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How does equity capital cost affect bank performance during a financial crisis?

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This article theoretically examines how equity capital cost affects return performance and safety of a bank and how this effect varies across a financial crisis comparing to a normal time when the bank manager's performance reveals the like of higher equity return and the dislike of higher equity risk. We derive two main results. First, an increase in the bank's equity capital cost from an increase of the interest rate of the Federal funds results in a reduced loan risk-taking at an increased optimal bank interest margin, implying better bank performance. Second, by ignoring the dislike, we find that the better performance is reinforced during a financial crisis but is reduced during a normal time. Financial crises and the dislike preference as such contribute a relatively low return and the stability of banking activities.

Keywords: bank interest margin; equity capital cost; barrier; utility maximization

JEL Classification: G21; G33

I. Introduction

The recent financial crises raise fundamental issues about the role of bank equity capital, particularly from the standpoint of bank performance related to profitability and stability. Not surprisingly, public outcries for increasing more bank capital during a financial crisis due to the safety net provided to banks because of the existence of externalities. And, thus financial efficiency can be improved by requiring banks to operate with more capital (Berger and Bouwman, 2013).[1] However, bankers often argue that holding more capital would jeopardize their performance and lead to less lending.[2] Given the divergent views in the literature, the issue of the effect of the capital cost instead of the capital quantity on bank performance largely remains silent. Equity capital cost is often used as a proxy for an opportunity cost

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[1] Related literature includes, for example, Kashyap *et al.* (2008), Acharya *et al.* (2011) and Hart and Zingales (2011).
[2] Academic literature argues that the perspective of the bankers need to be more nuanced (e.g. Jimenéz *et al.*, 2012; Osborne *et al.*, 2012).

of shareholders' investment, generally valued by the security market interest rate. Banks can hold liquid assets, for example, central bank reserves and/or Treasury bills, for a substitution purpose of earning asset portfolio. These assets earn the security market interest rate. Knowing how bank equity capital cost affects bank performance at different times (during a financial crisis and a normal time) is of paramount importance not only for bank managers to make their strategic decisions but also for regulators to contemplate micro- and macro-prudential banking regulation. The goal of this article is to theoretically examine the effect of equity capital cost on bank return performance, explicitly integrating the default risk with the equity volatility into a bank's utility maximization progress.

Banks are in the business of lending and borrowing money.[3] The bank interest margin, that is, the spread between the loan rate and the deposit rate, is one of the principal elements of cash flows and earnings. The bank interest margin is often used in the literature as a proxy for the efficiency of financial intermediation (Saunders and Schumacher, 2000).[4] The purpose of this article is to develop a model of bank spread behaviour by incorporating alternative preference considerations into a path-dependent, barrier option model. Our model features bank preferences revealing the like of higher net equity return, that is, equity return net of equity capital cost, and/or the dislike of higher equity risk in the spirit of Hermalin (2005). Path dependency based on the argument of Brockman and Turtle (2003) is an intrinsic and a fundamental characteristic of bank loans because the net equity return can be knocked out whenever a legally binding barrier is breached. Banks, during a period of a financial crisis, with high asset variability are likely to exhibit a higher probability of hitting the barrier before the expiration date than banks without such a characteristic. The inclusion of equity capital costs based on the argument of Peura and Keppo (2006) is an explicit treatment of the bank equity capital investment related to the opportunity costs of equity holders.

The results of this article show that an increase in the equity capital cost results in a decreased loan amount held by a bank at an increased bank interest margin. Equity capital cost as such makes the bank less prone to risk-taking, thereby contributing to a better return performance and the stability of the banking system. Most theories predict that the capital amount can enhance a bank's survival probability. Holding fixed bank's asset, liability portfolios and higher capital mechanically implies a lower likelihood of bankruptcy (Berger and Bouwman, 2013). A deeper justification is provided by our theoretical model. Higher equity capital cost perhaps due to an increase in the security market interest rate by the regulatory authority makes the bank more prudent to shift its investments to the Federal funds market and away from its loan portfolio. And, this leads to less probability during a financial crisis. Our results are largely supported by Mehran and Thakor (2011) and Thakor (2012).

Further, the two distinctions for our argument are whether bank preference reveals the dislike of higher equity risk or not and whether path dependency takes place. Both are relevant to the default risk in the bank's net equity return. Together they lead to the following four scenarios of the bank's utility optimization problems: (i) both with the barrier and the dislike; (ii) only with the barrier; (iii) only with the dislike and (iv) neither with the barrier nor the dislike. One immediate application of this article is to evaluate the plethora of modelling the bank's utility optimization problems proposed as alternatives for bank performance evaluation. We show that the positive impact on the bank interest margin from an increase in equity capital cost is less significant with consideration of both the barrier and the equity risk than the case of only either one being taken into account. In addition, the positive impact is less significant in the barrier case than that in the equity risk case, and is also less significant when both are ignored.

The regulation literature on bank performance is not even new but unsatisfying. When an increase in

[3] Two divergent approaches have been employed in the literature to model the financial intermediary (Sealey, 1980). The Markowitz–Tobin portfolio theory has the principal advantage of the explicit treatment of uncertainty. However, this approach assumes that asset and deposit markets are perfectly competitive. Klein (1971) bases his criticism on the existence of imperfectly competitive structures and shows that basic theorems of portfolio theory are not applicable under imperfect market structures. This article follows the spirit of the firm-theoretic approach.

[4] However, we note that there are many aspects of the debate over the cost of market power in banking, particularly related to social welfare loss versus cost inefficiency (see Maudos and De Guevara, 2007) that we are silent on.

the security market interest rate (and thus in the bank's equity capital cost) is recognized as a government intervention, we show that this intervention may have more significant impact on bank return and risk performance during a normal time. Episcopos (2008) argues that raising the barrier induces a wealth transfer from shareholders to the Federal Deposit Insurance Corporation (FDIC). It implies a better protection of the insurance fund. An increase in the bank's equity cost may also have more significant on bank performance with a less protection of the insurance fund by the FDIC, particularly with consideration of the dislike of higher equity cost. As a result, increasing the security market interest rate and a decreasing protection of the deposit insurance fund tend to increase bank profitability and stability. The utility maximization explicitly taking the barrier and the dislike into account is intimately relevant to bank regulation.

The article is organized as follows. Section II briefly reviews the related literature. Section III develops the basic structure of the model. Section IV derives the solution of the model and the comparative static analysis. Section V presents numerical exercises to explain and compare the possible comparative static results. The final section discusses the results and limitation of the model.

II. Related Literature

Our theory of bank capital is related to the following strands of the literature. The first is the literature on bank performance. Repullo (2004), Von Thadden (2004) and Berger and Bouwman (2013) emphasize the role of capital as a buffer to absorb shocks to earnings. In the screening-based theory of Coval and Thakor (2005), a minimum amount of capital is essential to the very viability of the bank. The asset substitution moral hazard theories argue that capital attenuated the excessive risk-taking incentives induced by limited liability, and that banks with more capital optimally choose less risky portfolios (Freixas and Rochet, 2008; Acharya *et al.*, 2011). While we also discuss bank capital, our focus on bank capital cost with the mechanical effect of bank interest margin determination takes our analysis in a different direction.

