Bank Loan Portfolio Allocation under Asymmetric Information*

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ABSTRACT

In this paper, we present a theoretical model of bank loan portfolio allocation. We model the allocation of bank loans between economic sectors, taking several issues into account, such as uncertainty, relationship banking, industrial organization of the banking sector, bank and borrower characteristics, monitoring and switching costs. We examine two cases: For a risk-neutral bank, we obtain analytical solutions to the model, and for a risk-averse bank we derive the efficient frontier. The paper examines the sensitivities of the equilibrium solution with respect to the bank's primary cost and profitability factors.

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1. Introduction

A large body of literature has identified *asymmetric information* as the defining characteristic of credit markets. Banks that are considering offering funding to potential borrowers are faced with an information problem, to the extent that borrowers are usually more informed about their own firms than lenders. As a result, banks often wind up approving some loans that are ex-post unprofitable. These informational asymmetries lead to credit rationing equilibria (e.g., Stiglitz and Weiss 1981). In addition, they may invalidate other standard competitive market results (e.g., Broecker 1990) and affect the bank's loan and credit allocation. In this paper, we build an integrated theoretical model that describes the bank's loan allocation between different economic sectors. In this model, we attempt to integrate various aspects of the bank's loan allocation decision that have been discussed separately, but which have not been previously integrated into an equilibrium model. Our model discusses the following issues: uncertainty, relationship banking, industrial organization of the banking sector, bank and borrower characteristics, monitoring and switching costs.

Although in this paper our primary interest is a bank's loan allocation between economic sectors, it is useful to begin with a brief description of the theoretical and empirical literature on bank credit allocation between private and public sectors and bank credit allocation between large and small enterprisers. The importance of these issues is clear: Bank lending constitutes a major source of funding - both for individuals as well as for smaller businesses.[1] Large businesses make heavy use of bank borrowing, as a form of

[1] SME financing is of great importance in transition countries, as small firms play an important role in the restructuring process by absorbing employees that lose their jobs in privatized, restructured or bankrupt state-owned enterprises (Kowalski and Janc 1999). Moreover, Calvo and Coricelli (1993) and Pawlowska and Mullineux (1999) show that the sharp decline in bank credit to Polish SMEs at the beginning of the transition process has significantly contributed to the heavy decline in output in this country. Carlin and Richthofen

short-term financing. Thus, the allocation of bank credit can have important practical consequences for the economy, and is a significant determinant of economic growth (see e.g. Levine 2005, Aghion 2006 and Papaioannou 2007). King and Levine (1993) study a panel of 77 countries and find that the degrees to which intermediaries allocate credit to private sector vs. the government or public enterprisers affect growth in these countries. Moreover, determining how the allocation of credit responds to shocks to the banking system may help us to better understand the channels by which the credit view of monetary policy works, and determine the relative impact of such policies across different sectors of the economy.

Dehesa et al. (2007) opines that banks are more willing to extend credit to the private sector if: (a) it is easy to obtain collateral; (b) there is timely information on borrowers' economic conditions through some institution; and (c) there is an efficient exchange of information which helps banks in their credit assessment decisions. Thus, the availability of information and the ability to return the credit during periods of distress are crucial aspects that affect banks' credit allocation between private and public sectors.

The literature on private/public bank allocation decision focuses on four primary factors. First, aggregate cross-country studies establish that a better **legal environment,** such as more reliable law enforcement by courts, not only fosters a bigger credit market but also shifts the composition of lending towards private sector capital formation.[2] Second, a high **inflation** rate increases the variance of the risky asset, which leads to an increase in the fraction of a bank's portfolio invested in government denominated assets (Druck and Garibaldi, 2000). Third, an increase in **risk-based capital requirements** can cause a bank to shift from riskier private loans to less risky government bonds.[3] Fourth, when **macroeconomic uncertainty** increases, the share of risky loans to total assets decreases, since uncertainty hinders a bank's ability to foresee investment opportunities.[4]

Bank loan allocation between small business and big business has been discussed in both the empirical and theoretical literature. The bank's internal and external

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(1995) find that the rapid growth of the SME sector and the availability of sufficient external funding for these firms, has contributed to the integration of the former East and West Germany.

[2] See for example Haselmann and Wachtel (2006), La Porta et al. (1997, 1998), Berger and Udell (2006), Shvets (2005), Demirguc-Kunt and Maksimovic (1998), Pistor et al. (2000), Johnson et al. (1999), Chemin (2004), Johnson et al. (2002), and Fabbri and Padula (2001).

[3] See Thakor (1996), Passmore and Sharpe (1994), Furfine (2001), and Thampy (2004).

[4] See Baum et al. (2005), Quagliariello (2007) and references therein.

environments affect this allocation. First, banking acquisitions and mergers may affect bank loan allocation by lowering the loan share of small business banks in favor of transactional activities.[5] Second, large banks devote a lower proportion of their lending activity to small businesses than small banks.[6] Third, Goldberg and White (1998) found that the loan portfolios of new banks contain a substantially higher percentage of small business loans. Fourth, as regards relationship banking: Petersen and Rajan (1994, 1995) find that the availability of credit to small businesses increases as banking relationships lengthen, or as competition in credit markets decreases.

In the remainder of this introduction, we review the literature on factors influencing banks' allocation decisions.

Industrial organization

The market power of a financial institution is reflected in its charter value or growth option. The charter value derives from many sources, such as monopoly rents in issuing deposits, economies of scale, superior information in financial markets, reputation and regulatory constrains.[7] Banks that operates in different economic sectors may have a different market power in each economic sector. Panzar and Rosse (1987) present a reduced form approach using industry or bank-level data that discriminates between perfect competition, monopolistic competition, and monopolies. Claessens and Laeven's study (2004) - the most comprehensive application to Panzar and Rosse's (1987) research - was conducted in 50 countries and empirically shows that most banking markets are actually characterized by monopolistic competition.

The impact of bank market concentration on bank loan rates has been tested in many studies. For the most part, these studies show that employing US and international data and regressing bank loan rates on the HHI of market concentration has a positive impact.[8]

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[5] See Alessandrini et al. (2006), Berger et al. (1999), Alessandrini et al. (2003), Stein (2002), Peek and Rosengren (1995, 1997), and references therein.

[6] See Berger et al. (1999), Keeton (1995), Berger et al. (1995), Berger and Udell (1995), Peek and Rosengren (1996), Strahan and Wston (1996, 1998), and Cole et al. (1997).

[7] See Berger et al. (1995), Bourke (1989), Molyneux and Thornton (1992), Fama (1980, 1985), James (1987), Greenbaum et al. (1989), Rajan (1992), Dell'Ariccia and Marquez (2003), Dell'Ariccia et al. (1999), Berger et al. (2005), Petersen and Rajan (2002), and Salas and Saurina (2004).

[8] See references in Table 4 in Degryse et al. (2008).

On the other hand, less market power means more competition. Bank competition affects the efficiency of credit allocation. Moreover, bad loans are more likely, the larger the number of banks competing for customers (see Schnitzer 1998, Hellmann et al. 2000, Besanko and Thakor 1993, Broecker 1990 and Riordan 1993). Bergstresser (2004) finds evidence that increasing concentration has been associated with reductions in the flow of bank capital to construction and land development loans - the highest-risk category of commercial bank loans. Keeley (1990) examines the relationship between bank market power and risk-taking, and concludes that banks with reduced market power have an increased portfolio risk, and pay higher default premia on uninsured deposits. Gan (2004) examines the experience of savings and loans in Texas during that state's oil/banking/real estate crisis of the 1980s, and finds that exposure to competition increased risk-taking in this sample of financial institutions during this period.

A bank's size may also influence its customer profile. Larger banks may have a comparative advantage in lending to larger customers, as they can exploit scale economies in evaluating the hard information that tends to be available for such customers. Smaller banks, however, may not be able to lend to larger companies because of size limitations, i.e. they are more constrained by regulatory lending limits. Small banks may also have a comparative advantage in processing soft information on SMEs, and small businesses may only be served on the basis of direct contact and soft information. Alternatively, large banks mainly lend to distant, large firms employing predominantly hard information in the loan decision.[9]

Relationship banking

Boot (2000), in his summary paper on relationship banking, argues that banks develop close relationships with borrowers over time, as they gather information about the borrowers. There are two types of information: "hard" information (for example, accounting numbers, financial ratios, etc.) can be passed on easily within the organization,

[9] See Berg, S. and M. Kim (1998), Berger et al. (1998), Keeton (1995), Berger et al. (1995), Berger and Udell (1995), Peek and Rosengren (1996), Strahan and Weston (1996, 1998), Cole, Goldberg, and White (1997), Levonian (1996), Gilbert and Belongia (1988), Berger et al. (2005), Cole et al. (2004), Uchida et al. (2006), and Strahan (2007).

while "soft" information (for example, a character assessment, and the degree of trust) is much harder to rely on (Degryse et al. 2008).[10]

The proprietary information about borrowers that banks obtain as part of their relationships may give them an information monopoly (Greenbaum et al. 1989). This happens because the informational advantage of inside banks, compared to outside banks, may imply that firms face informational switching costs when they are willing to borrow from outside banks or other finance providers (Degryse et al. 2008). In this case, the bank extracts a higher profit or higher interest rate from captured and lock-in (opaque) borrowers than from those borrowers who have ready access to other financing alternatives (Ausubel 1991). Kim et al. (2005) point estimate of the switching cost, obtained from panel data for Norwegian bank loans, is 4.12%, suggesting that switching costs are substantial in this market.

Proximity between the bank and the borrower, as a result of relationship banking, has been shown to facilitate monitoring and screening and can overcome problems of asymmetric information (see Rajan and Winton 1995). Dell'Ariccia et al. (1999) and Dell'Ariccia (1998) argue that banks obtain information about prospective clients from previous lending arrangements, and are therefore better able to distinguish the good and bad risks among borrowers with whom they have established a relationship, than among borrowers who are new and unknown to them.

Most studies find that relationship borrowers have better access to credit.[11] A bank that has a strong relationship with a firm is more likely to extend credit to the firm in response to its financial deterioration, than a non-relationship lender (Peek and Rosengren 2004, Kobayashi et al. 2002).

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[10] There are several defining characteristics of bank relationships, as defined in Degryse et al. (2008): (a) *Duration* is the length of time the relationship between the customer and the bank has continued. (b) *Scope* is the number of lending and non-lending products that a bank cross-sells to a firm. (c) *Number* (or Concentration) is the number of bank relationships the firm maintains, and the resulting concentration of borrowing (and other products obtained) at the bank, as firms often borrow extensively from one relationship lender, borrowing smaller amounts from multiple arm's length lenders. (d) *Bank control* is another dimension of the bank-firm relationship; a bank can own equity in the firm or may also dispatch board members - the so-called "bankers on board."

[11] See the reference in Table 15, Panel C in Degryse et al. (2008).

Macroeconomic conditions

Bank lending is *procyclical*; banks expand their loan portfolio in a business cycle upturn and reduce it over a downturn.[12] Although causality is a subject for dispute, recessions are often preceded by a sharp spike in the percentage of banks reporting a tightening of lending standards.[13]

When forced to reduce lending, banks will reallocate their portfolio towards more opaque borrowers. This reallocation, which we call a *"flight to captivity"* may coexist with the *"flight to quality"*, where banks faced with increased market interest rates tend to reduce lending to lower quality borrowers.[14] Baum et al. (2004) find that when faced with financial constraints managers restrict overinvestment in low quality projects, and use the flexibility of internal capital markets to provide funding for more valuable investment projects.

Collateral and recovery rate

Collateral can be used as a screening device; entrepreneurs are screened according to the amounts of collateral that they provide and the investments that they undertake.[15] Vennet et al. (2004) argue that the value of collateral is likely to be procyclical; asymmetric information will be relatively high in business cycle downturns and relatively low in booms. This implies that bank intermediation becomes riskier during downturns through a reduction in the value of collateral attached to outstanding loans, and an increase in the degree of asymmetric information. Furthermore, markets for collateral goods are very illiquid, due to strong insider-control (Berglof 1995, and Belyanova and Rozinsky 1995). Moreover, Dermine and de Carvalho (2006), using data from BCP Bank in Portugal, empirically prove that recovery rate is positively correlated with collateral rate.

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[12] See, for example, Borio et al. (2001), Ayuso et al. (2004), Lown and Morgan (2002,2006), Lown et al. (2000), and Asea and Blomberg (1998).

[13] See Lown and Morgan (2002) and Asea and Blomberg (1998).

[14] A large body of literature has examined this phenomenon, see for example, Dell'Ariccia and Marquez (2000), Asea and Blomberg (1998), Lang and Nakamura (1995), Bernanke et al. (1998), and the references therein).

