Bank Interest Margins under Information Asymmetry and Centralized vs. Decentralized Loan Rate Decisions: A Two-Stage Option Pricing Model

JYH-HORNG LIN[1], JYH-JIUAN LIN[2*] AND ROSEMARY JOU[3]
[1] Graduate Institute of International Business
Tamkang University
lin9015@mail.tku.edu.tw
[2] Department of Statistics
Tamkang University
117604@mail.tku.edu.tw
[3] Graduate Institute of Management Sciences
Tamkang University
151 Ying-Chuan Road, Tamsui, Taipei County 251,
TAIWAN
893560135@s93.tku.edu.tw

Abstract: The behavior of outside portfolio managers of large money-center banks as analyzed to date is silent. In a centralized loan portfolio construction with decentralized loan portfolio management, changes in the bank's degree of capital market imperfection have direct effects on the bank's interest margin through the centralized as well as the decentralized loan rate determinations. We use a two-stage model of option-based analysis to study how information asymmetry and optimal bank loan rates relate to one another. We find that the decentralized loan rate managed by the outside loan manager is positively related to the bank's degree of capital market imperfection. The centralized loan rate managed by the bank is positively related to its degree of capital market imperfection under strategic complements, but negatively under strategic substitutes.

Key-words: Centralized vs. decentralized loan rate; Information asymmetry; Black-Scholes formula.

1 Introduction

It is widely recognized that many financial institutions employ outside portfolio managers to manage part or all of their investable funds. The most likely institutions include pension funds, private endowments, and private trusts.[1] Although the employment of an outside portfolio manager is less likely to be currently observed in banking firms than

[1] See, for example, Elton and Gruber (2004).

that in the previous financial institutions, there may be instances when money-center banks have experienced diversified financial problems due to their information asymmetry or insufficiency of agricultural, real estate, and oil-related lending businesses. We do an alternative examination and argue that concerns with bank diversified lending quality may prompt money-center banks to adopt the outside administrator's portfolio management. The relevant problem of financial institutions delegating decision making has been recognized in the practitioners' literature on loan portfolio management (see, for example, diBartolomero (1999)).

In their recent paper on "Optimum Centralized Portfolio Construction with Decentralized Portfolio Management," Elton and Gruber (2004) argue that the centralized portfolio is unlikely to be optimum since the individually managed portfolios themselves are constructed without taking into account the portfolios of the other managers. Hence, information asymmetry takes place. Elton and Gruber (2004) construct a portfolio using standard portfolio theory to show that a central decision maker can make optimal decisions without requiring decentralized decision makers to reveal estimates of investment returns. Their model neatly presents how an implemental set of rules is derived to lead to optimal portfolios under centralized decision-making.

Their model explains why and how the centralized and decentralized decision makers make their own portfolio (risk) decisions, but not their own operation (rate and equity return) decisions, at least not major ones. As an alternative, we develop a model of centralized portfolio construction with decentralized portfolio management that integrates the risk considerations of the portfolio-theoretic approach with market conditions and cost considerations of the firm-theoretic approach. Banks are in the business of lending and borrowing money. Hirtle and Stiroh (2007) demonstrate that U. S. banks, particular the largest, have dramatically expanded their retail banking operations over the last few years. Earnings from the margin between interest rates on assets and interest rates on liabilities account for bank profits significantly. The aim of this paper is to examine the inter-relatedness of centralized and decentralized loan rate-setting behavior (bank interest margin determination) and information asymmetry.

To do this, we use a two-stage model of option-based valuation to examine a bank's choice of its centralized loan rate in the first stage, and the determination of the outside manager's decentralized loan rate in the second stage. In the decentralized loan-rate setting stage, we find that an increase in the degree of capital market imperfection increases the outside manager's optimal loan rate (and thus the bank's margin). In the centralized loan-rate setting stage, we show that an increase in the degree of capital market imperfection decreases (increases) the bank's optimal loan rate under strategic substitutes (strategic complements).

One immediate application of this paper is to evaluate the outside manager employment of lending arrangement proposed as an alternative for future loans. In particular, one frequent suggestion is for the bank to employ an outside manager when information in different markets is asymmetric. This paper provides one explanation why this should be expected since the bank's interest margin increases through its outsider manager's loan rate-setting with an increase in the degree of capital market imperfection.

