Credit Risk Hedging, Deposit Insurance Fund Protection, and Default Risk in Retail Banking during a Financial Crisis

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Abstract

The barrier options theory of corporate security valuation is applied to the contingent claims of a regulated bank. The regulator/insurer of the bank owns a down-and-in call option on the bank's assets which can be balanced against the expected coverage cost. This paper examines how the bank's credit risk hedging operation affects its spread behavior and performance and how these effects vary at various levels of the regulatory insurance fund protection. We find that an increase in the bank's credit risk hedging has a negative effect on its loan rate, deposit rate, default risk, and liability value. The regulatory deposit insurance fund protection reinforces the reduction in bank default risk, thereby contributing to the stability of the banking system. The insurance fund protection with credit risk hedging confirms the requirement of the Dodd-Frank Wall Street Reform and Consumer Protection Act.

Keywords: credit risk hedging, deposit insurance fund, spread behavior, default risk, barrier

1. Introduction

Credit derivatives are credit risk transfer tools that have been extensively used by banks over the last decades to actively manage credit risk (Note 1). The recent financial crisis raises a fundamental issue about the role of credit risk hedging including its effect on bank behavior, particularly from the standpoint of financial stability. Not surprisingly, credit risk transfer activities help manage bank risk (Cebenoyan and Strahan, 2004). Wagner and Marsh (2006) also suggest that the incentive of banks to transfer credit risk is aligned with the regulatory objective of improving stability, and so the recent development of credit derivative instruments is to be welcomed. However, Bedendo and Bruno (2012) demonstrate that the contribution of credit risk transfer with credit swaps to the 2007-2009 financial turmoil has been widely debated. A common view argues that credit risk transfer practices spur excessive credit growth and increase risk taking as a result of reduced monitoring incentives in credit risk transfer users (Brunnermeier, 2009).

Parallel to an increased importance of buying credit default swaps in order to hedging banks' trading (Mengle, 2007), there has been an ongoing discussion about the role of deposit insurance fund protection to influence bank behavior and make banks more robust against financial shocks, i.e., to strengthen the soundness and stability of banks in the usual parlance of the Federal Deposit Insurance Corporation (FDIC). Hamilton (2013) reports that the federal backstop, funded by assessments on banks, is at $33 billion at the end of 2012, resulting in a reserve ratio of 0.45 percent, up from a deficit of $20.9 billion at the end of 2009 as the credit crisis caused banks to fail. The Dodd-Frank Wall Street Reform and Consumer Protection Act (Dodd-Frank Act) requires that the deposit insurance fund reserve ratio reach 1.35 percent by September 30, 2020 (Note 2). This can be understood that inadequate deposit insurance funding can lead to costly delays in resolving failed banks and to the loss of credibility of the deposit insurance system (International Association of Deposit Insurers, 2009). Given the divergent views in the literature on credit risk transfer, the issue of the effects credit risk hedging has on bank performance, the magnitude of these effects, and how they might differ across different levels of regulatory deposit insurance fund protection in a financial crisis boils down to a crucial question. In particular, the goal of this paper is to examine the effects of credit risk hedging on bank interest margin, i.e., the spread between the loan rate and the deposit rate, and bank default risk explicitly considering regulatory deposit insurance fund protection.

Bank interest margin and default risk in banking are two key issues that concern bank managers. 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 financial intermediation efficiency (Saunders and Schumacher, 2000; Wong, 2011). Bank default risk related to bank survival is central not only in strategic decisions made by banks, but also in decisions made by regulators concerned about banking stability. Knowing how credit risk hedging affects bank performance including margin and default risk in a financial crisis is also of paramount importance for regulators contemplating micro- and macro-prudential banking regulation, particularly regulatory deposit insurance fund protection.

In light of previous work, the purpose of this paper is to develop a path-dependent, barrier option model of bank spread behavior that integrates regulatory deposit insurance fund protection into the firm-theoretic approach to banking and analyze the interaction between the protection regulation and credit risk hedging including its effect on spread behavior and further default risk in an individual bank's equity return. In particular, we consider the simultaneous impacts on the bank's loan rate and deposit rate (and thus on the bank's margin) from changes in hedging and regulation. The results of the model show that an increase in the credit risk hedging has a negative effect on loan rate, deposit rate, default risk, and the liability of the bank. In addition, we find that deposit insurance fund protection wakens this reduction in loan rate and deposit rate, but reinforces this reduction in bank default risk, and has an ambiguous effect on this reduction in the bank's liability. Furthermore, the direct effect of credit risk hedging on the default risk in the bank's equity return is unambiguously negative in sign. The indirect effect of credit risk hedging makes the bank less prudent and more prone to loan risk-taking, and simultaneously makes the bank reduce its deposit volume. The former adversely affects the stability of the banking system while the latter contributes the stability. This model provides us with a hunch that this indirect effect is positive in sign. The indirect effect is insufficient to offset the direct effect to give an overall negative response of bank default risk to an increase in credit risk hedging. Our results are largely consistent with the empirical findings of Cebenoyan and Strahan (2004) and Wagner and Marsh (2006). A further contribution of this paper is that it shows that deposit insurance fund protection reinforces this overall negative response of bank default risk that meets the requirement of the Dodd-Frank Act. The large value of the FDIC's contingent asset compared to its contingent liability implies that any deposit insurance scheme can be strengthened by barrier policies with bank credit hedging practices.

The paper is structured as follows. Section 2 presents related literature. Section 3 develops the basic structure of the model. Section 4 derives the solutions of the model and the comparative static analysis. Section 5 performs a numerical analysis to confirm the comparative static results. The final section concludes the paper.

2. Related Literature

Our theory of credit risk hedging is related to three strands of the literature. The first is the literature on credit risk transfer and banking stability, in which Duffie (2008), Bedendo and Bruno (2012), and Pausch and Welzel (2012) are major contributors. Duffie (2008) summarizes different aspects concerning credit risk transfer and on the whole takes a positive view: the principle benefits of credit risk transfer are earning-asset portfolio diversification and cost reduction of raising external capital for loan intermediation. Bedendo and Bruno (2012) document some potential beneficial effects of credit risk transfer on the economy since the funds released through credit risk transfer are subsequently invested by banks to sustain credit supply. Pausch and Welzel (2012) find that when capital adequacy regulation accepts credit default swaps as an instrument to mitigate credit risk, banks will engage in credit default swaps trading (Note 3). In other words, the bank reduces loan volume and increases interest rate on loans as a reaction to an increase in credit risk. While we also examine credit risk transfer, our focus on credit risk hedging aspects of deposit insurance fund protection takes our analysis in a different direction.

