controlling for the distance to default ratio. Moreover, Table 4 suggests that the IPP in our model appears to be positively related to the deposit to debt ratio, whereas the IPP in the Ronn and Verma model and the deposit to debt ratio show a less discernible relationship after controlling for the distance to defaults and banks' asset values. These results suggest that if the national depositor preference law is not considered, the deposit insurance premiums may be overpriced, particularly for large banks and those with low deposit to debt ratios.

(Table 4)

To gain a clearer understanding of the behavior of IPPs, we empirically examine the deposit insurance premiums in relation to bank size, distance to default, and deposit to debt ratios. In particular, we estimate the following regression in our analysis:

$$IPP_{i,t} = \beta_0 + \beta_1 B_1 / B_{i,t} + \beta_2 B_1 / B_{i,t} \times LD_{i,t} + \beta_3 DD_{i,t} + \beta_4 Size_{i,t} + \varepsilon_{i,t}, \qquad (17)$$

where $IPP_{i,t}$ is the IPP of insured deposits for bank *i* at time *t* in the Ronn and Verma model or in our model; $B_1/B_{i,t}$ is the deposit to debt ratio; $DD_{i,t}$ is the distance to default; $LD_{i,t}$ is a dummy variable that takes a value of one if a bank's *DD* is falling into the group of lowest *DD* (less than the 20th percentile); $Size_{i,t}$ is the natural log of the bank's assets; and $\varepsilon_{i,t}$ is the error term. Moreover, we use year dummies for each of the years in our tests to capture the influence of aggregate trends.

Panel A of Table 5 reveals that the IPPs in our model capture the effects from the deposit to debt ratios, suggesting that, after controlling for the bank size and distance to default, banks with higher deposit to debt ratios are charged higher premiums. By contrast, the IPPs in the Ronn and Verma model capture the effects of the deposit to debt ratio only when banks have a short distance to default. For most of the banks, the IPPs in the Ronn and Verma model do not vary according to the deposit to debt ratio, suggesting that the deposit to debt ratio is not adequately considered in the Ronn and Verma model.

An issue in our tests is that the ordinary least squares regression may cause a biased estimation because the IPPs are highly censored at zero. To address the potential censoring problems over the sample period, Eq. (17) is tested using a Tobit regression model. Panel B of Table 5 lists the empirical results. Although the estimates are different, the results and conclusions are the same under a Tobit model.

Another concern in the test is the error-in-variables problem because the true values of banks' assets, asset volatilities, and IPPs are unobservable. These variables are estimated from market data and are likely to be measured with error. To address this issue, the Fama–MacBeth two-pass methodology is employed to further examine the reliability of the estimates. Panel C of Table 5 indicates that the Fama–MacBeth regression confirms the reliability of the tests of Eq. (17).

(Table 5)

6. Conclusions

This study proposes a framework for the deposit insurance pricing with consideration of the national depositor preference law, the issuance of RCBs and other factors. The traditional option pricing approach for deposit insurance ignores depositor preference and the RCBs. Based on the U.S. Banking Act of 1935, conventional models assume that all debts are of equal liquidation priority. At the time of failure, depositors are entitled to a prorated fraction of the asset values with all debt holders. However, under the national depositor preference law of 1993, depositors and the FDIC have first priority claims over residual assets after paying the administrative expenses of receivers in liquidation. The issuance of RCBs can reduce the risk of bank failure and hence decrease the cost of the insurance company. Therefore, the FDIC can reduce the resolution costs and may charge lower insurance premiums to financial institutions.

Numerical results show that because of the new priority of the FDIC, the insurance premium under the Ronn and Verma (1986) model is always greater than that of the proposed model. The overestimates are particularly for banks with low deposit-to-debt ratios, low asset volatilities, and high asset-to-debt ratios. Under some conditions, the FDIC does not need to pay anything in the proposed model even if the bank is insolvent, suggesting that the national depositor preference law protect the FDIC from the risk of bank failure. Moreover, our model shows that the issuance of RCBs can decrease the failure probabilities of the banks when the FDIC permitted the troubled banks to remain open. However, the RCBs can decrease the deposit insurance premiums only when the issuance of RCBs is large enough to cover the shortfall of the FDIC's potential loss in the insolvency of the bank.

Empirical examinations reveal that the traditional deposit insurance pricing models are nested within our proposed framework. The first verification confirms that without depositor preference, the traditional pricing methods always overestimate the insurance premiums. A comparison of the estimated premiums reveals that, on average, the Ronn and Verma model overestimates the deposit insurance premiums by five times during our sample period. The results are consistent with those of Hirschhorn and Zervos (1990) and Kaufman (1997).

The second empirical examination illustrates that the traditional models overestimate the premiums, particularly for large banks. The Ronn and Verma model tends to overestimate premiums for larger banks more than it does for smaller banks in all four periods of our study because large banks rely more on funding through foreign deposits and other debts. The results are consistent with those of previous studies, such as Kaufman (1997) and Marino and Bennett (1999).

Our final regression results reveal that the total deposit to debt ratio is not adequately considered in the traditional model after we control for bank size and default probabilities, whereas it is priced in our proposed model. The results confirm that the traditional theoretical pricing models of deposit insurance ignore depositor preference.

Appendix

Appendix 1: Proof of Model 1

The valuation of deposit insurance premiums using the payoff function in Eq. (6) comprises two parts. The first part is the valuation for the following payoff function:

$$\begin{cases} \max\left[\lambda(FV_T(B_1) - kV_T), 0\right], & V_T < \rho FV_T(B'), \\ 0, & \textit{otherwise.} \end{cases} \tag{A.1}$$

Under the standard assumptions of the Black–Scholes option pricing model, the first part of the total dollar value of the deposit insurance premium (IP_{WC}) can be derived by applying the expectation of payoff (A.1) under the risk-neutral measure and discounting it using the risk-free rate:

$$\begin{aligned} IP_{WC} &= e^{-rT} E\left[\lambda \max\left(FV_T(B_1) - kV_T, 0\right) I_{\{V_T < \rho FV_T(B')\}}\right] \\ &= \lambda e^{-rT} E\left[\left(FV_T(B_1) - kV_T\right) I_{\{\{V_T < \rho FV_T(B')\} \cap \{FV_T(B_1) - kV_T > 0\}\}}\right] \\ &= \lambda e^{-rT} E\left[\left(FV_T(B_1) - kV_T\right) I_{\{\min[\rho FV_T(B'), FV_T(B_1)/k] > V_T\}}\right], \end{aligned}$$

where $E(.)$ is the expectation operator under the risk-neutral measure and $I_{\{.\}}$ is the indicator function of an event. $FV_T(B_1) = B_1 e^{rT}$ and V_T is log-normally distributed with a mean of $Ve^{(r-\delta)T}$ and a standard deviation of $\sigma_v \sqrt{T}$ under the risk neutral measure. Thus, we derive

$$IP_{WC} = \lambda \left\{B_1 N(-d_4) - e^{-\delta T} kVN(-d_3)\right\}. \tag{A.2}$$