The second strand is the modern equity capital cost literature. Estrella (2004) determines the optimal level of capital in the presence of capital costs and failure costs, and shows that minimum capital requirements based on Value at Risk are likely to be pro-cyclical. Zhu (2007) introduces an equilibrium model in which banks maximize expected discounted dividends net of capital costs but are constrained in their lending behaviour by minimum capital requirements. Peura and Keppo (2006) examine banks' optimal capital choice as a trade-off between the opportunity cost of equity capital, the loss of franchise value following a regulatory minimum capital violation and the cost of recapitalization. Heid and Krüger (2011) demonstrate that capital buffers mitigate volatility of banking lending. The primacy difference between our model and these papers is that we consider the effects on bank interest margin from changes in the opportunity cost of equity capital constrained in the bank's balance sheet activities.

The third strand of the literature is on the choice of an appropriate goal in modelling banks' optimization problem. Ho and Saunders (1981), Zarruk and Madura (1992) and Wong (1997) use a von Neumann–Morgenstern utility function defined in terms of profits to examine optimal bank interest margins. Hyun and Rhee (2011) also use a utility function characterized by the bank's preference to explain the role of capital, in which the banking industry after loan quality problems led to the most recent financial crisis. Alternatively, the broader contingent claims approach has found an application capital regulation related to the capital amount held by banks (e.g. Bhattacharya *et al.*, 2002; Episcopos, 2008). This article examines bank equity cost with spread behaviour based on an option-based utility maximization. The fundamental insight shared by these papers is that conformity is generated by a desire to distinguish oneself from the 'type', who wishes not to be identified. This insight is an important aspect of equity capital cost of shareholders and bank managers since the opportunity cost of shareholders has direct effects on bank spread behaviour. What distinguishes our work from this literature is that we focus on the commingling of the assessment of bank equity return with the assessment of bank equity risk and, in particular, we put on the impact on bank spread behaviour from changes in equity capital cost in the context option-based return-risk utility maximization during a financial crisis and comparing to the normal time.

III. The Model

The model is designed to capture the following characteristics of a banking firm. (1) The bank manager maximizes his/her own expected utility including his/her like of higher equity return and/or his/her dislike of higher equity risk during a normal time or a financial crisis. (2) The bank defaults when it fails to service its debt obligations including the two payments to depositors and shareholders in the spirit of Heid and Krüger (2011). (3) The barrier option theory of corporate security valuation is applied to the contingent claims of the bank (Episcopos, 2008); the work of Ronn and Verma (1986) with an application of Episcopos (2008) is used to value the bank's equity risk, and the framework of Brockman and Turtle (2003) is utilized to model the default risk in the bank's equity return. And, (4) the bank's objective function is specified as the expected value of a utility function that additively includes the like of higher equity returns and the dislike of higher equity risks weighted by default probabilities.[5]

Consider a bank that makes decisions in a single-period horizon with two dates, 0 and 1, denoted by $t \in [0,\ 1]$. At $t = 0$, the bank has the following balance sheet:

$$L + B = D + K \tag{1}$$

where $L > 0$ is the amount of loans, $B > 0$ 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 rate claims that mature at $t = 1$. The demand for loans is governed by a downward-sloping demand function, $L(R_L)$ with $\partial L/\partial R_L < 0$ and $\partial^2 L/\partial R_L^2 < 0$, where $R_L > 0$ is the loan interest rate chosen by the bank (Mukuddem-Petersen *et al.*, 2008).[6] Loans are risky in that they are subject to nonperformance. In addition to loans, liquid assets earn the security market interest rate of $R > 0$. The total assets $L + B$ in Equation 1 are financed partly by deposits. The supply of deposits is perfectly elastic at a constant market deposit rate, $R_D > 0$ (Tsai and Lin, 2013). Equity capital invested by the bank's shareholders at $t = 0$ is tied by regulation which is a fixed proportion q of the bank's deposits, $K \geq qD$ (VanHoose, 2007). This regulation forces the bank's capital position to reflect its asset portfolio risk, which is consistent with the recent Basel Accord.[7] As long as R is sufficiently higher than R_D, the capital requirement constraint is binding (Wong, 1997). Under the assumption, the bank's balance sheet constraint of Equation 1 can be restated as the form of $L + B = K(1/q + 1)$. The assumption of $R > R_D$ also implicitly indicates that equity capital is more costly than deposits since the security market interest rate is usually treated as an opportunity cost of equity capital. The explicit treatment of the equity capital opportunity cost demonstrates that the bank faces a trade-off between high profitability with low capital ratios and greater solvency with higher capital ratios. Under the circumstances, it is reasonable to assume that the bank's net equity return is the expected discounted dividends net of capital costs (Heid and Krüger, 2011).

We are now ready to solve for the bank's optimal choice of interest margin, that is, the spread between the loan rate chosen by the bank and the market deposit rate. We assume that the bank's manager maximizes either his/her own expected utility or that of those who exercise control over the bank's decisions.[8] As noted by Santomero (1984), the choice of an appropriate goal in modelling the bank's optimization problem remains a controversial issue. In our model, we assume that the bank's manager likes higher equity returns, but find the like with a dislike of the corresponding equity risk to be costly.[9] Applying Hermalin and Weisbach (1991) and Hermalin (2005), we assume the preference of

[5] Alternatively, it is recognized that the utility function may be superadditive, subadditive or multiplicative. We argue that the aforementioned issue may provide an ample opportunity for future research.
[6] Results to be derived from our model do not extend to the case where the bank is a price taker in the loan market (see Baltensperger, 1980).
[7] For the Basel Accord and bank bankruptcy analysis, see Chiu *et al.* (2009) and Cebula (2010).
[8] Given separation of management from ownership, the firm's managers may have incentives to make decisions that maximize their own expected utility (Jensen and Meckling, 1976).
[9] This dislike need not be particularly revealed. One could as easily interpret it as an amount a risk-averse manager is willing to forego in order to avoid a random level of equity returns. We will consider an alternative utility function without such a dislike in the following section.

the bank's manager can be aggregated in such a way that the bank acts as if it has a single-utility function that positively weights equity returns, but negatively weights equity risks. Assume further, as in Hermalin (2005), that the bank's utility function is additively separable. The objective can be stated as

$$\underset{R_{\mathrm{L}}}{\mathrm{Max}}\, U(S, \sigma_S) = (1 - P_{\mathrm{def}})S + P_{\mathrm{def}}(-\sigma_S) \tag{2}$$

where S is the market value of the bank's net equity, σ_S is the instantaneous SD of the return on S (the net equity risk) and P_{def} is the default probability in S.[10] Specifically, σ_S denotes the cost or disutility (dislike) incurred by the bank's manager and $1 - P_{\mathrm{def}}$ and P_{def} are the weights on the two components. The lower default probability implies the higher preference degree. The first term on the right-hand side of Equation 2 can be identified as the expected utility from the net equity return discounted by the preference degree of the higher return like relative to higher risk dislike, while the second term can be identified as the expected disutility from the net equity return risk discounted by the preference degree. As we discuss further below, the former can be motivated based on the argument about the equity return realization discounted by the effects of default risk on equity returns in the spirit of Vassalou and Xing (2004), while the latter can be motivated based on the argument about the equity risk realization in the spirit of Ronn and Verma (1986). The specifications of S, σ_S and P_{def} become crucial to explain bank spread behaviour in the utility maximization optimization.

