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A REALIZED CAPPED CALL OPTION FRAMEWORK FOR LOAN-RISK SENSITIVE INSURANCE PREMIUM VALUATION

Jyh Horng Lin[1] and Chuen Ping Chang[2,*]

[1]Department of International Business
Tamkang University
No. 151, Yingzhuan Rd., Tamsui Dist., New Taipei City 25137, Taiwan
lin9015@mail.tku.edu.tw

[2]Department of Wealth and Taxation Management
Kaohsiung University of Applied Sciences
No. 415, Jiangong Rd., Sanmin Dist., Kaohsiung City 807, Taiwan
*Corresponding author: cpchang@cc.kuas.edu.tw

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Abstract. *This paper examines the optimal interest margin, the spread between the loan rate and the deposit rate of a bank, when the risk of corporate borrower default is explicitly capped. Corporate borrower default risk is characterized by a lending function that includes corporate borrower risk and equity default probability. The equity of the bank can be viewed as a realized capped call option on its assets. This approach we will use is to calculate loan-risk sensitive insurance premium. The results show that when the investment value of the corporate borrower is high, market-based estimates of deposit insurance premium which ignore the realized cap are under valued. This type of situation calls for an increase in the deposit insurance premium in lieu with the asset risk of the corporate borrower. An increase in the corporate borrower's asset risk makes the bank more prone to loan risk-taking at a reduced margin when asset risk itself is low, but makes the bank more prudent to loan risk-taking at an increased margin when asset risk itself is high. Our results demonstrate why realized capped lending considerations may have further applicability to value fair deposit insurance premium in providing more stability in banking system.*

Keywords: Corporate borrower default risk, Realized capped call, Deposit insurance premium, Bank interest margin

1. **Introduction.** Most theoretical work done in the area of deposit insurance tends to confirm that deposit insurance is responsible for the increased risk taking activity in banks arising via moral hazard.[1] According to this confirmation, much of the theoretical literature on deposit guarantees has focused on their pricing and the feasibility of risk-adjusted insurance premia.[2] Specifically, the Federal Deposit Insurance Corporation (FDIC) announced an assessment of deposit insurance premium value is based on the total of the risk-related assets.[3] Motivated by the previous literature and the FDIC's announcement, we assess the extent to which corporate borrower asset risk affects pricing of deposit insurance through bank spread management.

Our paper makes several important contributions to the literature as a result of the following extensions in methodology and scope. First, on the methodological side, we

[1]About the moral hazard problem that related to deposit insurance, see, for example, Chen et al. [1], Nier and Baumann [2], Pennacchi [3], and Huizinga and Nicodème [4].

[2]The seminal work by Black and Scholes [5] on the valuation of options has led to an application in pricing of deposit insurance in the banking literature (for example, [6-9]).

[3]See http://www.fdic.gov/deposit/insurance/assessments/proposed.htm [10].

control for the corporate borrower's levels of investment related to risk by introducing a new framework not previously used in the context of deposit insurance pricing. Based on the standard work of Merton [11], the market-based estimation of deposit insurance premium can be viewed as a put option on the bank's asset value with a strike price equal to the book value of the bank's debt.[4] The underlying asset value of this standard work, however, does not specify risk characteristics and the necessity to model the equity of the bank as a standard or "naked" call option. This paper highlights the fact that the default risk in the corporate borrower's equity affects the distribution of bank loan repayments. The market value of the bank's underlying assets is specified as a realized value of loan repayments reduced by a realized value of a put option given to the corporate borrower who can sell its end-of-period asset at a price of its loan repayments to the bank. The realized loan repayment value is the value with the default-free probability in the corporate borrower's equity, while the realized put option is the option with the corporate borrower's default probability. The equity of the bank is viewed as a so-called "realized capped" call option on the bank's assets. As such, the deposit insurance premium of the FDIC's claim can be viewed as a realized capped put option that a capped put with the default probability in the bank's equity return.

Next regarding scope, to the best of our knowledge, we are the first to introduce the bank interest margin, i.e., the spread between the loan rate and the deposit rate, to price deposit insurance premia, explicitly taking into account of corporate borrower default risk. Lending involves acquiring costly information about an opaque corporate borrower. The bank anticipates credit risk compensation from the corporate borrower. The bank interest margin is one of the principal elements of bank net cash flows and after-tax earnings, which is often used in the literature as a proxy for the efficiency of financial intermediation [12,13]. Accordingly, deposit insurance premium evaluated at the optimal bank interest margin should be valued based on an explicit treatment of the risk characteristics of bank loans related to the corporate borrower's equity return and risk. This paper aims to fill this gap when calculating the loan-risk sensitive insurance premium.

A prime example of this is highlighted in a prior research by Dermine and Lajeri [9] which is modeled explicitly for the risk characteristics of bank assets and calculates loan-risk sensitive insurance premium but failed to consider the impact of a corporate borrower's investment level related to its invested-fund risk on the bank's lending strategies. Our contribution is to control for corporate borrower's levels of investment related to default risk, which enables us to better understand bank spread behavior and market-based estimation of deposit insurance premium. Our results indicate that the bank's equity is higher and the deposit insurance premium is lower when the market-based estimates of the bank's equity are based on a naked call than on a realized capped call. When the investment value of the corporate borrower is high, the bank's interest margin is negatively related to the corporate borrower's low asset risk, but positively related to the corporate borrower's high asset risk. Under the circumstances, the deposit insurance premium should be increased when the corporate borrower's asset risk increases.

One immediate application of the results is to evaluate the plethora of bank equity valuations proposed as alternatives for bank loans and fair deposit insurance premium estimates. Market-based estimates of deposit insurance premium which ignore the realized cap lead to undervaluation of the premium which may prompt the bank's moral hazard incentive. Our results also suggest that the deposit insurance premium valued at the realized capped call may be more sensible to loan risk-taking exclusively for the corporate

[4] A closely related group of papers, for example, Merton [6], Ronn and Verma [14], and Episcopos [15], uses contingent claims in order to price deposit insurance contracts on an actuarially fair basis that the liability to the FDIC is a European put option written on the assets of the bank.

borrower with high investment at a high risk level, thereby affecting the stability of the banking system. Our findings provide an alternative for affirming market-based estimates of deposit insurance premium for financial stability.

In related work, Delong and Saunders [16] found that banks in general had become a higher risk following the introduction of fixed-rate deposit insurance. Unlike Delong and Saunders [16], we find that the realized capped call estimated deposit insurance premium should be increased when the bank becomes at a higher risk due to its corporate borrower's investments status and default risk. Analyzing whether explicit deposit insurance actually influences the risk taking of bank is not considered. Rather, this paper explores the determinants of fair deposit insurance premiums based on a simple realized capped call option model under sources of corporate borrower defaults and bank interest margins. We acknowledge that the fairness of the deposit insurance premium is a highly debated issue, but will not be discussed in this paper.

The rest of this paper is organized as follows. Section 2 reviews related literature. Section 3 delineates the firm-theoretical call-option model of a bank capped by corporate borrower asset risk. Section 4 examines the effect of the corporate borrower default risk on the deposit insurance premium through bank interest margin decisions. Section 5 presents a numerical analysis. The final section contains the conclusion.

2. **Related Literature.** Our theory of credit risk management is related to four strands of the literature. The first is the literature on bank interest margin determination, in which Ho and Saunders [17], Angbazo [18], Maudos and de Guevara [19], and Hawtrey and Liang [20] are major contributors. The prevailing approach to analyzing bank interest margin has been the dealership model originated by Ho and Saunders [17]. In this model, banks are viewed as risk-averse dealers in loan and deposit markets where loan requests and deposit funds arrive nonsynchronously at random time intervals. These authors analyze the determinants of bank interest margins and find that the margin depends on market competition degree and interest rate risk. This model is further extended to account for default risk [18]. The most recent extension of the Ho and Saunders [17] is studied by Maudos and de Guevara [19], who included operating cost as an explicit component of bank interest margin and market power measurement. Hawtrey and Liang [20] study the effect of managerial efficiency on bank interest margins, particularly including risk aversion, interest rate volatility, and opportunity cost determinants. While we also explore the determinants of bank interest margin, our focus on the bank interest margin management aspects of the explicit treatment of corporate borrower asset risk takes our analysis in a different direction.

The second strand is the literature on the risk characteristics of bank assets. In a firm-theoretical model where loan losses are the source of uncertainty, changes in capital regulation or deposit insurance premium have direct effects on the bank interest margin [21]. Wong [22] also uses a firm-theoretical approach to explore the determinants of optimal bank interest margins under multiple sources of uncertainty and risk aversion. Dermine and Lajeri [9] adopt an option-based valuation model instead of the commonly used firm-theoretical approach to show that bank lending and credit risk create a specific stochastic process for the asset of a bank. Tsai et al. [12] examine the optimal bank interest margin for a barrier option model, in which a bank provides vendor financing for a borrowing firm in order to unload the distressed loans. The primary difference between our model and these papers is that we propose a model of bank interest margin determination under deposit insurance explicitly creating the need to model bank equity as a realized capped call option. We use the realized capped function to explicitly express the corporate borrower's asset risk.