[15] The bank can also use *maturity* as a screening device; lenders limit their exposure by forcing riskier borrowers to take short-term loans (Gottesman and G. Robert 2004).

Portion of successful loans

We briefly survey various theories relating to problematic loans. The classic theory is the "moral hazard" hypothesis, which attributes excessive risk-taking behavior to a situation where another party bears part of the risk and cannot easily charge for or prevent this risk-taking. Moral hazard considerations feature in much of the bank loan literature.[16]

Other aspects of problem loans are discussed in the literature. Guttentag and Herring (1984), for example, argue that *disaster myopia* arises when it is impossible to assign a probability to a future event. Such an event might be the result of a change in the economic regime, a change in the regulatory framework or either a natural or man-made disaster. If managers cannot discount the effects of a future negative event, then they may be more prone to credit expansion and, when the event happens, drastically cut lending.

Under the "bad luck" hypothesis**,** external events (e.g., a local plant closing) may precipitate an increase in problem loans for the bank.[17] Alternatively, under the "bad management" hypothesis, low measured cost efficiency is a signal of poor senior management practices, which apply to both day-to-day operations and to loan portfolio management.[18]

Monitoring

The downside risk of borrowing firms translates into the riskiness of the loans held by financial institutions and banks. Thus, quality- delegated monitoring directly affects the endogenous quality of their loans and, in turn, their default risk. Incentives to monitor are affected by the downside risk of the firms to which it lends (Jensen and Meckling (1976), Myers (1977)). The monitoring may be more effective during economic booms. During a positive economic period, borrowers are more motivated to be transparent than during a bad period. The basic rationale is that when everything is going well, the bank should invest

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[16] For example, Stiglitz and Weiss (1981), Diamond (1984), Keeley (1990), Hoff and Stiglitz (1997), Hellmann et al. (2000), Matutes and Vives (2000), Allen and Gale (2003), Repullo (2004), Boyd and De Nicolò (2005), Martinez and Repullo (2007).

[17] See for example Berger and DeYoung (1997), Kaminsky and Reinhart (1999), Calomiris and Mason (2000), Gambera (2000), Pesola (2001), Daly et al. (2003), Nuxoll et al. (2003), Salas and Saurina (2002), Gambacorta and Mistrulli (2004), Quagliariello (2009).

[18] See for example Kwan and Eisenbeis (1994), Rajan (1994), Peristiani (1997), DeYoung (1998), Hellman et al. (2000), Berger and Udell (2004).

more effort to achieve the same degree of transparency during bad periods as it enjoys during good periods.

Hence, we see that banks often use collateral as a screening device. A bank that asks for less collateral should invest more in its monitoring efforts, in order to maintain loan quality. In our model, we will try to show that a trade-off exists between screening and monitoring.

Creditors' legal rights and risk-based capital requirements

Haselmann and Wachtel (2006) empirically find that differences in the legal environment are an important determinant of bank loan portfolios' composition. Better legal systems are associated with less lending to low-asymmetric information customers, such as large and government-owned enterprises. Similarly, when bankers have positive perceptions of the legal environment, there tends to be relatively more lending to information-opaque borrowers, such as SMEs and mortgage borrowers. Consequently, a better legal environment not only fosters a bigger credit market, as established in aggregate cross-country studies, but also shifts the composition of lending towards private sector capital formation.

Bank ownership

Empirical evidence suggests that "outside" lenders often face difficulties (or hesitate) in extending credit to mainly small local firms. The local nature of most small enterprises makes monitoring easier for locally-based institutions.[19] This happens, in particular, when existing relationships between incumbent banks and borrowers are strong (Bergstrom et al. 1994) or when local judicial enforcement of creditors' rights is poor (Fabbri and Padula 2004 and Bianco et al. 2005). A recent paper by Berger et al. (2004) reveals that higher shares of community banks in local bank markets are associated with more overall bank lending, faster GDP growth, and higher SME employment.

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[19] See Shaffer (1998), Berger et al. (2001), Harm (2001), Guiso et al. (2004), Berger and Udell (2002), DeYoung et al. (1999) and Berger et al. (2001).

Summary

In the remaining sections of this paper we construct a theoretical model of banking that integrates significant aspects of the literature discussed above. Section 2 discusses the theoretical model, Section 3 proves results for a risk-neutral bank, Section 4 simulates and calibrates the model, and Section 5 presents conclusions.

Table 1 summarizes the previous literature review.

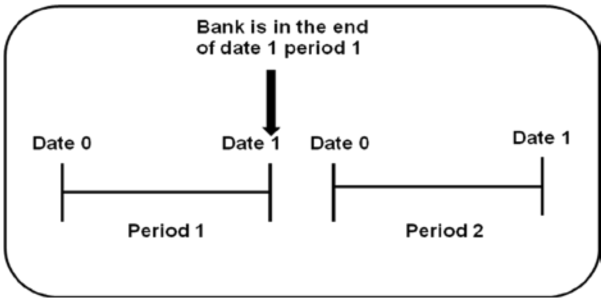
Table 1: Summary of literature		
Industrial Organization	IO.1	Banking markets are actually characterized by monopolistic competition.
	IO.2	The impact of bank market concentration on bank loan rates is positive.
	IO.3	Bad loans are more likely, the larger the number of banks competing for customers.
	IO.4	Large banks devote a lower proportion of their lending activity to small businesses than small banks.
Relationship banking	RB.1	Relationship banking facilitates monitoring and screening and increases the rate of successful loans.
	RB.2	Relationship banking gives banks an information monopoly.
	RB.3	Relationship borrowers have better access to credit.
Macroeconomic conditions	MC.1	Banks expand their loan portfolio in a business cycle upturn, and reduce it over a downturn.
Collateral and Recovery rate	CR.1	Collateral can be used as a screening device.
	CR.1.a	Increasing collateral increases the portion of successful loans.
	CR.1.b	Increasing collateral has a negative effect on the demand for loans.
	CR.2	Increasing collateral increases the recovery rate.
	CR.3	The value of collateral is likely to be pro-cyclical; this causes the recovery rate to also be pro-cyclical.
Portion of successful loans	PS.1	The portion of successful loans is pro-cyclical.
Monitoring	M.1	The quality of a bank's delegated monitoring directly affects the quality of its loans.
	M.2	Incentives to monitor are affected by the borrower's downside risk.
	M.3	There is a trade-off between screening and monitoring.
Creditors' legal rights	LR.1	Better legal systems are associated with more lending to SMEs and mortgage borrowers.
Bank ownership	BO.1	Outside lenders often face difficulties (or hesitate) in extending credit to mainly small local firms.

2. The theoretical model

In this section, we build an integrated theoretical model of a bank. The profit-maximizing bank in our model faces heterogeneous demand functions in each economic sector. The bank in our model has two decisions that must be made: loan allocation between economic sectors and how much should be invested in monitoring. Our bank is an incumbent and uses all the information gathered from its past activities and experience.

Our model is a two-date, two-period model. We assume that a profit-maximizing bank i can allocate loans between two sectors, and that the total bank loan portfolio is $\overline{L}_i$. $\{\alpha_{i1}, \alpha_{i2} -= 1-\alpha_{i1}\}$ is the proportion of bank i's loans to sectors 1 and 2. We assume all costs to be variable costs.[20]

In our model Bank is at the end of Date 1, Period 1



The existing loan portfolio allocation is denoted by $\alpha^p = \left\{\alpha_{i1}^P, \alpha_{i2}^P = 1-\alpha_{i1}^P\right\}$. A firm faces switching costs if it wants to switch from its current bank to another bank, while a bank faces switching costs if it wants to switch from its current loan sector allocation to another. We assume that there is a quadratic switching cost (*SC_i*) that the bank pays if it wants to switch from an existing allocation (α^p), to another allocation (α):

(2.1) $SC_i = 2sc_i \cdot \left(\left(\alpha_{i1} - \alpha_{i1}^p\right) \cdot \overline{L}_i\right)^2$

[20] In portfolio management, we traditionally distinguish between two methods of asset allocation. The *top-down* method consists of allocating capital to different asset classes, and then selecting the best securities within each asset class, while in the *bottom-up* approach, we directly select the best securities. The classical portfolio allocation approach is not feasible in bank loan allocation because the expected return and the variance in bank loan allocation are functions of the allocation. Second, modern portfolio theory is mainly about finding optimal risk/return trade-offs for (financial) assets. Unfortunately, loan portfolio adjustments cannot occur instantaneously, like in most other asset categories. Third, in most cases, the bank has accurate knowledge of its expected returns and risks. As for the correlation matrix, the problem is more complex: the bank does not have enough internal data and information to estimate it accurately. Still, the problem is more complicated for the correlation matrix of individual loans because some of these loans are not traded in the stock market, like the loans of small firms and private individuals.

Because there is inertia in the business cycle at the end of Period 1, the bank can forecast the probabilities of each sector's state; these probabilities are { p_1 , p_2 }, where p_j is the probability of being in a good state (G) in sector j, and $1\text{-}p_j$ of being in a bad state (B) in sector j. Writing ϕ for the joint probabilities of state occurrences, we write $\phi_{G,G}+\phi_{G,B}+\phi_{B,G}+\phi_{B,B}=1$; for example, $\phi_{G,B}$ is the joint probability of sector 1 being in state G and sector 2 being in state B. This means that the probability of good and bad states per sector is:

(2.2) $$\left\{p_1=\phi_{G,G}+\phi_{G,B},1-p_1=\phi_{B,B}+\phi_{B,G}\right\},\left\{p_2=\phi_{G,G}+\phi_{B,G};1-p_2=\phi_{B,B}+\phi_{G,B}\right\}$$

At the end of Period 1, the bank can approximate the relationship banking, RB_{ij}, in each sector, as well as forecast the portion of successful loans, PSL_{ij} , and the recovery rate, λ_{ij}, for a given collateral rate, CR_{ij} , and sector state {G,B} in each sector.[21]

At Date 0 of Period 2, bank i decides on the proportions {α_{i1} , α_{i2} -= 1-α_{i1} } of its total loan portfolio allocated to sectors 1 and 2. Given the total loan portfolio $\overline{L}_i$, this means that loans given to sectors 1 and 2 can be denoted by $\left\{\alpha_{i1}\overline{L}_i,\alpha_{i2}\overline{L}_i\right\}$. For simplicity's sake, the bank is assumed to be perfectly diversified within any sector to which it lends. We assume that the bank is a price taker in the input market, and we also assume that the loan portfolio $\overline{L}_i$ is financed by bank deposits at an interest rate *d*, so that the bank repays $(1+d)\cdot\overline{L}_i$ at Date 1.

2.1 The demand function

Banking markets are characterized by monopolistic competition.[22] To build the interest rate function, we assume imperfect competition and that bank i behaves strategically versus other banks.

In addition to inter-bank competition, the literature discusses six factors that affect the demand function for loans from bank i in sector j. First, firms belong to industries with different degrees of external financial dependence. This negatively affects sensitivity and

[21]We classify *a loan in default* when a formal restructuring process or bankruptcy procedure has started. We define *recovery rate* as the value of the loan one month after default.
[22] See Table 1 – Conclusion IO.1

positively affects the scope of the demand.[23] Second, the ratio between the size of the firms in sector j and the size of bank i affects the demand in this sector.[24] Third, the market power of bank i in sector j negatively affects sensitivity and positively affects the scope of the demand for bank i in this sector; market power itself will be positively affected by the firm-bank relationship in this sector.[25] Fourth, collateral rate as a screening instrument decreases the scope of the demand for bank i loans in sector j.[26] Fifth, a bad legal system will have a negative effect on the scope of the demand for bank i loans if the average size of the firms in this sector is small.[27] Sixth, engaging in foreign bank ownership will have a negative effect on the scope of the demand for bank i loans if the average size of the firms in this sector is small.[28]

We assume imperfect competition in each sector, so that bank i's interest rate for sector j, r_{ij} , is a function of the total loans given by all banks to sector j:

(2.3) $$r_{ij} = f_j\left[\sum_{i=1}^{N} L_{ij}\right] = f_j\left[L_j\right]$$

We assume that f_j depends on CR_{ij} ,the average collateral rate that bank i pledges in sector j, MP_{ij} the market power of bank i in sector j, BD_j bank financial dependence in sector j, FBS_{ij} is a dummy variable which equals 1 if the firm's average size in sector j and bank i's size are big or the firm's average size in sector j and bank i's size are small; otherwise, it equals 0. $LSFS_{ij}$ is a dummy variable which equals 0 if the legal system is bad and the firm's average size in sector j is small; otherwise, it equals 1. $BOFZ_{ij}$ is a dummy variable which equals 0 if the bank owners are foreign and the firm's average size in sector j is small; otherwise, it equals 1.