First, we propose an equity return framework for corporate security valuation based on a path-dependent, barrier option model. A direct implication of this framework is that equity will be priced as a down-and-out call (DOC) option on its underlying assets where its payoffs depend on the particular path followed by the underlying assets (Merton, 1973). In this context, the market value of the bank's net equity, S in Equation 2, can be written as[11]

$$S = \left[VN(d_1) - Ze^{-\delta}N(d_2)\right] - \left[V\left(\frac{H}{V}\right)^{2\eta} N(b_1) - Ze^{-\delta}\left(\frac{H}{V}\right)^{2\eta-2} N(b_2)\right] \tag{3}$$

where

$$V = (1 + R_{\mathrm{L}})L,$$

$$Z = (1 + R_{\mathrm{D}})\frac{K}{q} + (1 + R)K - (1 + R)\left[K\left(\frac{1}{q} + 1\right) - L\right],$$

$$\delta = R - R_{\mathrm{D}}, \eta = \frac{\delta}{\sigma^2} + \frac{1}{2},$$

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

$$b_1 = \frac{1}{\sigma}\left(\ln\frac{H^2}{VZ} + \delta + \frac{\sigma^2}{2}\right) \quad \forall Z \geq H, \quad b_2 = b_1 - \sigma$$

In Equation 3, V is the market value of the bank's loan repayments that varies continuously over the time interval based on a geometric Brownian motion of the form: $dV = \mu V dt + \sigma V dW$ where μ is the instantaneous expected rate of return on V, σ is the instantaneous SD of the return and W is a Wiener process. Z is the book value of the net obligation payments at $t = 1$, which is specified as the difference between the two payments to depositors (deposit costs), residual claimants (equity capital costs) and the repayments from the liquid asset investments. $\delta > 0$ is the spread rate between the security market interest rate and the deposit rate, that is, the continuously compounded riskless rate of return. H is the value of the bank's assets that triggers bankruptcy (this is the barrier or knockout value of the bank). $N(\cdot)$ is the standard normal cumulative distribution function evaluated at d_1, d_2, b_1 or b_2 in the model.

The first term on the right-hand side of Equation 3 is recognized as the difference between the expected value of loan repayments and the present value of the net obligation payments using the standard call (SC)

[10] Lin *et al.* (2012) also discuss the issue of equity quality during a financial crisis.

[11] In general, the standard down-and-out call option includes a standard call, a down-and-in call and the rebate payment. For simplicity, we follow Brockman and Turtle (2003) and consider only the case without the debate term.

option view of the bank. The inadequacy of the SC viewpoint arises because it ignores the consequences of bankruptcy at all points in time except maturity. The barrier, H, can be viewed as the value of loan repayments above which creditors cannot force dissolution. The second term is recognized as the difference between the SC and the DOC, which represents a down-and-in call (DIC) option of corporate bondholders (nonnegative) claim. If the SC valuation is a good representation of reality, then H should be zero, and hence the term DIC vanishes. Our model utilizes the role of barrier to describe the alternatives of bank states during a financial crisis ($H > 0$) or during a normal time ($H = 0$).

With information about Equation 3, we further apply Ronn and Verma (1986) and let σ_S in Equation 2 stand for the instantaneous SD of the return on S:

$$\sigma_S = \frac{V}{S}\frac{\partial S}{\partial V}\sigma \tag{4}$$

where

$$\begin{aligned}\frac{\partial S}{\partial V} = &\left[N(d_1) + V\frac{\partial N(d_1)}{\partial d_1}\frac{\partial d_1}{\partial V} - Ze^{-\delta}\frac{\partial N(d_2)}{\partial d_2}\frac{\partial d_2}{\partial V}\right] \\ &- \left[(1-2\eta)\left(\frac{H}{V}\right)^{2\eta}N(b_1)\right. \\ &+ V\left(\frac{H}{V}\right)^{2\eta}\frac{\partial N(b_1)}{\partial b_1}\frac{\partial b_1}{\partial V} \\ &+ \frac{Ze^{-\delta}}{V}(2\eta-2)\left(\frac{H}{V}\right)^{2\eta-2}N(b_2) \\ &\left. - Ze^{-\delta}\left(\frac{H}{V}\right)^{2\eta-2}\frac{\partial N(b_2)}{\partial b_2}\frac{\partial b_2}{\partial V}\right]\end{aligned}$$

Note that σ_S can be interpreted as the net equity risk, while σ can be interpreted as the loan risk. Whether or not σ_S is positively related to σ depends on the sign of the term $\partial S/\partial V$ in Equation 4, which captures the characteristics of the barrier used in the article. Again, during a normal time, the term H in Equation 4 is more likely to vanish. The equity risk in the SC valuation is in accordance with Ronn and Verma (1986) where the first term $[\cdot]$ on the right-hand side of $\partial S/\partial V$ exists only.

We also use information about Equation 3 to illustrate an application of the DOC framework and to predict the bankruptcy. Equation 3 implies a risk-neutral failure probability P_{def} in Equation 2 over the interval form $t \in [0,\ 1]$ and it can be specified as the form by following Brockman and Turtle (2003) to obtain the default probability of the bank's net equity returns and is written as

$$P_{\text{def}} = N(a_1) + e^{a_2}(1 - N(a_3)) \tag{5}$$

where

$$a_1 = \frac{1}{\sigma}\left(\ln\frac{H}{V} - \delta + \frac{\sigma^2}{2}\right), \quad a_2 = \frac{2}{\sigma^2}\left(\delta - \frac{\sigma^2}{2}\right)\ln\frac{H}{V},$$
$$a_3 = -\frac{1}{\sigma}\left(\ln\frac{H}{V} + \delta - \frac{\sigma^2}{2}\right)$$

We further follow Brockman and Turtle (2003) to use a simple form of $H = \alpha Z$ where $0 \leq \alpha < 1$ is the barrier-to-debt ratio. Equation 5 with the condition of α provides a meaningful ranking of the bank according to its susceptibility to default.

The two relevant distinctions for our model are whether the barrier is existent and whether the dislike in the utility objective is included. Together they lead to the following four scenarios:

(i) As a benchmark case, the barrier is existent and the dislike is included. The objective is Equation 2.
(ii) As (i), except that the dislike of σ_S is excluded.
(iii) When the barrier vanishes and the dislike is included, the objective becomes

$$U(SC, \sigma_{SC}) = (1 - P_{SC})SC + P_{SC}(-\sigma_{SC}) \tag{6}$$

where

$$SC = VN(d_1) - Ze^{-\delta}N(d_2),$$
$$\sigma_{SC} = \frac{V}{SC}\frac{\partial SC}{\partial V}\sigma,$$

$$P_{SC} = N(-d_3),$$
$$d_3 = \frac{1}{\sigma}\left(\ln\frac{V}{Z} + \mu - \frac{\sigma^2}{2}\right)$$

Note that d_3 tells us how many SDs of the log of the ratio of V/Z needs to be deviated from its mean in order to default (Vassalou and Xing, 2004). Although the value of SC does not depend on μ, d_3 does. This is because d_3 depends on the future value of assets which is given in d_1 and d_2 in Equation 6.

(iv) As (iii), except that the dislike of σ_{SC} is excluded.

In our model, the results derived from cases (i) and (ii) can be interpreted as ones during a financial crisis, while those from cases (iii) and (iv) can be interpreted as ones during a normal time. The results derived from cases (i) and (iii) can be identified as ones with additionally considering the preference of the dislike of higher equity risk, while those from cases (ii) and (iv) can be identified as ones without such that.