By dividing both sides of Eq. (A.2) by λB_1, we obtain the IPP_{WC} of insured deposits as shown in Eq. (7):

$$IPP_{WC} = N(-d_4) - e^{-\delta T} \frac{kV}{B_1} N(-d_3). \tag{A.3}$$

The second part corresponds to the pricing of the FDIC’s assistance costs. The FDIC’s liability due to its direct assistance provision is expressed as follows:

$$\max\left(\lambda FV_T(B_1)-V_T, 0\right), \qquad \text{if} \;\; \rho FV_T(B') \le V_T < FV_T(B'). \tag{A.4}$$

The present value of Eq. (A.4) under the risk neutral measure is as follows:

$$IP_{AC} = e^{-rT} E\left[\max\left(\lambda FV_T(B_1)-V_T, 0\right) I_{\{\rho FV_T(B') \le V_T < FV_T(B')\}}\right]$$

$$= e^{-rT} E\left[(\lambda FV_T(B_1)-V_T) I_{\{\{\rho FV_T(B') \le V_T < FV_T(B')\} \cap \{V_T < \lambda FV_T(B_1)\}\}}\right]. \tag{A.5}$$

When $\lambda B_1 \le \rho B'$, the indicator function $I_{\{\{\rho FV_T(B') \le V_T < FV_T(B')\} \cap \{V_T < \lambda FV_T(B_1)\}\}}$ is zero because $\{\rho FV_T(B') \le V_T < FV_T(B')\}$ and $\{V_T < \lambda FV_T(B_1)\}$ are two mutually exclusive events and, thus, the value of Eq. (A.5) is zero. When $\rho B' < \lambda B_1$ (and $B_1 < B'$ by definition), Eq. (A.5) becomes

$$\begin{aligned} IP_{AC} &= e^{-rT} E\left[(\lambda FV_T(B_1)-V_T) I_{\{\rho FV_T(B') \le V_T < \lambda FV_T(B_1)\}}\right] \\ &= e^{-rT}\left\{E\left[(\lambda FV_T(B_1)-V_T) I_{\{V_T < \lambda FV_T(B_1)\}}\right] - E\left[(\lambda FV_T(B_1)-V_T) I_{\{V_T < \rho FV_T(B')\}}\right]\right\} \end{aligned}$$

$$= \lambda B_1 N(-d_6) - e^{-\delta T} V N(-d_5) - \left\{\lambda B_1 N(-d_8) - e^{-\delta T} V N(-d_7)\right\}. \tag{A.6}$$

By dividing both sides of Eq. (A.6) by λB_1 and rearranging the terms, we obtain the FDIC's assistance cost per dollar of insured deposits as follows:

$$IPP_{AC} = \begin{cases} \left[N(-d_6) - N(-d_8)\right] - e^{-\delta T} \dfrac{V}{\lambda B_1}\left[N(-d_5) - N(-d_7)\right], & \text{if } \rho B' < \lambda B_1, \\ 0, & \text{otherwise.} \end{cases} \tag{A.7}$$

Combining Eqs. (A.3) and (A.7) yields the result of Eq. (7).

Q.E.D.

Appendix 2: Proof of Proposition 2

Eqs. (7) and (9) clearly show that when $B_1 \le k\rho B'$, the FDIC's assistance cost is zero and IPP_{WC} is a function of B_1 only because $A = \min\left(\frac{B_1}{k}, \rho B'\right) = \frac{B_1}{k}$. In other words, the IPP of insured deposits is a function of B_1 only and, thus, $\frac{\partial IPP_1}{\partial B_{RCB}} = -\frac{\partial IPP_1}{\partial B'} = 0$.

Similarly, when $k\rho B' < B_1 < \rho B'$, the FDIC's assistance cost is still zero but

IPP_{WC} is a function of B_1 and B' because $A = \min\left(\frac{B_1}{k}, \rho B'\right) = \rho B'$. Substituting $IPP_{AC} = 0$ and $A = \rho B'$ into Eq. (7) yields

$$IPP_1 = IPP_{WC} = N(-d_8) - e^{-\delta T}\frac{kV}{B_1}N(-d_7), \tag{A.8}$$

where $d_7 = \frac{\ln(V/\rho B') - \delta T + \frac{1}{2}\sigma_v^2 T}{\sigma_v\sqrt{T}}$ and $d_8 = d_7 - \sigma_v\sqrt{T}$. Taking the partial derivative of Eq. (A.8) with respect to B_{RCB} (through the chain rule), we obtain

$$\frac{\partial IPP_1}{\partial B_{RCB}} = -\frac{\partial IPP_1}{\partial B'} = \frac{1}{B'\sigma_v\sqrt{T}}\left(e^{-\delta T}\frac{kV}{B_1}n(-d_7) - n(-d_8)\right). \tag{A.9}$$

where *n(.)* is the probability density function for a standard normal distribution. Because $e^{-\delta T}n(-d_7) = \frac{\rho B'}{V}n(-d_8)$, we can simplify Eq. (A.9) to $\frac{\partial IPP_1}{\partial B_{RCB}} = \frac{n(-d_8)}{B'\sigma_v\sqrt{T}}\left(\frac{k\rho B'}{B_1} - 1\right)$, which is always negative because $\frac{n(-d_8)}{B'\sigma_v\sqrt{T}}$ is positive and $\frac{k\rho B'}{B_1} - 1$ is negative.

Finally, when $\rho B' \le B_1$, the FDIC's assistance cost is still zero and IPP_1 is a function of B_1 and B' if $\lambda B_1 \le \rho B'$. Hence, IPP_1 is identical to Eq. (A.8) and the partial derivative of Eq. (A.8) with respect to B_{RCB} is always negative, which is indicated in Eq. (A.9). When $\rho B' \le B_1$, both IPP_{AC} and IPP_1 are functions of B_1 and B' if $\lambda B_1 > \rho B'$. The partial derivative of IPP_{WC} with respect to B_{RCB} is identical to Eq. (A.9) because $A = \rho B'$ is also true when $\rho B' \le B_1$. Applying a procedure similar to that described previously, we obtain the partial derivative of IPP_{AC} with respect to B_{RCB} as follows:

$$\frac{\partial IPP_{AC}}{\partial B_{RCB}} = -\frac{\partial IPP_{AC}}{\partial B'} = \frac{n(-d_8)}{B'\sigma_v\sqrt{T}}\left(1 - \frac{\rho B'}{\lambda B_1}\right). \tag{A.10}$$

By combining Eqs. (A.9) and (A.10), we obtain the following desired result:

$$\frac{\partial IPP_1}{\partial B_{RCB}} = -\frac{\partial IPP_1}{\partial B'} = \frac{\rho n(-d_8)}{B_1 \sigma_v \sqrt{T}}\left(k - 1/\lambda\right),$$

which is always negative because $\frac{\rho n(-d_8)}{B_1 \sigma_v \sqrt{T}}$ is positive and $k - 1/\lambda$ is always negative (and $0 < k < 1$ by definition).

Q.E.D.

Appendix 3: Proof of Model 2

We first establish the following lemma to be used later in the proof.