The second strand is the deposit insurance fund protection literature. Sheehan (1998) focuses on the capitalization issue of the Bank Insurance Fund (BIF) and shows that the funding arrangement is sufficient to maintain BIF solvency if the prior history of losses is a good indicator of future losses. Oshinsky (1999) shows bank consolidation increasing the risk of BIF insolvency. Schoenmaker and Gros (2012) suggest that a deposit insurance authority should be established to stabilize the retail deposit base and resolve troubled cross-border banks and the deposit insurance fund would be fed through regular risk-based deposit insurance premiums with a fiscal backstop. Episcopos (2008) demonstrates that raising the regulatory deposit insurance protection leads to a transfer of wealth from the bank's stockholders to the insurer and reduces stockholder incentives to increase asset risk. The primary difference between our model and these papers is that we consider the effects of deposit insurance fund protection with credit risk hedging on bank interest margin and default risk.

The third strand is the literature on banking modeling approach to crises and normal times. Two related option-based approaches, in particular have been employed in the literature to model regulation to banking. A number of writers, e.g., Ronn and Verma (1986), Episcopos (2004), and Vassalou and Xing (2004), have adopted the path-independent option model based on Merton (1974) as their analytical apparatus. The principal advantage of this approach is the explicit treatment of uncertainty which has long played a prominent role in discussions of banking behavior. This approach, however, omits a key aspect of the problem of early closure particularly during financial crises. The papers including Bhattacharya et al. (1998), Brockman and Turtle (2003), and Episcopos (2008), for example, propose a framework for corporate security based on path-dependent, barrier option models. The fundamental advantage of this approach is also the explicit treatment of uncertainty, in particular early bank closure during a financial turmoil. In addition, the idea of early bank closure has deep roots in financial crisis period, during which protecting the insurance funds and the stability of the banking system are dominant issues (Acharya and Dreyfus, 1989; Brockman and Turtle, 2003). We use the methology of path dependency, integrate deposit insurance fund protection into the industrial organization approach to banking, and analyze the interaction between fund protection and credit risk hedging. Our contribution consists in including credit risk hedging and deposit insurance fund protection, and accounting for their impacts on bank interest margin and default risk in retail banking.

Overall, the literature to which our work is most directly related is that on conformity, particularly Wagner and Marsh (2006). Other examples are Maudos and de Guevara (2004), Williams (2007), Episcopos (2008), Bedendo and Bruno (2012), and Pausch and Welzel (2012). The fundamental insight shared by these papers is that conformity is generated by a design to distinguish oneself from the type with which one wishes not to be identified. This insight is an important aspect of credit risk hedging which is perfectly in line with the deposit insurance fund protection objective of making bank failure less likely. What distinguishes our work from this literature is our focus on the commingling of the assessment of the hedging with the assessment of the deposit insurance fund protection and, in particular, the emphasis we put on the bank spread behavior during a financial crisis.

3. The Model

To model bank behavior, we consider a banking firm that makes decisions in a single period horizon with two dates, 0 and 1, $t \in [0, 1]$. At $t = 0$, the bank has the following balance sheet:

$$(1-\theta)L + \theta L + B = D + K \tag{1}$$

where $(1-\theta)L > 0$ with $0 < \theta < 1$ is the amount of non-swapped loans and $\theta L > 0$ is the amount of swapped loans for credit risk hedging, $B > 0$ is the volume of risk-free liquid assets, $D > 0$ is the quantity of deposits, and $K > 0$ is the stock of equity capital.

The bank's loans belong to a single homogeneous class of fixed claims that mature at $t = 1$. The bank enjoys market power in its loan market. The decision on loans is made via the setting of loan rate $R_L > 0$ at $t = 0$. The demand for loans is governed by a downward-sloping demand function $L(R_L)$ where $\partial L / \partial R_L < 0$ and $\partial^2 L / \partial R_L^2 < 0$. This demand function is assumed to be a concave one (Tsai and Lin, 2013). Non-swapped loans are risky in that they are subject to non-performance. In addition to loans, liquid assets are also included in the earning-asset portfolio. Liquid assets B held by the bank during the period earn the security-market interest rate of $R > 0$. The earning-asset portfolio of the bank is financed partly by deposits. The bank also enjoys market power in its deposit market. The supply of deposits is governed by an upward-sloping supply function $D(R_D)$ where $R_D > 0$ is the deposit rate chosen by the bank. The supply of deposits is assumed to be a concave function with the conditions of $\partial D / \partial R_D > 0$ and $\partial^2 D / \partial R_D^2 < 0$ (Pausch and Welzel, 2012). By regulation, the bank is subject to the capital adequacy requirement: $K \geq qD$ where q is the required capital-to-deposits ratio (VanHoose, 2007). The capital requirement constraint will be binding as long as R is sufficiently higher than R_D (Wong, 1997). In the case of binding constraint, Eq. (1) can be rewritten as $(1-\theta)L + \theta L + B = (1+q)D$, which will be used in our model.

As noted by Santomero (1984), the choice of an appropriate goal in modeling the bank's optimization problem remains a controversial issue. In general, if the problem of early bank closure is emphasized, then the bank's objective is to maximize its market value based on a path-dependent, barrier option framework. The selection of our model's objective function follows Episcopos (2008). Specifically, we use the barrier option formula of Merton (1973) as a tool to understand the down-and-out call (*DOC*) option to bank equity in order to address the problem of early closure during a financial turmoil. It is argued that path dependency is an intrinsic and fundamental characteristic of assets because equity can be knocked out whenever a legally binding barrier is breached and will be priced as a *DOC* option (Brockman and Turtle, 2003). The market value of the bank's equity subject to Eq. (1) can be written as:

$$DOC = SC - DIC \tag{2}$$

where

$$SC = VN(d_1) - Ze^{-\delta}N(d_2)$$

$V = (1-\theta)(1+R_L)L$ with $dV = \mu V dt + \sigma V dW$

$Z = (1+R_D)D - (1+R)[(1+q)D - L] - \theta(1+R_L-\alpha)L$

$\delta = R - R_D$

$$d_1 = \frac{1}{\sigma}(\ln\frac{V}{Z} + \delta + \frac{\sigma^2}{2}),\ d_2 = d_1 - \sigma$$

$$DIC = V(\frac{H}{V})^{2\eta}N(b_1) - Ze^{-\delta}(\frac{H}{V})^{2\eta-2}N(b_2)$$

$$H = bZ,\ 0 < b < 1,\ \eta = \frac{\delta}{\sigma^2} + \frac{1}{2}$$

$$b_1 = \frac{1}{\sigma}(\ln\frac{H^2}{VZ} + \delta + \frac{\sigma^2}{2}),\ b_2 = b_1 - \sigma$$

Expression of *DOC* in Eq. (2) is explained as follows. The market value of the bank's underlying assets follows a geometric Brownian motion of dV where V is the repayment value of the bank's non-swapped loans, with an instantaneous drift μ, an instantaneous volatility σ, and a standard Wiener process W. We denote by Z the book value of the net-obligation payments, that is the difference between the payments to depositors and the two repayments from the liquid-asset investments and the counterparty in the credit risk transfer transaction. Note that α is the cost rate of hedging credit risk, which is assumed to be $(R_L - R) > \alpha$ to induce the bank to participate in the credit risk transfer (Note 4). If the hedging price is too high where $(R_L - R) < \alpha$, the decision of hedging will not be made and the bank will shift its investments to the liquid-asset market from its loan portfolio in order to gain risk diversification. δ is specified as the compounded riskless rate of return. H is the asset value that triggers bankruptcy, i.e., the barrier or the knock-out value of the bank. We follow Brockman and Turtle (2003) that the default barrier level H is proportional to Z by a barrier-to-debt ratio of b, $H = bZ$ where $0 < b < 1$. $N(\cdot)$ is the cumulative distribution function for a standard normal random variable.