IV. Solutions and Results

Case (i). Partially differentiating Equation 2 with respect to R_L, the first-order condition is given by

$$\frac{\partial U(S,\ \sigma_S)}{\partial R_L} = \left[-\frac{\partial P_{def}}{\partial R_L}S + (1-P_{def})\frac{\partial S}{\partial R_L}\right] - \left[\frac{\partial P_{def}}{\partial R_L}\sigma_S + P_{def}\frac{\partial \sigma_S}{\partial R_L}\right] = 0 \tag{7}$$

where

$$\frac{\partial P_{def}}{\partial R_L} = \frac{\partial N(a_1)}{\partial a_1}\frac{\partial a_1}{\partial R_L} + e^{a_2}\left[\frac{\partial a_2}{\partial R_L}(1-N(a_3)) - \frac{\partial N(a_2)}{\partial a_2}\frac{\partial a_2}{\partial R_L}\right]$$

$$\begin{aligned}\frac{\partial S}{\partial R_L} = & \left[\frac{\partial V}{\partial R_L}N(d_1) + \frac{\partial N(d_1)}{\partial d_1}\frac{\partial d_1}{\partial R_L} - \frac{\partial Z}{\partial R_L}e^{-\delta}N(d_2) - Ze^{-\delta}\frac{\partial N(d_2)}{\partial d_2}\frac{\partial d_2}{\partial R_L}\right] \\ & - \left[\frac{\partial V}{\partial R_L}\left(\frac{\alpha Z}{V}\right)^{2\eta}N(b_1) + V(2\eta)\left(\frac{\alpha Z}{V}\right)^{2\eta}\left(\frac{1}{Z}\frac{\partial Z}{\partial R_L} - \frac{1}{V}\frac{\partial V}{\partial R_L}\right) + V\left(\frac{\alpha Z}{V}\right)^{2\eta}\frac{\partial N(b_1)}{\partial b_1}\frac{\partial b_1}{\partial R_L} - \frac{\partial Z}{\partial R_L}e^{-\delta}\left(\frac{\alpha Z}{V}\right)^{2\eta-2}N(b_2) \right. \\ & \left. - Ze^{-\delta}(2\eta-2)\left(\frac{\alpha Z}{V}\right)^{2\eta-2}\left(\frac{1}{Z}\frac{\partial Z}{\partial R_L} - \frac{1}{V}\frac{\partial V}{\partial R_L}\right)N(b_2) - Ze^{-\delta}\left(\frac{\alpha Z}{V}\right)^{2\eta-2}\frac{\partial N(b_2)}{\partial b_2}\frac{\partial b_2}{\partial R_L}\right]\end{aligned}$$

$$\frac{\partial \sigma_S}{\partial R_L} = \left(\frac{1}{S}\frac{\partial V}{\partial R_L} - \frac{V}{S^2}\frac{\partial S}{\partial R_L}\right)\frac{\partial S}{\partial V}\sigma + \frac{V}{S}\frac{\partial^2 S}{\partial V \partial R_L}\sigma$$

We require that the second-order condition, $\partial^2 U(S,\ \sigma_S)/\partial R_L^2 < 0$, needs to be satisfied. The first term on the right-hand side of Equation 7 can be interpreted as the marginal weighted expected utility of loan rate, while the second term can be interpreted as the marginal weighted expected disutility of loan rate. The optimal loan rate is obtained where both the marginal values are equal. Sufficient condition for an optimum is that the utility function demonstrates the like of equity return and the dislike of equity risk. The first-order condition for the maximization of expected utility determines the optimal loan rate. If loan demand is relatively rate-elastic, a larger loan portfolio is possible at a reduced optimal loan rate. The increased loan amount implies that the bank is more prone to risk-taking, yielding a decreased equity return and an increased equity risk, *ceteris paribus*.

Consider next the impact on the optimal loan rate (and thus the optimal margin) from changes in the equity capital cost. Implicit differentiation of Equation 7 with respect to R yields

$$\left.\frac{\partial R_L}{\partial R}\right|_{U(S,\ \sigma_S)} = -\frac{\partial^2 U(S,\ \sigma_S)}{\partial R_L \partial R} \Big/ \frac{\partial^2 U(S,\ \sigma_S)}{\partial R_L^2} \tag{8}$$

where

$$\begin{aligned}\frac{\partial^2 U(S,\ \sigma_S)}{\partial R_L \partial R} = & \left[-\frac{\partial^2 P_{def}}{\partial R_L \partial R}S - \frac{\partial P_{def}}{\partial R_L}\frac{\partial S}{\partial R} - \frac{\partial P_{def}}{\partial R}\frac{\partial S}{\partial R_L} + (1-P_{def})\frac{\partial^2 S}{\partial R_L \partial R}\right] \\ & - \left[\frac{\partial^2 P_{def}}{\partial R_L \partial R}\sigma_S + \frac{\partial P_{def}}{\partial R_L}\frac{\partial \sigma_S}{\partial R} + \frac{\partial P_{def}}{\partial R}\frac{\partial \sigma_S}{\partial R_L} + P_{def}\frac{\partial^2 \sigma_S}{\partial R_L \partial R}\right]\end{aligned}$$

The first term $[\cdot]$ on the right-hand side of the numerator in Equation 8 can be interpreted as the equity return like effect, while the second term $[\cdot]$ can be interpreted as the equity risk dislike effect. The like effect captures the charge in R_{L} due to an increase in R, holding the marginal weighted expected disutility of loan rate constant. The dislike effect also captures this change, but holding the marginal weighted expected utility constant. Both the signs of the like and dislike effects are indeterminate.

Case (ii). Partially differentiating Equation 2 where $\sigma_S = 0$ with respect to R_{L}, the first-order condition is given by

$$\frac{\partial U(S)}{\partial R_{\mathrm{L}}} = -\frac{\partial P_{\mathrm{def}}}{\partial R_{\mathrm{L}}} S + (1 - P_{\mathrm{def}}) \frac{\partial S}{\partial R_{\mathrm{L}}} = 0 \tag{9}$$

We require that the second-order condition, $\partial^2 U(S)/\partial R_{\mathrm{L}}^2 < 0$, needs to be satisfied for the optimization maximization of Equation 9. The first term on the right-hand side of Equation 9 can be identified as the bank equity value weighted by the marginal default probability of loan rate, while the second term can be identified as the nondefault probability weighted by the marginal equity return of loan rate. The optimal loan rate is set when both the marginal values equal. Sufficient condition for an optimum is that the utility function demonstrates only the like of the equity return. In this case, the increased loan amount at a reduced optimal loan rate implies that the bank is more prone to risk-taking, yielding a decreased equity return, *ceteris paribus*.

Next, implicit differentiation of Equation 9 with respect to R yields

$$\left.\frac{\partial R_{\mathrm{L}}}{\partial R}\right|_{U(S)} = -\frac{\partial^2 U(S)}{\partial R_{\mathrm{L}} \partial R} \Big/ \frac{\partial^2 U(S)}{\partial R_{\mathrm{L}}^2} \tag{10}$$

where

$$\frac{\partial^2 U(S)}{\partial R_{\mathrm{L}} \partial R} = -\frac{\partial^2 P_{\mathrm{def}}}{\partial R_{\mathrm{L}} \partial R} S - \frac{\partial P_{\mathrm{def}}}{\partial R_{\mathrm{L}}} \frac{\partial S}{\partial R} - \frac{\partial P_{\mathrm{def}}}{\partial R} \frac{\partial S}{\partial R_{\mathrm{L}}} + (1 - P_{\mathrm{def}}) \frac{\partial^2 S}{\partial R_{\mathrm{L}} \partial R}$$