Two relevant distinctions have been employed in the literature to model the centralized decision maker delegating management responsibility. First, a number of authors, for example, Marschak and Radner (1972), and Ohlson (1975, 1979) have adopted a crucial assumption, that the decentralized managers are willing to provide all information to a centralized manager, as their analytical apparatus. This assumption has been examined for the pension fund problem by Rosenberg (1977) and diBartolomeo (1999). They argue that with full information, the decentralized portfolio managers will not make better decisions than the centralized decision maker. Second, Elton and Gruber (2004) argue that the decentralized portfolio managers are unwilling to fully share information with the centralized decision maker, and demonstrate how the centralized decision maker tries to optimally manage a set of decentralized portfolio managers.

What makes the analysis in our paper special is the realistic assumption that a decentralized manager is not willing to share information with the centralized manager, perhaps because the decentralized manager believes that the centralized manager (the bank in our model) has concealed some information concerning the quality of its lending portfolio. Thus, the bank's behavioral determination with the choices of strategic assumptions is made bearing in mind its impact on its decentralized manager's decision. Our paper can be viewed as an expansion of previous literature on centralized vs. decentralized decision-making and offers a solution to a portfolio allocation problem.

This paper is organized as follows. Section 2 presents the basic structure of the model. We then solve the decentralized problem of the bank's portfolio management in Section 3. Section 4 derives the solution of the centralized management and the comparative static analysis. Section 5 provides a conclusion to the study.

2 The Model

In order to get closed form, tractable solutions, a few simplifying assumptions are made. We shall point out when these assumptions affect the qualitative results derived in this paper.

Our model is myopic in the sense that all financial decisions are made and values are determined within a one-period horizon, $0 \le t \le 1$. At $t = 0$, the bank accepts D dollars in deposits. At $t = 1$, the bank provides depositors with a market rate of return equal to the risk-free rate, R_D. The bank is fully insured by the Federal Deposit Insurance Corporation (FDIC). We assume zero premiums paid by the bank for deposit insurance.[2] It should be apparent in what follows that this abstraction does not affect the basic conclusions of the paper.

Concerns about bank loan quality have promoted the regulatory authority to adopt a risk-based system of capital standards. Capital regulation requires equity capital K held by the bank tied to a fixed proportion q of the bank's deposits, $K \ge qD$. Following Zarruk and Madura (1992), the required ratio of capital-to-deposits q is an increasing function of the amount of the loans held by the bank at $t = 0$, $\partial q / \partial L = q' > 0$.

We start with a banking firm model of centralized portfolio construction with decentralized portfolio management. We assume that the bank (the centralized decision maker) employs only one outside loan manager to manage part of its investable risky assets. The bank may employ several outside portfolio managers to construct active portfolios. Adding this complexity affects none of the qualitative results since we follow Elton and Gruber (2004) assumption, in which a decentralized manager is only willing to share partial information with the centralized decision maker and none with the other managers.

Both the bank and its selected outside manager make term loans L and L_E, respectively, at $t = 0$, which mature and are paid off at $t = 1$. Both the two loan markets faced by the bank and the outside manager are imperfectly competitive in the sense that they have some market power in lending activities (see Wong (1997)).

The outside manager faces a loan demand function, which is a function of its loan interest rate, R_E, and the interest rate on the bank's loan interest rate, R_L, $L_E(R_L, R_E)$. The amount of loans decreases as the loan interest rate increases, $\partial L_E / \partial R_E < 0$. The demand for the outside manager's lending is a positive function of the interest rate on the bank's loans, $\partial L_E / \partial R_L > 0$. This positive relation captures the reallocation effect of the bank's earning-asset portfolio. It is reasonable to believe that L and L_E is gross substitutes in the centralized portfolio construction with decentralized portfolio

[2] Gianmarino, Lewis, and Sappington (1993) showed how more sophisticated fee schemes can be used to reduce the moral hazard issue.

management. We argue that the bank may not have incentives to employ the outside portfolio manager to manage part of its investable assets when L and L_E are gross complements. There are two reasons for our argument. First, bank management is limited to its liquidity or balance-sheet constraint. Second, portfolio management is generally related to risk diversification rather than risk concentration.