The term *SC* in Eq. (2) are recognized as the expected asset value and present value of the net-obligation payments using the standard call option view of the bank. The barrier H can be viewed as the value of non-swapped assets above which creditors cannot force dissolution. The omission of terms involving the barrier H, the term *DIC* (the down-and-in call option) in Eq. (2), will behave significant consequences especially when the likelihood of meeting the barrier is substantial. The *DIC* can be interpreted as bank depositors (non-negative) claim, which demonstrates protection to depositors by allowing them to "call in their chips" before asset values deteriorate further. It is seen easily that the barrier option in Eq. (2) is a wider class than the standard call option because as H approaches zero in Eq. (2), the *DIC* vanishes, and we can arrive at the usual Merton (1974) call option price that captures the value of bank equity.

Next, our approach in calculating default risk measures using information about Eq. (2) is very similar to the one used by Brockman and Turtle (2003). The default probability is the probability that V will be less than Z. The default probability, the default risk in the bank's equity return in the *DOC* valuation, is given by:

$$P_{def} = N(a_1) + e^{a_2}N(-a_3) \tag{3}$$

where

$a_1 = \frac{1}{\sigma}(\ln\frac{bZ}{V} - \delta + \frac{\sigma^2}{2})$, $a_2 = \frac{2}{\sigma^2}(\delta - \frac{\sigma^2}{2})\ln\frac{bZ}{V}$

$a_3 = -\frac{1}{\sigma}(\ln\frac{bZ}{V} + \delta - \frac{\sigma^2}{2})$

Although Eq. (3) estimates only a risk-neutral probability of bankruptcy, this still provides a meaningful ranking of the bank according to its alternative susceptibility to failure.

It is also interesting to use information about Eq. (2) to illustrate the bank's liability. As the barrier increases, debt behaves more like equity and equity converges to zero. Our approach in calculating the value of liabilities is very similar to the one outlined by Episcopos (2008). That is written as:

$$Ins = Ze^{-\delta} - Put + DIC \tag{4}$$

where

$$Put = Ze^{-\delta}N(-d_2) - VN(-d_1)$$

and where Put is the value of the standard European put.

The first two terms on the right-hand side of Eq. (4) represent the Merton (1974) value of debt. The first term is the discount value of the payment to depositors. The second term is the put option or the value of the fair insurance needed in order to make deposits risk free. The third term represents the value of the FDIC's contingent asset or the knock-out value of the bank. Depositors would cash in on this option if they were able to jointly seize the asset of the bank when the bank's assets dropped to H. As pointed out by Episcopos (2008), in practice, coordination costs would make it difficult for depositors to jointly take legal actions against the bank. As much more suitable environment for the barrier model to hold is created if regulation is in effect. The Federal Deposit Insurance Corporation Improvement Act (FDICIA) has conferred wide powers to the FDIC to seize the assets of the bank and act in the place of insured depositors in the courts. In other words, the FDIC controls the barrier. Given current regulation statuses, it is safe to say that the value of liabilities in Eq. (4) is in the hands of the FDIC, especially after the FDIC has been named a receiver. In turn, the FDIC has to allocate this value to the insured depositors, other claimants, and itself.

4. Solutions and Results

With all the assumption in place, we are now ready to solve for the bank's optimal choices of loan rate and deposit rate simultaneously. The bank seeks to maximize the market value of the equity based on Eq. (2). The first-order conditions for the maximization of the bank's equity are:

$$\frac{\partial DOC}{\partial R_L} = \frac{\partial SC}{\partial R_L} - \frac{\partial DIC}{\partial R_L} = 0 \tag{5}$$

$$\frac{\partial DOC}{\partial R_D} = \frac{\partial SC}{\partial R_D} - \frac{\partial DIC}{\partial R_D} = 0 \tag{6}$$

We assume that the equilibrium is locally strictly stable, which implies that

$$\frac{\partial^2 DOC}{\partial R_L^2} < 0,\ \frac{\partial^2 DOC}{\partial R_D^2} < 0,\ \text{and}\ \Delta = \frac{\partial^2 DOC}{\partial R_L^2}\frac{\partial^2 DOC}{\partial R_D^2} - \frac{\partial^2 DOC}{\partial R_L \partial R_D}\frac{\partial^2 DOC}{\partial R_D \partial R_L} > 0 \tag{7}$$

In addition, think of $\partial^2 DOC/\partial R_L \partial R_D$ as $\partial/\partial R_D(\partial DOC/\partial R_L)$. That is, the term represents the change in the marginal equity value of loan rate of being a bit more "aggressive" when R_D set by the bank becomes more aggressive. If $\partial^2 DOC/\partial R_L \partial R_D$ is negative, we say that the bank regards its loan rate as a strategic substitute to its deposit rate, and if $\partial^2 DOC/\partial R_L \partial R_D > 0$, we say that the bank regards its loan rate as a strategic complement based on the argument in the spirit of Bulow et al. (1985). The interpretation of $\partial^2 DOC/\partial R_D \partial R_L$ follows a similar argument as in the case of $\partial^2 DOC/\partial R_L \partial R_D$ above. The first term on the right-hand side in Eq. (5) can be interpreted as the marginal equity value of loan rate in the SC option valuation, while the second term can be interpreted as the marginal knock-out value of loan rate. The optimal loan rate is determined where both the marginal value are equal. Similarly, the optimal deposit rate is determined where the marginal equity value of deposit rate in the SC option valuation equals the marginal knock-out value of deposit rate. We can further substitute both the optimal loan and deposit rates to obtain the default probability in Eq. (3) and the liability value in Eq. (4) staying on the optimization.