Lemma 1

Consider the process $X_t = \sigma W_t + vt$, *where* W *is a standard Brownian motion. Assume* $m_t^X = \min_{u \in [0,t]} X_u$. *The joint distribution of* X_t *and* m_t^X *is expressed as follows:*

$$P\left(X_t \le x, m_t^X \ge y\right) = N\left(\frac{-y + vt}{\sigma\sqrt{t}}\right) - N\left(\frac{-x + vt}{\sigma\sqrt{t}}\right)$$

$$+ e^{\frac{2vy}{\sigma^2}}\left[N\left(\frac{2y - x + vt}{\sigma\sqrt{t}}\right) - N\left(\frac{y + vt}{\sigma\sqrt{t}}\right)\right], \ \forall y \le 0 \text{ and } y \le x .$$

Moreover, the following formula is valid for every $y \le 0$

$$P\left(m_t^X \le y\right) = N\left(\frac{y - vt}{\sigma\sqrt{t}}\right) + e^{\frac{2vy}{\sigma^2}} N\left(\frac{y + vt}{\sigma\sqrt{t}}\right).$$

Proof of Lemma 1:

According to Musiela and Rutkowski (1997, Corollary B.3.3, Corollary B.3.4), the following formulae are valid:

$$P\left(X_t \ge x, m_t^X \ge y\right) = N\left(\frac{-x + vt}{\sigma\sqrt{t}}\right) - e^{\frac{2vy}{\sigma^2}} N\left(\frac{2y - x + vt}{\sigma\sqrt{t}}\right), \ \forall y \le 0 \text{ and } y \le x , \quad \text{(A.11)}$$

$$P\left(m_t^X \ge y\right) = N\left(\frac{-y + vt}{\sigma\sqrt{t}}\right) - e^{\frac{2vy}{\sigma^2}} N\left(\frac{y + vt}{\sigma\sqrt{t}}\right). \quad \text{(A.12)}$$

Substituting Eqs. (A.11) and (A.12) into the following formulae proves the lemma:

$$P\left(X_t \le x, m_t^X \ge y\right) = P\left(m_t^X \ge y\right) - P\left(X_t \ge x, m_t^X \ge y\right),$$

$$P\left(m_t^X \le y\right) = 1 - P\left(m_t^X \ge y\right).$$

Q.E.D. of Lemma 1.

The valuation of deposit insurance premiums with respect to the payoff function in Eq. (10) comprises two parts. The first is related to the FDIC's assistance costs and expressed as follows:

$$IP'_{AC} = E\left[e^{-rT}\max\left(\lambda FV_T(B_1) - V_T, 0\right) I_{\{V_t > \rho FV_t(B'),\ \forall t\in[0,T]\}}\right]$$

$$= E\left[\left(\lambda B_1 - \hat{V}_T\right) I_{\left\{\{\hat{V}_T > \rho B',\ \forall t\in[0,T]\}\cap\{\lambda B_1 > \hat{V}_T\}\right\}}\right], \tag{A.13}$$

where $\hat{V}_t = V_t e^{-rt}$. Under the risk neutral measure, we have $\hat{V}_t = Ve^{X_t}$, where $X_t = \hat{\mu}t + \sigma_v W_t$ and $\hat{\mu} = -\delta - \frac{1}{2}\sigma_v^2$. Consequently, we have

$$\left\{\hat{V}_T > \rho B',\ \forall t\in[0,T]\right\} = \left\{\min_{0\le t\le T}\hat{V}_t > \rho B'\right\} = \left\{\min_{0\le t\le T} Ve^{X_T} > \rho B'\right\} = \left\{m_t^X > \ln(\frac{\rho B'}{V})\right\}.$$

Thus, (A.13) can be rewritten as $IP'_{AC} = \lambda B_1 E\left(I_D\right) - VE\left(e^{X_T} I_D\right)$, where

$$D = \left\{X_T < \ln(\frac{\lambda B_1}{V}),\ m_t^X > \ln(\frac{\rho B'}{V})\right\}.$$

Therefore, the FDIC's assistance cost per dollar of insured deposits can be written as

$$IPP'_{AC} = \frac{IP'_{AC}}{\lambda B_1} = E\left(I_D\right) - \frac{V}{\lambda B_1} E\left(e^{X_T} I_D\right). \tag{A.14}$$

Applying Lemma 1 and the Girsanov theorem to Eq. (A.14) yields IPP'_{AC} of Eq. (11).

The valuation of the second part relates to the early closure when a bank's asset value reaches the barrier level before the next audit date and can be expressed as follows:

$$IPP'_{WC} = E\left[e^{-r\tau}\max\left(\lambda(FV_\tau(B_1) - k\rho FV_\tau(B')), 0\right) I_{\{V_\tau \le \rho FV_\tau(B')\ for\ some\ \tau\in[0,T]\}}\right]$$

$$= E\left[\lambda \max\left(B_1 - k\rho B', 0\right) I_{\left\{\hat{V}_\tau \le \rho B' \text{ for some } \tau \in [0,T]\right\}}\right]$$

$$= \lambda \max\left(B_1 - k\rho B', 0\right) E\left(I_G\right), \qquad \text{(A.15)}$$

where $G = \left\{ m_t^X \le \ln(\dfrac{\rho B'}{V}) \right\}$. Dividing both sides of Eq. (A.15) by λB_1 yields the following result:

$$IPP'_{WC} = \max\left(1 - k\rho B'/B_1, 0\right) E\left(I_G\right). \qquad \text{(A.16)}$$

Finally, applying Lemma 1 to Eq. (A.16) leads to the IPP'_{WC} of Eq. (11).

Q.E.D.

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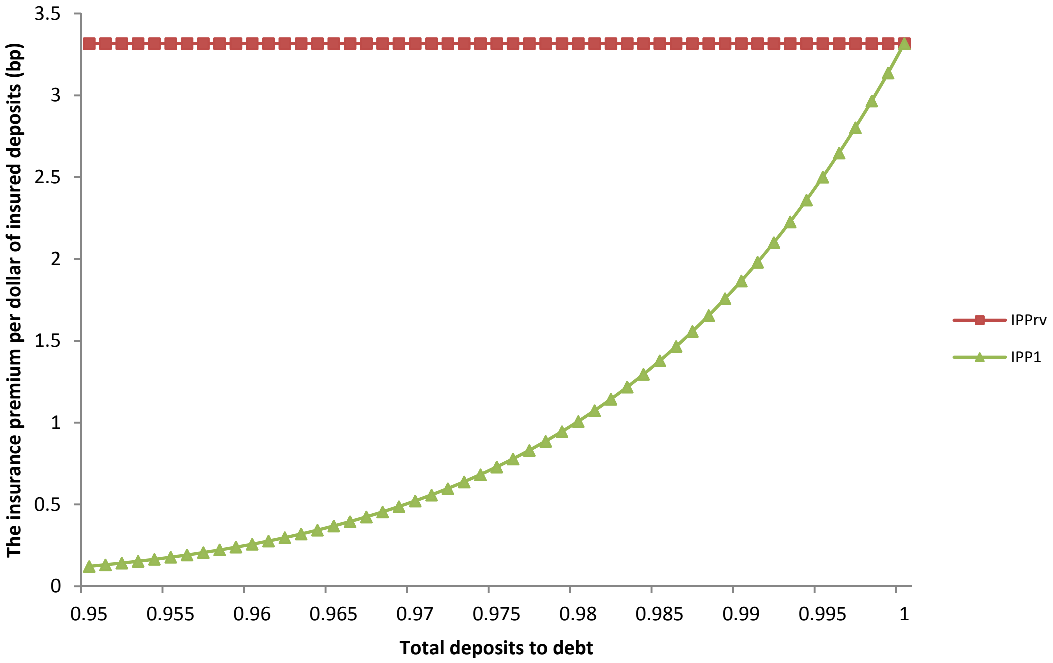

Fig. 1. Insurance premium per dollar of insured deposits. This figure shows the relationship between the estimated deposit insurance premium and the total deposit to debt ratio. The parameters are set with the following values, which are estimated from the sampled U.S. banks: $V/B = 1.1096$, $\sigma_v = 0.0494$, and $\delta = 0$. T = 1 is adopted from Ronn and Verma (1986).