The third strand is the modern deposit insurance literature. Wheelock and Kumbhakar [23] document that deposit insurance subsidizes risk taking; therefore, creating moral hazard in that banks with insured deposits will find it optimal to assume more risks than they would otherwise. Demirguc-Kunt and Detragiache [24] indicate that deposit insurance may increase bank stability by reducing information-driven depositor runs, while deposit insurance may decrease bank stability by encouraging risk-taking on the part of banks. Laeven [25] shows that a relatively high cost of deposit insurance indicates a bank taking excessive risks. Demirguc-Kunt et al. [26] find that deposit insurance may reduce moral hazard if non-deposit creditors are left out. Davis and Obasi [27] suggest that deposit insurance mainly affects bank risk through its relationship with profitability and asset quality. Prior papers largely tend to confirm that deposit insurance is responsible for the increased risk taking activity in banks via moral hazard, but fail to consider the impact of borrower asset quality on deposit insurance premium. This omission is crucial since bank lending and credit risk create a specific stochastic process for the asset of a bank and the leverage relevant for the insurer is the deposits to borrower asset quality. Our main work is to control for the corporate borrower's investment level, which enables us to better understand the impact of borrower risk on deposit insurance premium.

The fourth strand of the literature to which our work is most directly related on conformity, particularly the issue of credit risk and interest margin as in Maudos and de Guevara [19], Williams [28], and Hawtrey and Liang [20], and the issue of credit risk and deposit insurance premium as in Wheelock and Kumbhaker [23], Demirguc-Kunt and Detragiache [24], and Laeven [25]. The fundamental insight shared by these papers is that conformity is generated by a desire to distinguish oneself from the type with which one wishes not to be identified. This insight is an important aspect of pricing deposit insurance premium as well, since bank managers and policy regulators agree with this pricing one to avoid being identified as untalented in estimating bank equity values. What distinguishes our work from this literature is our focus on commingling of the assessment of the corporate borrower's asset risk with the assessment of deposit insurance premium priced through bank interest margin determination and, in particular, the emphasis we put on the relationship between borrower asset risk and actuarially fair deposit insurance premium in the context of bank interest margin determination.

3. **The Model.** Consider a one-period ($t \in [0, 1]$) contingent-claim framework that comprises a corporate borrower, a bank with insured deposits, and a deposit insurer: (i) the corporate borrower funds its investment with a bank loan; but (ii) the bank realizes the potential risk of borrower default; so (iii) the bank's equity is valued with assets and insured liabilities explicitly taking the potential default of the corporate borrower into account; and (iv) the market-based evaluation of deposit insurance premium is priced explicitly with corporate borrower default risk. (i), (iii) and (iv) imply that the framework will have to incorporate three distinct but related option-based valuation methods. The advantage of this framework allows us to examine the relationships among potential borrower default risk, bank behavior, and deposit insurance premium.

3.1. **Corporate borrower.** The equity of the corporate borrower is viewed as a call option on its assets since equity holders are residual claimants on the corporate borrower's assets after all other obligations have been met [11]. The strike price of the call is the book value of the corporate borrower's liabilities. We assume that the capital structure of the corporate borrower includes debt and equity. The market value of the corporate borrower's underlying assets varies continuously over the single-period horizon based on the stochastic process of a geometric Brownian motion (GBM) as described below:

$$dA = \mu_A A dt + \sigma_A dW_A \tag{1}$$

where A is the firm's asset value, μ_A is the instantaneous expected rate of return on A, σ_A is the instantaneous standard deviation of the return, and W_A is a Wiener process. We denote by V the book value of the debt at $t = 0$, that has maturity at $t = 1$. The book value of the corporate borrower's debt payment at $t = 1$ is specified as $V = (1 + R_L)L$, where R_L is the loan rate set by the bank and L is the loan amount borrowed from the bank at $t = 0$. The promised face payment value of V plays the role of the strike price since the market value of equity can be thought of as a call option on A with time to expiration at $t = 1$. The market value of the corporate borrower's equity, S_A, will then be given by the Black and Scholes [5] formula for the call option:[5]

$$S_A = AN(a_1) - Ve^{-R_L}N(a_2) \tag{2}$$

where $a_1 = \frac{1}{\sigma_A}\left(\ln \frac{A}{V} + R_L + \frac{\sigma_A^2}{2}\right)$, $a_2 = a_1 - \sigma_A$, and $N(\cdot)$ = the cumulative density function of the standard normal distribution.

Default occurs when the corporate borrower cannot fulfill its obligation, repaying borrower loan. Given the limited liability of the firm, the value of the loan at $t = 1$ is the promised payment on the loan reduced by a put option given to the corporate borrower who can sell its asset A at $t = 1$ at a price V, that the bank (the lender) takes over the corporate borrower's asset A when it defaults. Similarly, define P_A to be the put option written on A and with an strike price equal to V, that the bank has effectively written to the corporate borrower's equity holders:

$$P_A = Ve^{-R_L}N(-a_2) - AN(-a_1) \tag{3}$$

The effects of default risk on equity returns may be not readily apparent since equity holders are the residual claimants on the corporate borrower's cash flows and there is no promised nominal return in equities. The default probability becomes an issue to evaluate the default of the corporate borrower. The default probability is the probability that the corporate borrower's assets will be less than the book value of the bank's liabilities. Our approach in calculating the default probability using information about Equation (2) is very similar to the one outlined in Vassalou and Xing [29]. In that case, the theoretical probability of default is given by:

$$P_{def,A} = N(-a_3) \tag{4}$$

where

$$a_3 = \frac{1}{\sigma_A}\left(\ln \frac{A}{V} + \mu_A - \frac{\sigma_A^2}{2}\right)$$

Default occurs when the ratio of the value of assets to liabilities is less than 1, or its log is negative. The distance to default a_3 tells us by how many standard deviations the log of this ratio needs to deviate from its mean in order for default to occur. Notice that although Equation (2) does not depend on μ_A, Equation (4) does. This is because a_3 in Equation (4) depends on the future value of asset which is given in Equation (2).

Using information about Equations (2)-(4), we can further define the realized loan payment to the bank from the corporate borrower as:

$$V_A = (1 - P_{def,A})(1 + R_L)L - P_{def,A}P_A \tag{5}$$

[5] In Merton's [11] model, the equity of a firm is viewed as a call option on the firm's assets. Recent related literature includes, for example, dynamic investment strategy in Wang and Wang [30], bank interest margin with vendor financing in Tsai et al. [12], and bank interest margin with structural break barrier in Tsai et al. [13].

We model Equation (5) such that loan payment includes $(1+R_L)L$ with default-free probability $(1-P_{def,A})$ and P_A with default probability $P_{def,A}$. This setting is understood that $(1+R_L)L$ is less likely to come into effect and P_A is less likely vanish, as $P_{def,A}$ increases. This is because the corporate borrower's default may or may not occur. Equation (5) will be used in a later subsection when the equity of the bank is analyzed.

3.2. **Bank.** We consider the bank that has the following balance sheet at $t = 0$:

$$L + B = D + K \tag{6}$$

where B is the amount of liquid assets, D is the quantity of deposits, and K is the stock of equity capital. Loan demand faced by the bank is governed by a downward-sloping demand function, $L(R_L)$ and $\partial L/\partial R_L < 0$, where R_L is chosen by the bank [31]. Liquid assets in the bank's earning-asset portfolio earn the security-market interest of R. The total assets financed at $t = 0$ are partly by deposits. The bank provides depositors with a market rate of return equal to the risk-free rate of R_D. The bank's deposits are insured by a government-funded deposit insurance scheme. For simplicity, we assume that the bank pays no insurance premium at any time. For capital regulation purposes, we assume that equity capital held by the bank tied by the regulation to be a fixed proposition q of the bank's deposits, $K \geq qD$. The required capital-to-deposits ratio q is assumed to be an increasing function of the loans held by the bank at $t = 0$, $\partial q/\partial L > 0$. This system of capital standards is designed to force the bank's capital positions to reflect their asset portfolio risks. When the capital requirement constraint is binding, the balance-sheet constraint of Equation (6) can be restated as $L + B = K(1/q + 1)$.[6]

The equity of the bank is viewed as a call option on the bank's risky loans in that loans are explicitly subject to non-performance. We model such underlying assets by V_A in Equation (6). The repayment value as such completely describes the non-performance from the potential risk of borrower default faced by the bank. The market value of the bank's underlying assets follows a GBM of the form:

$$dV_A = \mu V_A dt + (\sigma + \sigma_A) V_A dW \tag{7}$$

where V_A is the value of the bank's assets, with an instantaneous drift μ, and an instantaneous volatility $\sigma + \sigma_A$ where σ_A is from Equation (1). A standard Wiener process is W. Equation (7) indicates that the impact on the bank' underlying assets from the expected performance of the borrowing firm is limited to the instantaneous volatility [32]. This is because μ is unchanged or changed insignificantly but the instantaneous volatility is increased by σ_A when the asset substitution problem takes place [33]. In the context of our model, the expression of the bank's equity is the residual value of the bank after meeting all of the obligations:[7]

$$S = V_A N(d_1) - Ze^{-\delta} N(d_2) \tag{8}$$

where

$$Z = \frac{(1+R_D)K}{q} - (1+R)\left[K\left(\frac{1}{q}+1\right) - L\right], \quad \delta = R - R_D$$

$$d_1 = \frac{1}{\sigma + \sigma_A}\left(\ln\frac{V_A}{Z} + \delta + \frac{(\sigma+\sigma_A)^2}{2}\right), \quad d_2 = d_1 - (\sigma + \sigma_A)$$

We label this valuation as realized capped call option since the underlying asset in Equation (8) is defined as the realized value of V_A rather than as the value of V in Equation

[6] The capital requirement constraint will be binding as long as R is sufficiently higher than R_D.