Case (iii). Partially differentiating Equation 6 with respect to R_{L}, the first-order condition is given by

$$\frac{\partial U(SC,\ \sigma_{SC})}{\partial R_{\mathrm{L}}} = \left[-\frac{\partial P_{SC}}{\partial R_{\mathrm{L}}} SC + (1 - P_{SC}) \frac{\partial SC}{\partial R_{\mathrm{L}}}\right] - \left[\frac{\partial P_{SC}}{\partial R_{\mathrm{L}}} \sigma_{SC} + P_{SC} \frac{\partial \sigma_{SC}}{\partial R_{\mathrm{L}}}\right] = 0 \tag{11}$$

where

$$\frac{\partial P_{SC}}{\partial R_{\mathrm{L}}} = -\frac{\partial P_{SC}}{\partial d_3} \frac{\partial d_3}{\partial R_{\mathrm{L}}}$$

$$\frac{\partial SC}{\partial R_{\mathrm{L}}} = \frac{\partial V}{\partial R_{\mathrm{L}}} N(d_1) + V \frac{\partial N(d_1)}{\partial d_1} \frac{\partial d_1}{\partial R_{\mathrm{L}}} - \frac{\partial Z}{\partial R_{\mathrm{L}}} e^{-\delta} N(d_2) - Z e^{-\delta} \frac{\partial N(d_2)}{\partial d_2} \frac{\partial d_2}{\partial R_{\mathrm{L}}}$$

$$\frac{\partial \sigma_{SC}}{\partial R_{\mathrm{L}}} = \left[\left(\frac{1}{SC} \frac{\partial V}{\partial R_{\mathrm{L}}} - \frac{V}{SC^2} \frac{\partial SC}{\partial R_{\mathrm{L}}}\right) N(d_1) + \frac{V}{SC} \frac{\partial N(d_1)}{\partial d_1} \frac{\partial d_1}{\partial R_{\mathrm{L}}}\right] \sigma$$

We require that the second-order condition, $\partial^2 U(SC,\ \sigma_{SC})/\partial R_{\mathrm{L}}^2 < 0$, needs to be satisfied for the optimization maximization of Equation 11. According to the equilibrium condition of Equation 13, we obtain the optimal loan rate.

Next, implicit differentiation of Equation 11 with respect to R yields

$$\left.\frac{\partial R_{\mathrm{L}}}{\partial R}\right|_{U(SC,\ \sigma_{SC})} = -\frac{\partial^2 U(SC,\ \sigma_{SC})}{\partial R_{\mathrm{L}} \partial R} \Big/ \frac{\partial^2 U(SC,\ \sigma_{SC})}{\partial R_{\mathrm{L}}^2} \tag{12}$$

where

$$\frac{\partial^2 U(SC,\ \sigma_{SC})}{\partial R_{\mathrm{L}} \partial R} = \left[-\frac{\partial^2 P_{SC}}{\partial R_{\mathrm{L}} \partial R} SC - \frac{\partial P_{SC}}{\partial R_{\mathrm{L}}} \frac{\partial SC}{\partial R} - \frac{\partial P_{SC}}{\partial R} \frac{\partial SC}{\partial R_{\mathrm{L}}} + (1 - P_{SC}) \frac{\partial^2 SC}{\partial R_{\mathrm{L}} \partial R}\right] - \left[\frac{\partial^2 P_{SC}}{\partial R_{\mathrm{L}} \partial R} \sigma_{SC} + \frac{\partial P_{SC}}{\partial R_{\mathrm{L}}} \frac{\partial \sigma_{SC}}{\partial R} + \frac{\partial P_{SC}}{\partial R} \frac{\partial \sigma_{SC}}{\partial R_{\mathrm{L}}} + P_{SC} \frac{\partial^2 \sigma_{SC}}{\partial R_{\mathrm{L}} \partial R}\right]$$

The first term $[\cdot]$ on the right-hand side of the numerator in Equation 12 can be identified as the like effect in form of the SC equity return, while the second term $[\cdot]$ can be identified as the dislike effect in form of the SC equity risk.

Case (iv). Partially differentiating Equation 6 where $\sigma_{SC} = 0$ with respect to R_L, the first-order condition is given by

$$\frac{\partial U(SC)}{\partial R_L} = -\frac{\partial P_{SC}}{\partial R_L} SC + (1 - P_{SC})\frac{\partial SC}{\partial R_L} = 0 \tag{13}$$

We require that the second-order condition, $\partial^2 U(SC)/\partial R_L^2 < 0$, needs to be satisfied for the optimization maximization. The optimal loan rate can be obtained from the equilibrium condition of Equation 13.

Further, implicit differentiation of Equation 13 with respect to R yields

$$\left.\frac{\partial R_L}{\partial R}\right|_{U(SC)} = -\frac{\partial^2 U(SC)}{\partial R_L \partial R} \Big/ \frac{\partial^2 U(SC)}{\partial R_L^2} \tag{14}$$

where

$$\frac{\partial^2 U(SC)}{\partial R_L \partial R} = -\frac{\partial^2 P_{SC}}{\partial R_L \partial R} SC - \frac{\partial P_{SC}}{\partial R_L}\frac{\partial SC}{\partial R} - \frac{\partial P_{SC}}{\partial R}\frac{\partial SC}{\partial R_L} + (1 - P_{SC})\frac{\partial^2 SC}{\partial R_L \partial R}$$

It is well recognized that the added complexity of the option-based utility valuation does not always lead to clear-cut results of Equations 8, 10, 12 and 14. But we can certainly denote tendencies for reasonable parameter levels that roughly correspond to the comparative static results. These four cases will be analysed and compared in the next section using a numerical exercise approach.

V. Numerical Exercises

Unless otherwise stated, a more tractable scenario assumes that the parameter levels are $R_D = 2.25\%$, $L + B = 335.50$, $D = 305$, $q = 10.00\%$, $\sigma = 0.20$, $\mu = 0.15$ and $\alpha = 0.60$ for a hypothetical bank. Let $(R_L\%, L)$ change from (5.00, 298) to (6.25, 273) due to the conditions of $\partial L/\partial R_L < 0$ and $\partial^2 L/\partial R_L^2 < 0$, and let $R\%$ increase from 2.75 to 4.50.[12] The condition of $R > R_D$ indicates the existence of capital cost (Heid and Krüger, 2011), the condition of $R_L > R$ implies the fund reserve as liquidity and substitution in the earning asset portfolio (Kashyap *et al.*, 2002), and the condition of $R_L > R_D$ demonstrates the bank interest margin as a proxy for the efficiency of financial intermediation (Tsai, 2012). The regulatory parameter of $q = 10.00\%$ illustrates a possible specification of capital adequacy requirements, which is implicitly consistent with the standardized approach of the Basel Accord (VanHoose, 2007). $\alpha = 0.60$ indicates a possible level of barrier (Brockman and Turtle, 2003).[13]

Case (i). We first compute the value $U(S,\ \sigma_S)$ based on the specification of Equation 2. Next, using equilibrium information about Equation 7, we calculate $\partial U^2(S,\ \sigma_S)/\partial R_L \partial R$ and $\partial U^2(S,\ \sigma_S)/\partial R_L^2$ in order to obtain the comparative static result of $\partial R_L/\partial R$ in Equation 8. The findings are summarized in Table 1.

In Table 1, we observe the results of $U(S,\ \sigma_S) > 0$, $\partial^2 U(S,\ \sigma_S)/\partial R_L^2 < 0$ and $\partial R_L/\partial R > 0$.[14] Note that $\partial^2 U(S,\ \sigma_S)/\partial R_L^2 < 0$ confirms the second-order condition. The optimal loan rate is set to be 5.50% approximately that is observed from the shaded areas in Table 1. $\partial R_L/\partial R > 0$observed from the last panel demonstrates that, as the cost of bank equity capital

[12] The riskless rate $R\%$ is given by the compounded return on 1-year US treasuring bills. According to Brockman and Turtle (2003), the mean value of $R\%$ is 5.81% with a corresponding SD of 2.07%. For simplicity, our numerical analysis is limited to the range between 2.75% and 4.50%.