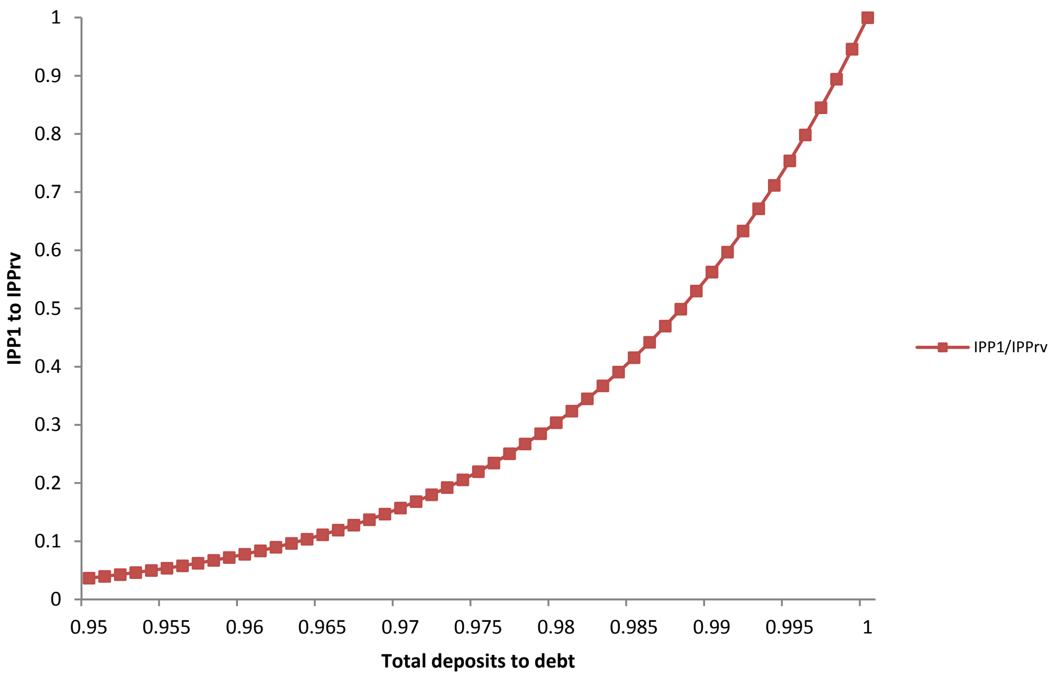

Fig. 2. IPP_1 to IPP_{rv} ratio. This figure shows the relationship between the IPP_1 to IPP_{rv} ratio and the ratio of total deposits to debt. The parameter settings, which are estimated from the sampled U.S. banks, are as follows: $V/B = 1.1096$, $\sigma_v = 0.0494$, and $\delta = 0$. T = 1 is adopted from Ronn and Verma (1986).

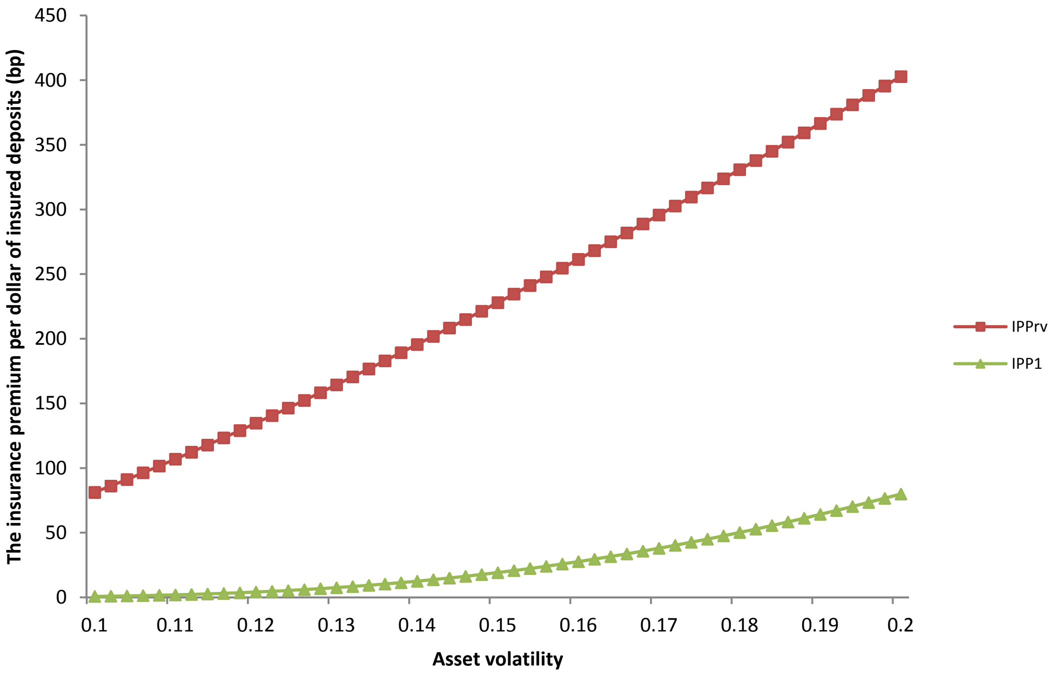

Fig. 3. Insurance premium per dollar of insured deposits. This figure shows the relationship between the estimated deposit insurance premium and the asset volatility. The input parameters are set with the following values, which are estimated from the sampled U.S. banks: $V/B = 1.1096$, $B_1/B = 0.8346$, and $\delta = 0$. $T = 1$ is adopted from Ronn and Verma (1986).