[7] Note that the administrative costs of loans and deposits and the fixed costs are omitted for simplicity, see [34].

(2).[8] Similarly, define P to be the put option written on V_A and with a strike price equal to Z, the liability to the insurer is a put option written on the asset of the bank:

$$P = Ze^{-\delta}N(-d_2) - V_A N(-d_1) \tag{9}$$

Again, we follow Vassalou and Xing [29] to define the default probability in the bank's equity return as:

$$P_{def,V_A} = N(-d_3) \tag{10}$$

where

$$d_3 = \frac{1}{\sigma + \sigma_A}\left(\ln\frac{V_A}{Z} + \mu - \frac{(\sigma + \sigma_A)^2}{2}\right)$$

3.3. **Insurer.** We assume that the insurer examines the bank at $t = 1$, which coincides with the maturity of current assets. Using information about Equations (9) and (10), we can further define the realized put option of the actuarially fair deposit insurance premium as:

$$P_I = P_{def,V_A} \times P \tag{11}$$

The insurance liability occurs because the put on the loan repayment of the bank, explicitly associated with the credit risk from the borrowing firm, will be exercised when the bankruptcy prediction of the bank is discounted by its default probability. Again, this discounted factor used in Equation (11) is understood because there is no promised nominal return in the bank's equities.

4. **Solving the Model.** With all the assumptions in place, we are ready to solve for the bank's optimal choice of R_L. The first-order condition for the maximization of the market value of the bank's equity is:

$$\frac{\partial S}{\partial R_L} = \frac{\partial V_A}{\partial R_L}N(d_1) + V_A\frac{\partial N(d_1)}{\partial d_1}\frac{\partial d_1}{\partial R_L} - \frac{\partial Z}{\partial R_L}e^{-\delta}N(d_2) - Ze^{-\delta}\frac{\partial N(d_2)}{\partial d_2}\frac{\partial d_2}{\partial R_L} = 0 \tag{12}$$

where

$$\frac{\partial V_A}{\partial R_L} = (1 - P_{def,A})\frac{\partial S_A}{\partial R_L} - P_{def,A}\frac{\partial P_A}{\partial R_L} - (S_A + P_A)\frac{\partial P_{def,A}}{\partial R_L} < 0$$

$$\frac{\partial Z}{\partial R_L} = \left[\frac{(R - R_D)Kq'}{q^2} + (1 + R)\right]\frac{\partial L}{\partial R_L} < 0, \quad V_A\frac{\partial N(d_1)}{\partial d_1}\frac{\partial d_1}{\partial R_L} = Ze^{-\delta}\frac{\partial N(d_2)}{\partial d_2}\frac{\partial d_2}{\partial R_L}$$

The second-order condition is required to be satisfied, that is, $\partial^2 S/\partial R_L^2 < 0$. The first term on the right-hand side of Equation (12) can be explained as the bank's risk-adjusted value for its marginal risky-asset repayment of loan rate, while the third term can be explained as the risk-adjusted value for its marginal net-obligation payment. The value of the marginal net-obligation payment is negative in sign, and then the value of the marginal loan repayment is negative based on the first-order condition. The bank determines the optimal loan rate to maximize its market value of the equity when both the marginal values are equal. We further substitute the optimal loan rate to obtain the actuarially fair deposit insurance premium in Equation (11) staying on the optimization.

The optimal bank interest margin is given by the difference between the optimal loan rate and the fixed deposit rate. Since the deposit rate is not a choice variable of the bank, examining the impact of parameter on the optimal bank interest margin is tantamount to examining that on the optimal loan rate. Consider next the impact on the actuarially fair deposit insurance evaluated at the optimal loan rate from changes in the borrower firm's

[8]When the underlying asset is defined as V as in Dermine and Lajeri [9], the lending function of the bank creates the need to model as a capped call option. When the underlying asset is specified as V_A in our model, the lending function of the bank creates the need to model as a realized capped call option.

asset's volatility. Differentiation of Equation (11) evaluated at the equilibrium condition of Equation (12) with respect to σ_A yields:

$$\frac{dP_I}{d\sigma_A} = \frac{\partial P_I}{\partial \sigma_A} + \frac{\partial P_I}{\partial R_L}\frac{\partial R_L}{\partial \sigma_A} \tag{13}$$

where

$$\frac{\partial P_I}{\partial \sigma_A} = \frac{\partial P_{def,V_A}}{\partial \sigma_A}P + P_{def,V_A}\frac{\partial P}{\partial \sigma_A}$$

$$\frac{\partial P_I}{\partial R_L} = \frac{\partial P_{def,V_A}}{\partial R_L}P + P_{def,V_A}\frac{\partial P}{\partial R_L}, \quad \frac{\partial R_L}{\partial \sigma_A} = -\frac{\partial^2 S}{\partial R_L \partial \sigma_A}\bigg/\frac{\partial^2 S}{\partial R_L^2}$$

The first term on the right-hand side of Equation (13) can be interpreted as the direct effect, while the second term can be interpreted as the indirect effect. The direct effect captures the change in P_I due to an increase in σ_A, holding the loan rate constant. The indirect effect arises because an increase in σ_A changes the insurance premium by $L(R_L)$ in every possible state. Both the effects are indeterminate because the added complexity of option valuations does not always lead to clear-cut results. In the next section, we use numerical exercises to explain the reasoning behind the comparative static results of Equation (13).

5. **Numerical Exercises.** Starting from a set of assumptions on $R = 4.00\%$, $R_D = 3.00\%$, $K = 20$, $q = 10.00\%$, $\sigma = 0.10$ and $\mu_A = 0.10$, we first calculate the market value of the bank equity S and thus the term $\partial R_L/\partial \sigma_A$ which are consistent with Equations (8) and (13). Let $(R_L\%, L)$ change from $(5.00, 210)$ to $(6.50, 198)$ due to $\partial L/\partial R_L < 0$, and let σ_A increase from 0.02 to 0.20. $R_L > R$ in the numerical exercises indicates fund reserves as substitution in the earning-asset portfolio [34]. $R_L > R_D$ implies that the bank interest margin as a proxy for the efficiency of financial intermediation [35]. The specification of capital adequacy requirements is consistent with the standardized approach of capital regulation, which is set by $q = K/D = 10.00\%$ [36].

The relevant distinctions for the argument about Equation (13) are the following three scenarios: (i) the realized loan repayment to the bank from the corporate borrower is capped and specified as Equation (5) with a high level of $A = 300$, (ii) that as Equation (5) with a low level of $A = 250$, and (iii) that as Equation (5) equal to $(1+R_L)L$. Scenarios (i) and (ii) can be motivated based on a realized capped call argument while scenario (iii) can be motivated based on a standard naked call argument. These three scenarios will be compared in the following using the comparative static results of Equation (13). Before proceeding with the analysis of Equation (13), we present the values of V_A at the levels of $A = 300$ and 250, and $V_A = (1 + R_L)L$ to explain the need of the three scenarios. The findings are summarized in Table 1.

In Table 1, we have the results of $\partial V_A/\partial R_L < 0$ and $\partial V_A/\partial \sigma_A < 0$ at the level of $A = 300$ in scenario (i). In scenario (ii), we have the result of $\partial V_A/\partial R_L < 0$ when σ_A is low and $\partial V_A/\partial R_L > 0$ when σ_A is high, and $\partial V_A/\partial \sigma_A < 0$ at the level of $A = 250$. In scenario (iii), we have the result of $\partial V_A/\partial R_L < 0$ at the level of $V_A = (1+R_L)L$, which is invariant to σ_A. These inconsistent results observed from the three scenarios suggest incentives to study the effects of corporate borrower default on the deposit insurance premium. As pointed out by Demirguc-Kunt et al. [37], it is a dilemma that has caused deposit insurance to come under public scrutiny and has given rise to widespread discussions of deposit insurance reform. Our work contributes to the existing literature by exploring firm-theoretical aspects of deposit insurance and bank risk relationship.