We assume that:

[23] Giannetti and Ongena (2008) measure bank dependence in a given sector by the ratio of short-term loans and long-term debt to total liabilities.
[24] See Table 1 – Conclusion IO.4
[25] See Table 1 – Conclusion IO.2
[26] See Table 1 – Conclusion CR.1.b
[27] See Table 1 – Conclusion LR.1
[28] See Table 1 – Conclusion BO.1

$$r_{ij} = \beta_{ij} - \omega_{ij} \cdot \alpha_{ij} \cdot \overline{L}_i - \omega_{ij} \cdot \sum_{k \neq i}^{N} L_{kj} \left[\alpha_{ij} \cdot \overline{L}_i \right]$$

$$r_{ij} = \beta_{ij} - \omega_{ij} \cdot \left(\alpha_{ij} \cdot \overline{L}_i + \sum_{k \neq i}^{N} L_{k1} \left[\alpha_{ij} \cdot \overline{L}_i \right] \right)$$

$$= \beta_{ij} - \omega_{ij} \cdot \left(\alpha_{ij} \cdot \overline{L}_i + \mu_{ij} \cdot \alpha_{ij} \cdot \overline{L}_i \right)$$

(2.4) $$= \beta_{ij} - \omega_{ij} \cdot \alpha_{ij} \cdot \overline{L}_i \cdot \left(1 + \mu_{ij} \right)$$

$$where: 0 \leq \mu_{ij} \leq 1$$

$$\beta_{ij} \left[\overset{-}{CR}_{ij}, \overset{+}{MP}_{ij}, \overset{+}{BD}_j, \overset{+}{FBS}_{ij}, \overset{+}{LSFS}_{ij}, \overset{+}{BOFZ}_{ij} \right]$$

$$\omega_{ij} \left[\overset{-}{MP}_{ij}, \overset{-}{BD}_j, \overset{-}{FBS}_{ij} \right]$$

The model assumes that β_{ij} is a constant and it is negatively affected by CR_{ij} and positively affected by MP_{ij}, BD_{ij}, FBS_{ij}, $LSFS_{ij}$, $BOFZ_{ij}$. ω_{ij} is the demand sensitivity for bank i loans in sector *j*; we assume that it depends negatively on MP_{ij}, BD_{ij}, FBS_{ij}. μ_{ij} measures the reactions of bank i's rivals. A high μ_{ij} means aggressive competition, whereas $\mu_{ij} = 0$ indicates a monopoly bank. We assume that $r_{ij} > 0$ for $0 < \alpha_{ij} \leq 1$. This means that $\beta_{ij} > \omega_{ij} \cdot \left(1 + \mu_{ij} \right) \left(\overline{L}_i \right)$.

2.2 Loan monitoring

Our model distinguishes between three types of loan outcomes: *Successful loans* are repaid in full with interest; the rate of successful loans in bank i sector j at state s is $PSL_{ij}(s)$. The principal of *non-performing loans* is repaid, but not the interest on these loans, and *insolvent loans* are repaid (if at all) at less than their principal. The recovery rate in bank i sector j at state s is $\lambda_{ij}(s)$. The division between insolvent and non-performing loans can be affected by the bank's investment in monitoring (see Figure 2.1 below).[29]

[29] See Table 1 – Conclusion M.1

Bank Loan Distribution Chart

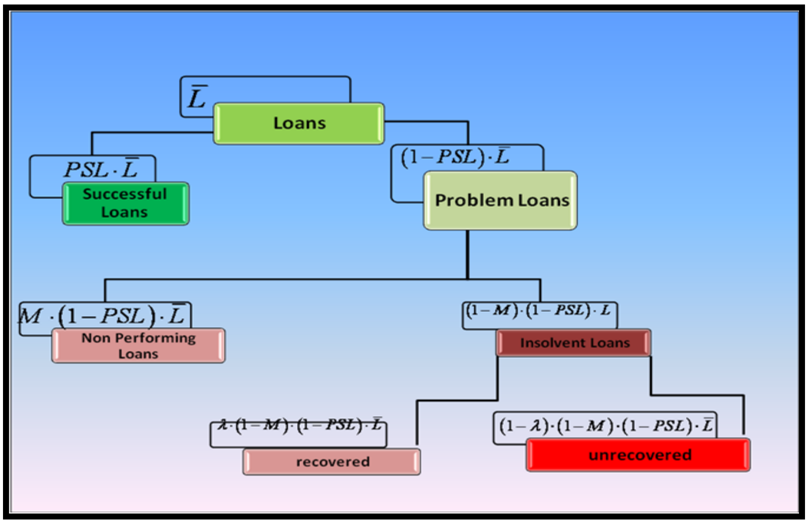


Figure 2.1: In State 1, loans are either successful or problematic, the problematic loans are either non-performing or insolvent, and some of the insolvent loans are recovered, while others are unrecovered.

The bank has the opportunity to monitor the loans at a cost of mis_{ij} per unit loaned to sector j; the overall monitoring cost in sector j will be $mis^*_{i1}(s)\cdot\alpha_{i1}\cdot\overline{L}_i$. The effectiveness of this monitoring is denoted by em_{ij} which is an index move between 1 and 10, where 10 indicates a very high level of effectiveness. Monitoring must begin after loans are made (at Date 1); this means that the state of the sector is known. Monitoring lets the bank spot troubled borrowers before their situations become hopeless, allowing the bank to increase its average recovery rate by invoking protective agreements, renegotiating maturing loans, forcing foreclosures, and so forth.

The effectiveness of monitoring depends on the macroeconomic conditions in sector j (s_j, which is either G or B) and on the relationship banking *(RB_{ij})* in this sector.[30] In good states, monitoring is more effective because the asymmetric information is less severe. We denote the rate of the problematic loans that become non-performing by M_{ij}:

(2.5) $$M_{ij} = em_{ij}\left(\overset{+}{RB}_{ij}, \overset{+}{s}_j\right)\cdot\left(mis_{ij}\right)^{1/2}$$

[30] See Table 1 – Conclusions M.2 and RB.1

The sum of non-performing loans is $M_{ij}\left(s_j\right)\cdot\left(1-PSL_{ij}\left(s\right)\right)\cdot\alpha_j\cdot\overline{L}$. We assume that M_{ij} is an increasing and concave function of the per-loan cost of monitoring mis_{ij}. The variable mis_{ij} is one of the bank's choice variables in our model.

2.3 Building the profit function

In this section, we construct the bank's expected profit function. For the sake of convenience, we list our notation below:

$PSL_{ij}\left(s_j\right)$	Portion of successful loans
$PSL_{ij}\left(s_j\right)\cdot\alpha_1\cdot\overline{L}$	Sum of successful loans
$\left(1-PSL_{ij}\left(s_j\right)\right)\cdot\alpha_j\cdot\overline{L}$	Sum of problematic loans
$M_{ij}\left(s_j\right)\cdot\left(1-PSL_{ij}\left(s\right)\right)\cdot\alpha_j\cdot\overline{L}$	Sum of non-performing
$\left(1-M_{ij}\left(s_j\right)\right)\cdot\left(1-PSL_{ij}\left(s\right)\right)\cdot\alpha_j\cdot\overline{L}$	Sum of insolvent loans
$\lambda_{ij}\left(s_j\right)$	Recovery rate
$\left(\lambda_{ij}\left(s\right)\right)\left(1-M_{ij}^*\right)\cdot\left(1-PSL_{ij}\left(s\right)\right)\cdot\alpha_j\cdot\overline{L}$	The sum gotten back from default loans
$\left(1-\lambda_{ij}\left(s\right)\right)\left(1-M_{ij}^*\right)\cdot\left(1-PSL_{ij}\left(s\right)\right)\cdot\alpha_j\cdot\overline{L}$	The sum lost from default loans
* j=sector, s= sector state (good or bad) , i=bank * Portion of successful loans and recovery rates are pro-cyclical[31]	

Bank i maximizes its expected profits $\pi_i^e=\sum_{s\in\{G,B\}}\sum_{s\in\{G,B\}}\phi_{s,t}\cdot\pi_i\left(s,t\right)$, where $\phi_{s,t}$ is the probability of the joint probabilities of state occurrences, and π(s,t) is the bank's net profits from its loan portfolio in state s in sector 1 and state t in sector 2:

[31] See Table 1 – Conclusions PS.1 and CR.3

$$\begin{aligned}\pi_i(s,t) = &\underbrace{r_{i1}\cdot PSL_{i1}(s)\cdot\alpha_{i1}\cdot\overline{L}_i}_{\text{Sector 1 successful loan revenue}} + \underbrace{r_{i2}\cdot PSL_{i2}(s)\cdot(1-\alpha_{i1})\cdot\overline{L}_i}_{\text{Sector 2 successful loan revenue}}\\
&\underbrace{-\left(1-\lambda_{i1}(s)\right)\left(1-M_{i1}^{*}(s)\right)\cdot\left(1-PSL_{i1}(s)\right)\cdot\alpha_{i1}\cdot\overline{L}_i}_{\text{Loss on sector 1 insolvent loans}}\\
&\underbrace{-\left(1-\lambda_{i2}(t)\right)\left(1-M_{i2}^{*}(t)\right)\cdot\left(1-PSL_{i2}(t)\right)\cdot\left(1-\alpha_{i2}\right)\cdot\overline{L}_i}_{\text{Loss on sector 2 insolvent loans}}\\
&-\underbrace{mis_{i1}^{*}(s)\cdot\alpha_{i1}\cdot\overline{L}_i}_{\text{Investment in sector 1 loan monitoring}}-\underbrace{mis_{i2}^{*}(t)\cdot(1-\alpha_{i1})\cdot\overline{L}_i}_{\text{Investment in sector 2 loan monitoring}}-\underbrace{d\cdot\overline{L}_i}_{\text{Cost of deposits}}-\underbrace{2sc_i\cdot\left(\left(\alpha_{i1}-\alpha_{i1}^{p}\right)\cdot\overline{L}_i\right)^2}_{\text{Switching cost of changing the loan portfolio composition}}\end{aligned}$$

And as we prove in Appendix A, Section A.2, Equation A.2.8, the expected profit will be:

$$\begin{aligned}\pi_i^{e}(\alpha_{i1}) = {}& AVPSL_{i1}\cdot r_{i1}\cdot\alpha_{i1}\cdot\overline{L}_i - AVLOS_{i1}\cdot\alpha_{i1}\cdot\overline{L}_i - AVMCOST_{i1}\cdot\alpha_{i1}\cdot\overline{L}_i\\
&+AVPSL_{i2}\cdot r_{i2}\cdot(1-\alpha_{i1})\cdot\overline{L}_i - AVLOS_{i2}\cdot(1-\alpha_{i1})\cdot\overline{L}_i - AVMCOST_{i2}\cdot(1-\alpha_{i1})\cdot\overline{L}_i\\
&-d\cdot\overline{L}_i-2sc_i\cdot\left(\left(\alpha_{i1}-\alpha_{i1}^{p}\right)\cdot\overline{L}_i\right)^2\end{aligned}$$

Where:

$AVPSL_{ij}$	average portion of successful loans	$AVPSL_{ij}=p_j\cdot PSL_{ij}(G)+\left(1-p_j\right)\cdot PSL_{ij}(B)$
$AVLOS_{ij}$	average loss from loans	$AVLOS_{ij}=p_j\cdot\left[\left(1-PSL_{ij}(G)\right)\cdot\left(1-M_{ij}^{*}(G)\right)\cdot\left(1-\lambda_{ij}(G)\right)\right]+\left(1-p_j\right)\cdot\left[\left(1-PSL_{ij}(B)\right)\cdot\left(1-M_{ij}^{*}(B)\right)\cdot\left(1-\lambda_{ij}(B)\right)\right]$
$AVMCOST_{ij}$	average investment in monitoring	$AVMCOST_{ij}=p_j\cdot mis_{ij}(G)+\left(1-p_j\right)\cdot mis_{ij}(B)$
* j=sector, i=bank		