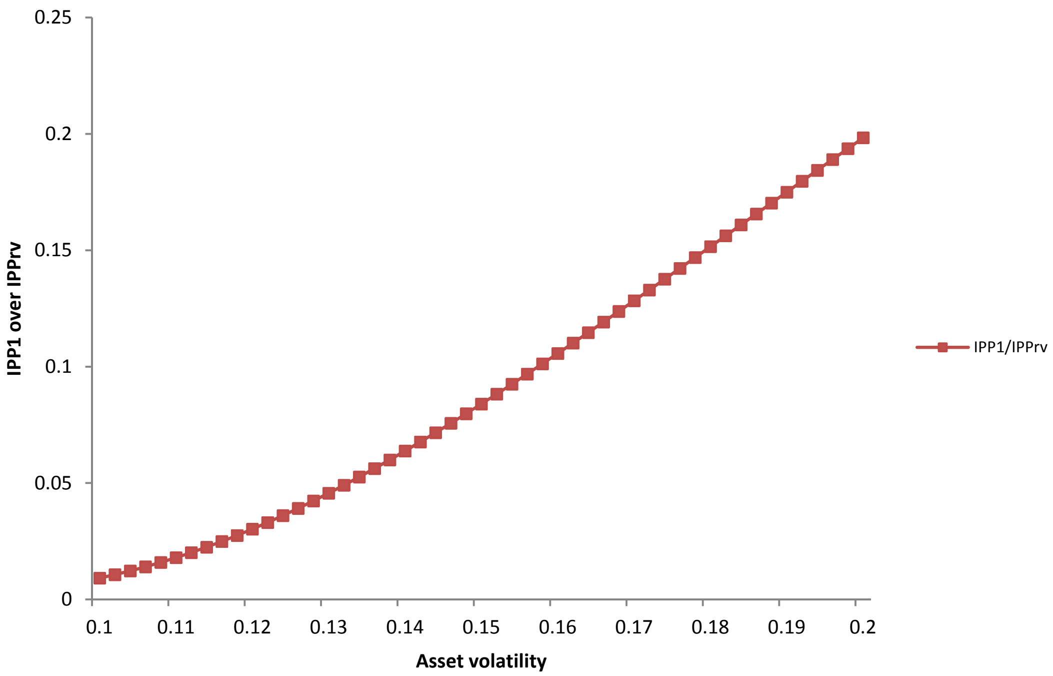

Fig. 4. *IPP_1* to *IPP_{rv}* ratio. This figure shows the relationship between the *IPP_1* to *IPP_{rv}* ratio and the asset volatility. The parameter settings, which are estimated from the sampled U.S. banks, are as follows: $V/B = 1.1096$, $B_1/B = 0.8346$, and $\delta = 0$. $T = 1$ is adopted from Ronn and Verma (1986).

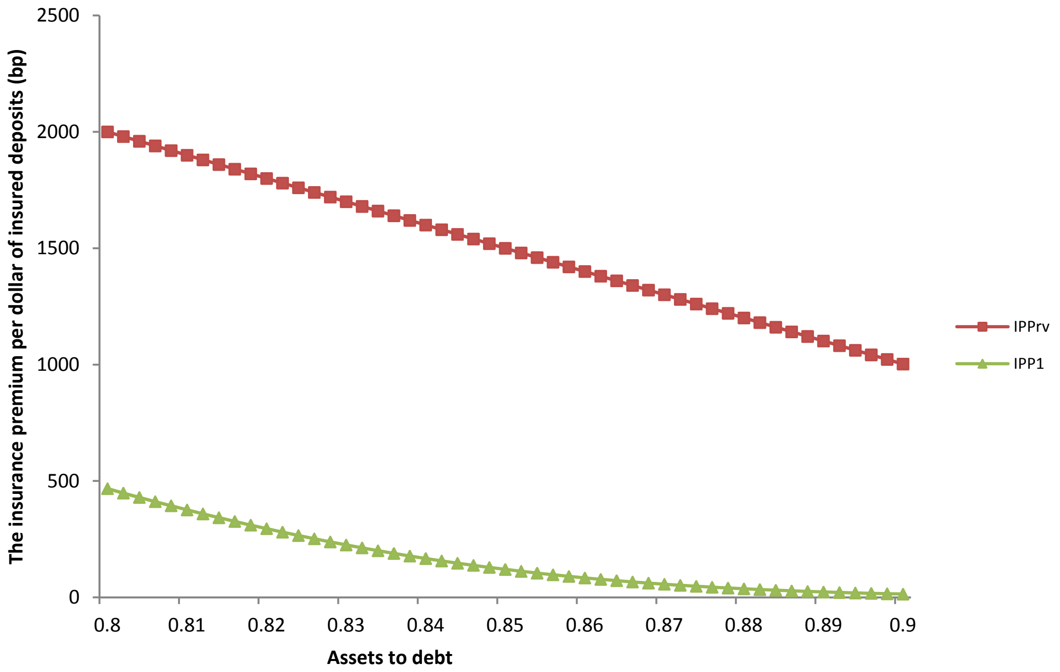

Fig. 5. Insurance premium per dollar of insured deposits. This figure shows the relationship between the estimated deposit insurance premium and the asset to debt ratio. The parameters are set with the following values, which are estimated from the sampled U.S. banks: $B_1/B = 0.8346$, $\sigma_v = 0.0494$, and $\delta = 0$. T = 1 is adopted from Ronn and Verma (1986).

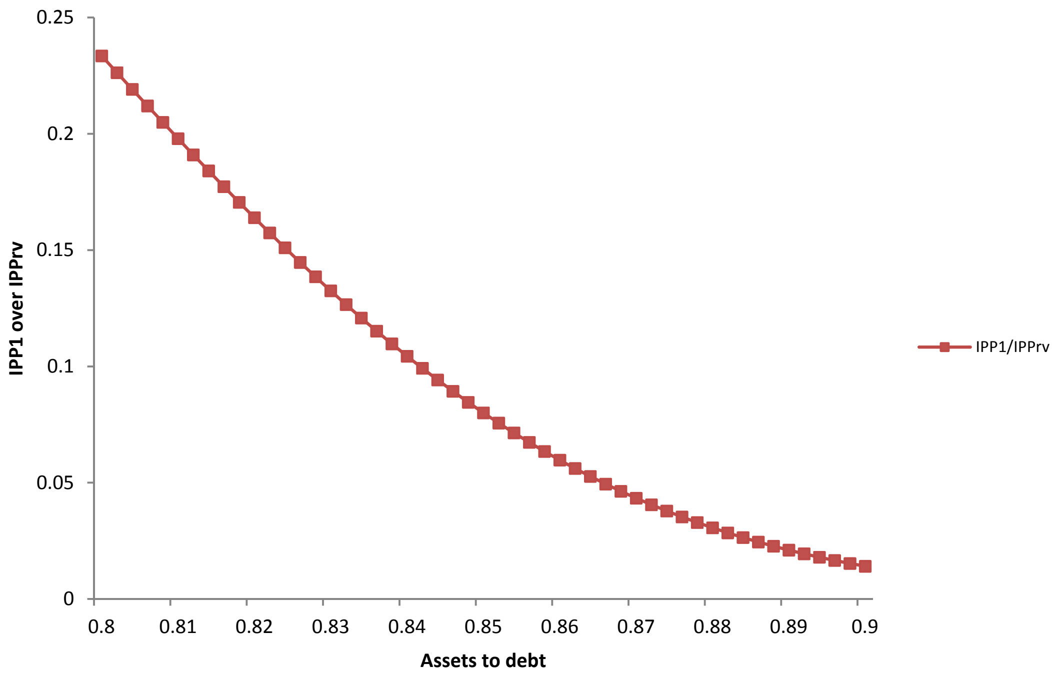

Fig. 6. *IPP_1* to *IPP_{rv}* ratio. This figure shows the relationship between the *IPP_1* to *IPP_{rv}* ratio and the asset to debt ratio. The parameter settings, which are estimated from the sampled U.S. banks, are as follows: $B_1/B = 0.8346$, $\sigma_v = 0.0494$, and $\delta = 0$. T = 1 is adopted from Ronn and Verma (1986).