We use numerical exercises to explain the results of Equation (13) in the first scenario of $A = 300$. In Table 2, $S > 0$ consistent with Equation (8) is observed from the first

TABLE 1. Values of V_A at different scenarios*

	$(R_L\%, L)$						
σ_A	$(5.00, 210)$	$(5.25, 208)$	$(5.50, 206)$	$(5.75, 204)$	$(6.00, 202)$	$(6.25, 200)$	$(6.50, 198)$
	Scenario (i), V_A, $A = 300$						
0.02	220.5000	218.9200	217.3300	215.7300	214.1200	212.5000	210.8700
0.04	220.5000	218.9200	217.3300	215.7300	214.1200	212.5000	210.8700
0.06	220.5000	218.9200	217.3300	215.7300	214.1200	212.5000	210.8700
0.08	220.5000	218.9200	217.3300	215.7300	214.1200	212.5000	210.8700
0.10	220.4938	218.9155	217.3267	215.7277	214.1183	212.4988	210.8692
0.12	220.4073	218.8460	217.2712	215.6837	214.0837	212.4718	210.8482
0.14	220.0079	218.5047	216.9811	215.4384	213.8776	212.2995	210.7050
0.16	219.0062	217.6133	216.1912	214.7413	213.2650	211.7636	210.2384
0.18	217.2359	215.9937	214.7141	213.3986	212.0487	210.6656	209.2509
0.20	214.6982	213.6257	212.5103	211.3531	210.1553	208.9180	207.6425
	Scenario (ii), V_A, $A = 250$						
0.02	220.5000	218.9200	217.3300	215.7300	214.1200	212.5000	210.8700
0.04	220.5000	218.9200	217.3300	215.7300	214.1200	212.5000	210.8700
0.06	220.4788	218.9070	217.3222	215.7254	214.1174	212.4985	210.8692
0.08	219.8996	218.4698	216.9962	215.4855	213.9431	212.3737	210.7809
0.10	217.4731	216.4261	215.2903	214.0744	212.7868	211.4351	210.0265
0.12	212.8841	212.3131	211.6274	210.8337	209.9389	208.9497	207.8729
0.14	206.8098	206.6642	206.3988	206.0177	205.5250	204.9252	204.2230
0.16	200.0272	200.2090	200.2777	200.2350	200.0830	199.8240	199.4606
0.18	193.0740	193.4907	193.8049	194.0172	194.1283	194.1391	194.0506
0.20	186.2541	186.8329	187.3207	187.7172	188.0223	188.2360	188.3586
	Scenario (iii), $V_A = (1 + R_L)L$						
	220.5000	218.9200	217.3300	215.7300	214.1200	212.5000	210.8700

*Parameter value, unless stated otherwise, $\mu_A = 0.10$.

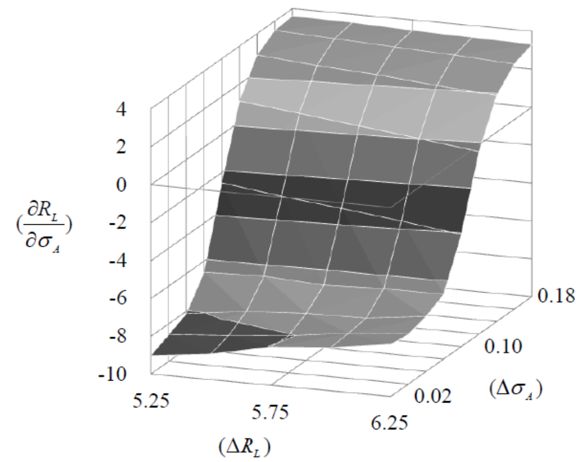

FIGURE 1. $\partial R_L/\partial\sigma_A$ at the level of $A = 300$

panel. The second panel implies $\partial^2 S/\partial R_L \partial\sigma_A$ is negative in sign when σ_A is low and is positive when σ_A is high. The third panel indicates $\partial^2 S/\partial R_L^2 < 0$ that confirms the second-order condition of Equation (9). Accordingly, we have the result of $\partial R_L/\partial\sigma_A < 0$ when σ_A is low and $\partial R_L/\partial\sigma_A > 0$ when σ_A is high as shown in Figure 1.

As the bank faces increasing asset risk of the corporate borrower, it must now provide a return to a larger risk base. One way the bank may attempt to augment its total returns is by shifting its investments to its loan portfolio and away from the liquid assets when the asset risk of the corporate borrower is low. If loan demand is relatively rate-elastic, a larger

TABLE 2. Values of S and $\partial R_L/\partial \sigma_A$ at the level of $A = 300^*$

σ_A	$(R_L\%, L)$ (5.00, 210)	(5.25, 208)	(5.50, 206)	(5.75, 204)	(6.00, 202)	(6.25, 200)	(6.50, 198)
	S						
0.02	28.6076	28.9735	29.3352	29.6923	30.0448	30.3925	30.7350
0.04	29.6049	29.9353	30.2618	30.5843	30.9025	31.2163	31.5255
0.06	30.7339	31.0316	31.3255	31.6155	31.9015	32.1833	32.4608
0.08	31.9602	32.2277	32.4915	32.7514	33.0073	33.2592	33.5069
0.10	33.2543	33.4952	33.7320	33.9646	34.1931	34.4174	34.6375
0.12	34.5428	34.7701	34.9912	35.2064	35.4158	35.6196	35.8181
0.14	35.6431	35.8874	36.1207	36.3437	36.5569	36.7609	36.9562
0.16	36.3464	36.6428	36.9229	37.1872	37.4366	37.6716	37.8930
0.18	36.5501	36.9217	37.2730	37.6044	37.9164	38.2096	38.4845
0.20	36.2804	36.7331	37.1638	37.5727	37.9598	38.3254	38.6699
	$\partial^2 S/\partial R_L \partial \sigma_A$						
$0.02 \sim 0.04$	–0.0355	–0.0352	–0.0346	–0.0343	–0.0339	–0.0333	
$0.04 \sim 0.06$	–0.0327	–0.0326	–0.0325	–0.0322	–0.0320	–0.0317	
$0.06 \sim 0.08$	–0.0302	–0.0301	–0.0301	–0.0301	–0.0299	–0.0298	
$0.08 \sim 0.10$	–0.0266	–0.0270	–0.0273	–0.0274	–0.0276	–0.0276	
$0.10 \sim 0.12$	–0.0136	–0.0157	–0.0174	–0.0191	–0.0205	–0.0216	
$0.12 \sim 0.14$	0.0170	0.0122	0.0078	0.0038	0.0002	–0.0032	
$0.14 \sim 0.16$	0.0521	0.0468	0.0413	0.0362	0.0310	0.0261	
$0.16 \sim 0.18$	0.0752	0.0712	0.0671	0.0626	0.0582	0.0535	
$0.18 \sim 0.20$	0.0811	0.0794	0.0775	0.0751	0.0724	0.0696	
	$\partial^2 S/\partial R_L^2$						
0.02	–	–0.0042	–0.0046	–0.0046	–0.0048	–0.0052	–
0.04	–	–0.0039	–0.0040	–0.0043	–0.0044	–0.0046	–
0.06	–	–0.0038	–0.0039	–0.0040	–0.0042	–0.0043	–
0.08	–	–0.0037	–0.0039	–0.0040	–0.0040	–0.0042	–
0.10	–	–0.0041	–0.0042	–0.0041	–0.0042	–0.0042	–
0.12	–	–0.0062	–0.0059	–0.0058	–0.0056	–0.0053	–
0.14	–	–0.0110	–0.0103	–0.0098	–0.0092	–0.0087	–
0.16	–	–0.0163	–0.0158	–0.0149	–0.0144	–0.0136	–
0.18	–	–0.0203	–0.0199	–0.0194	–0.0188	–0.0183	–
0.20	–	–0.0220	–0.0218	–0.0218	–0.0215	–0.0211	–
	$\partial R_L/\partial \sigma_A = -(\partial^2 S/\partial R_L \partial \sigma_A)/(\partial^2 S/\partial R_L^2)$						
$0.02 \sim 0.04$	–	–9.0256	–8.6500	–7.9767	–7.7045	–7.2391	–
$0.04 \sim 0.06$	–	–8.5789	–8.3333	–8.0500	–7.6190	–7.3721	–
$0.06 \sim 0.08$	–	–8.1351	–7.7179	–7.5250	–7.4750	–7.0952	–
$0.08 \sim 0.10$	–	–6.5854	–6.5000	–6.6829	–6.5714	–6.5714	–
$0.10 \sim 0.12$	–	–2.5323	–2.9492	–3.2931	–3.6607	–4.0755	–
$0.12 \sim 0.14$	–	1.1091	0.7573	0.3878	0.0217	–0.3678	–
$0.14 \sim 0.16$	–	2.8712	2.6139	2.4295	2.1528	1.9191	–
$0.16 \sim 0.18$	–	3.5074	3.3719	3.2268	3.0957	2.9235	–
$0.18 \sim 0.20$	–	3.6091	3.5550	3.4450	3.3674	3.2986	–

*Parameter values, unless stated otherwise, $R = 4.00\%$, $R_D = 3.00\%$, $K = 20$, $q = 10.00\%$, $\sigma = 0.10$ and $\mu_A = 0.10$.

loan portfolio is possible at a reduced margin. However, when the corporate borrower's asset risk is high, a small loan portfolio is possible at an increased margin. The reasoning is straightforward. One of the risks of making a bank loan is credit risk capped by the realized corporate borrower default. At a given high level of the corporate borrower's investment return related to its repayment ability, the bank is more willing to lend the corporate borrower induced by a reduced loan rate (and thus a reduced margin) when the risk of borrower default is lower than that induced by an increased loan rate when