As mentioned previously, the outside portfolio manager is not willing to share all lending information with the bank, and this is expected to lead to sub-optimal portfolios due to information asymmetry. Applying Kashyap, Rajan, and Stein (2002), we can model this adverse-selection problem explicitly. For the sake of transparency, we adopt a very simple quadratic formulation where the outside manager's lending repayments at $t = 1$ is defined as $V_E = (1 + R_E)(L_E - cL_E^2 / 2)$. Here c measures the degree of capital market imperfection-- the larger it is, the more costly the outside manager's lending relative to the frictionless case. The premium $cL_E^2 / 2$ can be treated as the maximum amount the bank is willing to forego in order to avoid a random level of its profits due to information asymmetry.

The bank has a loan demand function, which is a function of its loan interest rate, the interest rate on the outside manager decision, and the degree of capital market imperfection, $L(R_L, R_E, c)$. Loan demand faced by the bank is a downward-sloping function of the loan rate, $\partial L / \partial R_L < 0$. The demand for loans is a positive function of the interest rate on the outside manager's lending rate, $\partial L / \partial R_E > 0$. The interpretation of this relation follows a similar argument as in the case of $\partial L_E / \partial R_L > 0$. The demand for loans is a negative function of the bank's degree of capital market imperfection, $\partial L / \partial c < 0$. This assumption implies that the bank will decrease its lending with the presence of a higher degree of capital market imperfection.

When the capital requirement constraint is binding, the shadow price with the constraint is zero and the bank's q is equal to the regulatory minimum capital-to-deposits ratio. [3] At the beginning of the period, the bank has the following liquidity or capital constraint:

$$L + L_E + B = D + K = K(\frac{1}{q} + 1) \qquad (1)$$

where B is a composite variable that

[3] If the capital constraint is not binding, the bank's q is greater than the required minimum ratio. The quantity of residual money market assets is exhausted and money market interest rates no longer are a useful measure of the marginal cost of lending. From the viewpoint of efficiency, our model is limited to analyzing the binding case. We note that the results derived from our model do not extend to the case where the bank's capital constraint is not binding.

measures the difference between money market borrowing and lending.[4] To provide the liquidity on demand, the bank can lend and borrow in the money market at a given market rate, R.

At any time during the period horizon, the repayment of the risky loans under the bank's determination is:

$$V\begin{cases} = (1+R_L)L = V^0 \\ \qquad\qquad \textit{if no loan losses} \\ < V^0 \qquad \textit{if loan losses} \end{cases} \quad (2)$$

Given the constraint in equation (1), the value of the bank's earning-asset portfolio is:

$$A = V + V_E + (1+R)[K(\frac{1}{q}+1) - L - L_E] \quad (3)$$

The value of the bank's equity return at $t=1$ is the residual value of the bank after meeting all of the obligations:

$$S = \max\{0,\ A - (1+R_D)K/q\} \quad (4)$$

The bank's total obligations or total costs, $(1+R_D)K/q$ in our model, are only the deposit payment costs. Both the resource costs of serving total loans, liquidity, and deposits, and the fixed cost are omitted for simplicity.

We follow a number of previous authors, for example, Mullins and Pyle (1994), Lin, Lin, and Jou (2009), and Lin, Chang, and Lin (2009), and assume the objective of the bank to be the maximization of market value of equity return. To do this, besides the first fold of the centralized decision maker's task of deciding how much to invest in each portfolio, the second fold is to give the outside manager instructions that will result in its making an optimal loan rate (R_E) determination from the point of view of the overall plan.[5] Overall, the bank's objective is to instruct the outside manager to select R_E and then to set its loan rate R_L to maximize the market value of equity return.

Our model applies Merton's method (1974) of the option-based valuation that the bank's equity capital can be viewed as a call option in its risky assets. The interpretation is that equity holders are residual claimants on the bank's risky assets after all of the other obligations have been met.[6] In

[4] Results derived from our model do not extend to the case where bond is not treasury bond (low-yield, risk-free) bond, but high-yield bond in money markets (Lee and Cheng (2008)).

[5] Elton and Gruber (2004, p.483) demonstrate that there are in general four folds of the centralized decision maker's task. Besides the first and second folds mentioned above, the third fold is to design optimal incentives for decentralized decision makers (see, for example, Stoughton, 1993), and the fourth fold is to evaluate the decentralized performance (see, for example, Gervais, Lynch, and Musto, 2002). These two folds are not major issues in our paper.