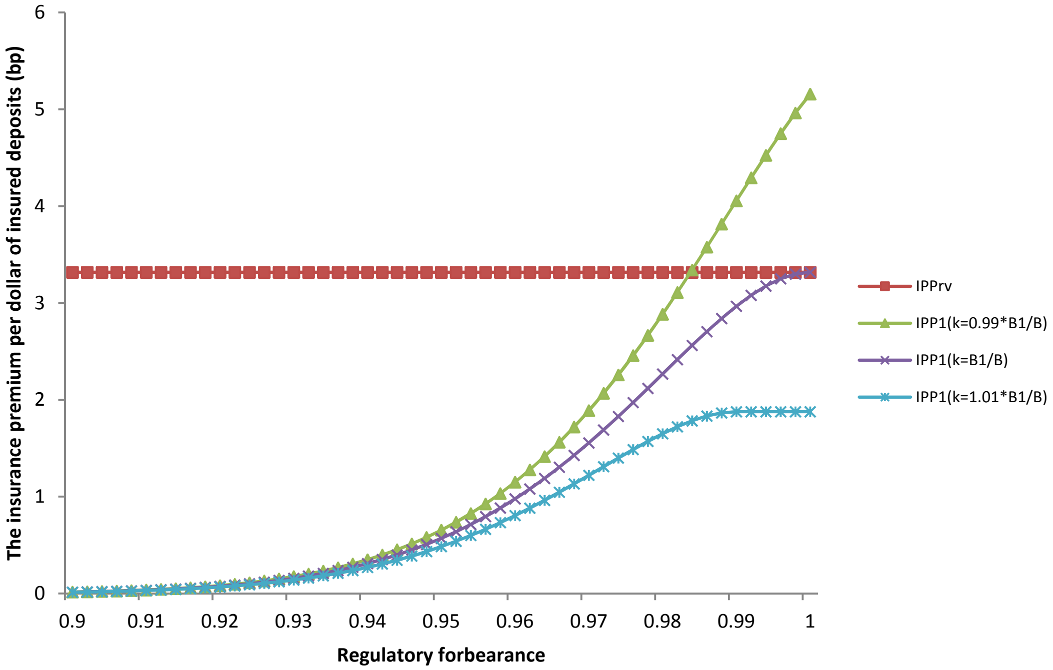

Fig. 7. Insurance premium per dollar of insured deposits. This figure shows the relationship between the estimated deposit insurance premium and the regulatory forbearance. The parameters are set with the following values, which are estimated from the sampled U.S. banks: $V/B = 1.1096$, $B_1/B = 0.8346$, $\sigma_V = 0.0494$, and $\delta = 0$. $T = 1$ and $B_{RCB} = 0$ are adopted from Ronn and Verma (1986).

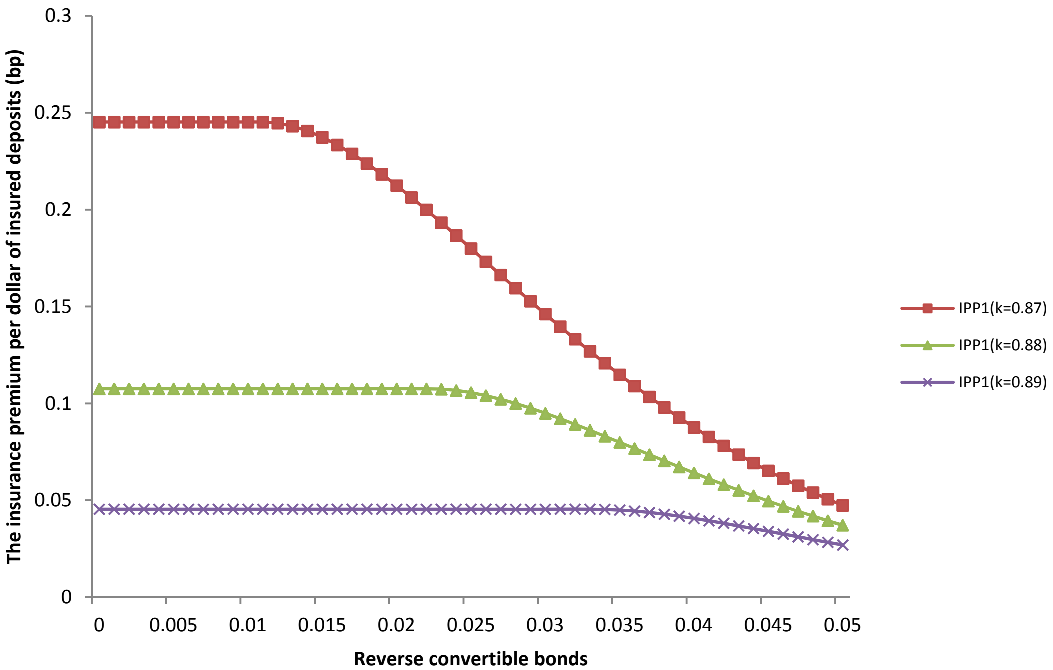

Fig. 8. Insurance premium per dollar of insured deposits. This figure shows the relationship between the estimated deposit insurance premium and the reverse convertible bonds. The parameters are set with the following values, which are estimated from the sampled U.S. banks: $V/B = 1.1096$, $B_1/B = 0.8346$, $\sigma_V = 0.0494$, and $\delta = 0$. $T = 1$ and $\rho = 0.97$ are adopted from Ronn and Verma (1986).

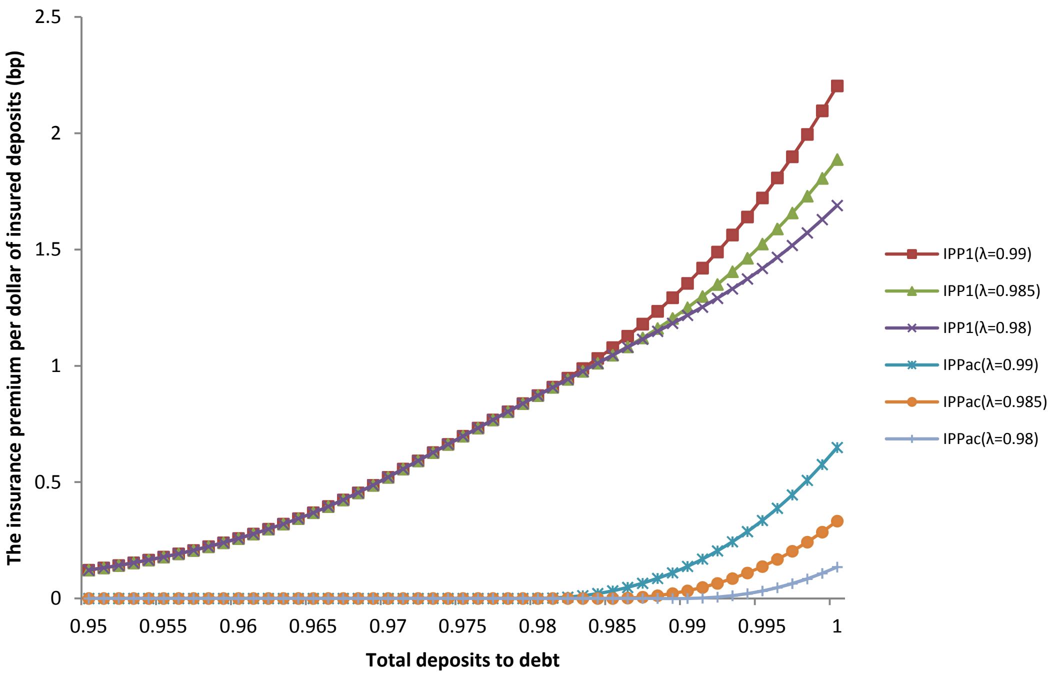

Fig. 9. Insurance premium per dollar of insured deposits. This figure shows the relationship between the estimated deposit insurance premium and the total deposit to debt ratio. The parameters are set with the following values, which are estimated from the sampled U.S. banks: $V/B = 1.1096$, $\sigma_v = 0.0494$, and $\delta = 0$. $T = 1$, $\rho = 0.97$, $B_{RCB} = 0$, and $k = 1$ are adopted from Ronn and Verma (1986).