[13] According to the empirical study of Brockman and Turtle (2003), the average barrier is 0.6920 with a corresponding SD of 0.2259, and the barrier in retail is 0.6681 with a corresponding SD of 0.2024 during the sample period of 1981–1998. In our numerical exercises, we assume that the barrier is equal to 0.60, allowing the inclusion of a more realistic state.

[14] The number of $\partial R_L/\partial R$ evaluated at the optimal loan rate is rather small. This result is understood because the dependent variable R_L is a function of R, R_D, B, D, q, σ, μ and α in our model. According to the empirical results observed from Slovin and Sushka (1983), the effects of $\partial R_L/\partial R$ are 0.2573, 0.0958, 0.0282, 0.0466, 0.0221, 0.0253, 0.031 and 0.0758 as the independent variables are increased.

Table 1. Values of $U(S, \sigma_S)$ and $\partial R_L/\partial R$ in Equation 8

	(R_L%, L)					
R%	(5.00, 298)	(5.25, 295)	(5.50, 291)	(5.75, 286)	(6.00, 280)	(6.25, 273)
	$U(S, \sigma_S)$					
2.75	29.4440	29.6068	29.6646	29.6128	29.4467	29.1613
3.00	29.8568	30.0231	30.0846	30.0363	29.8737	29.5919
3.25	30.2724	30.4423	30.5073	30.4627	30.3037	30.0255
3.50	30.6907	30.8643	30.9330	30.8920	30.7366	30.4621
3.75	31.1119	31.2891	31.3614	31.3241	31.1724	30.9016
4.00	31.5358	31.7167	31.7926	31.7590	31.6111	31.3440
4.25	31.9625	32.1470	32.2266	32.1967	32.0526	31.7893
4.50	32.3918	32.5800	32.6634	32.6372	32.4968	32.2375
	$\partial^2 U(S, \sigma_S)/\partial R_L^2$, %					
2.75	–	−10.4917	−10.9614	−11.4378	−11.9206	–
3.00	–	−10.4932	−10.9628	−11.4390	−11.9215	–
3.25	–	−10.4937	−10.9632	−11.4390	−11.9211	–
3.50	–	−10.4934	−10.9626	−11.4380	−11.9193	–
3.75	–	−10.4921	−10.9610	−11.4358	−11.9164	–
4.00	–	−10.4900	−10.9584	−11.4325	−11.9121	–
4.25	–	−10.4870	−10.9549	−11.4282	−11.9067	–
4.50	–	−10.4832	−10.9504	−11.4229	−11.9001	–
	$\partial R_L/\partial R = (\partial^2 U(S,\sigma_S)/\partial R_L \partial R)/(\partial^2 U(S,\sigma_S)/\partial R_L^2)$					
2.75→3.00	–	0.0342	0.0326	0.0311	0.0298	–
3.00→3.25	–	0.0344	0.0329	0.0315	0.0303	–
3.25→3.50	–	0.0346	0.0332	0.0319	0.0307	–
3.50→3.75	–	0.0348	0.0334	0.0322	0.0312	–
3.75→4.00	–	0.0350	0.0337	0.0326	0.0316	–
4.00→4.25	–	0.0351	0.0340	0.0329	0.0321	–
4.25→4.50	–	0.0353	0.0342	0.0333	0.0325	–

Notes: The value of utility in Equation 2 is computed using the following parameter values, unless indicated otherwise: $R_D = 2.25\%$, $L + B = 335.50$, $D = 305$, $q = 10.00\%$, $\sigma = 0.20$, $\mu = 0.10$ and $\alpha = 0.60$.

increases (i.e. the government increases the interest rate of Federal funds), the bank interest margin is increased.

Intuitively, as the bank is regulated by an increase of the interest rate of the Federal funds, it must now provide a return to a higher equity capital cost, explicitly taking an equity risk dislike into account. One way the bank may attempt to augment its total returns is by shifting its investments from its loan portfolio to the Federal funds market. If loan demand is relatively rate-elastic, a smaller loan portfolio and larger Federal funds are possible at an increased margin. Furthermore, an increased loan rate set by the bank can be explained as an increased bank interest margin positively related to the like, while a decreased loan amount held by the bank can be explained as a decreased loan risk positively related to the dislike. As a result, the bank's utility increases when the bankfaces a higher capital cost. Our result is consistent with the finding of Wong (1997) that the optimal loan rate (and thus the optimal bank interest margin) is positively related to the interest rate of the Federal funds, and it leads to decrease the loan risk-taking at an increased margin. It further implies a better return and risk performance for the bank.[15] Our finding also provides an alternative explanation for that equity capital cost attenuates the excessive risk-taking incentives induced by bank spread behaviour,

[15] Note that the bank's objective in Wong (1997) is to set the loan rate to maximize the expected value of a Von Neumann–Morgenstern utility function defined in terms of profits, subject to the bank's liquidity constraint. The comparative static result obtained above is based on a constant level of capital. Wong (1997) demonstrates that an increase in the bank's equity capital will decrease the optimal bank interest. Zarruk and Madura (1992) also argue that an increase in the capital-to-deposits ratio decreases the optimal bank interest margin. In this article, we do not address the issue of capital regulation.

Table 2. Values of $U(S)$ and $\partial R_L/\partial R$ in Equation 10

$R\%$	$(R_L\%,\ L)$ (5.00, 298)	(5.25, 295)	(5.50, 291)	(5.75, 286)	(6.00, 280)	(6.25, 273)
	$U(S)$					
2.75	29.4552	29.6175	29.6749	29.6227	29.4561	29.1704
3.00	29.8675	30.0334	30.0944	30.0458	29.8828	29.6006
3.25	30.2827	30.4522	30.5168	30.4718	30.3124	30.0338
3.50	30.7006	30.8738	30.9421	30.9007	30.7450	30.4700
3.75	31.1214	31.2982	31.3701	31.3324	31.1804	30.9092
4.00	31.5449	31.7254	31.8010	31.7670	31.6187	31.3513
4.25	31.9712	32.1554	32.2347	32.2044	32.0599	31.7963
4.50	32.4003	32.5881	32.6711	32.6446	32.5038	32.2441
	$\partial^2 U(S)/\partial R_L^2, \%$					
2.75	–	−10.4903	−10.9601	−11.4365	−11.9194	–
3.00	–	−10.4919	−10.9617	−11.4379	−11.9204	–
3.25	–	−10.4926	−10.9622	−11.4380	−11.9201	–
3.50	–	−10.4924	−10.9617	−11.4371	−11.9185	–
3.75	–	−10.4913	−10.9602	−11.4350	−11.9157	–
4.00	–	−10.4893	−10.9577	−11.4319	−11.9116	–
4.25	–	−10.4864	−10.9543	−11.4277	−11.9062	–
4.50	–	−10.4827	−10.9500	−11.4225	−11.8997	–
	$\partial R_L/\partial R = -(\partial^2 U(S)/\partial R_L \partial R)/(\partial^2 U(S)/\partial R_L^2)$					
2.75→3.00	–	0.0343	0.0327	0.0312	0.0298	–
3.00→3.25	–	0.0345	0.0329	0.0316	0.0303	–
3.25→3.50	–	0.0347	0.0332	0.0319	0.0308	–
3.50→3.75	–	0.0349	0.0335	0.0323	0.0312	–
3.75→4.00	–	0.0351	0.0338	0.0327	0.0317	–
4.00→4.25	–	0.0352	0.0340	0.0330	0.0321	–
4.25→4.50	–	0.0354	0.0343	0.0333	0.0325	–

Notes: The value of utility in Equation 2 with $\sigma_S = 0$ is computed using the following parameter values, unless indicated otherwise: $R_D = 2.25\%$, $L + B = 335.50$, $D = 305$, $q = 10.00\%$, $\sigma = 0.20$, $\mu = 0.10$ and $\alpha = 0.60$.

supported by Freixas and Rochet (2008) and Acharya *et al.* (2011).