TABLE 3. Values of P_I and $dP_I/d\sigma_A$ at the level of $A = 300^*$

σ_A	$(R_L\%, L)$ $(5.00, 210)$	$(5.25, 208)$	$(5.50, 206)$	$(5.75, 204)$	$(6.00, 202)$	$(6.25, 200)$	$(6.50, 198)$
	P_I						
0.02	0.0673	0.0591	0.0518	0.0452	0.0395	0.0343	0.0298
0.04	0.1842	0.1660	0.1493	0.1341	0.1203	0.1077	0.0962
0.06	0.3804	0.3488	0.3195	0.2922	0.2670	0.2435	0.2219
0.08	0.6596	0.6124	0.5681	0.5264	0.4873	0.4505	0.4161
0.10	1.0192	0.9551	0.8942	0.8366	0.7819	0.7302	0.6813
0.12	1.4602	1.3767	1.2974	1.2218	1.1500	1.0817	1.0166
0.14	2.0041	1.8951	1.7917	1.6935	1.6003	1.5116	1.4273
0.16	2.6969	2.5510	2.4134	2.2833	2.1604	2.0440	1.9338
0.18	3.5919	3.3947	3.2093	3.0348	2.8705	2.7157	2.5695
0.20	4.7338	4.4699	4.2222	3.9894	3.7706	3.5647	3.3710
	$\partial P_I/\partial\sigma_A$: direct effect						
$0.02 \sim 0.04$	0.1169	0.1069	0.0975	0.0889	0.0808	0.0734	0.0664
$0.04 \sim 0.06$	0.1962	0.1828	0.1702	0.1581	0.1467	0.1358	0.1257
$0.06 \sim 0.08$	0.2792	0.2636	0.2486	0.2342	0.2203	0.2070	0.1942
$0.08 \sim 0.10$	0.3596	0.3427	0.3261	0.3102	0.2946	0.2797	0.2652
$0.10 \sim 0.12$	0.4410	0.4216	0.4032	0.3852	0.3681	0.3515	0.3353
$0.12 \sim 0.14$	0.5439	0.5184	0.4943	0.4717	0.4503	0.4299	0.4107
$0.14 \sim 0.16$	0.6928	0.6559	0.6217	0.5898	0.5601	0.5324	0.5065
$0.16 \sim 0.18$	0.8950	0.8437	0.7959	0.7515	0.7101	0.6717	0.6357
$0.18 \sim 0.20$	1.1419	1.0752	1.0129	0.9546	0.9001	0.8490	0.8015
	$(\partial P_I/\partial R_L)(\partial R_L/\partial\sigma_A)$: indirect effect						
$0.02 \sim 0.04$	–	0.1507	0.1315	0.1101	0.0971	0.0833	–
$0.04 \sim 0.06$	–	0.2514	0.2275	0.2029	0.1790	0.1592	–
$0.06 \sim 0.08$	–	0.3604	0.3218	0.2942	0.2751	0.2441	–
$0.08 \sim 0.10$	–	0.4010	0.3744	0.3656	0.3397	0.3213	–
$0.10 \sim 0.12$	–	0.2008	0.2230	0.2364	0.2500	0.2653	–
$0.12 \sim 0.14$	–	–0.1147	–0.0744	–0.0361	–0.0019	0.0310	–
$0.14 \sim 0.16$	–	–0.3951	–0.3401	–0.2986	–0.2506	–0.2115	–
$0.16 \sim 0.18$	–	–0.6503	–0.5884	–0.5302	–0.4792	–0.4274	–
$0.18 \sim 0.20$	–	–0.8940	–0.8276	–0.7538	–0.6934	–0.6389	–
	direct effect + indirect effect = total effect						
$0.02 \sim 0.04$	–	0.2482	0.2204	0.1909	0.1705	0.1497	–
$0.04 \sim 0.06$	–	0.4216	0.3856	0.3496	0.3148	0.2849	–
$0.06 \sim 0.08$	–	0.6090	0.5560	0.5145	0.4821	0.4383	–
$0.08 \sim 0.10$	–	0.7271	0.6846	0.6602	0.6194	0.5865	–
$0.10 \sim 0.12$	–	0.6040	0.6082	0.6045	0.6015	0.6006	–
$0.12 \sim 0.14$	–	0.3796	0.3973	0.4142	0.4280	0.4417	–
$0.14 \sim 0.16$	–	0.2266	0.2497	0.2615	0.2818	0.2950	–
$0.16 \sim 0.18$	–	0.1456	0.1631	0.1799	0.1925	0.2083	–
$0.18 \sim 0.20$	–	0.1189	0.1270	0.1463	0.1556	0.1626	–

*Parameter values, unless stated otherwise, $R = 4.00\%$, $R_D = 3.00\%$, $K = 20$, $q = 10.00\%$, $\sigma = 0.10$, $\mu = 0.10$ and $\mu_A = 0.10$.

the risk is high. When the corporate borrower's asset risk is explicitly treated as interest rate and credit risk, the positive effect of asset risk on bank interest margin is consistent with the empirical findings of Maudos and de Guevara [19]. However, when the corporate borrower's asset risk is explicitly recognized as interest rate volatility, the negative effect of asset risk on bank interest margin is consistent with the empirical findings of Williams [28] and Hawtrey and Liang [20].

In Table 3, we further consider the effect of borrower asset risk on the deposit insurance premium. $P_I > 0$ is shown in the first panel. The direct effect observed from the second panel is unambiguously positive because an increase in the borrower asset risk makes loans more risky to grant and thus more costly to deposit insurance, ceteris paribus. The sign of the indirect effect shown in the third panel is positive when borrower asset risk is low. This is because an increase in σ_A decreases R_L obtained from Table 2 and P_I is increased as the risky loans held by the bank increases at a reduced loan rate. However, the indirect effect is negative in sign when borrower asset risk is high. The total effect is positive observed from the last panel. When σ_A is low, the indirect effect reinforces the direct effect to give an overall positive response of P_I to an increase in σ_A. When σ_A is high, the negative indirect effect is insufficient to offset the positive direct effect to give a net positive response of P_I to an increase in σ_A. Overall, we conclude that, as the risk of corporate borrower assets increases, the FDIC's claim value is increased as shown in Figure 2.

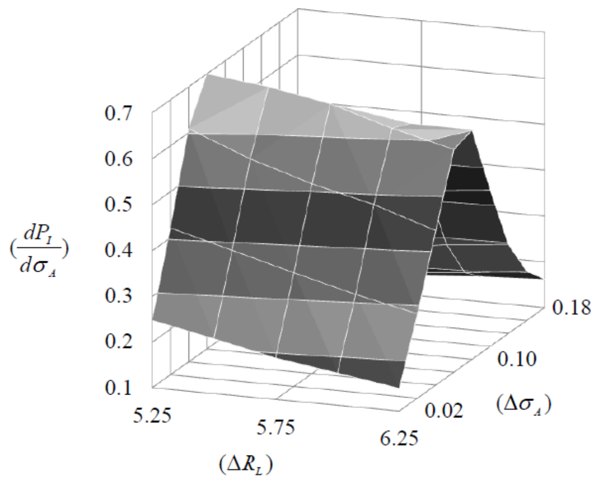

FIGURE 2. $dP_I/d\sigma_A$ at the level of $A = 300$

As mentioned previously, the bank's deposit is insured by the deposit insurer; however, for simplicity, we assume that the bank pays a zero insurance premium. One immediate application of our conclusion presented above may confirm the empirical findings of Wheelock and Kumbhaker [23] and Garcia [38]: moral hazard occurs when protection causes the beneficiaries of deposit insurance (captured by a zero insurance premium in our model) to be careless in the approach to bank soundness.

Next, we consider a low level of the corporate borrower's asset value $A = 250$ (scenario (ii)) relative to $A = 300$ and various levels of bank interest margin with borrower asset risks. The findings are summarized in Tables 4 and 5.

In Table 4, we observe the results of $S > 0$ from the first panel. The term in the second panel is indeterminate in sign. The term in the third panel implies the validness of the second-order condition of Equation (12). The comparative static result presented in the last panel shows that an increase in the corporate borrower's asset risk has an indeterminate effect on the bank's interest margin without imposing some assumptions as shown in Figure 3.

According to the results presented in the last panel of Table 4, an increase in the corporate borrower's asset risk decreases the bank interest margin only up to a certain threshold. If this is the case, an increase in the asset risk increases the loan amount held by the bank at a reduced margin. Asset risk as such makes the bank less prudent and more prone to risk-taking when the corporate borrower's asset risk is low, thereby adversely affecting the stability of the banking system. This result is largely supported

TABLE 4. Values of S and $\partial R_L/\partial\sigma_A$ at the level of $A = 250^*$