Having examined the solutions to the bank's optimization problem, we consider the effects on the optimal loan rate and deposit rate from changes in the amount of credit risk hedging. These results will be used when the two effects on default risk and liability value are analyzed. Implicitly differentiating Eqs. (5) and (6) with respect to θ, and then solving for these effects using Cramer's rule yield:

$$\frac{\partial R_L}{\partial \theta} = \left(\frac{\partial^2 DOC}{\partial R_L \partial \theta}\frac{\partial^2 DOC}{\partial R_D^2} - \frac{\partial^2 DOC}{\partial R_L \partial R_D}\frac{\partial^2 DOC}{\partial R_D \partial \theta}\right) / \Delta \tag{8}$$

$$\frac{\partial R_D}{\partial \theta} = \left(\frac{\partial^2 DOC}{\partial R_L^2}\frac{\partial^2 DOC}{\partial R_D \partial \theta} - \frac{\partial^2 DOC}{\partial R_L \partial \theta}\frac{\partial^2 DOC}{\partial R_D \partial R_L}\right) / \Delta \tag{9}$$

We consider next the impacts on the default risk in the bank's equity return and the liability value from changes in the level of credit risk hedging. Differentiating Eqs. (3) and (4) evaluated at the optimal loan rate and deposit rate with respect to θ yields, respectively:

$$\frac{dP_{def}}{d\theta} = \frac{\partial P_{def}}{\partial \theta} + \frac{\partial P_{def}}{\partial R_L}\frac{\partial R_L}{\partial \theta} + \frac{\partial P_{def}}{\partial R_D}\frac{\partial R_D}{\partial \theta} \tag{10}$$

$$\frac{dIns}{d\theta} = \frac{\partial Ins}{\partial \theta} + \frac{\partial Ins}{\partial R_L}\frac{\partial R_L}{\partial \theta} + \frac{\partial Ins}{\partial R_D}\frac{\partial R_D}{\partial \theta} \tag{11}$$

The first term on the right-hand side of Eq. (10) can be identified as the direct effect, while the second and third terms can be identified as the indirect effect. The direct effect captures the change in P_{def} due to an increase in θ, holding the optimal loan and deposit rates constant. The indirect effect arises because an increases in θ changes in P_{def} by $L(R_L)$ and $D(R_D)$ evaluated at the optimal rates in every possible state. This indirect effect demonstrates the effect of θ on P_{def} when loan rate and deposit rate decisions are made simultaneously. The interpretation of Eq. (11) follows a similar argument as in the case of Eq. (10).

The added complexity of the barrier option with credit risk hedging does not always lead to clear-cut results in particular when the simultaneous effects are analyzed. However, we can certainly speak of tendencies for reasonable parameter levels corresponding to Eqs. (8) and (9) with DOC of Eq. (2), Eqs. (10) with P_{def} of Eq. (3), and Eqs. (11) with Ins of Eq. (4) associated with the equilibrium condition of Eqs. (5) and (6). Toward that end, we compute derivatives of the value function of barrier. The numerical examples provide intuition regarding the problems at hand, i.e., the comparative static results of Eq. (8) ~ (11) in our model.

5. Numerical Analysis

In the following numerical analysis, the parameter values, unless otherwise indicated, are assumed to be $R = 4.0\%$, $\alpha = 0.25\%$, $q = 8.5\%$, and $\sigma = 0.3$. Let $(R_L\%, L)$ change from (4.5, 200) to (5.1, 179) in order to capture the mentioned conditions of $\partial L / \partial R_L < 0$ and $\partial^2 L / \partial R_L^2 < 0$. Let $(R_D\%, D)$ change from (3.5, 206) to (2.9, 185) to capture the conditions of $\partial D / \partial R_D > 0$ and $\partial^2 D / \partial R_D^2 < 0$. These parameter levels used for our analysis are explained as follows. (i) The assumption of $R > R_D$ is made based on the argument of Wong (1997), implying that the capital requirement constraint will binding as long as R is sufficiently larger than R_D. (ii)

$\alpha = 0.25\%$ demonstrates the price of hedging credit risk where $(R_L - \alpha) > R$. If the price is high where $(R_L - \alpha) < R$, the bank has no incentives to participate in the hedging transaction, instead of shifting its investments to the liquid-asset market from its loan portfolio. (iii) The specification of capital adequacy requirement is consistent with the Basel approach, which is set by the capital-to-deposits ratio $K / D = q = 8.5\%$ (VanHoose, 2007). For example, if $D = 185$, then $K = 15.725$ at $q = 8.5\%$. In this case, the capital-to-asset ratio is 7.8625% when $L = 200$. The bundle of $(R_D\%, D) = (2.9, 185)$ is invalid for our analysis since the capital adequacy requirement is not met. But if $D = 191$, then $K = 16.235$ at $q = 8.5\%$. Under the circumstances, the capital-to-asset ratio is 8.12% when $L = 200$, which meets the requirement. (iv) The condition of $R_L > R_D$ indicates that bank interest margin is a proxy for the efficiency of financial intermediation (Saunders and Schumacher, 2000). (v) The condition of $R_L > R$ implies the scope for asset substitution (Kashyap et al., 2002).

First of all, we compute equity components of bank value including SC, DIC, and DOC based on Eq. (2) at $\theta = 0.1$ and $b = 0.6$ (Note 5). The findings are summarized in Table 1.

Table 1. Equity components of bank value at $\theta = 0.1$

	$(R_L\%, L)$						
$(R_D\%, D)$	(4.5, 200)	(4.6, 199)	(4.7, 197)	(4.8, 194)	(4.9, 190)	(5.0, 185)	(5.1, 179)
	SC						
(3.5, 206)	33.3059	33.3353	33.2535	33.0593	32.7517	32.3300	31.7939
(3.4, 205)	33.4721	33.5015	33.4194	33.2245	32.9158	32.4927	31.9549
(3.3, 203)	33.5805	33.6097	33.5270	33.3311	33.0209	32.5959	32.0557
(3.2, 200)	33.6292	33.6580	33.5744	33.3770	33.0649	32.6374	32.0942
(3.1, 196)	33.6163	33.6445	33.5597	33.3605	33.0460	32.6154	32.0685
(3.0, 191)	33.5403	33.5677	33.4813	33.2800	32.9626	32.5284	31.9771
(2.9, 185)	33.3999	33.4262	33.3381	33.1342	32.8135	32.3751	31.8186
	DIC						
(3.5, 206)	0.0175	0.0171	0.0164	0.0155	0.0144	0.0132	0.0118
(3.4, 205)	0.0173	0.0168	0.0162	0.0153	0.0142	0.0130	0.0117
(3.3, 203)	0.0172	0.0168	0.0161	0.0152	0.0142	0.0129	0.0116
(3.2, 200)	0.0173	0.0168	0.0162	0.0153	0.0142	0.0130	0.0117
(3.1, 196)	0.0175	0.0170	0.0164	0.0155	0.0144	0.0132	0.0118
(3.0, 191)	0.0179	0.0174	0.0167	0.0158	0.0147	0.0135	0.0121
(2.9, 185)	0.0185	0.0180	0.0173	0.0163	0.0152	0.0140	0.0126
	DOC						
(3.5, 206)	33.2884	33.3182	33.2371	33.0438	32.7373	32.3168	31.7821
(3.4, 205)	33.4548	33.4846	33.4032	33.2092	32.9016	32.4797	31.9433
(3.3, 203)	33.5633	33.5930	33.5109	33.3159	33.0068	32.5829	32.0441
(3.2, 200)	33.6119	33.6412	33.5582	33.3617	33.0507	32.6244	32.0825
(3.1, 196)	33.5988	33.6275	33.5433	33.3450	33.0316	32.6022	32.0566
(3.0, 191)	33.5224	33.5502	33.4646	33.2642	32.9479	32.5149	31.9649
(2.9, 185)	33.3815	33.4083	33.3208	33.1179	32.7982	32.3611	31.8061

Notes: Parameter values, unless stated otherwise: $R = 4.0\%$, $\alpha = 0.25\%$, $q = 8.5\%$, $\sigma = 0.3$, $\theta = 0.1$, and $b = 0.6$.