3. The equilibrium for a risk-neutral bank

In this section, we assume that the bank is risk-neutral, so that its utility is an increasing function of its expected profits. At Date 1 in Period 2 the bank chose the optimal investment in monitoring, thus maximizing bank profits at sector j in state *s*. As we prove in Appendix A, Section A.1 the optimal investment in monitoring in sector j in state *s* will be:

$$mis_{ij}^{*}(s)=\left(0.5\cdot em_{ij}(s)\cdot\left(1-PSL_{ij}(s)\right)\cdot\left(1-\lambda_{ij}(s)\right)\right)^{2}$$

and

$$\frac{\partial\pi_i(s,t)}{\partial^2 mis_{ij}}<0$$

At Date 0, in Period 2 the bank will see $mis_{ij}^{*}(s)$ and choose the optimal allocation, thus maximizing the expected profits. As we prove in Appendix A, Section A.3 the optimal allocation will be:

$$\alpha_{i1}^{*}=\frac{\begin{bmatrix}AVPSL_{i1}\cdot(\beta_{i1})-AVLOS_{i1}-AVMCOST_{i1}+2AVPSL_{i2}\cdot\omega_{i2}\cdot(1+\mu_{i2})\cdot\bar{L}_i\\-AVPSL_{i2}\beta_{i2}+AVLOS_{i2}+AVMCOST_{i2}+4sc_i\cdot\alpha_{i1}^{p}\cdot\bar{L}_i\end{bmatrix}}{\left[2AVPSL_{i1}\cdot\left(\omega_{i1}\cdot(1+\mu_{i1})\right)+2AVPSL_{i2}\cdot\left(\omega_{i2}\cdot(1+\mu_{i2})\right)+4sc_i\right]\left(\bar{L}_i\right)}$$

and

$$\frac{\partial\pi_i^{e}(\alpha_{i1})}{\partial^2\alpha_{i1}}<0$$

Where:

Additional notation: All of the variables defined below are positive. Throughout, j denotes the loan sector, while i denotes the bank.	
$mis_{ij}^{*}(s)$	Optimal monitoring investment
$em_{ij}(s)$	Effectiveness of monitoring
$PSL_{ij}(s)$	Portion of successful loans
$\lambda_{ij}(s)$	Recovery rate
α_{i1}^{*}	Optimal allocation
p_j	Probability of a good state
$AVPSL_{ij}$	Average rate of successful loans
$AVLOS_{ij}$	Average loss from loans
$AVMCOST_{ij}$	Average monitoring investment
$\bar{L}_i$	Number of loans given to the two sectors
r_{ij}	Interest rate
β_{ij}	The constant in the interest rate function

w_{ij}	Demand sensitivity
μ_{ij}	Bank's expectations about the reactions of its rivals
MP_{ij}	Market power
RB_{ij}	Relationship banking
BD_j	Bank's finance dependence
FBS_{ij}	Firm's bank size ratio
$LSFS_{ij}$	Dummy variable which equals 0 if the legal system is bad and the firm's average size in sector j is small; otherwise, it equals 1.
$BOFZ_{ij}$	Dummy variable which equals 0 if the bank owners are foreign and the firm's average size in sector j is small; otherwise, it equals 1.
sc_i	Coefficient in the switching cost function
α_{i1}^{p}	Allocation of bank's loan portfolio to sector j in the previous period

Proposition 1: The optimal investment in monitoring at Date 1 in bank i in sector j in state s, $mis_{ij}^{*}(s)$, is a convex, increasing function of the effectiveness of monitoring in bank i in sector j, $em_{ij}(s)$. $mis_{ij}^{*}(s)$ is a convex decreasing function of the rate of successful loans and the recovery rate, $PSL_{ij}(s)$ and $\lambda_{ij}(s)$.[32]

Proof: In Appendix A, Equations A.1.3 – A.1.8, we prove that:

$$\left\{\frac{\partial mis_{ij}^{*}(s)}{\partial em_{ij}(s)}>0;\frac{\partial mis_{ij}^{*}(s)}{\partial^{2} em_{ij}(s)}>0\right\};\left\{\frac{\partial mis_{ij}^{*}(s)}{\partial PSL_{ij}(s)}<0,\frac{\partial mis_{ij}^{*}(s)}{\partial^{2} PSL_{ij}(s)}<0\right\};\left\{\frac{\partial mis_{ij}^{*}(s)}{\partial \lambda_{ij}(s)}<0,\frac{\partial mis_{ij}^{*}(s)}{\partial^{2} \lambda_{ij}(s)}<0\right\}$$

Proposition 2: If a portion of successful loans, $PSL_{ij}(s)$ and recovery rate $\lambda_{ij}(s)$, are increasing functions of the collateral rate CR_{ij}[33], together with the results of Proposition 1, then the monitoring investment will be a decreasing function of CR_{ij}. **A tradeoff exists between screening and monitoring.**[34]

Proposition 3: α^{*}_{i1} is a concave function of $AVPSL_{i1}$ with a unique internal maximum. α^{*}_{i1} is a convex function of $AVPSL_{i2}$ with a unique internal minimum.

Proof: From Appendix B, Equations B.1.1 – B.1.4

[32] See Table 1 – Conclusion M.2
[33] See Table 1 – Conclusions CR.1.a and CR.2
[34] See Table 1 – Conclusion M.3

$$\frac{\partial \alpha_{i1}^*}{\partial AVPSL_{i1}} = \frac{2r_{i1}^* - \beta_{i1}}{(Den)}; \frac{\partial \alpha_{i1}^*}{\partial^2 AVPSL_{i1}} = \frac{-\left[2r_{i1}^* - \beta_{i1}\right] \cdot 4\left(\omega_{i1} \cdot (1+\mu_{i1})\right) \cdot \bar{L}}{(Den)^2}$$

$$\frac{\partial \alpha_{i1}^*}{\partial AVPSL_{i2}} = \frac{\beta_{i2} - 2r_{i2}^*}{(Den)}; \frac{\partial \alpha_{i1}^*}{\partial^2 AVPSL_{i2}} = \frac{-2\left(2\left(\omega_{i2} \cdot (1+\mu_{i2})\right) \cdot \bar{L}_i\right)\left[\beta_{i2} - 2r_{i2}^*\right]}{(Den)^2}$$

r_{i1}^* is a decreasing function of α^*_{i1} and r_{i2}^* is an increasing function of α^*_{i1}, for a low value of α^*_{i1} $\frac{\partial \alpha_{i1}^*}{\partial AVPSL_{i1}} > 0; \frac{\partial \alpha_{i1}^*}{\partial^2 AVPSL_{i1}} < 0; \frac{\partial \alpha_{i1}^*}{\partial AVPSL_{i2}} < 0; \frac{\partial \alpha_{i1}^*}{\partial^2 AVPSL_{i2}} > 0$

And for a high value of α^*_{i1} $\frac{\partial \alpha_{i1}^*}{\partial AVPSL_{i1}} < 0; \frac{\partial \alpha_{i1}^*}{\partial^2 AVPSL_{i1}} > 0; \frac{\partial \alpha_{i1}^*}{\partial AVPSL_{i2}} > 0; \frac{\partial \alpha_{i1}^*}{\partial^2 AVPSL_{i2}} < 0$

Proposition 4: α^*_{i1} is a linear, decreasing function of $AVLOS_{i1}$ and $AVMCOST_{i1}$ and is a linear, increasing function of $AVLOS_{i2}$ and $AVMCOST_{i2}$

Proof: In Appendix B, Equations B.2.1 - B.2.4 and B.3.1 - B.3.4, we prove that:

$$\left\{\frac{\partial \alpha_{i1}^*}{\partial AVLOS_{i1}} < 0, \frac{\partial \alpha_{i1}^*}{\partial^2 AVLOS_{i1}} = 0\right\}; \left\{\frac{\partial \alpha_{i1}^*}{\partial AVLOS_{i2}} > 0, \frac{\partial \alpha_{i1}^*}{\partial AVLOS_{i2}} = 0\right\}$$

$$\left\{\frac{\partial \alpha_{i1}^*}{\partial AVMCOST_{i1}} < 0, \frac{\partial \alpha_{i1}^*}{\partial AVMCOST_{i1}} = 0\right\}; \left\{\frac{\partial \alpha_{i1}^*}{\partial AVMCOST_{i2}} > 0, \frac{\partial \alpha_{i1}^*}{\partial AVMCOST_{i2}} = 0\right\}$$

Proposition 5: α^*_{i1} is an increasing function of r_{i1} and a decreasing function of r_{i2}.

Proof: In Appendix B, Equation B.7.2, we prove that: $\left\{\frac{\partial \alpha_{i1}^*}{\partial r_{i1}} > 0, \frac{\partial \alpha_{i1}^*}{\partial r_{i2}} < 0\right\}$.

Proposition 6: α^*_{i1} is a linear, increasing function of α_{i1}^p.

Proof: In Appendix B, Equations B.9.1 and B.9.2, we prove that: $\left\{\frac{\partial \alpha_{i1}^*}{\partial \alpha_{i1}^p} > 0, \frac{\partial \alpha_{i1}^*}{\partial^2 \alpha_{i1}^p} = 0\right\}$

Proposition 7: α^*_{i1} is a convex, decreasing function of switching cost sc_i if $\alpha_{i1}^p < \alpha_{i1}^*$, and a concave, increasing function of sc_i if $\alpha_{i1}^p > \alpha_{i1}^*$.

Proof: See proof in Appendix B, Equations B.8.1 and B.8.2.

Proposition 8: α_{i1}^* is an increasing function of $PSL_{i1}(s)$, $\lambda_{i1}(s)$, $em_{i1}(s)$ and p_1.[35] α_{i1}^* is a decreasing function of $PSL_{i2}(s)$, $\lambda_{i2}(s)$, $em_{i2}(s)$ and p_2.

---

[35] See Table 1 – Conclusion MC.1

Proof: In Section 4, we show by simulation that:

$$\left\{\frac{\partial\alpha_{i1}^*}{\partial PSL_{i1}(s)}>0,\frac{\partial\alpha_{i1}^*}{\partial PSL_{i2}(s)}<0\right\};\left\{\frac{\partial\alpha_{i1}^*}{\partial\lambda_{i1}(s)}>0,\frac{\partial\alpha_{i1}^*}{\partial\lambda_{i2}(s)}<0\right\};$$
$$\left\{\frac{\partial\alpha_{i1}^*}{\partial em_{i1}(s)}>0\ ,\frac{\partial\alpha_{i1}^*}{\partial em_{i2}(s)}<0\right\};\left\{\frac{\partial\alpha_{i1}^*}{\partial p_1}>0;\frac{\partial\alpha_{i1}^*}{\partial p_2}<0\ \right\}$$

Proposition 9: α_{i1}^* is an increasing function of MP_{i1}, RB_{i1}[36], BD_1, FBS_{i1}, $BOFZ_{i1}$ and a decreasing function of MP_{i2} , RB_{i2} , BD_2 , FBS_{i2} and $BOFZ_{i1}$.

Proof: In Appendix B, Equations B.10.1 to B.15.1, we prove that:

$$\left\{\frac{\partial\alpha_{i1}^*}{\partial MP_{i1}}>0,\frac{\partial\alpha_{i1}^*}{\partial MP_{i2}}<0\right\};\left\{\frac{\partial\alpha_{i1}^*}{\partial RB_{i1}}>0,\frac{\partial\alpha_{i1}^*}{\partial RB_{i2}}<0\right\}$$
$$;\left\{\frac{\partial\alpha_{i1}^*}{\partial BD_1}>0,\frac{\partial\alpha_{i1}^*}{\partial BD_2}<0\right\};\left\{\frac{\partial\alpha_{i1}^*}{\partial FBS_{i1}}>0,\frac{\partial\alpha_{i1}^*}{\partial FBS_{i2}}<0\right\}$$
$$\left\{\frac{\partial\alpha_{i1}^*}{\partial LSFS_1}>0,\frac{\partial\alpha_{i1}^*}{\partial LSFS_2}<0\right\};\left\{\frac{\partial\alpha_{i1}^*}{\partial BOFZ_{i1}}>0,\frac{\partial\alpha_{i1}^*}{\partial BOFZ_{i2}}<0\right\}$$

Proposition 10: α^*_{i1} is a concave function of CR_{i1} with a unique internal maximum. α^*_{i1} is a convex function of CR_{i2} with a unique internal minimum.