Case (ii). Based on the observations of Table 2, $\partial^2 U(S)/\partial R_L^2 < 0$ indicates the validness of the second-order condition. The optimal loan rate is approximately 5.50% observed from the shaded area of the first panel. The result of $\partial R_L/\partial R > 0$ observed from the last panel demonstrates that an increase in the equity capital cost has a positive effect on the bank interest margin when the dislike of higher equity risk is ignored. The interpretation of this result follows a similar argument as in the case of the barrier option with disutility of case (i). Basically, increases in the cost of equity encourage the bank to shifts to the Federal funds from its loan portfolio. In an imperfect loan market, the bank must increase the size of its spread in order to reduce the amount of loans.

Case (iii). In Table 3, we have the results of $U(SC,\ \sigma_{SC}) > 0$, $\partial^2 U(SC,\ \sigma_{SC})/\partial R_L^2 < 0$ and $\partial R_L/\partial R > 0$. The optimal loan rate is approximately 6.00% observed from the shaded area in the first panel. The result of $\partial R_L/\partial R > 0$ is observed from the last panel when the SC framework is a good representation of reality (i.e. the barrier should be zero). There is again the bank interest margin positively related to equity capital cost.

Case (iv). In Table 4, we observe the results of $U(SC) > 0$, $\partial^2 U(SC)/\partial R_L^2 < 0$ and $\partial R_L/\partial R > 0$. The optimal loan rate is approximately 6.00% based on the numerical parameters used in the exercise. Again, we have the result of $\partial R_L/\partial R > 0$ observed from the last panel when the barrier and the dislike are ignored.

Based on the results presented in Tables 1–4, it has been consistently shown that an increase in the

Table 3. Values of $U(SC, \sigma_{SC})$ and $\partial R_L/\partial R$ in Equation 12

	$(R_L\%, L)$					
$R\%$	(5.00, 298)	(5.25, 295)	(5.50, 291)	(5.75, 286)	(6.00, 280)	(6.25, 273)
	$U(SC,\ \sigma_{SC})$					
2.75	20.5165	20.7575	20.9244	21.0127	21.0176	20.9343
3.00	20.8079	21.0546	21.2276	21.3225	21.3346	21.2590
3.25	21.1014	21.3538	21.5330	21.6347	21.6541	21.5864
3.50	21.3970	21.6551	21.8407	21.9492	21.9760	21.9163
3.75	21.6947	21.9586	22.1505	22.2660	22.3003	22.2488
4.00	21.9944	22.2642	22.4626	22.5851	22.6271	22.5839
4.25	22.2962	22.5719	22.7768	22.9065	22.9563	22.9215
4.50	22.6000	22.8817	23.0932	23.2301	23.2878	23.2617
	$\partial^2 U(SC, \sigma_{SC})/\partial R_L^2$					
2.75	–	−0.0741	−0.0787	−0.0834	−0.0882	–
3.00	–	−0.0736	−0.0782	−0.0828	−0.0876	–
3.25	–	−0.0731	−0.0776	−0.0823	−0.0870	–
3.50	–	−0.0725	−0.0771	−0.0817	−0.0865	–
3.75	–	−0.0720	−0.0765	−0.0811	−0.0858	–
4.00	–	−0.0714	−0.0759	−0.0805	−0.0852	–
4.25	–	−0.0708	−0.0753	−0.0799	−0.0845	–
4.50	–	−0.0702	−0.0746	−0.0792	−0.0838	–
	$\partial R_L/\partial R = -(\partial^2 U(SC,\ \sigma_{SC})/\partial R_L \partial R)/(\partial^2 U(SC,\ \sigma_{SC})/\partial R_L^2)$					
2.75→3.00	–	0.0835	0.0851	0.0867	0.0882	–
3.00→3.25	–	0.0851	0.0870	0.0888	0.0905	–
3.25→3.50	–	0.0868	0.0889	0.0909	0.0928	–
3.50→3.75	–	0.0886	0.0909	0.0931	0.0952	–
3.75→4.00	–	0.0904	0.0929	0.0953	0.0977	–
4.00→4.25	–	0.0922	0.0949	0.0976	0.1002	–
4.25→4.50	–	0.0941	0.0970	0.0999	0.1027	–

Notes: The value of utility in Equation 6 is computed using the following parameter values, unless indicated otherwise: $R_D = 2.25\%$, $L + B = 335.50$, $D = 305$, $q = 10.00\%$, $\sigma = 0.20$, $\mu = 0.10$ and $\alpha = 0.60$.

interest rate of Federal funds (and hence an increase in the bank's equity capital cost) has a positive effect on the bank interest margin. It is interesting to further compare those four cases in order to analyse the robustness of the equity capital cost impacts. The findings are summarized in Table 5.

We have the following several main results. First, we show that the optimal bank margin with high loan variability ($\alpha = 0.60$ perhaps during a financial crisis) is smaller than that with low one ($\alpha = 0$ perhaps during a normal time). This result is intuitive because the bank can lend from both the loan and the liquid asset market. As loans credit risk burden makes the bank less prone to loan risk-taking at a lower margin. Loan variability as such further decreases the weighted default probability and then increases the like of higher equity return and/or decreases the dislike of higher equity risk. And, this results in an increase of the bank's maximum utility as observed from the upper panel of Table 5.

Next, in the four scenarios observed from the lower panel, we have shown that an increase in the bank's equity capital cost has a positive effect on margin and a negative effect on loan risk-taking incentives, implying a better return and risk performance. Overall, we can argue that an increase in the interest of Federal funds by the government, even though the bank's equity capital cost may have been increased, can contribute to increase bank profitability and to stabilize the banking system. As a benchmark, the bank's utility maximization in case (i) explicitly considers both the barrier of bankruptcy probability during a financial crisis and the dislike of higher equity risk due to the revealed preference. Comparing these four scenarios, both the utility performance and the equity cost effect on margin may be