In Table 1, we present the computed results that $SC > 0$, $DIC > 0$, and $DOC > 0$. Consistent with the empirical findings of Brockman and Turtle (2003), we argue that the barrier option framework is a good representation of reality because the knock-out value of DIC is positive. Market-based estimates of bank equity which ignore the barrier lead to overestimation. More importantly, the shaded areas represent an approximate optimal loan rate 4.6% at various levels of deposit rate and an approximate optimal deposit rate 3.2% at various levels of loan rate. The maximum DOC value is 33.6412 at the optimal rate bundle $(R_L\%, R_D\%) = (4.6, 3.2)$ with given parameter values of $\theta = 0.1$ and $b = 0.6$. These results will be used for the following computational exercises.

Table 2. Values of DOC at various level of θ where $\partial DOC / \partial R_L = 0$ or $\partial DOC / \partial R_D = 0$

θ	$(R_D\%, D)$ (3.5, 206)	(3.4, 205)	(3.3, 203)	(3.2, 200)	(3.1, 196)	(3.0, 191)	(2.9, 185)
	DOC at $(R_L\%, L) = (4.6, 199)$ where $\partial DOC / \partial R_L = 0$						
0.10	33.3182	33.4846	33.5930	33.6412	33.6275	33.5502	33.4083
0.15	32.1339	32.2965	32.4001	32.4428	32.4226	32.3380	32.1877
0.20	30.9606	31.1195	31.2185	31.2554	31.2285	31.1362	30.9772
0.25	29.8006	29.9560	30.0503	30.0814	30.0474	29.9469	29.7787
0.30	28.6569	28.8088	28.8984	28.9235	28.8822	28.7730	28.5948
0.35	27.5330	27.6817	27.7665	27.7854	27.7364	27.6180	27.4290
θ	$(R_L\%, L)$ (4.5, 200)	(4.6, 199)	(4.7, 197)	(4.8, 194)	(4.9, 190)	(5.0, 185)	(5.1, 179)
	DOC at $(R_D\%, D) = (3.2, 200)$ where $\partial DOC / \partial R_D = 0$						
0.10	33.6119	33.6412	33.5582	33.3617	33.0507	32.6244	32.0825
0.15	32.4062	32.4428	32.3740	32.1988	31.9160	31.5250	31.0257
0.20	31.2112	31.2554	31.2013	31.0476	30.7935	30.4383	29.9821
0.25	30.0293	30.0814	30.0422	29.9105	29.6856	29.3669	28.9545
0.30	28.8631	28.9235	28.8997	28.7906	28.5955	28.3139	27.9461
0.35	27.7163	27.7854	27.7775	27.6917	27.5272	27.2836	26.9614

Notes: Parameter values, unless stated otherwise: $R = 4.0\%$, $\alpha = 0.25\%$, $q = 8.5\%$, $\sigma = 0.3$, and $b = 0.6$. The results at $\theta = 0.1$ are obtained from the shaded areas in Table 1.

It is required to compute the DOC value at various level of θ for the comparative static analysis of Eqs. (8) ~ (11). The upper panel of Table 2 demonstrates the DOC with the condition of $\partial DOC/\partial R_L = 0$ at various levels of $(R_D\%, D)$ and θ, while the lower panel demonstrates the DOC with the condition of $\partial DOC/\partial R_D = 0$ at various levels of $(R_L\%, L)$ and θ. The maximum DOC value is 33.6412 at the optimal rate bundle $(R_L\%, R_D\%) = (4.6, 3.2)$ when $\theta = 0.1$, as shown in Table 1, 33.4428 when $\theta = 0.15, \ldots, \text{etc}$. It is interesting that, as the value of credit risk hedging increases, DOC value is decreased. The result is understood because credit risk hedging is costly.

Before proceeding with the analysis of Eqs. (8) and (9), we need to confirm the second-order and stability conditions based on Eqs. (5) ~ (7). The findings are summarized in Table 3.

Table 3. Values of $\partial^2 DOC / \partial R_L^2$, $\partial^2 DOC / \partial R_L \partial R_D$, $\partial^2 DOC / \partial R_D^2$, $\partial^2 DOC / \partial R_D \partial R_L$, and Δ at various levels of θ

θ	$\partial^2 DOC / \partial R_L^2$	$\partial^2 DOC / \partial R_L \partial R_D$	$\partial^2 DOC / \partial R_D^2$	$\partial^2 DOC / \partial R_D \partial R_L$	Δ
0.10	-9.0208	0.0398	-6.1924	0.0398	55.8587
0.15	-9.0481	0.0394	-6.2835	0.0394	56.8518
0.20	-9.0842	0.0392	-6.3860	0.0392	58.0099
0.25	-9.1294	0.0393	-6.5021	0.0393	59.3586
0.30	-9.1837	0.0396	-6.6346	0.0396	60.9292
0.35	-9.2472	0.0402	-6.7871	0.0402	62.7603

Notes: Parameter values, unless stated otherwise: $R = 4.0\%$, $\alpha = 0.25\%$, $q = 8.5\%$, $\sigma = 0.3$, and $b = 0.6$. The results are computed based on the conditions of DOC at $(R_L\%, L) = (4.6, 199)$ and $(R_D\%, D) = (3.2, 200)$, which are observed from the shaded areas in Table 2.

In Table 3, we show that the equilibrium is locally strictly stable, which implies that $\partial^2 D / \partial R_L^2 < 0$,

$\partial^2 D / \partial R_D^2 < 0$, and $\Delta > 0$. The term $\partial^2 DOC / \partial R_L \partial R_D = \partial / \partial R_D (\partial DOC / \partial R_L) > 0$ indicates that the bank regards its deposit rate as a strategic complement to its loan rate in retail banking. With a strategic complement, the deposit rate responds to more aggressive play with more aggressive play (increases the loan rate). The term $\partial^2 DOC / \partial R_D \partial R_L = \partial / \partial R_L (\partial DOC / \partial R_D) > 0$ demonstrates that the bank also regards its loan rate as a strategic complement to its deposit rate.

Table 4. Responsiveness of bank optimal loan rate and deposit rate to θ

θ	$\partial^2 DOC / \partial R_L \partial\theta$	$\partial^2 DOC / \partial R_D \partial\theta$	$\partial R_L / \partial\theta$	$\partial R_D / \partial\theta$
0.10→0.15	1.4645	1.1154	-0.1631	-0.1812
0.15→0.20	1.5174	1.1391	-0.1685	-0.1823
0.20→0.25	1.5805	1.1676	-0.1748	-0.1839
0.25→0.30	1.6564	1.2025	-0.1822	-0.1860
0.30→0.35	1.7487	1.2454	-0.1912	-0.1889

Notes: Parameter values, unless stated otherwise: $R = 4.0\%$, $\alpha = 0.25\%$, $q = 8.5\%$, $\sigma = 0.3$, and $b = 0.6$. The results are computed based on the conditions of DOC at $(R_L\%, L) = (4.6, 199)$ and $(R_D\%, D) = (3.2, 200)$, which are observed from the shaded areas in Table 2.