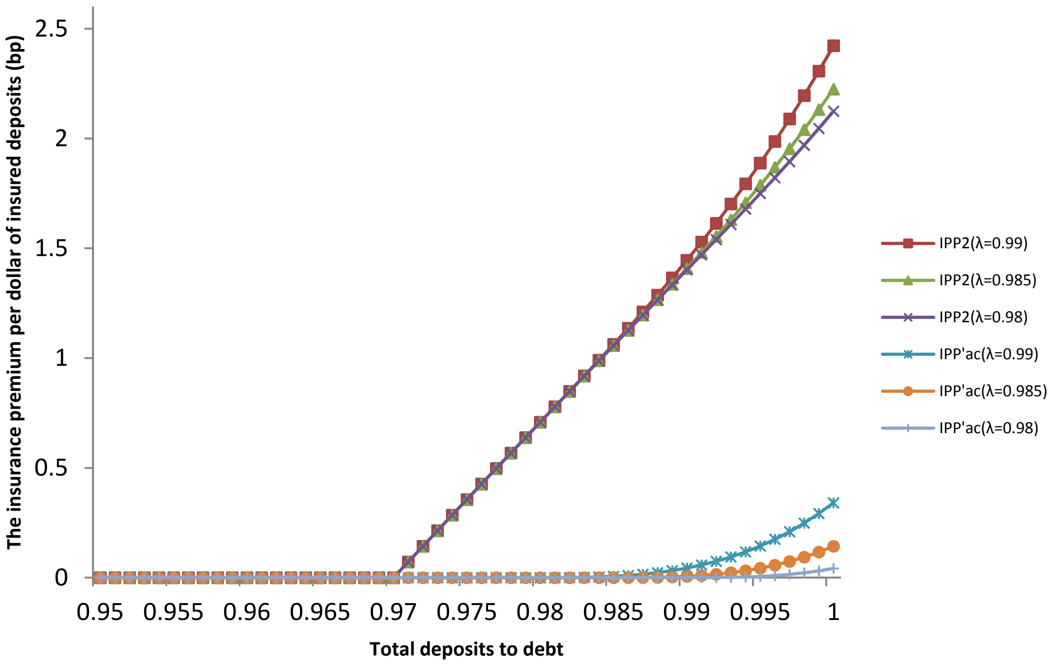

Fig. 10. Insurance premium per dollar of insured deposits. This figure shows the relationship between the estimated deposit insurance premium and the total deposit to debt ratio. The parameters are set with the following values, which are estimated from the sampled U.S. banks: $V/B = 1.1096$, $\sigma_v = 0.0494$, and $\delta = 0$. $T = 1$, $\rho = 0.97$, $B_{RCB} = 0$, and $k = 1$ are adopted from Ronn and Verma (1986).

Table 1

Summary Statistics

Summary statistics are provided for 1,260 sample banks and 21,390 bank-quarter observations over the 1993–2014 period. The statistics are calculated from the quarterly data. Total assets and asset volatilities are estimated using the Ronn and Verma estimation procedure. Distance to default is calculated using the equation $(V-B)/(V\sigma_v)$, based on Merton (1974). IPP_{RV} is the insurance premium per dollar of insured deposits from the Ronn and Verma (1986) model. IPP_1 is the insurance premium per dollar of insured deposits from the proposed model in Eq. (8).

	Mean	Standard deviation	Skewness	Minimum	Percentile 25	Median	Percentile 75	Maximum
Equity, E ($MM)	663.39	3,244.29	16.10	0.73	34.36	82.19	307.06	94,681.80
Total debt, B ($MM)	5,026.17	29,034.31	18.52	16.93	333.23	780.29	2,226.26	888,511.00
Total deposits, B_1 ($MM)	3,823.36	20,845.19	18.54	13.13	282.05	651.74	1,844.50	661,815.00
Total assets, V ($MM)	5,535.03	31,283.8	18.34	20.43	370.38	851.00	2,489.07	950,069.20
Asset volatilities, σ_v	0.05	0.03	2.31	0.00	0.03	0.04	0.05	0.25
Assets to debt, V/B	1.11	0.08	1.48	0.76	1.06	1.10	1.15	1.82
Deposits to debt, B_1/B	0.84	0.12	-1.18	0.21	0.78	0.87	0.93	1.00
Distance to default, DD	2.38	1.79	2.23	-10.37	1.38	2.23	3.26	35.91
IPP_{RV} (bp)	33.22	111.95	8.28	0	0.02	1.31	15.78	2,516.27
IPP_1 (bp)	6.65	55.96	15.86	0	0	0	0.01	1,850.69

Table 2

Insurance premium per dollar of insured deposits across years

The insurance premium per dollar of insured deposits across years. IPP_{RV} is the insurance premium per dollar of insured deposits from the Ronn and Verma (1986) model. IPP_1 is the insurance premium per dollar of insured deposits under the national depositor preference law from the proposed model in Eq. (8). *FDIC Official* is the FDIC assessment rate across years.

	IPP_{RV} (bp)	IPP_1 (bp)	FDIC Official(bp)	IPP_1/IPP_{rv}
1993	42.66	20.07	23-31	0.47
1994	30.35	11.32	23-31	0.37
1995	20.25	7.26	4-31	0.36
1996	12.45	3.04	0-27	0.24
1997	12.70	2.78	0-27	0.22
1998	19.17	3.80	0-27	0.20
1999	16.04	1.15	0-27	0.07
2000	32.29	4.50	0-27	0.14
2001	17.48	2.63	0-27	0.15
2002	12.25	1.92	0-27	0.16
2003	5.19	0.39	0-27	0.08
2004	5.57	0.44	0-27	0.08
2005	2.59	0.03	0-27	0.01
2006	3.04	0.78	0-27	0.26
2007	12.13	0.54	5-43	0.04
2008	132.18	18.52	5-43	0.14
2009	172.46	31.97	7-77.5	0.19
2010	68.03	6.53	7-77.5	0.10
2011	46.26	4.51	2.5-45	0.10
2012	33.11	8.02	2.5-45	0.24
2013	10.27	1.47	2.5-45	0.14
2014	5.89	1.24	2.5-45	0.21
Average	33.22	6.65		0.20
Average (excluding 2008-2009)	23.58	5.03		0.21

Table 3

Insurance premium per dollar of insured deposits by size

The insurance premium per dollar of insured deposits by size. Five portfolios are formed by the market value of banks' assets. *P1* is the bank group with an asset size less than 20%. *P2* is the bank group with an asset size of 20%–40%. *P3* is the bank group with an asset size of 40%–60%. *P4* is the bank group with an asset size of 60%–80%. *P5* is the bank group with an asset size greater than 80%. IPP_{RV} is the insurance premium per dollar of insured deposits from the Ronn and Verma (1986) model. IPP_1 is the insurance premium per dollar of insured deposits from the proposed model in Eq. (6).