σ_A	$(R_L\%, L)$ (5.00, 210)	(5.25, 208)	(5.50, 206)	(5.75, 204)	(6.00, 202)	(6.25, 200)	(6.50, 198)
	S						
0.02	28.6076	28.9735	29.3352	29.6923	30.0448	30.3925	30.7350
0.04	29.6048	29.9353	30.2618	30.5843	30.9025	31.2163	31.5255
0.06	30.7167	31.0210	31.3191	31.6117	31.8993	32.1820	32.4601
0.08	31.4864	31.8696	32.2241	32.5541	32.8636	33.1559	33.4336
0.10	30.9509	31.5791	32.1506	32.6700	33.1421	33.5714	33.9624
0.12	29.0353	29.9314	30.7650	31.5371	32.2494	32.9044	33.5045
0.14	26.4126	27.4887	28.5146	29.4880	30.4073	31.2718	32.0811
0.16	23.7034	24.8577	25.9800	27.0664	28.1133	29.1177	30.0772
0.18	21.2405	22.3990	23.5425	24.6665	25.7667	26.8392	27.8805
0.20	19.1387	20.2589	21.3772	22.4890	23.5903	24.6771	25.7455
	$\partial^2 S/\partial R_L\partial\sigma_A$						
$0.02 \sim 0.04$	–0.0354	–0.0352	–0.0346	–0.0343	–0.0339	–0.0333	
$0.04 \sim 0.06$	–0.0262	–0.0284	–0.0299	–0.0306	–0.0311	–0.0311	
$0.06 \sim 0.08$	0.0789	0.0564	0.0374	0.0219	0.0096	–0.0004	
$0.08 \sim 0.10$	0.2450	0.2170	0.1894	0.1626	0.1370	0.1133	
$0.10 \sim 0.12$	0.2679	0.2621	0.2527	0.2402	0.2257	0.2091	
$0.12 \sim 0.14$	0.1800	0.1923	0.2013	0.2070	0.2095	0.2092	
$0.14 \sim 0.16$	0.0782	0.0964	0.1130	0.1276	0.1399	0.1502	
$0.16 \sim 0.18$	0.0042	0.0212	0.0376	0.0533	0.0681	0.0818	
$0.18 \sim 0.20$	–0.0383	–0.0252	–0.0122	0.0011	0.0143	0.0271	
	$\partial^2 S/\partial R_L^2$						
0.02	–	–0.0042	–0.0046	–0.0046	–0.0048	–0.0052	–
0.04	–	–0.0040	–0.0040	–0.0043	–0.0044	–0.0046	–
0.06	–	–0.0062	–0.0055	–0.0050	–0.0049	–0.0046	–
0.08	–	–0.0287	–0.0245	–0.0205	–0.0172	–0.0146	–
0.10	–	–0.0567	–0.0521	–0.0473	–0.0428	–0.0383	–
0.12	–	–0.0625	–0.0615	–0.0598	–0.0573	–0.0549	–
0.14	–	–0.0502	–0.0525	–0.0541	–0.0548	–0.0552	–
0.16	–	–0.0320	–0.0359	–0.0395	–0.0425	–0.0449	–
0.18	–	–0.0150	–0.0195	–0.0238	–0.0277	–0.0312	–
0.20	–	–0.0019	–0.0065	–0.0105	–0.0145	–0.0184	–
	$\partial R_L/\partial\sigma_A = -(\partial^2 S/\partial R_L\partial\sigma_A)/(\partial^2 S/\partial R_L^2)$						
$0.02 \sim 0.04$	–	–8.8000	–8.6500	–7.9767	–7.7045	–7.2391	–
$0.04 \sim 0.06$	–	–4.5806	–5.4364	–6.1200	–6.3469	–6.7609	–
$0.06 \sim 0.08$	–	1.9652	1.5265	1.0683	0.5581	–0.0274	–
$0.08 \sim 0.10$	–	3.8272	3.6353	3.4376	3.2009	2.9582	–
$0.10 \sim 0.12$	–	4.1936	4.1089	4.0167	3.9389	3.8087	–
$0.12 \sim 0.14$	–	3.8307	3.8343	3.8262	3.8230	3.7899	–
$0.14 \sim 0.16$	–	3.0125	3.1476	3.2304	3.2918	3.3452	–
$0.16 \sim 0.18$	–	1.4133	1.9282	2.2395	2.4585	2.6218	–
$0.18 \sim 0.20$	–	–13.2632	–1.8769	0.1048	0.9862	1.4728	–

*Parameter values, unless stated otherwise, $R = 4.00\%$, $R_D = 3.00\%$, $K = 20$, $q = 10.00\%$, $\sigma = 0.10$ and $\mu_A = 0.10$.

by the empirical evidence of Hawtrey and Liang [20]. By contrast, when the corporate borrower's asset risk is high, asset risk as such makes the bank less prone to risk-taking. This result is supported by Maudos and de Guevara [19].

In Table 5, we further consider the direct, indirect and total effects of σ_A on P_I at the level of $A = 250$. P_I is positive observed from the first panel. The direct effect presented in the second panel is consistently positive, that is, an increase in σ_A increases P_I, ceteris

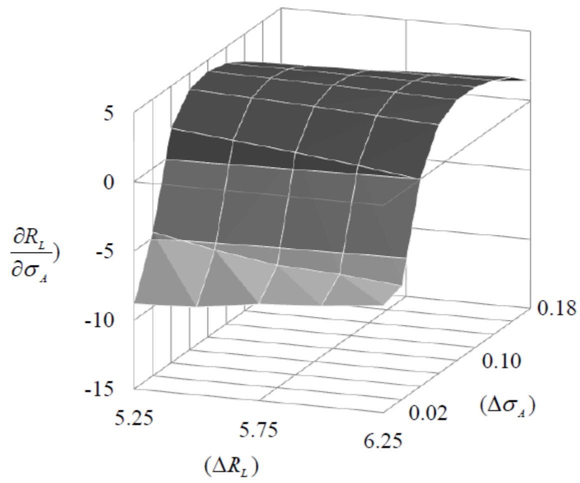

FIGURE 3. $\partial R_L/\partial\sigma_A$ at the level of $A = 250$

paribus. However, both the indirect and total effects observed from the third and last panels, respectively, are indeterminate as shown in Figure 4.

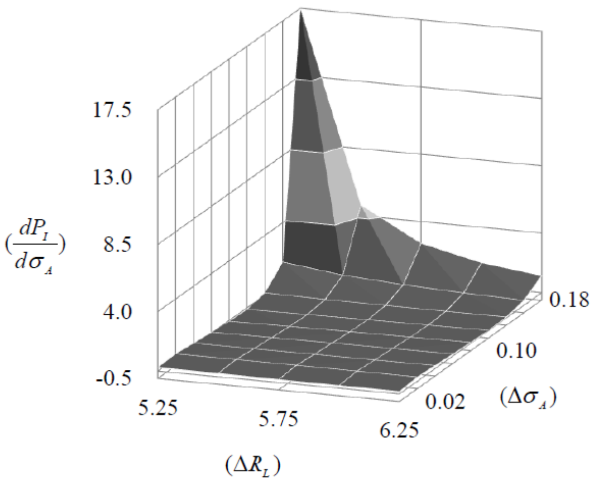

FIGURE 4. $dP_I/d\sigma_A$ at the level of $A = 250$

It is interesting that the positive direct effect explains increasing the liability of the insurer having resulted from increasing the corporate borrower's asset risk. The intuition is obvious. However, when the bank interest margin determination is further explicitly considered to further analyze the impact on the liability of the insurer, the results become diversified. The positive total effect is supported by Wheelock and Kumbhaker [23] and Garcia [38], while the negative total effect is supported by Demirguc-Kunt and Detragiache [24].

Comparing scenarios $A = 300$ and $A = 250$, we have some inconsistent results. These results are understood because of $\partial V_A/\partial\sigma_A < 0$ at the level of $A = 300$, and $\partial V_A/\partial\sigma_A < 0$ when σ_A is low and $\partial V_A/\partial\sigma_A > 0$ when σ_A is high at the level of $A = 250$, as mentioned in Table 1. Furthermore, the underlying asset volatility at different asset values has an ambiguous effect on a realized capped call option. When the underlying asset in the call option of the corporate borrower's equity is low, for example, $A = 250$, the corporate borrower will suffer losses on investment. In response to this potential problem, the bank may not be willing to provide funds to the corporate borrower due to a higher credit risk.