[6] V sometimes follows a geometric Brownian motion, $dV = \mu V dt + \sigma V dW$, where μ is an instantaneous drift, σ is an instantaneous volatility, and W is a standard Wiener process. Structural changes expressed by structural equation modeling (see Shih, Lin, Hsiao, Huang, Chiu, and Chen (2009)) are possible. Such concerns are beyond the scope of this paper.

our model, the strike price of the call option is the book value (or default-free value) of the bank's liabilities net of the outside manager's lending repayments, as well as the default-free money market funds. We note that the value of the outside manager's lending repayments is default-free because the cost of information asymmetry (through premium, $cL_E^{\ 2}/2$) has been explicitly introduced to the model. Thus, when the value of the bank's risky assets is less than the strike price, its value of equity capital is equal to zero.

The objective function, as described by equation (4), has the feature of a contingent claim that the bank's market value of equity capital can be an option-based value of call options effectively purchased by the equity holders of the bank. To illustrate this feature, we express equation (4) as:[7]

$$Max \quad S = VN(d_1) - Ze^{-\mu}N(d_2) \tag{5}$$

[7] As pointed out by Black and Cox (1976), a possible weakness of this approach is that default only occurs at maturity of the risky loans. They propose to incorporate a barrier on the market value of firm asset for triggering default prior to the maturity. Their approach is recognized as a down-and-call option pricing model. Galluzio (1999) and Chou and Wang (2007) use the down-and-call option pricing approach for their discussions. Gontis, Ruseckas, and Kononovičius (2010), and Power and Turvey (2010) present a nonlinear stochastic differential equation which mimics the probability density function of returns. Alternatively, we use the Black and Scholes' (1973) formula, which is a nonlinear option-based function of the equity return. Results to be derived from our model do not extend to the down-and-call option pricing case.

where,

$$Z = \frac{(1+R_D)K}{q} - \{(1+R_E)(L_E - \frac{cL_E^2}{2}) + (1+R)[K(\frac{1}{q}+1) - L - L_E]\}$$

$$d_1 = \frac{1}{\sigma}(\ln\frac{V}{Z} + \mu + \frac{1}{2}\sigma^2)$$

$$d_2 = d_1 - \sigma$$

$$\sigma_2 = \sigma_V^{\ 2} + \sigma_1^{\ 2} - 2\rho_{V,1}\sigma_V\sigma_1$$

$$\mu = R - R_D$$

In equation (5), the bank's equity market value consists of two terms. The first term associated with $N(d_1)$ can be treated as the risk-adjusted present value of the bank's interest earned from its risky loans. The second term associated with $N(d_2)$ can be recognized as the risk-adjusted present value of the bank's net obligations to its initial depositors above and beyond its default-free value from the outside manager's loan repayments. The cumulative standard normal distributions of $N(d_1)$ and $N(d_2)$ are the risk-adjusted factors of the first and second terms in equation (5) respectively. σ^2 is the variance with σ_v and σ_1 being the instantaneous standard deviation of the rates of returns on the risky and default-free assets respectively. $\rho_{v,\,1}$ is the instantaneous correlation coefficient between the two earning assets of the bank's portfolio. μ is the net deposit spread rate, which is defined as the difference between R and R_D.

3 Decentralized Loan-Rate Setting Stage

The role of the bank is to use R_E determined by the outside manager, and then to determine its optimal loan rate, R_L, to maximize the market value of the centralized portfolio. The two-stage setting unwinds in the two distinct stages of the determinations of R_L and R_E. In the first stage of centralized portfolio construction, the bank's loan rate is determined and remains fixed for the remainder for the model. In the second stage of decentralized portfolio management, the bank's loan rate is revealed and the outside manager's loan rate is set. As we see below, the bank's loan rate determination influences its outside manager's loan rate decision. The outside manager's loan rate decision is made taking into account the bank's loan rate determination in the first stage. Conversely, in the first stage, the bank's loan rate determination is made bearing in mind its impact on the equilibrium of the outside manager's loan-rate setting stage. Following Kreps and Wilson (1982), we recognize that the equilibrium for the bank's loan rate choice and its outside manager's loan rate determination is sequential. We solve this two-stage model using backward induction. Applying that method here, we analyze the decentralized loan-rate setting stage first, and then examine the centralized loan-rate setting stage in the next section.