Proof: See proof in Appendix B, Equations B.16.1 and B.16.2

[36] See Table 1 – Conclusion RB.3

4. Simulation

In this section, we simulate the optimal allocation, α_{i1}^{*}, as a function of four parameters $\left\{PSL_{ij}\left(B\right),\lambda_{ij}\left(B\right),em_{ij}\left(B\right),p_{j}\right\}$.[37] We build the efficient frontier for bank i's expected return and standard deviation. We choose these parameters because the sign of the derivation of α_{i1}^{*} on these parameters is unclear, and we prefer the simulation to making more and more vague and unrealistic assumptions. In order to do this, we assume that the sectors are equal, which means that all the parameters in the two sectors are the same and equal to:

(4.1)

$$\left\{\varphi_{G,G}=0.55,\ \varphi_{G,B}=\varphi_{B,G}=0.15,\varphi_{B,B}=0.15,\ p_{j}=0.7,1-p_{j}=0.3\right\}$$
$$\left\{d=0.02,\ \overline{L}_{i}=0.25,sc_{i}=0.01,\alpha_{i1}^{p}=0.5\right\};\left\{PSL_{ij}\left(G\right)=0.95,\ PSL_{ij}\left(B\right)=0.85\right\}$$
$$\left\{\beta_{ij}=0.3,\ \omega_{ij}=0.2,\ \mu_{ij}=0.5\right\};\left\{\lambda_{ij}\left(G\right)=0.85,\ \lambda_{ij}\left(B\right)=0.75\right\};\left\{em_{ij}\left(G\right)=7,\ em_{ij}\left(B\right)=5\right\}$$

Where:

$\varphi_{s,t}$	The joint probability of being in state s in sector 1 and in state t in sector 2
p_{j}	The probability of a good state
d	Interest rate paid for depositors
$\overline{L}_{i}$	The number of loans given to the two sectors
sc_{i}	The coefficient in the switching cost function
α_{i1}^{p}	T Allocation of the bank's loan portfolio to sector 1 in the previous period
$PSL_{ij}\left(s\right)$	Portion of successful loans
β_{ij}	The constant in the interest rate function
ω_{ij}	Demand sensitivity
μ_{ij}	The bank's expectations about its rivals' reactions
$\lambda_{ij}\left(s\right)$	Recovery rate
$em_{ij}\left(s\right)$	Effectiveness of monitoring
* j=sector, s= sector state (good or bad) , i=bank	

[37] We choose $\left\{PSL_{ij}\left(B\right),\lambda_{ij}\left(B\right),em_{ij}\left(B\right)\right\}$, rather than $\left\{PSL_{ij}\left(G\right),\lambda_{ij}\left(G\right),em_{ij}\left(G\right)\right\}$ because they give the same result.

4.1 Simulation of $\{PSL_{ij}(B), \lambda_{ij}(B), em_{ij}(B), p_j\}$

In this subsection, we show a variety of numerical simulations of our model.

Figure 4.1 shows the portion of successful loans in bank i in sectors 1 and 2 in a bad state.

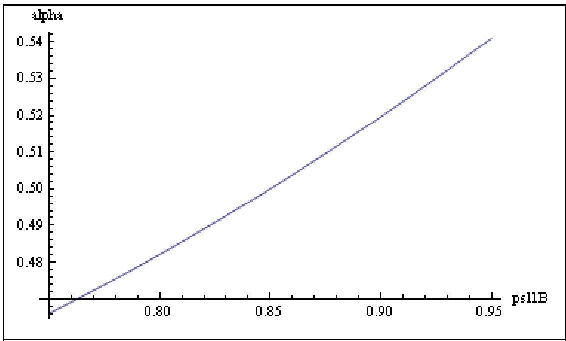


Figure 4.1.A: The vertical and horizontal axes are the optimal allocation (α_{i1}^{*}) and the portion of successful loans in a bad state in sector 1 $PSL_{i1}(B)$, respectively. The range of $PSL_{i1}(B)$ is [0.75,0.95].

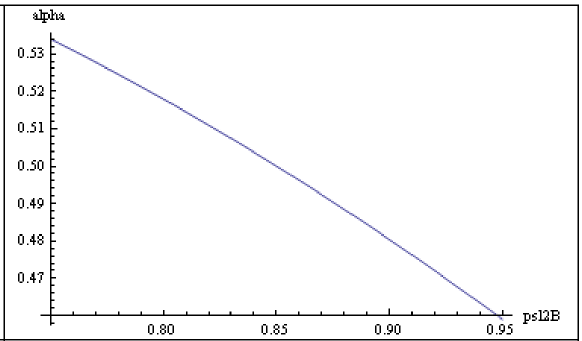


Figure 4.1.B: The vertical and horizontal axes are the optimal allocation (α_{i1}^{*}) and the portion of successful loans in sector 2 in a bad state $PSL_{i2}(B)$, respectively. The range of $PSL_{i2}(B)$ is [0.75,0.95].

Figure 4.2 shows the recovery rate of bad loans in bank i in sector 1 in bad states:

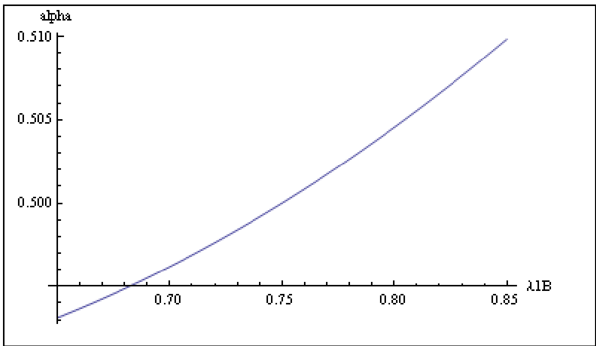


Figure 4.2.A: The vertical and horizontal axes are the optimal allocation (α_{i1}^{*}) and the recovery rate in sector 1 $\lambda_{i1}(B)$, respectively. The range of $\lambda_{i1}(B)$ is [0.65,0.85].

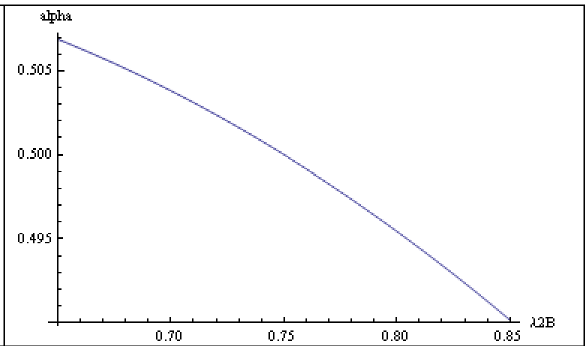


Figure 4.2.B: The vertical and horizontal axes are the optimal allocation (α_{i1}^{*}) and the recovery rate in sector 2 $\lambda_{i2}(B)$, respectively. The range of $\lambda_{i2}(B)$ is [0.65,0.85].

Figure 4.3 shows the effectiveness of monitoring in bank i in sector 1 in bad states:

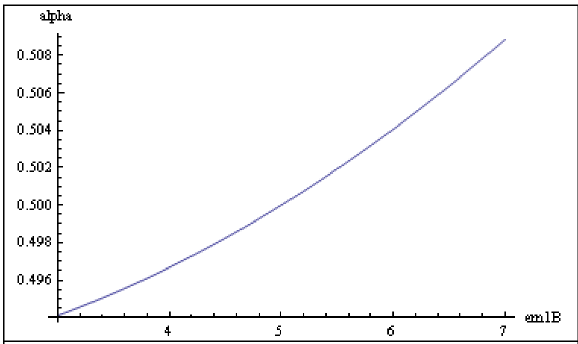


Figure 4.3.A: The vertical and horizontal axes are the optimal allocation $\left(\alpha_{i1}^{*}\right)$ and the effectiveness of monitoring in sector 1 $em_{i1}\left(B\right)$, respectively. The range of $em_{i1}\left(B\right)$ is [3,7].

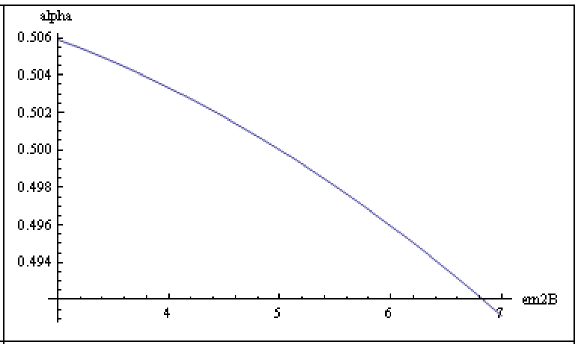


Figure 4.3.B: The vertical and horizontal axes are the optimal allocation $\left(\alpha_{i1}^{*}\right)$ and the effectiveness of monitoring in sector 2 $em_{i2}\left(B\right)$, respectively. The range of $em_{i2}\left(B\right)$ is [3,7].

Figure 4.4 shows the probability of a good state in sectors 1 and 2:

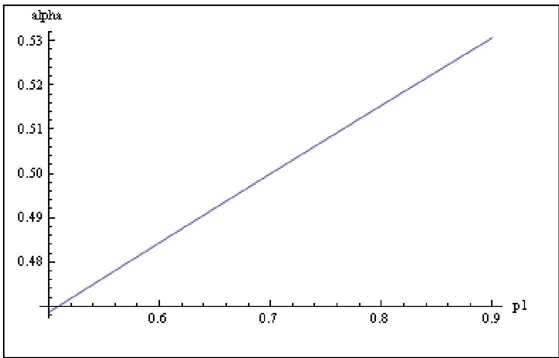


Figure 4.4.A: The vertical and horizontal axes are the optimal allocation $\left(\alpha_{i1}^{*}\right)$ and the probability of a good state in sector 1 p_1, respectively. The range of p_1 is [0.5,0.9].

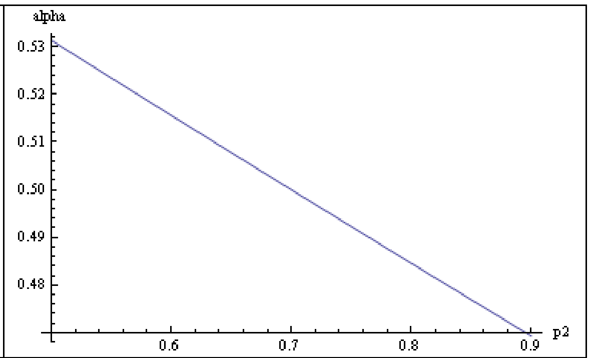


Figure 4.4.B: The vertical and horizontal axes are the optimal allocation $\left(\alpha_{i1}^{*}\right)$ and the probability of a good state in sector 2 p_1, respectively. The range of p_2 is [0.5,0.9].

From the simulations, we conclude that:

$$\left\{\frac{\partial\alpha_{i1}^{*}}{\partial PSL_{i1}\left(s\right)}>0,\frac{\partial\alpha_{i1}^{*}}{\partial PSL_{i2}\left(s\right)}<0\right\};\left\{\frac{\partial\alpha_{i1}^{*}}{\partial\lambda_{i1}\left(s\right)}>0,\frac{\partial\alpha_{i1}^{*}}{\partial\lambda_{i2}\left(s\right)}<0\right\};$$

$$\left\{\frac{\partial\alpha_{i1}^{*}}{\partial em_{i1}\left(s\right)}>0\ ,\frac{\partial\alpha_{i1}^{*}}{\partial em_{i2}\left(s\right)}<0\right\};\left\{\frac{\partial\alpha_{i1}^{*}}{\partial p_1}>0;\frac{\partial\alpha_{i1}^{*}}{\partial p_2}<0\ \right\}$$

We were not able to prove these results analytically.

4.2 Mean/variance – functional form

In this section, we assume that the bank maximizes a concave utility function of its expected return and profit standard deviation: $U = U\left(\frac{\overset{+}{\pi_i^e}}{\bar{L}_i}; \frac{\overset{-}{\sigma_i^2\left(\pi_i^e\right)}}{\bar{L}_i}\right)$, where:

$$\pi_i^e = \sum_{s\in\{G,B\}} \sum_{s\in\{G,B\}} \phi_{s,t} \cdot \pi_i(s,t); \qquad \sigma_i\left(\pi_i^e\right) = \sqrt{\sum_{s\in\{G,B\}} \sum_{s\in\{G,B\}} \phi_{s,t} \cdot \left(\pi_i^2(s,t) - \left(\pi_i^e\right)\right)^2}$$

Equal sectors

Our first simulation assumes that the sector parameters are equal. We then vary bank i's loan allocation to sectors 1 and 2 $\{\alpha_{i1}, \alpha_{i2} = 1-\alpha_{i1}\}$. The remaining parameters are given below:

$$\{\varphi_{G,G} = 0.55,\ \varphi_{G,B} = \varphi_{B,G} = 0.15, \varphi_{B,B} = 0.15,\ p_j = 0.7, 1-p_j = 0.3\}$$
$$\{d = 0.02,\ \bar{L}_i = 0.25, tc_i = 0.01, \alpha_{i1}^p = 0.5\}; \{PSL_{ij}(G) = 0.95,\ PSL_{ij}(B) = 0.85\}$$
$$\{\beta_{ij} = 0.3,\ \omega_{ij} = 0.2,\ \mu_{ij} = 0.5\}; \{\lambda_{ij}(G) = 0.85,\ \lambda_{ij}(B) = 0.75\}; \{em_{ij}(G) = 7,\ em_{ij}(B) = 5\}$$

As shown in Figure 4.5 below, there is a positive correlation between the expected returns and the standard deviation of the returns. The bank maximizes its profits when $\alpha_{i1} = 0.5$ (point A), and gets the same profit when it fully focuses on either sector 1 or sector 2 (point B). A risk-averse bank will choose to be at point C.