TABLE 5. Values of P_I and $dP_I/d\sigma_A$ at the level of $A = 250^*$

σ_A	$(R_L\%, L)$ (5.00, 210)	(5.25, 208)	(5.50, 206)	(5.75, 204)	(6.00, 202)	(6.25, 200)	(6.50, 198)
				P_I			
0.02	0.0673	0.0591	0.0518	0.0452	0.0395	0.0343	0.0298
0.04	0.1842	0.1660	0.1493	0.1341	0.1203	0.1077	0.0962
0.06	0.3812	0.3493	0.3197	0.2924	0.2670	0.2436	0.2219
0.08	0.6927	0.6358	0.5843	0.5376	0.4948	0.4556	0.4195
0.10	1.2565	1.1382	1.0348	0.9438	0.8631	0.7912	0.7268
0.12	2.2832	2.0442	1.8367	1.6561	1.4981	1.3595	1.2374
0.14	3.9564	3.5292	3.1560	2.8296	2.5437	2.2927	2.0719
0.16	6.3543	5.6851	5.0932	4.5697	4.1066	3.6968	3.3340
0.18	9.4312	8.4935	7.6522	6.8983	6.2232	5.6190	5.0785
0.20	13.0560	11.8508	10.7549	9.7599	8.8576	8.0405	7.3012
	$\partial P_I/\partial\sigma_A$: direct effect						
$0.02 \sim 0.04$	0.1169	0.1069	0.0975	0.0889	0.0808	0.0734	0.0664
$0.04 \sim 0.06$	0.1970	0.1833	0.1704	0.1583	0.1467	0.1359	0.1257
$0.06 \sim 0.08$	0.3115	0.2865	0.2646	0.2452	0.2278	0.2120	0.1976
$0.08 \sim 0.10$	0.5638	0.5024	0.4505	0.4062	0.3683	0.3356	0.3073
$0.10 \sim 0.12$	1.0267	0.9060	0.8019	0.7123	0.6350	0.5683	0.5106
$0.12 \sim 0.14$	1.6732	1.4850	1.3193	1.1735	1.0456	0.9332	0.8345
$0.14 \sim 0.16$	2.3979	2.1559	1.9372	1.7401	1.5629	1.4041	1.2621
$0.16 \sim 0.18$	3.0769	2.8084	2.5590	2.3286	2.1166	1.9222	1.7445
$0.18 \sim 0.20$	3.6248	3.3573	3.1027	2.8616	2.6344	2.4215	2.2227
	$(\partial P_I/\partial R_L)(\partial R_L/\partial\sigma_A)$: indirect effect						
$0.02 \sim 0.04$	–	0.1470	0.1315	0.1101	0.0971	0.0833	–
$0.04 \sim 0.06$	–	0.1356	0.1484	0.1554	0.1485	0.1467	–
$0.06 \sim 0.08$	–	–0.1012	–0.0713	–0.0457	–0.0219	0.0010	–
$0.08 \sim 0.10$	–	–0.3957	–0.3308	–0.2774	–0.2301	–0.1905	–
$0.10 \sim 0.12$	–	–0.8702	–0.7421	–0.6346	–0.5459	–0.4650	–
$0.12 \sim 0.14$	–	–1.4296	–1.2515	–1.0939	–0.9596	–0.8368	–
$0.14 \sim 0.16$	–	–1.7831	–1.6478	–1.4960	–1.3490	–1.2136	–
$0.16 \sim 0.18$	–	–1.1890	–1.4537	–1.5119	–1.4854	–1.4171	–
$0.18 \sim 0.20$	–	14.5351	1.8675	–0.0945	–0.8058	–1.0889	–
	direct effect + indirect effect = total effect						
$0.02 \sim 0.04$	–	0.2445	0.2204	0.1909	0.1705	0.1497	–
$0.04 \sim 0.06$	–	0.3060	0.3067	0.3021	0.2844	0.2724	–
$0.06 \sim 0.08$	–	0.1634	0.1739	0.1821	0.1901	0.1986	–
$0.08 \sim 0.10$	–	0.0548	0.0754	0.0909	0.1055	0.1168	–
$0.10 \sim 0.12$	–	–0.0683	–0.0298	0.0004	0.0224	0.0456	–
$0.12 \sim 0.14$	–	–0.1103	–0.0780	–0.0483	–0.0264	–0.0023	–
$0.14 \sim 0.16$	–	0.1541	0.0923	0.0669	0.0551	0.0485	–
$0.16 \sim 0.18$	–	1.3700	0.8749	0.6047	0.4368	0.3274	–
$0.18 \sim 0.20$	–	17.6378	4.7291	2.5399	1.6157	1.1338	–

*Parameter values, unless stated otherwise, $R = 4.00\%$, $R_D = 3.00\%$, $K = 20$, $q = 10.00\%$, $\sigma = 0.10$, $\mu = 0.10$, and $\mu_A = 0.10$.

The comparison is supported by the dilemma argument in the spirit of Demirguc-Kunt et al. [37], and suggests that the effects of the corporate borrower's asset risk on bank interest margin and then the deposit insurance premium depend on the realized capped credit risk explicitly related to the corporate borrower's investment returns and risks.

In the following subsection, we use a naked call methodology to apply in a realized capped world to assess the extent of the bias. As mentioned earlier in scenario (iii), V_A in Equation (8) is specified as $(1 + R_L)L$ when the default probability in the corporate borrower's equity is equal to zero. The results are summarized in Tables 6 and 7.

First, we observe $S > 0$ from the first panel of Table 6. $\partial^2 S/\partial R_L \partial \sigma_A$ is consistently negative observed from the second panel. $\partial^2 S/\partial R_L^2 < 0$ in the third panel implies the validness of the second-order condition for the equity maximization. As a result, we have the result of $\partial R_L/\partial \sigma_A < 0$ observed from the last panel as shown in Figure 5.

Our result is supported by the empirical findings of Williams [28] and Hawtrey and Liang [20]. Next, in Table 7, we have the value of $P_I > 0$ observed from the first panel. The direct effect presented in the second panel is unambiguously positive since an increase

Table 6. Values of S and $\partial R_L/\partial \sigma_A$ when $V_A = (1 + R_L)L^*$

σ_A	$(R_L\%, L)$ (5.00, 210)	(5.25, 208)	(5.50, 206)	(5.75, 204)	(6.00, 202)	(6.25, 200)	(6.50, 198)
	S						
0.02	28.6076	28.9735	29.3352	29.6923	30.0448	30.3925	30.7350
0.04	29.6049	29.9353	30.2618	30.5843	30.9025	31.2163	31.5255
0.06	30.7339	31.0316	31.3255	31.6155	31.9015	32.1833	32.4608
0.08	31.9602	32.2277	32.4915	32.7514	33.0073	33.2592	33.5069
0.10	33.2591	33.4987	33.7345	33.9665	34.1944	34.4184	34.6381
0.12	34.6130	34.8266	35.0364	35.2422	35.4440	35.6416	35.8352
0.14	36.0093	36.1985	36.3837	36.5649	36.7420	36.9150	37.0837
0.16	37.4386	37.6046	37.7666	37.9245	38.0782	38.2277	38.3729
0.18	38.8938	39.0378	39.1776	39.3133	39.4447	39.5717	39.6945
0.20	40.3696	40.4925	40.6111	40.7254	40.8353	40.9409	41.0421
	$\partial^2 S/\partial R_L \partial \sigma_A$						
$0.02 \sim 0.04$	–0.0355	–0.0352	–0.0346	–0.0343	–0.0339	–0.0333	
$0.04 \sim 0.06$	–0.0327	–0.0326	–0.0325	–0.0322	–0.0320	–0.0317	
$0.06 \sim 0.08$	–0.0302	–0.0301	–0.0301	–0.0301	–0.0299	–0.0298	
$0.08 \sim 0.10$	–0.0279	–0.0280	–0.0279	–0.0280	–0.0279	–0.0280	
$0.10 \sim 0.12$	–0.0260	–0.0260	–0.0262	–0.0261	–0.0264	–0.0261	
$0.12 \sim 0.14$	–0.0244	–0.0246	–0.0246	–0.0247	–0.0246	–0.0249	
$0.14 \sim 0.16$	–0.0232	–0.0232	–0.0233	–0.0234	–0.0235	–0.0235	
$0.16 \sim 0.18$	–0.0220	–0.0222	–0.0222	–0.0223	–0.0225	–0.0224	
$0.18 \sim 0.20$	–0.0211	–0.0212	–0.0214	–0.0215	–0.0214	–0.0216	
	$\partial^2 S/\partial R_L^2$						
0.02	–	–0.0042	–0.0046	–0.0046	–0.0048	–0.0052	–
0.04	–	–0.0039	–0.0040	–0.0043	–0.0044	–0.0046	–
0.06	–	–0.0038	–0.0039	–0.0040	–0.0042	–0.0043	–
0.08	–	–0.0037	–0.0039	–0.0040	–0.0040	–0.0042	–
0.10	–	–0.0038	–0.0038	–0.0041	–0.0039	–0.0043	–
0.12	–	–0.0038	–0.0040	–0.0040	–0.0042	–0.0040	–
0.14	–	–0.0040	–0.0040	–0.0041	–0.0041	–0.0043	–
0.16	–	–0.0040	–0.0041	–0.0042	–0.0042	–0.0043	–
0.18	–	–0.0042	–0.0041	–0.0043	–0.0044	–0.0042	–
0.20	–	–0.0043	–0.0043	–0.0044	–0.0043	–0.0044	–
	$\partial R_L/\partial \sigma_A = -(\partial^2 S/\partial R_L \partial \sigma_A)/(\partial^2 S/\partial R_L^2)$						
$0.02 \sim 0.04$	–	–9.0256	–8.6500	–7.9767	–7.7045	–7.2391	–
$0.04 \sim 0.06$	–	–8.5789	–8.3333	–8.0500	–7.6190	–7.3721	–
$0.06 \sim 0.08$	–	–8.1351	–7.7179	–7.5250	–7.4750	–7.0952	–
$0.08 \sim 0.10$	–	–7.3684	–7.3421	–6.8293	–7.1538	–6.5116	–
$0.10 \sim 0.12$	–	–6.8421	–6.5500	–6.5250	–6.2857	–6.5250	–
$0.12 \sim 0.14$	–	–6.1500	–6.1500	–6.0244	–6.0000	–5.7907	–
$0.14 \sim 0.16$	–	–5.8000	–5.6829	–5.5714	–5.5952	–5.4651	–
$0.16 \sim 0.18$	–	–5.2857	–5.4146	–5.1860	–5.1136	–5.3333	–
$0.18 \sim 0.20$	–	–4.9302	–4.9767	–4.8864	–4.9767	–4.9091	–

*Parameter values, unless stated otherwise, $R = 4.00\%$, $R_D = 3.00\%$, $K = 20$, $q = 10.00\%$, $\sigma = 0.10$ and $\mu_A = 0.10$.