	IPP_{RV}	IPP_1	B_1/B	V/B	σ_V	DD	IPP_1/IPP_{RV}
Panel A: Portfolios for the Whole Period 1993-2014							
P1	44.64	16.01	0.87	1.12	0.056	2.16	0.36
P2	40.08	8.08	0.86	1.10	0.046	2.22	0.20
P3	29.76	4.15	0.85	1.09	0.040	2.22	0.14
P4	32.74	3.53	0.83	1.11	0.043	2.32	0.11
P5	18.85	1.44	0.80	1.13	0.041	2.96	0.08
Panel B: Portfolios for Estimation Period 1993-1995: FDIC Official rate 4-31 bp							
P1	47.12	24.81	0.92	1.11	0.057	1.87	0.52
P2	48.93	20.10	0.90	1.09	0.052	1.73	0.41
P3	24.98	6.90	0.88	1.08	0.045	1.84	0.28
P4	14.84	3.57	0.86	1.10	0.039	2.48	0.24
P5	5.94	0.56	0.80	1.10	0.031	3.05	0.09
Panel C: Portfolios for Estimation Period 1996-2006: FDIC Official rate 0-27 bp							
P1	24.50	4.85	0.84	1.14	0.057	2.45	0.20
P2	19.65	3.59	0.83	1.12	0.048	2.49	0.18
P3	12.11	2.43	0.82	1.11	0.044	2.63	0.20
P4	10.25	0.86	0.79	1.13	0.046	2.75	0.08
P5	6.59	0.36	0.76	1.16	0.047	3.14	0.05
Panel D: Portfolios for Estimation Period 2007-2010: FDIC Official rate 5-77.5 bp							
P1	166.44	43.69	0.85	1.06	0.062	1.21	0.26
P2	103.71	13.00	0.85	1.05	0.045	1.09	0.13
P3	99.11	12.44	0.84	1.07	0.047	1.14	0.13
P4	89.66	5.699	0.83	1.08	0.050	1.16	0.06
P5	74.40	6.300	0.79	1.10	0.053	1.66	0.08
Panel E: Portfolios for Estimation Period 2011-2014: FDIC Official rate 2.5-45 bp							
P1	44.77	9.32	0.90	1.09	0.037	2.42	0.21
P2	30.43	5.59	0.90	1.07	0.030	2.29	0.18
P3	25.58	2.50	0.88	1.09	0.035	2.46	0.10
P4	10.86	1.26	0.87	1.12	0.039	2.91	0.12
P5	8.46	0.20	0.85	1.12	0.033	3.40	0.02

Table 4

Relationship between IPP, size, distance to default, and B_1/B

Insurance premium per dollar of insured deposits. A total of 27 portfolios are formed by banks' assets, distance to default, and deposit to debt ratio. IPP_{RV} is the insurance premium per dollar of insured deposits from the Ronn and Verma (1986) model. IPP_1 is the insurance premium per dollar of insured deposits from the proposed model in Eq. (8).

		Distance to default					
Assets		Low		Medium		High	
Panel A: IPP_{RV}							
Small	Low B_1/B		116.9675		4.3870		0.0965
	Medium B_1/B	122.2295	127.3095	4.6893	4.6583	0.1050	0.1045
	High B_1/B		122.4114		5.0226		0.1141
Medium	Low B_1/B		95.5070		3.2261		0.0413
	Medium B_1/B	98.9414	103.3069	3.2836	3.2610	0.0428	0.0408
	High B_1/B		98.0103		3.3638		0.0464
Large	Low B_1/B		54.6530		0.4434		0.0022
	Medium B_1/B	69.2191	79.6530	0.4348	0.4144	0.0023	0.0026
	High B_1/B		73.3512		0.4465		0.0021
Panel B: IPP_1							
Small	Low B_1/B		4.1252		0.0051		0.0000
	Medium B_1/B	37.5066	27.7731	0.7041	0.1046	0.0093	0.0001
	High B_1/B		80.6215		2.0025		0.0277
Medium	Low B_1/B		3.8102		0.0003		0.0000
	Medium B_1/B	14.9776	9.4298	0.2744	0.0159	0.0016	0.0000
	High B_1/B		31.6927		0.8070		0.0049
Large	Low B_1/B		0.4194		0.0000		0
	Medium B_1/B	6.3786	3.2187	0.0082	0.0002	0.0000	0.0000
	High B_1/B		15.4977		0.0244		0.0000

Table 5

Regression results for the deposit to debt ratio, distance to default, and bank size

Regression results of deposit insurance premiums on the deposit to debt ratio, distance to default, and bank size. IPP_{RV} is the insurance premium per dollar of insured deposits from the Ronn and Verma (1986) model. IPP_1 is the insurance premium per dollar of insured deposits from the proposed model in Eq. (8). B_1/B is the ratio of deposits to debt. *DD* is the distance to default. *Size* is the natural log of banks' assets. *LD* is a dummy variable that takes a value of one if a bank's DD is falling into the group of lowest DD (less than the 20th percentile). *** Significant at the 1% level. ** Significant at the 5%level.

Panel A: Ordinary least squares regressions

	IPP_{RV}	IPP_{RV}	IPP_{RV}	IPP_{RV}	IPP_1	IPP_1	IPP_1	IPP_1
Consta	17.79***	12.13**	101.08**	51.30***	-22.74***	-24.20***	2.04	-12.23***
B_1/B	28.13***	-3.08	15.57***	-3.90	48.42***	40.38***	43.04***	37.45***
B_1/B		154.91**		128.59**		39.91***		36.85***
DD			-21.53**	-9.42***			-4.36***	-0.89***
Size			-3.83***	-1.84***			-1.53***	-0.96***

Panel B: Tobit regressions

	IPP_{RV}	IPP_{RV}	IPP_{RV}	IPP_{RV}	IPP_1	IPP_1	IPP_1	IPP_1
Consta	18.43***	12.87**	105.55**	65.23***	-472.50**	-472.77**	-408.85**	-415.51**
B_1/B	26.61***	-5.22	19.52***	2.79	517.84**	499.89**	523.84**	518.04**
B_1/B		156.94**		101.13**		69.41***		17.62***
DD			-35.66**	-21.49**			-25.32***	-22.12***
Size			-1.10**	-0.48			-3.16***	-2.91***

Panel C: Fama-MacBeth regressions

	IPP_{RV}	IPP_{RV}	IPP_{RV}	IPP_{RV}	IPP_1	IPP_1	IPP_1	IPP_1
Consta	-112.39**	-79.98**	83.44***	82.99***	-52.66***	-45.36***	-0.58	1.75
B_1/B	166.92**	122.88**	10.63	-0.60	68.24***	58.25***	26.23**	20.84***
B_1/B		34.88***		18.12***		7.40***		5.61***
DD			-25.53**	-16.65**			-4.61***	-1.77
Size			-3.33***	-4.28***			-1.33***	-1.77***