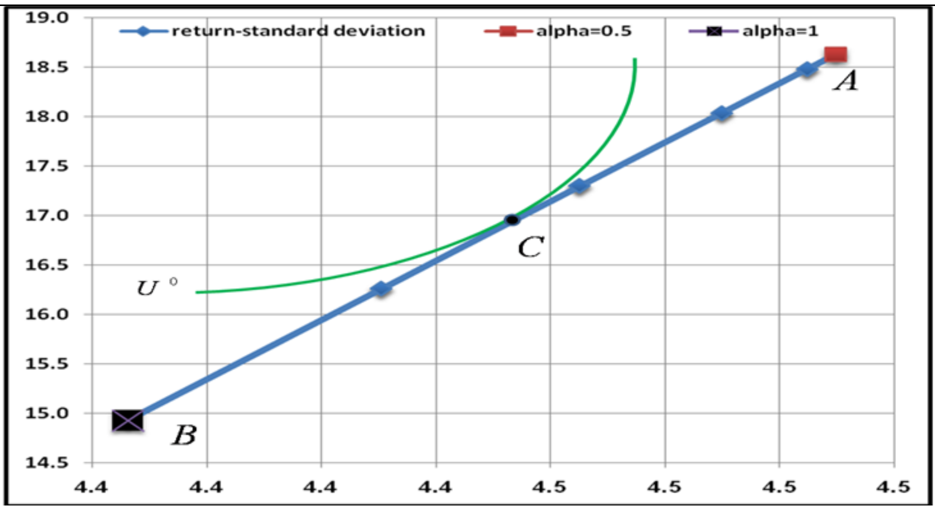


Figure 4.5: The vertical and horizontal axes are the expected profit and the standard deviation, respectively. U^0 is the utility of bank i. At point B α_{i1}=0,1 and at point A α_{i1}=0.5, point C is the meeting point between the utility function of the risk-averse bank and the efficient frontier.

High probability of successful loans in bank i in sector 1

In the simulation of this sub-sector, we vary α but assume that the following parameters have different values. Varying other parameters in our base case gives similar qualitative results.

$$\{PSL_{i1}(G)=0.95>PSL_{i2}(G)=0.9\};\{PSL_{i1}(B)=0.85>PSL_{i2}(B)=0.8\}$$

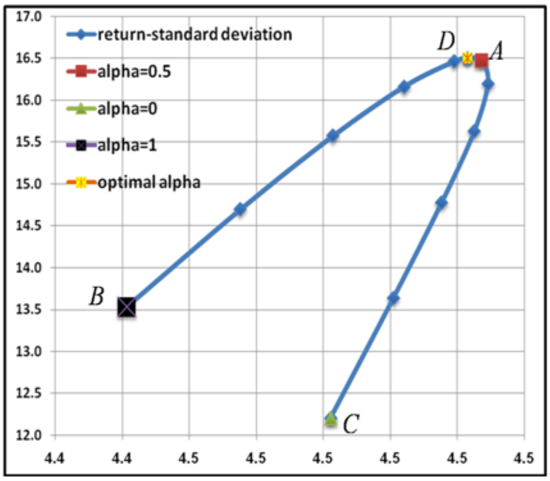


Figure 4.6.A: The vertical and horizontal axes are the expected return and the standard deviation, respectively. At point B and C α_{i1}=0,1 , respectively while at point A α_{i1}=0.5. Point D is the maximum profit when α^*_{i1}=0.56.

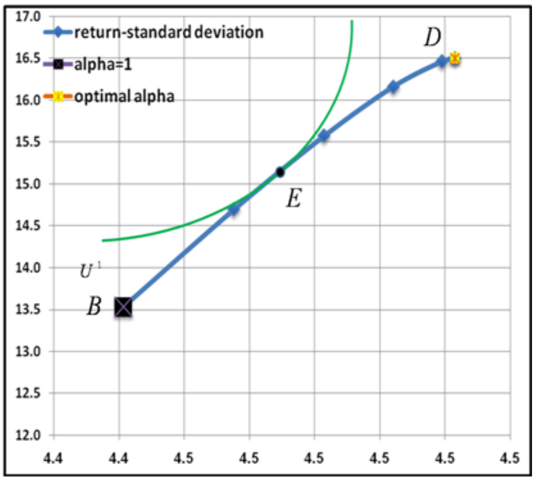


Figure 4.6.B: The vertical and horizontal axes are the expected return and the standard deviation, respectively. U^1 is the utility of bank i. At point B α_{i1}=1, while point D is the maximum profit when α^*_{i1}=0.56. Point E is the meeting point between the utility function of the risk-averse bank and the efficient frontier.

A profit-maximizing bank will choose point D in Figure 4.6, whereas a utility-maximizing bank will choose point E.

5. Conclusion

In this paper, we build a theoretical model of bank loan portfolio allocation. The model takes into account uncertainty, relationship banking, imperfect competition, monitoring, and transition costs. We show results both for risk-neutral bank that maximizes expected profits and also for a risk-averse banks maximizing a concave utility function of the mean and standard deviation of profits. For a risk-neutral bank, we obtain analytical solutions to the model, while for a risk-averse bank we derive the efficient frontier. The paper examines the sensitivities of the equilibrium solution with respect to the bank's primary cost and profitability factors.

Within the framework of our model, we are able to derive a large number of analytical results with respect to monitoring, the tradeoff between screening and monitoring, and the form of the bank allocation decision between sectors. Simulations of the model yield interesting results about parameter values.

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Appendix A

A.1 Optimal monitoring investment

In section 2, we show that the bank's net profits from its loan portfolio in state s in sector 1 and in state t in sector 2 at Date 1 in Period 2 , π_i(s,t) will be:

$$\pi_i(s,t) = r_{i1} \cdot PSL_{i1}(s) \cdot \alpha_{i1} \cdot \overline{L}_i + r_{i2} \cdot PSL_{i2}(s) \cdot (1-\alpha_{i1}) \cdot \overline{L}_i$$
$$-(1-\lambda_{i1}(s))(1-M^*_{i1}(s)) \cdot (1-PSL_{i1}(s)) \cdot \alpha_{i1} \cdot \overline{L}_i$$
$$-(1-\lambda_{i2}(t))(1-M^*_{i2}(t)) \cdot (1-PSL_{i2}(t)) \cdot (1-\alpha_{i2}) \cdot \overline{L}_i$$
$$-mis^*_{i1}(s) \cdot \alpha_{i1} \cdot \overline{L}_i - mis^*_{i2}(t) \cdot (1-\alpha_{i1}) \cdot \overline{L}_i - d \cdot \overline{L}_i - 2sc_i \cdot \left((\alpha_{i1} - \alpha^p_{i1}) \cdot \overline{L}_i\right)^2$$

We derive π_i(s,t) on $mis_{ij}(s)$ and get:

$$\frac{\partial \pi_i(s,t)}{\partial mis_{ij}(s)} = (1-\lambda_{ij}(s))\left(\frac{\partial M_{ij}(s)}{\partial mis_{ij}(s)}\right) \cdot (1-PSL_{ij}(s)) \cdot \alpha_{ij} \cdot \overline{L}_i - \alpha_{ij} \cdot \overline{L}_i$$

Now we find $mis_{ij}(s)$ which maximizes π_i(s,t) :

$$\frac{\partial \pi_i(s,t)}{\partial mis_{ij}(s)} = 0$$

$$(1-\lambda_{ij}(s))\left(\frac{\partial M_{ij}(s)}{\partial mis_{ij}(s)}\right) \cdot (1-PSL_{ij}(s)) \cdot \alpha_{ij} \cdot \overline{L}_i = \alpha_{ij} \cdot \overline{L}_i$$

$$(1-\lambda_{ij}(s))\left(\frac{\partial M_{ij}(s)}{\partial mis_{ij}(s)}\right) \cdot (1-PSL_{ij}(s)) = 1$$

$$(1-\lambda_{ij}(s))\left(em_{ij}(s) \cdot 0.5 \cdot (mis_{ij}(s))^{-\frac{1}{2}}\right) \cdot (1-PSL_{ij}(s)) = 1$$

$$(mis^*_{ij}(s))^{-\frac{1}{2}} = \frac{1}{em_{ij}(s) \cdot 0.5 \cdot (1-PSL_{ij}(s)) \cdot (1-\lambda_{ij}(s))}$$

The optimal investment in monitoring in sector j in state s will be:

$$(A.1.1) \qquad mis^*_{ij}(s) = 0.5 \cdot \left(em_{ij}(s) \cdot (1-PSL_{ij}(s)) \cdot (1-\lambda_{ij}(s))\right)^2$$

And the second derivation of $\pi_i(s,t)$ on $mis_{ij}(s)$ will be:

$$(A.1.2) \qquad \frac{\partial \pi_i(s,t)}{\partial^2 mis_{ij}} = -\left[(1-\lambda_{ij}(s))\left(em_{ij}(s) \cdot 0.25 \cdot (mis_{ij}(s))^{-1\frac{1}{2}}\right) \cdot (1-PSL_{ij}(s)) \cdot \alpha_{ij} \cdot \overline{L}_i\right] < 0$$

In A.1.3 - A.1.8 we find the first and second derivation of $mis_{ij}(s)$ on $em_{ij}(s)$, $PSL_{ij}(s)$ and $\lambda_{ij}(s)$.

$$(A.1.3) \qquad \frac{\partial mis_{ij}^{*}(s)}{\partial em_{ij}(s)} = \Big(\big(1-PSL_{ij}(s)\big)\cdot\big(1-\lambda_{ij}(s)\big)\Big)^{2}\cdot em_{ij}(s) > 0$$

$$(A.1.4) \qquad \frac{\partial mis_{ij}^{*}(s)}{\partial^{2} em_{ij}(s)} = \Big(\big(1-PSL_{ij}(s)\big)\cdot\big(1-\lambda_{ij}(s)\big)\Big)^{2} > 0$$

$$(A.1.5) \qquad \frac{\partial mis_{ij}^{*}(s)}{\partial PSL_{ij}(s)} = -\Big(em_{ij}(s)\cdot\big(1-\lambda_{ij}(s)\big)\Big)^{2}\cdot PSL_{ij}(s) < 0$$

$$(A.1.6) \qquad \frac{\partial mis_{ij}^{*}(s)}{\partial^{2} PSL_{ij}(s)} = -\Big(em_{ij}(s)\cdot\big(1-\lambda_{ij}(s)\big)\Big)^{2} < 0$$

$$(A.1.7) \qquad \frac{\partial mis_{ij}^{*}(s)}{\partial \lambda_{ij}(s)} = -\Big(em_{ij}(s)\cdot\big(1-PSL_{ij}(s)\big)\Big)^{2}\cdot \lambda_{ij}(s) < 0$$

$$(A.1.8) \qquad \frac{\partial mis_{ij}^{*}(s)}{\partial^{2} \lambda_{ij}(s)} = -\Big(em_{ij}(s)\cdot\big(1-PSL_{ij}(s)\big)\Big)^{2} < 0$$

A.2 The expected profit

In section 3, we show that the bank's net profits from its loan portfolio in state s in sector 1 and in state t in sector 2 at Date 1 in Period 2 , π_t(s,t) will be:

$$(A.2.1) \qquad \pi_i(s,t) = \begin{pmatrix} r_{i1}\cdot PSL_{i1}(s)\cdot\alpha_{i1}\cdot\overline{L}_i + r_{i2}\cdot PSL_{i2}(t)\cdot(1-\alpha_{i1})\cdot\overline{L}_i \\ -\big(1-\lambda_{i1}(s)\big)\big(1-M_{i1}^{*}(s)\big)\cdot\big(1-PSL_{i1}(s)\big)\cdot\alpha_{i1}\cdot\overline{L}_i \\ -\big(1-\lambda_{i2}(t)\big)\big(1-M_{i2}^{*}(t)\big)\cdot\big(1-PSL_{i2}(t)\big)\cdot(1-\alpha_{i2})\cdot\overline{L}_i \\ -mis_{i1}^{*}(s)\cdot\alpha_{i1}\cdot\overline{L}_i - mis_{i2}^{*}(t)\cdot(1-\alpha_{i1})\cdot\overline{L}_i \\ -d\cdot\overline{L}_i - 2sc_i\cdot\Big(\big(\alpha_{i1}-\alpha_{i1}^{p}\big)\cdot\overline{L}_i\Big)^{2} \end{pmatrix}$$