The results of Eqs. (8) and (9) based on the computed results presented in Table 4 are stated in the following proposition.

Proposition 1. An increase in the amount of credit risk hedging simultaneously decreases the loan rate and the deposit rate, increases the bank interest margin when the amount of credit risk hedging is low, and decreases the margin when the amount of credit risk hedging is high.

As the bank increasingly gets involved in credit risk hedging activity, it now provides a return to a less credit 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-asset market. If loan demand is relatively rate-elastic, a larger loan portfolio is possible at a reduced loan rate. Our findings are consistent with Pausch and Welzel (2012): a bank increases loan volume and decreases interest rate on loans as a reaction to a decrease in credit risk by hedging, and Bedendo and Bruno (2012): credit risk transfer practices (credit risk hedging in our model) increase loan risk taking. As the bank increases the credit risk hedging transaction, it also provides a return to a higher hedging cost base. An alternative way the bank may attempt to augment its total returns is by decreasing its deposit volume as a reaction to an increase in hedging cost. If deposit supply is relatively rate-elastic, a smaller deposit volume is possible at a reduced deposit rate.

In addition, it is interesting that, as the amount of credit risk hedging increases, both the loan rate and the deposit rate are decreased, but the bank interest margin is increased when the hedging amount is a small scale and the margin is decreased when the hedging amount is large. The result is understood because the credit risk is less likely come into effect and the hedging cost is less likely to vanish, as the hedging amount increases. As noted earlier, the bank interest margin is one of the principal elements of bank earnings. Credit risk hedging as such makes the bank more prone to loan risk taking and less deposit cost burden when the hedging is at a lower level, thereby constituting bank profitability, but adversely affecting the stability of the banking system. Williams (2007) finds empirical evidence that bank interest margin is negatively related to credit risk (implying that positively related to credit risk hedging); however, Maudos and de Guevara (2004) finds empirical evident that bank interest margin is positively related to credit risk (implying that negatively related to credit risk hedging). Thus, their alternative findings lend support to Proposition 1.

Table 5. Values of P_{def} at various levels of θ where $\partial DOC / \partial R_L = 0$ or $\partial DOC / \partial R_D = 0$

θ	$(R_D\%, D)$ (3.5, 206)	(3.4, 205)	(3.3, 203)	(3.2, 200)	(3.1, 196)	(3.0, 191)	(2.9, 185)
	P_{def} at $(R_L\%, L) = (4.6, 199)$ where $\partial DOC / \partial R_L = 0$						
0.10	0.0484	0.0479	0.0475	0.0474	0.0475	0.0478	0.0484
0.15	0.0458	0.0453	0.0450	0.0448	0.0450	0.0453	0.0459
0.20	0.0431	0.0425	0.0422	0.0421	0.0422	0.0426	0.0433
0.25	0.0401	0.0395	0.0392	0.0391	0.0393	0.0397	0.0404
0.30	0.0368	0.0363	0.0360	0.0360	0.0361	0.0366	0.0373
0.35	0.0333	0.0328	0.0325	0.0325	0.0327	0.0332	0.0339
θ	$(R_L\%, L)$ (4.5, 200)	(4.6, 199)	(4.7, 197)	(4.8, 194)	(4.9, 190)	(5.0, 185)	(5.1, 179)
	P_{def} at $(R_D\%, D) = (3.2, 200)$ where $\partial DOC / \partial R_D = 0$						
0.10	0.0480	0.0474	0.0466	0.0455	0.0443	0.0428	0.0410
0.15	0.0455	0.0448	0.0440	0.0430	0.0417	0.0402	0.0384
0.20	0.0427	0.0421	0.0413	0.0402	0.0389	0.0374	0.0356
0.25	0.0398	0.0391	0.0383	0.0372	0.0359	0.0344	0.0326
0.30	0.0366	0.0360	0.0351	0.0340	0.0327	0.0312	0.0294
0.35	0.0332	0.0325	0.0316	0.0306	0.0293	0.0277	0.0260

Notes: Parameter values, unless stated otherwise: $R = 4.0\%$, $\alpha = 0.25\%$, $q = 8.5\%$, $\sigma = 0.3$, and $b = 0.6$.

It is necessary to elaborate on default risk issue. The upper panel of Table 5 demonstrates the P_{def} value with the condition of $\partial DOC / \partial R_L = 0$ at various levels of $(R_D\%, D)$ and θ, while the lower panel demonstrates the P_{def} value with the condition of $\partial DOC / \partial R_D = 0$ at various levels of $(R_L\%, L)$ and θ. The default probability is 0.0474 at the optimal rate bundle $(R_L\%, R_D\%,) = (4.6, 3.2)$ with $\theta = 0.10$, 0.0448 with $\theta = 0.20$, $\ldots$, etc. These computed results will be used when Eq. (10) are analyzed.

Table 6. Responsiveness of bank default risk to θ

θ	$\partial P_{def} / \partial \theta$	$\partial P_{def} / \partial R_L$	$\partial P_{def} / \partial R_D$	$dP_{def} / d\theta$
0.10→0.15	-0.0508	-0.0061	0.0013	-0.0500
0.15→0.20	-0.0548	-0.0062	0.0011	-0.0539
0.20→0.25	-0.0592	-0.0063	0.0009	-0.0582
0.25→0.30	-0.0639	-0.0064	0.0007	-0.0628
0.30→0.35	-0.0689	-0.0065	0.0005	-0.0678

Notes: Parameter values, unless stated otherwise: $R = 4.0\%$, $\alpha = 0.25\%$, $q = 8.5\%$, $\sigma = 0.3$, and $b = 0.6$. The results are computed based on the conditions of P_{def} at $(R_L\%, L) = (4.6, 199)$ and $(R_D\%, D) = (3.2, 200)$, which are observed from the shaded areas in Table 5.

The result of Eq. (10) based on the observation shown in Table 6 are stated in the following proposition.

Proposition 2. As increase in the amount of credit risk hedging decreases the default risk in the bank's equity return.

In Eq. (10), the direct effect captures the change in P_{def} due to an increase in θ, holding the loan rate and the deposit rate constant. It is unambiguously negative ($\partial P_{def} / \partial \theta < 0$ observed from Table 6) because an increase in credit risk hedging results in decreasing the bank's default risk, ceteris paribus. The indirect effect on the default risk from an increase in θ through the loan rate adjustment $(\partial P_{def} / \partial R_L)(\partial R_L / \partial \theta)$ is positive in sign, where $\partial P_{def} / \partial R_L < 0$ is observed from Table 6 and $\partial R_L / \partial \theta < 0$ is observed from Table 4. The result is understood because an increase in credit risk hedging decreases the loan rate. Loan rate determination as such makes the bank more prone to loan risk-taking, thereby increasing the default risk in the bank's equity return. In addition, the indirect effect on the default risk from an increase in θ through R_D adjustment $(\partial P_{def} / \partial R_D)(\partial R_D / \partial \theta)$ is negative in sign. The result is understood because an increase in the credit risk hedging decreases the deposit rate. Deposit rate determination as such makes the bank less deposit cost burden, thereby decreasing the default risk in the bank's equity return. Since the positive indirect effect through loan rate adjustment is insufficient to offset the direct effect and the negative indirect effect through deposit rate adjustment reinforces the direct effect, both the effects give an overall negative response of P_{def} to an increase in θ. As a result, we show that an increase in the credit risk hedging decreases the default risk in the bank's equity return. Our result can be used to explain the aforementioned findings of Wagner and Marsh (2006).