Partially differentiating equation (5) with respect to R_E, the first-order condition is given by:

$$\frac{\partial S}{\partial R_E} = \frac{\partial V}{\partial R_E} N(d_1) + V \frac{\partial N(d_1)}{\partial d_1} \frac{\partial d_1}{\partial R_E} - \frac{\partial Z}{\partial R_E} e^{-\mu} N(d_2) - Z e^{-\mu} \frac{\partial N(d_2)}{\partial d_2} \frac{\partial d_2}{\partial R_E} = 0 \tag{6}$$

where

$$\frac{\partial V}{\partial R_E} = (1+R_L)\frac{\partial L}{\partial R_E} > 0$$

$$\frac{\partial Z}{\partial R_E} = \frac{(R-R_D)Kq'}{q^2}\left(\frac{\partial L}{\partial R_E} + \frac{\partial L_E}{\partial R_E}\right) - [L_E(1-\frac{cL_E}{2}) + (1+R_E)(1-cL_E)\frac{\partial L_E}{\partial R_E} - (1+R)(\frac{\partial L}{\partial R_E} + \frac{\partial L_E}{\partial R_E})]$$

A problem in applying equation (5) is in calculating the cumulative normal distribution $N(\cdot)$. In equation (5), there is

$$\begin{aligned} d_2^2 &= d_1^2 + \sigma^2 - 2d_1\sigma \\ &= d_1^2 - 2(\ln\frac{V}{Z} + \mu) \end{aligned} \tag{7}$$

Following Hull (1993), we can use numerical procedures to evaluate $N(d_2)$. One such approximation is expressed as

$$N(d_2) = 1 - (a_1 k + a_2 k^2 + a_3 k^3)\frac{\partial N(d_2)}{\partial d_2} \tag{8}$$

where

$k = 1/(1+\alpha d_2)$

$\alpha = 0.33267$, $a_1 = 0.436183$,

$a_2 = -0.1201676$, $a_3 = 0.9372980$

$$\frac{\partial N(d_2)}{\partial d_2} = \frac{1}{\sqrt{2\pi}} e^{(-d_2^2/2)} > 0$$

In equation (6), we can rewrite the term $\partial N(d_2)/\partial d_2$ as follows.

$$\frac{\partial N(d_2)}{\partial d_2} = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(d_1^2 - 2(\ln\frac{V}{Z} + \mu))}$$
$$= \frac{\partial N(d_1)}{\partial d_1}\frac{V}{Z}e^{\mu} \tag{9}$$

Further,

$$V\frac{\partial N(d_1)}{\partial d_1}\frac{\partial d_1}{\partial R_E} - Ze^{-\mu}\frac{\partial N(d_2)}{\partial d_2}\frac{\partial d_2}{\partial R_E}$$
$$= (V\frac{\partial N(d_1)}{\partial d_1} - Ze^{-\mu}\frac{\partial N(d_1)}{\partial d_1}\frac{V}{Z}e^{\mu})\frac{\partial d_1}{\partial R_E} = 0 \tag{10}$$

where

$$\frac{\partial d_2}{\partial R_E} = \frac{\partial d_1}{\partial R_E} \neq 0$$

Imposing condition (10) on the first-order condition in equation (6), we have the following simplied form:

$$\frac{\partial S}{\partial R_E} = \frac{\partial V}{\partial R_E}N(d_1) - \frac{\partial Z}{\partial R_E}e^{-\mu}N(d_2) = 0 \tag{11}$$

where a sufficient condition for an optimum is $\partial^2 S/\partial R_E^2 < 0$.

In equilibrium condition (11), the first term on the right-hand side is the marginal risk-adjusted loan repayments of R_E, describing how changes in the outside manager's loan rate-setting affect the bank's risk-adjusted loan repayments. This term is positive in sign since L and L_E is gross substitutes. The second term is the marginal risk-adjusted net obligations of R_E, which is positive based on the equilibrium condition. In the decentralized loan rate-setting stage, the outside manager maximizes the market value of the bank's equity return anticipating resolution in the optimal R_E determination.