We substitute A.2.1 in $\pi_i^e = \sum_{s\in\{G,B\}}\sum_{s\in\{G,B\}} \phi_{s,t}\cdot\pi_i(s,t)$ and get:

$$\begin{aligned} \pi_i^e = {} & \big(\phi_{G,G}+\phi_{G,B}\big) r_{i1}\cdot PSL_{i1}(G)\cdot\alpha_{i1}\cdot\overline{L}_i + \big(\phi_{B,G}+\phi_{B,B}\big) r_{i1}\cdot PSL_{i1}(B)\cdot\alpha_{i1}\cdot\overline{L}_i \\ & -\big(\phi_{G,G}+\phi_{G,B}\big)\big(1-\lambda_{i1}(G)\big)\big(1-M_{i1}^{*}(G)\big)\cdot\big(1-PSL_{i1}(G)\big)\cdot\alpha_{i1}\cdot\overline{L}_i \\ & -\big(\phi_{B,G}+\phi_{B,B}\big)\big(1-\lambda_{i1}(B)\big)\big(1-M_{i1}^{*}(B)\big)\cdot\big(1-PSL_{i1}(B)\big)\cdot\alpha_{i1}\cdot\overline{L}_i \\ & -\big(\phi_{G,G}+\phi_{G,B}\big)\cdot mis_{i1}^{*}(G)\cdot\alpha_{i1}\cdot\overline{L}_i - \big(\phi_{B,G}+\phi_{B,B}\big)\cdot mis_{i1}^{*}(B)\cdot\alpha_{i1}\cdot\overline{L}_i \\ (A.2.2) \qquad & +\big(\phi_{G,G}+\phi_{B,G}\big) r_{i2}\cdot PSL_{i2}(G)\cdot(1-\alpha_{i1})\cdot\overline{L}_i + \big(\phi_{G,B}+\phi_{B,B}\big) r_{i2}\cdot PSL_{i2}(B)\cdot(1-\alpha_{i1})\cdot\overline{L}_i \end{aligned}$$

$$-\left(\phi_{G,G}+\phi_{B,G}\right)\cdot\left(1-\lambda_{i2}\left(G\right)\right)\left(1-M_{i2}^{*}\left(G\right)\right)\cdot\left(1-PSL_{i2}\left(G\right)\right)\cdot\left(1-\alpha_{i2}\right)\cdot\overline{L}_i$$
$$-\left(\phi_{G,B}+\phi_{B,B}\right)\cdot\left(1-\lambda_{i2}\left(B\right)\right)\left(1-M_{i2}^{*}\left(B\right)\right)\cdot\left(1-PSL_{i2}\left(B\right)\right)\cdot\left(1-\alpha_{i2}\right)\cdot\overline{L}_i$$
$$-\left(\phi_{G,G}+\phi_{B,G}\right)mis_{i2}^{*}\left(G\right)\cdot\left(1-\alpha_{i1}\right)\cdot\overline{L}_i-\left(\phi_{G,B}+\phi_{B,B}\right)mis_{i2}^{*}\left(G\right)\cdot\left(1-\alpha_{i1}\right)\cdot\overline{L}_i$$
$$-d\cdot\overline{L}_i-2sc_i\cdot\left(\left(\alpha_{i1}-\alpha_{i1}^{p}\right)\cdot\overline{L}_i\right)^2$$

We know from section 2, equation 2.2 that:

$$p_1=\phi_{G,G}+\phi_{G,B};\ 1-p_1=\phi_{B,B}+\phi_{B,G};\ p_2=\phi_{G,G}+\phi_{B,G};\ 1-p_2=\phi_{B,B}+\phi_{G,B}$$

We substitute this in equation A.2.2 and get:

$$\begin{aligned}\pi_i^e=\ & p_1\cdot r_{i1}\cdot PSL_{i1}\left(G\right)\cdot\alpha_{i1}\cdot\overline{L}_i+\left(1-p_1\right)\cdot r_{i1}\cdot PSL_{i1}\left(B\right)\cdot\alpha_{i1}\cdot\overline{L}_i\\
&-p_1\left(1-\lambda_{i1}\left(G\right)\right)\left(1-M_{i1}^{*}\left(G\right)\right)\cdot\left(1-PSL_{i1}\left(G\right)\right)\cdot\alpha_{i1}\cdot\overline{L}_i\\
&-\left(1-p_1\right)\left(1-\lambda_{i1}\left(B\right)\right)\left(1-M_{i1}^{*}\left(B\right)\right)\cdot\left(1-PSL_{i1}\left(B\right)\right)\cdot\alpha_{i1}\cdot\overline{L}_i\\
&-p_1\cdot mis_{i1}^{*}\left(G\right)\cdot\alpha_{i1}\cdot\overline{L}_i-\left(1-p_1\right)\cdot mis_{i1}^{*}\left(B\right)\cdot\alpha_{i1}\cdot\overline{L}_i\\
&+p_2\cdot r_{i2}\cdot PSL_{i2}\left(G\right)\cdot\left(1-\alpha_{i1}\right)\cdot\overline{L}_i+\left(1-p_2\right)r_{i2}\cdot PSL_{i2}\left(B\right)\cdot\left(1-\alpha_{i1}\right)\cdot\overline{L}_i\\
&-p_2\cdot\left(1-\lambda_{i2}\left(G\right)\right)\left(1-M_{i2}^{*}\left(G\right)\right)\cdot\left(1-PSL_{i2}\left(G\right)\right)\cdot\left(1-\alpha_{i2}\right)\cdot\overline{L}_i\\
&-\left(1-p_2\right)\cdot\left(1-\lambda_{i2}\left(B\right)\right)\left(1-M_{i2}^{*}\left(B\right)\right)\cdot\left(1-PSL_{i2}\left(B\right)\right)\cdot\left(1-\alpha_{i2}\right)\cdot\overline{L}_i\\
&-p_2\cdot mis_{i2}^{*}\left(G\right)\cdot\left(1-\alpha_{i1}\right)\cdot\overline{L}_i-\left(1-p_2\right)\cdot mis_{i2}^{*}\left(G\right)\cdot\left(1-\alpha_{i1}\right)\cdot\overline{L}_i\\
&-d\cdot\overline{L}_i-2sc_i\cdot\left(\left(\alpha_{i1}-\alpha_{i1}^{p}\right)\cdot\overline{L}_i\right)^2\end{aligned}\tag{A.2.3}$$

We now rearrange A.2.3 in another way and get:

$$\begin{aligned}\pi_i^e\left(\alpha_{i1}\right)=&\left[p_1\cdot PSL_{i1}\left(G\right)+\left(1-p_1\right)\cdot PSL_{i1}\left(B\right)\right]\cdot r_{i1}\cdot\alpha_{i1}\cdot\overline{L}_i+\\
&-\begin{bmatrix}p_1\cdot\left(1-PSL_{i1}\left(G\right)\right)\cdot\left(1-M_{i1}^{*}\left(G\right)\right)\cdot\left(1-\lambda_{i1}\left(G\right)\right)\\+\left(1-p_1\right)\cdot\left(1-PSL_{i1}\left(B\right)\right)\cdot\left(1-M_{i1}^{*}\left(B\right)\right)\cdot\left(1-\lambda_{i1}\left(B\right)\right)\end{bmatrix}\cdot\alpha_{i1}\cdot\overline{L}_i\\
&-\left[p_1\cdot mis_{i1}^{*}\left(G\right)+\left(1-p_1\right)\cdot mis_{i1}^{*}\left(B\right)\right]\cdot\alpha_{i1}\cdot\overline{L}_i\\
&+\left[p_2\cdot PSL_{i2}\left(G\right)+\left(1-p_2\right)\cdot PSL_{i2}\left(B\right)\right]\cdot r_{i2}\cdot\left(1-\alpha_{i1}\right)\cdot\overline{L}_i+\\
&-\begin{bmatrix}p_2\cdot\left(1-PSL_{i2}\left(G\right)\right)\cdot\left(1-M_{i2}^{*}\left(G\right)\right)\cdot\left(1-\lambda_{i2}\left(G\right)\right)\\+\left(1-p_2\right)\cdot\left(1-PSL_{i2}\left(B\right)\right)\cdot\left(1-M_{i2}^{*}\left(B\right)\right)\cdot\left(1-\lambda_{i2}\left(B\right)\right)\end{bmatrix}\cdot\left(1-\alpha_{i1}\right)\cdot\overline{L}_i\\
&-\left[p_2\cdot mis_{i2}^{*}\left(G\right)+\left(1-p_2\right)\cdot mis_{i2}^{*}\left(B\right)\right]\cdot\left(1-\alpha_{i1}\right)\cdot\overline{L}_i\\
&-d\cdot\overline{L}_i-2tc_i\cdot\left(\left(\alpha_{i1}-\alpha_{i1}^{p}\right)\cdot\overline{L}_i\right)^2\end{aligned}\tag{A.2.4}$$

Now note that the average portion of successful loans $AVPSL_{ij}$ equals:

$$AVPSL_{ij}=p_j\cdot PSL_{ij}\left(G\right)+\left(1-p_j\right)\cdot PSL_{ij}\left(B\right)\tag{A.2.5}$$

And that the average loss from loans $AVLOS_{ij}$ equals:

$$AVLOS_{ij} = p_j \cdot \left(1-PSL_{ij}(G)\right)\cdot\left(1-M_{ij}^*(G)\right)\cdot\left(1-\lambda_{ij}(G)\right)$$

$$(A.2.6) \qquad +\left(1-p_j\right)\cdot\left(1-PSL_{ij}(B)\right)\cdot\left(1-M_{ij}^*(B)\right)\cdot\left(1-\lambda_{ij}(B)\right)$$

And finally, the average investment in monitoring $AVMCOST_{ij}$ equals:

$$(A.2.7) \qquad AVMCOST_{ij} = \left[p_j \cdot mis_{ij}^*(G) + \left(1-p_j\right)\cdot mis_{ij}^*(B)\right]$$

Now, we substitute A.2.5, A.2.6 and A.2.7 in A.2.4 and get:

$$\pi_i^e(\alpha_{i1}) = AVPSL_{i1}\cdot r_{i1}\cdot\alpha_{i1}\cdot\overline{L}_i - AVLOS_{i1}\cdot\alpha_{i1}\cdot\overline{L}_i - AVMCOST_{i1}\cdot\alpha_{i1}\cdot\overline{L}_i$$

$$(A.2.8) \qquad AVPSL_{i2}\cdot r_{i2}\cdot(1-\alpha_{i1})\cdot\overline{L}_i - AVLOS_{i2}\cdot(1-\alpha_{i1})\cdot\overline{L}_i - AVMCOST_{i2}\cdot(1-\alpha_{i1})\cdot\overline{L}_i$$

$$-d\cdot\overline{L}_i - 2tc_i\cdot\left(\left(\alpha_{i1}-\alpha_{i1}^p\right)\cdot\overline{L}_i\right)^2$$

A.3 The optimal allocation

Firstly, we derive the expected profit on α_{ij} and get:

$$\frac{\partial\pi_i^e(\alpha_{i1})}{\partial\alpha_{i1}} = AVPSL_{i1}\cdot r_{i1}\cdot\overline{L}_i + AVPSL_{i1}\cdot f_1^{'}(L_1)\frac{\partial L_1}{\partial\alpha_{i1}}\cdot\alpha_{i1}\cdot\overline{L}_i - AVLOS_{i1}\cdot\overline{L}_i - AVMCOST_{i1}\cdot\overline{L}_i$$

$$(A.4.1) \qquad + AVPSL_{i2}\cdot\frac{\partial r_{i2}}{\partial\alpha_{i1}}\cdot\overline{L}_i\cdot(1-\alpha_{i1}) - AVPSL_{i2}\cdot r_{i2}\cdot\overline{L}_i + AVLOS_{i2}\cdot\overline{L}_i + AVMCOST_{i2}\cdot\overline{L}_i$$

$$-4sc_i\cdot\left(\left(\alpha_{i1}-\alpha_{i1}^p\right)\cdot\left(\overline{L}_i\right)^2\right)$$

From equation 2.4, we know that: $r_{ij} = \beta_{ij} - \omega_{ij}\cdot\left(1+\mu_{ij}\right)\left(\alpha_{ij}\cdot\overline{L}_i\right)$

So

$$(A.4.2) \qquad \frac{dr_{i1}}{d\alpha_{i1}} = -\omega_{i1}\cdot(1+\mu_{i1})\cdot\overline{L}_i$$

$$(A.4.3) \qquad \frac{dr_{i2}}{d\alpha_{i1}} = \omega_{i2}\cdot(1+\mu_{i2})\cdot\overline{L}_i$$