Table 7. Values of Ins at various levels of θ where $\partial DOC / \partial R_L = 0$ or $\partial DOC / \partial R_D = 0$

θ	$(R_D\%, D)$ (3.5, 206)	(3.4, 205)	(3.3, 203)	(3.2, 200)	(3.1, 196)	(3.0, 191)	(2.9, 185)
	Ins at $(R_L\%, L) = (4.6, 199)$ where $\partial DOC / \partial R_L = 0$						
0.10	154.0204	153.8540	153.7456	153.6974	153.7111	153.7884	153.9303
0.15	144.7970	144.6344	144.5308	144.4881	144.5083	144.5929	144.7432
0.20	135.5626	135.4037	135.3047	135.2678	135.2947	135.3870	135.5460
0.25	126.3149	126.1595	126.0652	126.0341	126.0681	126.1686	126.3368
0.30	117.0509	116.8990	116.8094	116.7843	116.8256	116.9348	117.1130
0.35	107.7671	107.6184	107.5336	107.5147	107.5637	107.6821	107.8711
θ	$(R_L\%, L)$ (4.5, 200)	(4.6, 199)	(4.7, 197)	(4.8, 194)	(4.9, 190)	(5.0, 185)	(5.1, 179)
	Ins at $(R_D\%, D) = (3.2, 200)$ where $\partial DOC / \partial R_D = 0$						
0.10	154.4881	153.6974	152.0749	149.6191	146.3283	142.2006	137.2336
0.15	145.2438	144.4881	142.9461	140.6164	137.4975	133.5875	128.8840
0.20	135.9888	135.2678	133.8059	131.6020	128.6545	124.9617	120.5211
0.25	126.7207	126.0341	124.6521	122.5735	119.7969	116.3206	112.1423
0.30	117.4369	116.7843	115.4816	113.5278	110.9215	107.6611	103.7442
0.35	108.1337	107.5147	106.2908	104.4611	102.0243	98.9789	95.3224

Notes: Parameter values, unless stated otherwise: $R = 4.0\%$, $\alpha = 0.25\%$, $q = 8.5\%$, $\sigma = 0.3$, and $b = 0.6$.

Table 8. Responsiveness of Ins to θ

θ	$\partial Ins/\partial\theta$	$\partial Ins/\partial R_L$	$\partial Ins/\partial R_D$	$dIns / d\theta$
0.10→0.15	-184.1858	-7.9068	0.4820	-182.9832
0.15→0.20	-184.4071	-7.5570	0.4263	-183.2115
0.20→0.25	-184.6729	-7.2099	0.3693	-183.4807
0.25→0.30	-184.9958	-6.8659	0.3109	-183.8024
0.30→0.35	-185.3928	-6.5257	0.2508	-184.1923

Notes: Parameter values, unless stated otherwise: $R = 4.0\%$, $\alpha = 0.25\%$, $q = 8.5\%$, $\sigma = 0.3$, and $b = 0.6$. The results are computed based on the conditions of Ins at $(R_L\%, L) = (4.6, 199)$ and $(R_D\%, D) = (3.2, 200)$, which are observed from the shaded areas in Table 7.

We use the results observed from Tables 4, 7, and 8 to explain the comparative static results of Eq. (11). The upper panel in Table 7 indicates the Ins value with the condition of $\partial DOC / \partial R_L = 0$ at various levels of $(R_D\%, D)$ and θ, while the lower panel indicates the Ins value with the condition of $\partial DOC / \partial R_D = 0$ at various levels of $(R_L\%, L)$ and θ. The values presented in Table 8 are computed based on the observations in Tables 4 and 7. Accordingly, we have the following proposition.

Proposition 3. An increase in the amount of credit risk hedging decreases the bank's liability.

The first term on the right-hand side of Eq. (11) can be identified as the direct effect, which captures the change in Ins due to an increase in θ, holding both the optimal loan rate and deposit rate constant. It is unambiguously negative ($\partial Ins / \partial\theta < 0$ obtained from Table 8) because, as the credit risk hedging increases, resulting in decreasing the value of bank loans due to hedging cost increased, the value of the FDIC's contingent liability is increased, but the value of the FDIC's contingent asset is decreased, ceteris paribus. The second term can be identified the indirect effect, which captures the change in Ins due to an increase in θ through the loan rate adjustment. It is positive in sign since $\partial R_L / \partial\theta < 0$ is obtained from Table 4 and $\partial Ins / \partial R_L < 0$ is obtained from Table 8. The result is understood because an increase in the credit risk hedging spurs loan risk taking and hence increases the bank's liability. The third term can be identified the indirect effect, which captures the change in Ins due to an increase in θ through the deposit rate adjustment. This effect is negative in sign since $\partial R_D / \partial\theta < 0$ is obtained from Table 4 and $\partial Ins / \partial R_D > 0$ is obtained is obtained from Table 8. The result is understood because an increase in the credit risk hedging decreases deposit cost burden and hence decreases the bank's liability. The total indirect effect is positive because the former negative effect is insufficient to offset the latter positive effect. Since the positive total indirect effect is insufficient to offset the negative direct effect to give an overall negative response of Ins to an increase in θ, we have the result of Proposition 3.

Table 9. Responsiveness of R_L, R_D, P_{def}, and Ins to θ at various levels of b

	b		
θ	0.6	0.7	0.8
	$\partial R_L / \partial\theta$ (R_L%, R_D%)		
0.10→0.15	-0.1631 (4.6, 3.2)	-0.1185 (4.6, 3.2)	-0.0691 (5.0, 3.2)
0.15→0.20	-0.1685 (4.6, 3.2)	-0.1306 (4.6, 3.2)	-0.0694 (5.0, 3.2)
0.20→0.25	-0.1748 (4.6, 3.2)	-0.1454 (4.6, 3.2)	-0.0726 (5.0, 3.2)
0.25→0.30	-0.1822 (4.6, 3.2)	-0.1640 (4.6, 3.2)	-0.0805 (5.0, 3.2)
0.30→0.35	-0.1912 (4.6, 3.2)	-	-0.0958 (5.0, 3.2)
	$\partial R_D / \partial\theta$		
0.10→0.15	-0.1812	-0.1732	-0.1682
0.15→0.20	-0.1823	-0.1742	-0.1661
0.20→0.25	-0.1839	-0.1756	-0.1640
0.25→0.30	-0.1860	-0.1775	-0.1620
0.30→0.35	-0.1889	-0.1695	-0.1601
	$dP_{def} / d\theta$		
0.10→0.15	-0.0500	-0.1202	-0.2196
0.15→0.20	-0.0539	-0.1312	-0.2421
0.20→0.25	-0.0582	-0.1436	-0.2676
0.25→0.30	-0.0628	-0.1575	-0.2964
0.30→0.35	-0.0678	-	-0.3290
	$dIns / d\theta$		
0.10→0.15	-182.9832	-185.0235	-184.8400
0.15→0.20	-183.2115	-185.1156	-184.7438
0.20→0.25	-183.4807	-185.2308	-184.5040
0.25→0.30	-183.8024	-185.3759	-184.0771
0.30→0.35	-184.1923	-	-183.4038