Table 4. Values of $U(SC)$ and $\partial R_L/\partial R$ in Equation 14

	$(R_L\%, L)$					
$R\%$	(5.00, 298)	(5.25, 295)	(5.50, 291)	(5.75, 286)	(6.00, 280)	(6.25, 273)
	$U(SC)$					
2.75	20.8929	21.1267	21.2864	21.3675	21.3654	21.2751
3.00	21.1821	21.4215	21.5873	21.6750	21.6799	21.5972
3.25	21.4735	21.7185	21.8905	21.9849	21.9969	21.9219
3.50	21.7669	22.0177	22.1959	22.2970	22.3164	22.2493
3.75	22.0624	22.3190	22.5035	22.6115	22.6383	22.5793
4.00	22.3600	22.6224	22.8133	22.9283	22.9627	22.9118
4.25	22.6597	22.9279	23.1253	23.2474	23.2894	23.2469
4.50	22.9613	23.2356	23.4395	23.5687	23.6186	23.5845
	$\partial^2 U(SC)/\partial R_L^2$					
2.75	–	−0.0740	−0.0786	−0.0833	−0.0881	–
3.00	–	−0.0735	−0.0781	−0.0828	−0.0876	–
3.25	–	−0.0730	−0.0776	−0.0823	−0.0871	–
3.50	–	−0.0725	−0.0771	−0.0817	−0.0865	–
3.75	–	−0.0720	−0.0765	−0.0812	−0.0859	–
4.00	–	−0.0714	−0.0760	−0.0806	−0.0853	–
4.25	–	−0.0709	−0.0754	−0.0800	−0.0846	–
4.50	–	−0.0703	−0.0748	−0.0793	−0.0840	–
	$\partial R_L/\partial R = -(\partial^2 U(SC)/\partial R_L \partial R)/(\partial^2 U(SC)/\partial R_L^2)$					
2.75→3.00	–	0.0827	0.0841	0.0853	0.0865	–
3.00→3.25	–	0.0843	0.0859	0.0874	0.0888	–
3.25→3.50	–	0.0860	0.0878	0.0895	0.0911	–
3.50→3.75	–	0.0877	0.0897	0.0916	0.0935	–
3.75→4.00	–	0.0895	0.0917	0.0938	0.0959	–
4.00→4.25	–	0.0913	0.0937	0.0961	0.0984	–
4.25→4.50	–	0.0932	0.0958	0.0984	0.1010	–

Notes: The value of utility in Equation 6 with $\sigma_{SC} = 0$ is computed using the following parameter values, unless indicated otherwise: $R_D = 2.25\%$, $L + B = 335.50$, $D = 305$, $q = 10.00\%$, $\sigma = 0.20$, $\mu = 0.10$ and $\alpha = 0.60$.

overestimated if the dislike preference is not included. The results can also be applied to the cases without considering the barrier (cases (iii) and (iv)). In addition, the utility performance is underestimated and the equity cost effect on margin is overestimated without barrier. Accordingly, we argue that the choice of an appropriate goal in modelling the bank's optimization problem is a crucial issue.

One immediate application of this article is to propose a conceptual structure for the degree of risk aversion based on the barrier and the dislike realization instead of the commonly used exogenous approach. In particular, the degree of risk aversion captured only by the default risk in the bank's equity returns without considering both the barrier and the dislike, case (iv), can be recognized as most likely the weakest one, whereas case (i) is most likely the strongest one. We show that bank performance related to profitability and stability decreases as the bank increases its risk aversion. If the barrier is not existent, a bank may increase its performance as the bank becomes more risk-averse dominated by only the dislike ($U(SC, \sigma_{SC})$ in case (iii) versus $U(SC)$ in case (iv)). If the dislike is ignored, a bank decreases its performance as the bank becomes more risk-averse dominated by only the barrier ($U(S, \sigma_S)$ in case (i) versus $U(S)$ in case (ii)). As a result, if the barrier is inevitable during a financial crisis, a bank manager should explicitly integrate the equity risk with its utility maximization to increase its performance when a bank facing a high equity capital cost.

The importance of the barrier and the dislike realization should be emphasized in modelling the bank's optimization problem, particularly when the government regulates the interest rate of the Federal

Table 5. Robustness with respect to *R*

	$\alpha = 0.60$ during a financial crisis		$\alpha = 0$ during a normal time	
	$\sigma_S > 0$	$\sigma_S = 0$	$\sigma_{SC} > 0$	$\sigma_{SC} = 0$
	$R^*_{:L} = 5.50\%$	$R^*_{:L} = 5.50\%$	$R^*_{:L} = 6.00\%$	$R^*_{:L} = 6.00\%$
$R\%$	Case (i)	Case (ii)	Case (iii)	Case (iv)
	$U(S,\ \sigma_S)$	$U(S)$	$U(SC,\ \sigma_{SC})$	$U(SC)$
3.00	30.0846	30.0944	21.3346	21.6799
3.25	30.5073	30.5168	21.6541	21.9969
3.50	30.9330	30.9421	21.9760	22.3164
3.75	31.3614	31.3701	22.3003	22.6383
4.00	31.7926	31.8010	22.6271	22.9627
4.25	32.2266	32.2347	22.9563	23.2894
4.50	32.6634	32.6711	23.2878	23.6186
	$\partial R_L / \partial R$			
2.75→3.00	0.0326	0.0327	0.0882	0.0865
3.00→3.25	0.0329	0.0329	0.0905	0.0888
3.25→3.50	0.0332	0.0332	0.0928	0.0911
3.50→3.75	0.0334	0.0335	0.0952	0.0935
3.75→4.00	0.0337	0.0338	0.0977	0.0959
4.00→4.25	0.0340	0.0340	0.1002	0.0984
4.25→4.50	0.0342	0.0343	0.1027	0.1010

Notes: The results of cases (i)–(iv) are collected from the shaded areas of Tables 1–4, respectively. The maximum levels of utility in cases (i) and (ii) are $U(S,\ \sigma_S)$ and $U(S)$ with a corresponding approximate optimal loan rate (R^*_L) of 5.50%, and those in cases (iii) and (iv) are $U(SC,\ \sigma_{SC})$ and $U(SC)$ with $R^*_{:L} = 6.00\%$.

funds and the FDIC attempts to protect its deposit insurance fund. Brockman and Turtle (2003) argue that firms with high asset variability are likely to exhibit a higher probability of hitting the barrier before the expiration date than the others. Barrier can also reduce bank performance as equity capital cost increases. Further, Episcopos (2008) argue that banking is an ideal environment for the barrier option model because the FDIC as a regulator/ insurer controls the barrier in a very direct manner by the power vested by the FDIC Improvement Act. Raising the barrier induces a wealth transfer to the FDIC from shareholders, implying a better protection of the insurance fund. Under such circumstances, we show that bank performance reduces as the bank's equity capital cost increases. As a result, we suggest that the bank should attenuate the excessive risk-taking incentives in its loan portfolio investment and explicitly take its equity risk dislike preference into account for obtaining a better return and risk performance when the regulatory authorities increase the security market interest rate and decrease the deposit insurance fund protection.

VI. Conclusion

This article proposes a utility framework for bank regulation based on the barrier option model of Brockman and Turtle (2003) and the equity risk model of Ronn and Verma (1986). Several results are derived and those should be of interest to investors, bank managers and policymakers. For example, an increase in the bank's equity capital cost due to increasing the interest rate of the Federal funds by the government results in decreasing the excessive loan risk-taking incentives at an increased bank interest margin. This simply implies a better return and risk performance for the bank. Under certain circumstances, an increase in the barrier due to a better protection of deposit insurance fund can reduce the bank's performance. Furthermore, an increase in the barrier with the consideration of the equity risk in the bank's utility objective increases the bank's performance. In conclusion, it is shown that the barrier and the dislike of higher equity risk are intimately relevant to bank spread behaviour under government regulation.

Another issue that has not been addressed is the dislike of higher equity risk linking to credit risk transfer. Since the dislike and/or the barrier may be replaced by credit risk transfers at costs, whether the results derived from this article can be applied to the credit risk transfer case may be an interesting issue. In a very simple rational expectation framework, the answer is expected to be positive. Of course, in a world without such a strict rational expectation requirement, other factors would affect the costs of credit risk transfers. For example, credit risk pricing may play a very important role and add complexity due to information asymmetries. Such a concern is beyond the scope of our study and so is not addressed here. What this article does demonstrate, however, is the important role played by the dislike of the preferences and the barrier in the equity return valuation in affecting bank spread behaviour.

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