Consider next the impact on the outside manager's optimal loan rate from a change in the degree of capital market imperfection due to information asymmetry. Implicit differentiation of equation (11) with respect to c yields:

$$\frac{\partial R_E}{\partial c} = -\frac{\partial^2 S}{\partial R_E \partial c} / \frac{\partial^2 S}{\partial R_E^2} \tag{12}$$

where

$$\frac{\partial^2 S}{\partial R_E \partial c} = \frac{\partial^2 V}{\partial R_E \partial c}N(d_1) - \frac{\partial^2 Z}{\partial R_E \partial c}e^{-\mu}N(d_2)$$
$$+\frac{\partial V}{\partial R_E}(\frac{\partial N(d_1)}{\partial d_1} - \frac{N(d_1)}{N(d_2)}\frac{\partial N(d_2)}{\partial d_2})\frac{\partial d_1}{\partial c}$$

$$\frac{\partial^2 V}{\partial R_E \partial c} = 0$$

$$\frac{\partial^2 Z}{\partial R_E \partial c} = -\frac{2(R-R_D)K(q')^2}{q^3} \times$$

$$\frac{\partial L}{\partial c}\left(\frac{\partial L}{\partial R_E}+\frac{\partial L_E}{\partial R_E}\right)+\left[\frac{L_E^2}{2}+(1+R_E)L_E\frac{\partial L_E}{\partial R_E}\right]$$

$$< 0$$

$$\frac{\partial N(d_1)}{\partial d_1}-\frac{N(d_1)}{N(d_2)}\frac{\partial N(d_2)}{\partial d_2}$$
$$=\left(1-\frac{VN(d_1)}{Ze^{-\mu}N(d_2)}\right)\frac{\partial N(d_1)}{\partial d_1}<0$$

$$\frac{\partial d_1}{\partial c}=\frac{1}{\sigma c}\left(\frac{c}{V}\frac{\partial V}{\partial c}-\frac{c}{Z}\frac{\partial Z}{\partial c}\right)$$

The term, $\partial d_1/\partial c$, can be interpreted as the difference between the information asymmetry elasticity of loan repayments, $(c/V)(\partial V/\partial c)$, and that of net obligations, $(c/Z)(\partial Z/\partial c)$. The information asymmetry elasticity of loan repayments is unambiguously negative because an increase in the degree of capital market imperfection makes the bank's risky loans more costly to grant. The information asymmetry elasticity of net obligations is indeterminate in sign. However, our model provides us with a hunch that this difference should be negative since information asymmetry is a loan-repayment issue rather than a net-obligation one in our setting of the paper. Thus, we have $\partial d_1/\partial c<0$. In light of previous work, we establish the following proposition.

Proposition 1: An increase in the degree of capital market imperfection increases the outside manager's loan rate.

Intuitively, there is the potential for adverse selection in the capital market, perhaps because the outside manager, who is not willing to fully share information with the bank (the centralized decision maker), has gained some information as to the quality of the bank's earning-asset portfolio, and can use this information to exploit the centralized decision maker. When the outside manager has a higher degree of information asymmetry in the capital market, the outside manager provides a return to a less lending base by increasing loan rate R_E. If loan demand (L_E) is relatively rate-elastic, a less of the outside manager's lending repayment is possible at an increased loan rate R_E.

Applying Kashyap, Rahan, and Stein's argument (2002, p.42), we further argue that the higher the degree of information asymmetry, the more costly employing the outside manager is to the centralized decision maker. An implication of the above argument is that the prudent man law spells out the costs of the centralized decision maker delegating management costs. For example, the New York State Law on estate powers and trusts states that "The prudent investor standard authorizes a trustee to delegate investment and management functions if consistent with the duty to exercise skill, including special investment skills." In Proposition 1, the "special investment skills" can be recognized as the outside manager's loan determination, and the costs of "special investment skills" can be recognized as the centralized decision maker's delegating costs due to information asymmetry.

4 Centralized Loan-Rate Setting Stage

We realize that a decentralized loan rate (R_E) determination affects its centralized loan rate decision (R_L). Thus, in our model, to choose the optimal centralized loan rate, the centralized decision maker must take the decentralized loan rate determination into account. The selected centralized loan rate maximized the bank's equity return along its outside manager's loan-rate setting equilibrium condition in equation (11). Under a unique market equilibrium assumption, $R_E(R_L)$ completely characterizes the outside manager's loan-rate equilibrium as a function of the bank's loan rate. We can substitute $S(R_L, R_E, c)$ to obtain $S(R_L, R_E(R_L), c)$. Accordingly, the bank solves the following objective, $\underset{R_L}{Max}\ S(R_L, R_E(R_L), c)$, where S is defined in equation (5). With all of the assumptions in place, we are now ready to solve for the bank's optimal choice of R_L. Partial differentiating equation S with respect to R_L, the first-order condition is given by:

$$\frac{\partial S}{\partial R_L} = \frac{\partial V}{\partial R_L} N(d_1) + V \frac{\partial N(d_1)}{\partial d_1} \frac{\partial d_1}{\partial R_L} - \frac{\partial Z}{\partial R_L} e^{-\mu} N(d_2) - Z\mathrm{e}^{-\mu} \frac{\partial N(d_2)}{\partial d_2} \frac{\partial d_2}{\partial R_L} = 0 \tag{13}$$

where

$$\frac{\partial V}{\partial R_L} = L + (1+R_L)\alpha_L$$

$$\frac{\partial Z}{\partial R_L} = \frac{(R-R_D)Kq'(\alpha_L+\alpha_E)}{q^2} - [L_E(1-\frac{cL_E}{2})\frac{\partial R_E}{\partial R_L} + (1+R_E)(1-cL_E)\alpha_E - (1+R)(\alpha_L+\alpha_E)]$$

$$\alpha_L = \frac{\partial L}{\partial R_L} + \frac{\partial L}{\partial R_E}\frac{\partial R_E}{\partial R_L}$$

$$\alpha_E = \frac{\partial L_E}{\partial R_L} + \frac{\partial L_E}{\partial R_E}\frac{\partial R_E}{\partial R_L}$$

$$V\frac{\partial N(d_1)}{\partial d_1}\frac{\partial d_1}{\partial R_L} = Ze^{-\mu}\frac{\partial N(d_2)}{\partial d_2}\frac{\partial d_2}{\partial R_L}$$

$$\frac{\partial d_1}{\partial R_L} = \frac{\partial d_2}{\partial R_L}$$

A sufficient condition for an optimum is $\partial^2 S/\partial {R_L}^2 < 0$. The terms α_L and α_E represent how changes in centralized loan rate-setting affect the bank's loan amount and outside manager's loan amount, respectively. Both signs of α_L and α_E depend on a strategic assumption of the bank's centralized portfolio construction with decentralized portfolio management, $\partial R_E/\partial R_L$. We apply Bulow, Geanakoplos, and Klemperer (1985) and demonstrate that a crucial strategy in determining the nature of the interactive strategy is whether the bank regards both centralized and decentralized loans as strategic substitutes or strategic complements. In other words, will a more aggressive strategy by the outside manager in the marginal lending and money market investment elicit an aggressive response from the centralized loan rate- setting, or will an aggressive strategy more likely be met with accommodation? We discuss this in more detail below.

The term $\partial R_E/\partial R_L$ is equal to $-(\partial^2 S/\partial R_E \partial R_L)/(\partial^2 S/\partial R_E{}^2)$. The numerator represents the changes in the outside manager's marginal lending when the bank adjusts its loan rate-setting. If this numerator is negative (and thus $\partial R_E/\partial R_L < 0$), the bank regards both centralized and decentralized loans as strategic substitutes, accordingly, $\alpha_L < 0$ and $\alpha_E > 0$. Based on rather general assumptions, it is reasonable to believe that the impact on the bank's lending from a change in the centralized loan rate-setting (the own-rate effect) is more significant than the impact on the outside manager's lending from a change in the centralized loan rate-setting (the cross-rate effect), at least in the short run. Thus, the sign of $(\alpha_L + \alpha_E)$ is negative. But if the numerators $\partial^2 S/\partial R_E \partial R_L$ are positive (and thus $\partial R_E/\partial R_L > 0$), the bank regards both centralized and decentralized loans as strategic complements. α_L is still negative since the direct effect ($\partial L/\partial R_L$) is in general more significant than the indirect effect $((\partial L/\partial R_E)(\partial R_E/\partial R_L))$. α_E follows a similar argument as in the case of α_L. Accordingly, $(\alpha_L + \alpha_E)$ is also negative.

In equation (13), the term associated with $N(d_1)$ represents how changes in the bank's loan rate affect its lending repayment with decentralized portfolio management. This risk-adjusted present value for marginal lending repayments can be recognized as the interest rate elasticity of the bank's loan demand evaluated at the optimal R_L. This elasticity demonstrates that the bank operates on the elasticity portion of its loan demand curve $L(R_L, R_E(R_L), c)$, just as a monopolistic firm does. The value of the bank's loan repayments decrease when the bank increases its loan rate-setting under strategic substitutes. The term associated with $N(d_2)$ represents how changes in the bank's loan rate affect its net-obligation payment with decentralized portfolio management. The value of this term is also negative in sign because of the existence of the first-order condition of equation (13).