Notes: Parameter values, unless stated otherwise: $R = 4.0\%$, $\alpha = 0.25\%$, $q = 8.5\%$, and $\sigma = 0.3$. The results at $b = 0.6$ and 0.7 ($b = 0.8$) are computed based on the values of DOC, P_{def}, and Ins at the optimal loan rate of 4.6% (5.0%) and the optimal deposit rate of 3.2%. The results at $b = 0.6$ are collected from Tables 4, 6, and 8. The results at $b = 0.7$ and 0.8 are obtained by following the similar computation as in the case of $b = 0.6$.

The results of Eqs. (8) ~ (11) at various levels of regulatory deposit insurance fund protection presented in Table 9 are stated in the following proposition.

Proposition 4. An increase in the credit risk hedging decreases the optimal loan rate, the optimal deposit rate, the default risk in the bank's equity return, and the bank's liability. An increase in the regulatory deposit insurance fund protection weakens the reduction in the optimal loan rate and the optimal deposit rate, and reinforces the reduction in the default risk.

It is necessary to elaborate on the regulatory deposit insurance fund protection issue. The results presented in Tables 1 ~ 8 are based on the case of $b = 0.6$. We further consider the results at various levels of $b = 0.7$ and 0.8. The findings are summarized in Table 9. In the first panel, we show that an increase in the credit risk hedging increases the loan amount held by the bank at a reduced loan rate. Furthermore, the negative impact on loan rate is reduced as the insurer increases the protection of deposit insurance fund. We argue that the credit risk hedging results in increasing loan risk taking, which is reduced by increasing the regulatory deposit insurance fund protection. The FDIC as a regulator and insurer controls the barrier related to deposit insurance fund protection in a very direct manner by the power vested in it by the FDICIA. Furthermore, the Dodd-Frank Act requires that the deposit insurance fund reserve ratio reach 1.35 percent by 2020 (the actual reserve ratio is 0.45 percent in 2012), as noted earlier. Our result suggests that the incentive of an individual bank to transfer credit risk with credit derivatives is aligned with the regulatory objective of reducing risk taking, which is consistent with the finding of Wagner and Marsh (2006).

In the second panel, we show that an increase in the credit risk hedging decreases the deposit volume absorbed by the bank at a reduced deposit rate. The negative impact on deposit rate is reduced as the insurer increases its deposit insurance fund protection. We argue that the credit risk hedging results in decreasing deposit cost burden, which is further reduced by increasing the insurance fund protection. Regulation with the FDICIA and the Dodd-Frank Act as such is expected to reach the goal of increasing the deposit insurance fund reserve ratio. In the third panel, we find that an increase in the credit risk hedging decreases the default risk in the bank's equity return. The negative impact on the default risk is increased by increasing the insurance fund protection. Thus, our result can be used to explain the aforementioned finding of Wagner and Marsh (2006). In the last panel, we find that an increase in the credit risk hedging consistently decreases the value of the bank's liability at various levels of the regulatory deposit insurance fund protection. However, deposit insurance fund protection does not always reinforce this reduction in the bank's liability value depending on the FDIC's claim liability value and the bank's knock-out value.

6. Conclusion

In this paper, we model a bank taking deposits and granting risky loans which is subject to regulatory deposit insurance fund protection and may engage in credit risk hedging in a financial turmoil. We take specific care to integrate deposit insurance fund protection related to the FDICIA and the Dodd-Frank Act into the barrier option valuation approach to retail banking for our analysis of spread behavior and default probability of an individual bank. This enables us to examine the interaction of deposit insurance fund protection and credit risk hedging. We find that an increase in the bank's credit risk hedging simultaneously decreases its loan rate and deposit rate, and thus increases its interest margin when the credit risk hedging scale is not large. As a result, we argue that the credit risk hedging practice increases loan risk taking but decreases deposit cost and hence increases the bank's profit. Furthermore, the regulatory deposit insurance fund protection weakens increased loan risk taking and decreased deposit cost. In addition, we also find that an increase in the bank's credit risk hedging decreases the default risk, and further the negative impact is increased as the deposit insurance fund protection increases. Our findings support a common view that credit risk hedging increases loan risk taking. However, our analysis suggests that the incentive of an individual bank to hedge credit risk is aligned with the regulatory objective of deposit insurance fund protection of improving stability, and so the credit risk hedging practices are to be welcomed. More importantly, the credit risk hedging practices with regulatory deposit insurance fund protection largely meet the requirement of the Dodd-Frank Act.

One issue that has not been addressed is the alternative credit risk transfer tools of loan sales and securitization that also have been extensively used by banks to manage credit risk actively. In particular, is it the case that the results of this paper also apply to the alternative case? We are silent on this question and do not attempt to compare the efficiency of the credit derivatives to alternative instruments. Such concerns are beyond the scope of this paper and so are not addressed here. What this paper does demonstrate, however, is the important role played by credit risk hedging aligned with regulatory deposit insurance fund protection in affecting bank spread behavior and financial stability in retail banking.

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Notes

Note 1. Credit risk transfer tools in general include loan sales, securitization, and credit derivatives. This paper focuses only on credit derivatives that insure banks against the default risk of their borrowers in exchange for a fee. See Bedendo and Bruno (2012) for the joint usage of the three credit risk transfer tools. Hirtle (2009) indicates that those tools are normally seen by banks as complements rather than as substitutes.

Note 2. See Dodd-Frank Wall Street Reform and Consumer Protection Act, Pub. L. No. 111-203, § 334(d), 124 Stat. 1376, 1539 (2010) (codified at 12 U.S.C. § 1817(nt)).

Note 3. Wagner and Marsh (2006) suggest that the incentive of banks to transfer credit risk is aligned with the regulatory objective of improving stability, and so the recent development of credit derivative instrument is to be welcomed.

Note 4. One can attach two interpretations to the parameter α. When transferring credit risk to another investor, a bank incurs two major costs: the lemons premium that the investor charges because of the bank's inside information regarding the credit risk and moral hazard resulting in inefficient control by the lender of borrowers' default risks (Duffie, 2008). It is suggested that further modeling these two major costs is required to analyze credit risk transfer transactions, but not our primary focus in this paper.

Note 5. According to the empirical findings in Brockman and Turtle (2003), average barrier estimates by years are ranged from 0.5900 to 0.8395.