TABLE 7. Values of P_I and $dP_I/d\sigma_A$ when $V_A = (1+R_L)L^*$

σ_A	$(R_L\%, L)$ (5.00, 210)	(5.25, 208)	(5.50, 206)	(5.75, 204)	(6.00, 202)	(6.25, 200)	(6.50, 198)
	P_I						
0.02	0.0673	0.0591	0.0518	0.0452	0.0395	0.0343	0.0298
0.04	0.1842	0.1660	0.1493	0.1341	0.1203	0.1077	0.0962
0.06	0.3804	0.3488	0.3195	0.2922	0.2670	0.2435	0.2219
0.08	0.6596	0.6124	0.5681	0.5264	0.4872	0.4505	0.4161
0.10	1.0188	0.9548	0.8940	0.8364	0.7818	0.7301	0.6812
0.12	1.4520	1.3705	1.2926	1.2183	1.1473	1.0797	1.0152
0.14	1.9520	1.8528	1.7576	1.6661	1.5784	1.4943	1.4136
0.16	2.5120	2.3952	2.2825	2.1739	2.0693	1.9684	1.8714
0.18	3.1255	2.9913	2.8614	2.7357	2.6142	2.4967	2.3831
0.20	3.7869	3.6356	3.4887	3.3462	3.2079	3.0739	2.9439
	$\partial P_I/\partial\sigma_A$: direct effect						
$0.02 \sim 0.04$	0.1169	0.1069	0.0975	0.0889	0.0808	0.0734	0.0664
$0.04 \sim 0.06$	0.1962	0.1828	0.1702	0.1581	0.1467	0.1358	0.1257
$0.06 \sim 0.08$	0.2792	0.2636	0.2486	0.2342	0.2202	0.2070	0.1942
$0.08 \sim 0.10$	0.3592	0.3424	0.3259	0.3100	0.2946	0.2796	0.2651
$0.10 \sim 0.12$	0.4332	0.4157	0.3986	0.3819	0.3655	0.3496	0.3340
$0.12 \sim 0.14$	0.5000	0.4823	0.4650	0.4478	0.4311	0.4146	0.3984
$0.14 \sim 0.16$	0.5600	0.5424	0.5249	0.5078	0.4909	0.4741	0.4578
$0.16 \sim 0.18$	0.6135	0.5961	0.5789	0.5618	0.5449	0.5283	0.5117
$0.18 \sim 0.20$	0.6614	0.6443	0.6273	0.6105	0.5937	0.5772	0.5608
	$(\partial P_I/\partial R_L)(\partial R_L/\partial\sigma_A)$: indirect effect						
$0.02 \sim 0.04$	–	0.1507	0.1315	0.1101	0.0971	0.0833	–
$0.04 \sim 0.06$	–	0.2514	0.2275	0.2029	0.1790	0.1592	–
$0.06 \sim 0.08$	–	0.3604	0.3218	0.2950	0.2743	0.2441	–
$0.08 \sim 0.10$	–	0.4480	0.4229	0.3729	0.3699	0.3184	–
$0.10 \sim 0.12$	–	0.5330	0.4867	0.4633	0.4249	0.4209	–
$0.12 \sim 0.14$	–	0.5855	0.5627	0.5283	0.5046	0.4673	–
$0.14 \sim 0.16$	–	0.6537	0.6172	0.5828	0.5646	0.5301	–
$0.16 \sim 0.18$	–	0.6866	0.6806	0.6301	0.6009	0.6059	–
$0.18 \sim 0.20$	–	0.7243	0.7092	0.6758	0.6669	0.6382	–
	direct effect + indirect effect = total effect						
$0.02 \sim 0.04$	–	0.2482	0.2204	0.1909	0.1705	0.1497	–
$0.04 \sim 0.06$	–	0.4216	0.3856	0.3496	0.3148	0.2849	–
$0.06 \sim 0.08$	–	0.6090	0.5560	0.5152	0.4813	0.4383	–
$0.08 \sim 0.10$	–	0.7739	0.7329	0.6675	0.6495	0.5835	–
$0.10 \sim 0.12$	–	0.9316	0.8686	0.8288	0.7745	0.7549	–
$0.12 \sim 0.14$	–	1.0505	1.0105	0.9594	0.9192	0.8657	–
$0.14 \sim 0.16$	–	1.1786	1.1250	1.0737	1.0387	0.9879	–
$0.16 \sim 0.18$	–	1.2655	1.2424	1.1750	1.1292	1.1176	–
$0.18 \sim 0.20$	–	1.3516	1.3197	1.2695	1.2441	1.1990	–

*Parameter values, unless stated otherwise, $R = 4.00\%$, $R_D = 3.00\%$, $K = 20$, $q = 10.00\%$, $\sigma = 0.10$, $\mu = 0.10$ and $\mu_A = 0.10$.

in the asset risk of the corporate borrower increases the deposit insurance premium, ceteris paribus. The indirect effect observed from the third panel is also positive in sign. This is because an increase in the asset risk of the corporate borrower results in decreasing the bank's interest margin ($\partial R_L/\partial\sigma_A < 0$ as known from Table 6), which further results in increasing the deposit insurance premium ($\partial P_I/\partial R_L < 0$). The indirect effect reinforces the direct effect to given an overall positive response of P_I to an increase in σ_A as shown in the last panel as shown in Figure 6. Our result is largely supported by Wheelock and Kumbhaker [23] and Garcia [38].

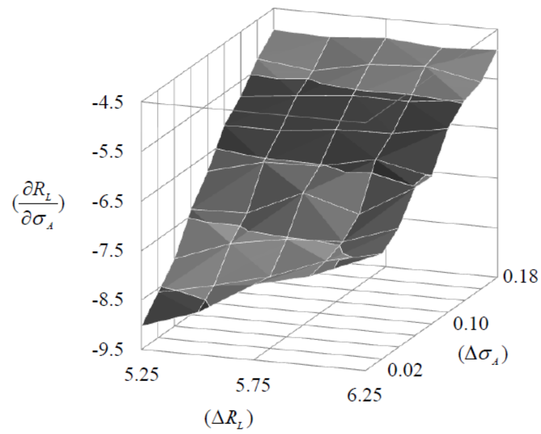

FIGURE 5. $\partial R_L/\partial\sigma_A$ when $V_A = (1 + R_L)L$

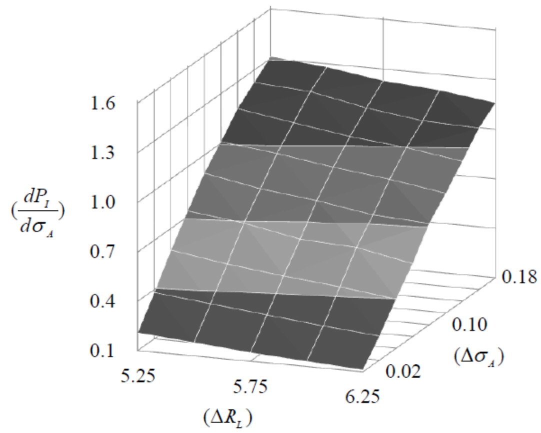

FIGURE 6. $dP_I/d\sigma_A$ when $V_A = (1 + R_L)L$

In the three scenarios reported, the market-based estimates of the bank's equity which ignore the realized cap are highest and the bank's equity with the realized cap at a low level of the corporate borrower's investment return related to its loan payment ability is lowest. These results are understood because the default from the corporate borrower likely comes into effect in the bank's equity viewed as a realized capped call option on its assets. In addition, the market-based estimates of deposit insurance premium of the FDIC's claim value which ignore the realized cap are lowest and the claim value with the realized cap at a low level of the corporate borrower's investment return is highest. The interpretation of these results follows a similar argument as in the case of the bank's equity valuation. Further, an interest result is that as the corporate borrower asset risk is raised, the total effect on the deposit insurance premium is increased in the scenario of the realized capped call only the corporate borrower with a high level of investment and in the scenario of the naked call. These two conclusions indicate that the corporate borrower's investment returns and risks play important roles in affecting the bank's equity values and the FDIC's claim values. Our findings provide alternative explanations for the evidence concerning the assessment of deposit insurance premium related to corporate borrower default risk and bank spread behavior.

6. **Conclusions.** This paper proposes an alternative framework for bank deposit insurance premium valuations based on the bank's equity viewed as a realized capped call

option on its assets. This framework develops a model based on bank spread behavior that is explicitly capped by corporate borrower default risk. Our model allows the inclusion of more realistic market and credit risk cost conditions along with the more appropriate behavioral mode of loan rate-setting. A failure to recognize this realized cap would lead to undervaluation of the deposit insurance premium and leave the FDIC over-exposed to bank risk-taking at a reduced margin. However, we need to point out one important implication. When the economy recovers from the distress, the corporate borrower investment return is expected to increase. One way the bank may attempt to augment its total returns is by shifting its investments to its loan portfolio and away from the Federal funds market, resulting in increasing the FDIC over-exposed to bank loan risk taking when the realized cap is ignored, thereby adversely affecting the stability of the banking system. It is necessary that the realized cap should be explicitly factored into the specification of risk-based deposit insurance premium.

One caveat that should be stressed is that the deposit insurer cannot opt for bank closure until the expiration of the insurance period in our analysis. This paper does not deal with many other important issues of using path dependent, barrier options in some form to address the problem of early bank closure [39,40]. While they are undoubtedly significant issues, they can be perhaps best understood only when barriers are economically and statistically significant in a large cross-section of financial firms. Such concerns are beyond the scope of this paper and therefore are not addressed here. What this paper does demonstrate, however, is the important role played by corporate borrower default risk capped into the call valuation of bank equity in affecting risk-based insurance premium estimates and invariably the stability of banking system.

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