Condition (13) implies that the bank sets its optimal loan rate at the point where the marginal loan repayment of loan rate equals the marginal net-obligation payment. The result of the equilibrium condition demonstrates the importance on strategic effect that the centralized portfolio construction has on decentralized portfolio management. What is significant is that the optimal centralized portfolio depends not only on lending market power utilization but also on the strategic aspect of decentralized diversification management under information asymmetry.

We consider next the impact on the bank's optimal loan rate from changes in information asymmetry. Implicit differentiation of equation (13) with respect to c yields:

$$\frac{\partial R_L}{\partial c} = -\frac{\partial^2 S}{\partial R_L \partial c} / \frac{\partial^2 S}{\partial R_L^2} \qquad (14)$$

where

$$\frac{\partial^2 S}{\partial R_L \partial c} = \frac{\partial^2 V}{\partial R_L \partial c} N(d_1) - \frac{\partial^2 Z}{\partial R_L \partial c} e^{-\mu} N(d_2)$$

$$+ \frac{\partial V}{\partial R_L} \left(\frac{\partial N(d_1)}{\partial d_1} - \frac{N(d_1)}{N(d_2)} \frac{\partial N(d_2)}{\partial d_2} \right) \frac{\partial d_1}{\partial c}$$

In the term $\partial^2 S / \partial R_L \partial c$, the difference between the first term and the second term can be interpreted as the mean profit effect, while the third term can be interpreted as the variance or risk effect. The mean profit effect captures the difference changes in $\partial V / \partial R_L$ and $\partial Z / \partial R_L$ due to an increase in c. The sign of this mean profit effect is indeterminate. The variance effect demonstrates the changes in $N(d_1)$ and $N(d_2)$ due to an increase in c. The sign of this variance effect is negative since the three terms in this effect are all negative in sign.

When the mean profit effect is negative, the variance effect reinforces the mean profit effect. The total effect of an increase in c on the optimal bank interest rate is unambiguously negative. The negative total effect implies that the bank regards loan rate-setting and information asymmetry as strategic substitutes in Bulow, Geanakoplos, and Klemperer's (1985) sense.s But if the mean profit is positive, it is reasonable to believe that the negative variance is insufficient to offset the mean profit effect since c is modeled in the mean profit effect directly, but indirectly in the variance effect. Under the circumstances, the total effect of an increase in c on the optimal bank interest rate is positive. This positive total effect implies the bank regards loan rate-setting and information asymmetry as strategic complements.

The result of equation (14) is stated in the following proposition.

Proposition 2: An increase in the degree of capital market imperfection decreases (increases) the bank's optimal loan rate under strategic substitutes (strategic complements).

There is the potential for adverse selection in the capital market, perhaps because the outside manager has gained some information, but is not willing to share with the centralized decision maker. Accordingly, the outside manager can use this information to exploit the centralized decision maker. When the bank has a higher degree of capital market imperfection, it provides a return to a larger lending base due to be exploited by its outsider manager. One way the bank may attempt to increase its total returns is by increasing total loan repayments at a reduced loan rate under strategic substitutes.

5 Conclusions

This paper explores the optimal bank interest margin determination based on an option-based firm-theoretic model under the centralized loan portfolio construction with decentralized loan management. The model demonstrates how capital market imperfection and risk conditions jointly determine the optimal bank interest margin decision. We find that an increase in the bank's (the centralized decision maker's) degree of capital market imperfection increases the decentralized (the outsider manger's) loan rate and thus the bank's interest margin, increases its loan rate under strategic complements, and decreases its loan rate under strategic substitutes. One way the bank may attempt to augment its total equity returns is by employing a outside manage for diversified lending activities since there is information asymmetry in different loan markets. Insofar as such changes in optimal loan rates in our two-stage framework affect the bank's ability to sustain information asymmetry, these effects are relevant considerations in any centralized restructuring of the decentralized portfolio management.

One issue that has not been addressed in the optimal centralized loan portfolio construction when the decentralized managers are willing to provide all information to the centralized manager. Results to be derived from our model do not extend to the case when the assumption of perfect capital markets is made since a linear objective function would be appropriate (see Santomero (1984)). 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 centralized loan portfolio construction in affecting bank interest margin determination.

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