We substitute 2.4, A.4.2 and A.4.3 in A.4.1 and get:

$$\frac{\partial\pi_i^e(\alpha_{i1})}{\partial\alpha_{i1}} = \begin{bmatrix} -2AVPSL_{i1}\cdot\left(\omega_{i1}\cdot(1+\mu_{i1})\right) \\ -2AVPSL_{i2}\cdot\left(\omega_{i2}\cdot(1+\mu_{i2})\right) - 4tc \end{bmatrix}\cdot\alpha_{i1}\cdot\left(\overline{L}_i\right)^2$$

$$+ AVPSL_{i1}\cdot(\beta_{i1})\cdot\overline{L}_i - AVLOS_{i1}\cdot\overline{L}_i - AVMCOST_{i1}\cdot\overline{L}_i$$

$$(A.4.4) \qquad + 2AVPSL_{i2}\cdot\left(\omega_{i2}\cdot(1+\mu_{i2})\right)\cdot\left(\overline{L}_i\right)^2 - AVPSL_{i2}\cdot\beta_{i2}\cdot\overline{L}_i$$

$$+ AVLOS_{i2}\cdot\overline{L}_i + AVMCOST_{i2}\cdot\overline{L}_i + 4sc_i\cdot\alpha_{i1}^p\cdot\left(\overline{L}_i\right)^2$$

We equate A.4.4 to 0 and obtain the optimal allocation:

$$(A.4.5) \qquad \alpha_{i1}^{*} = \frac{\begin{array}{l} AVPSL_{i1}\cdot(\beta_{i1}) - AVLOS_{i1} - AVMCOST_{i1} \\ +2AVPSL_{i2}\cdot\left(\left(\omega_{i2}\cdot(1+\mu_{i2})\right)\cdot\left(\bar{L}_i\right)\right) - AVPSL_{i2}\beta_{i2} \\ +AVLOS_{i2} + AVMCOST_{i2} + 4tc_i\cdot\alpha_{i1}^{p}\cdot\bar{L}_i \end{array}}{\left[2AVPSL_{i1}\cdot\left(\omega_{i1}\cdot(1+\mu_{i1})\right) + 2AVPSL_{i2}\cdot\left(\omega_{i2}\cdot(1+\mu_{i2})\right) + 4sc_i\right]\left(\bar{L}_i\right)}$$

We also find the second derivation, which is equal to:

$$(A.4.6) \qquad \frac{\partial\pi_i^{e}(\alpha_{i1})}{\partial^2\alpha_{i1}} = \left[-2AVPSL_{i1}\cdot\left(\omega_{i1}\cdot(1+\mu_{i1})\right) - 2AVPSL_{i2}\cdot\left(\omega_{i2}\cdot(1+\mu_{i2})\right) - 4sc_i\right]\left(\bar{L}_i\right)^2 < 0$$

Appendix B

From Appendix A, equations A.1.2, A.2.5-A.2.7, we prove that:

$$mis_{ij}^{*}(s) = mis_{ij}^{*}(s) = \left(0.5\cdot em_{ij}(s)\cdot\left(1-PSL_{ij}(s)\right)\cdot\left(1-\lambda_{ij}(s)\right)\right)^2 \Rightarrow$$

$$M_{ij}^{*} = em_{ij}(s)\cdot\left(mis_{ij}^{*}\right)^{0.5} = em_{ij}(s)\cdot\left(0.5\cdot em_{ij}(s)\cdot\left(1-PSL_{ij}(s)\right)\cdot\left(1-\lambda_{ij}(s)\right)\right)$$

$$AVPSL_{ij} = p_j\cdot PSL_{ij}(G) + (1-p_j)\cdot PSL_{ij}(B)$$

$$AVLOS_{ij} = p_j\cdot\left(1-PSL_{ij}(G)\right)\cdot\left(1-M_{ij}^{*}(G)\right)\cdot\left(1-\lambda_{ij}(G)\right) + (1-p_j)\cdot\left(1-PSL_{ij}(B)\right)\cdot\left(1-M_{ij}^{*}(B)\right)\cdot\left(1-\lambda_{ij}(B)\right)$$

$$AVMCOST_{ij} = \left[p_j\cdot mis_{ij}^{*}(G) + (1-p_j)\cdot mis_{ij}^{*}(B)\right]$$

We also define the following new notation:

$$Num = AVPSL_{i1}\cdot(\beta_{i1}) - AVLOS_{i1} - AVMCOST_{i1} + 2AVPSL_{i2}\cdot\left(\left(\omega_{i2}\cdot(1+\mu_{i2})\right)\cdot\left(\bar{L}_i\right)\right)$$
$$-AVPSL_{i2}\beta_{i2} + AVLOS_{i2} + AVMCOST_{i2} + 4tc_i\cdot\alpha_{i1}^{p}\cdot\bar{L}_i$$

$$Den = \left[2AVPSL_{i1}\cdot\left(\omega_{i1}\cdot(1+\mu_{i1})\right) + 2AVPSL_{i2}\cdot\left(\omega_{i2}\cdot(1+\mu_{i2})\right) + 4sc_i\right]\left(\bar{L}_i\right)$$

Since $\alpha_{i1}^{*} = \frac{Num}{Den}, 0 \le \alpha_{i1}^{*} \le 1$ it follow that $0 \le Num \le Den$ and $Den > 0$

B.1 Average rate of successful loans in sectors 1 and 2

$$(B.1.1) \quad \begin{cases} \dfrac{\partial\alpha_{i1}^{*}}{\partial AVPSL_{i1}} = \dfrac{\beta_{i1} - 2\left(\omega_{i1}\cdot(1+\mu_{i1})\right)\cdot\bar{L}_i\cdot\alpha_{i1}^{*}}{(Den)} \\ \dfrac{\partial\alpha_{i1}^{*}}{\partial AVPSL_{i1}} = \dfrac{2\left(\beta_{i1} - \left(\omega_{i1}\cdot(1+\mu_{i1})\right)\cdot\bar{L}_i\cdot\alpha_{i1}^{*}\right) - \beta_{i1}}{(Den)} = \dfrac{2r_{i1}^{*} - \beta_{i1}}{(Den)} \end{cases}$$

$$(B.1.2)\begin{cases}\dfrac{\partial\alpha_{i1}^{*}}{\partial^{2}AVPSL_{i1}}=\dfrac{-\left[\beta_{i1}-2\left(\omega_{i1}\cdot(1+\mu_{i1})\right)\cdot\overline{L}_{i}\cdot\alpha_{i1}^{*}\right]\cdot4\left(\omega_{i1}\cdot(1+\mu_{i1})\right)\cdot\overline{L}}{(Den)^{2}}\\ \dfrac{\partial\alpha_{i1}^{*}}{\partial^{2}AVPSL_{i1}}=\dfrac{-\left[2r_{i1}^{*}-\beta_{i1}\right]\cdot4\left(\omega_{i1}\cdot(1+\mu_{i1})\right)\cdot\overline{L}}{(Den)^{2}}\end{cases}$$

$$(B.1.3)\begin{cases}\dfrac{\partial\alpha_{i1}^{*}}{\partial AVPSL_{i2}}=\dfrac{\left(2\left(\omega_{i1}\cdot(1+\mu_{i2})\right)\cdot\left(1-\alpha_{i1}^{*}\right)\overline{L}_{i}-\beta_{i2}\right)}{(Den)}\\ \dfrac{\partial\alpha_{i1}^{*}}{\partial AVPSL_{i2}}=\dfrac{\beta_{i2}-2r_{i2}^{*}}{(Den)}\end{cases}$$

$$(B.1.4)\begin{cases}\dfrac{\partial\alpha_{i1}^{*}}{\partial^{2}AVPSL_{i2}}=\dfrac{-2\left(2\left(\omega_{i2}\cdot(1+\mu_{i2})\right)\cdot\overline{L}_{i}\right)\left[2\left(\omega_{i2}\cdot(1+\mu_{i2})\right)\cdot\left(1-\alpha_{i1}^{*}\right)\overline{L}_{i}-\beta_{i2}\right]}{(Den)^{2}}\\ \dfrac{\partial\alpha_{i1}^{*}}{\partial^{2}AVPSL_{i2}}=\dfrac{-2\left(2\left(\omega_{i2}\cdot(1+\mu_{i2})\right)\cdot\overline{L}_{i}\right)\left[\beta_{i2}-2r_{i2}^{*}\right]}{(Den)^{2}}\end{cases}$$

B.2 Average loss from successful loans in sectors 1 and 2

$$(B.2.1)\qquad \frac{\partial\alpha_{i1}^{*}}{\partial AVLOS_{i1}}=-\frac{1}{Den}<0;\quad (B.2.2)\qquad \frac{\partial\alpha_{i1}^{*}}{\partial^{2}AVLOS_{i1}}=0$$

$$(B.2.3)\qquad \frac{\partial\alpha_{i1}^{*}}{\partial AVLOS_{i2}}=\frac{1}{Den}>0;\quad (B.2.4)\qquad \frac{\partial\alpha_{i1}^{*}}{\partial^{2}AVLOS_{i2}}=0$$

B.3 Average investment in monitoring in sectors 1 and 2

$$(B.3.1)\qquad \frac{\partial\alpha_{i1}^{*}}{\partial AVMCOST_{i1}}=-\frac{1}{Den}<0;(B.3.2)\qquad \frac{\partial\alpha_{i1}^{*}}{\partial^{2}AVMCOST_{i1}}=0$$

$$(B.3.3)\qquad \frac{\partial\alpha_{i1}^{*}}{\partial AVMCOST_{i2}}=\frac{1}{Den}>0;\quad (B.3.4)\qquad \frac{\partial\alpha_{i1}^{*}}{\partial^{2}AVMCOST_{i2}}=0$$

B.4 The constant in the interest rate function of the demand to bank i's interest rate in sectors 1 and 2

$$(B.4.1)\qquad \frac{\partial\alpha_{i1}^{*}}{\partial\beta_{i1}}=\frac{AVPSL_{i1}}{Den}>0;\quad (B.4.2)\qquad \frac{\partial\alpha_{i1}^{*}}{\partial^{2}\beta_{i2}}=0$$

$$(B.4.3)\qquad \frac{\partial\alpha_{i1}^{*}}{\partial\beta_{i2}}=-\frac{AVPSL_{i2}}{Den}<0\ ;\ (B.4.4)\qquad \frac{\partial\alpha_{i1}^{*}}{\partial^{2}\beta_{i2}}=0$$

B.5 The demand sensitivity to bank i‘s interest rate in sectors 1 and 2

$(B.5.1)$ $$\left\{\frac{\partial \alpha_{i1}^*}{\partial \omega_{i1}} = \frac{-2AVPSL_{i1}\cdot \overline{L}_i \cdot (1+\mu_{i1})\cdot Num}{(Den)^2} = \frac{-2AVPSL_{i1}\cdot \overline{L}_i \cdot (1+\mu_{i1})\cdot \alpha_{i1}^*}{Den} < 0\right.$$

$(B.5.2)$ $$\left\{\frac{\partial \alpha_{i1}^*}{\partial^2 \omega_{i1}} = \frac{\left(2AVPSL_{i1}\cdot \overline{L}_i \cdot (1+\mu_{i1})\right)^2 \cdot Num}{(Den)^3} > 0\right.$$

$(B.5.3)$ $$\left\{\frac{\partial \alpha_{i1}^*}{\partial \omega_{i2}} = \frac{2AVPSL_{i2}\cdot \left(\overline{L}_i\right)\cdot (1+\mu_{i2})\cdot (Den - Num)}{(Den)^2} > 0\right.$$

$(B.5.4)$ $$\left\{\frac{\partial \alpha_{i1}^*}{\partial^2 \omega_{i2}} = \frac{-\left(2AVPSL_{i2}\cdot \left(\overline{L}_i\right)\cdot (1+\mu_{i2})\right)^2 \cdot (Den - Num)}{(Den)^3} < 0\right.$$

B.6 Bank i's expectation about its rivals' reaction in sectors 1 and 2

$(B.6.1)$ $$\left\{\frac{\partial \alpha_{i1}^*}{\partial \mu_{i1}} = \frac{-2AVPSL_{i1}\cdot \overline{L}_i \cdot (\omega_{i1})\cdot Num}{(Den)^2} = \frac{-2AVPSL_{i1}\cdot \overline{L}_i \cdot (\omega_{i1})\cdot \alpha_{i1}^*}{Den} < 0\right.$$

$(B.6.2)$ $$\left\{\frac{\partial \alpha_{i1}^*}{\partial^2 \mu_{i1}} = \frac{\left(2AVPSL_{i1}\cdot \overline{L}_i \cdot (\omega_{i1})\right)^2 \cdot Num}{(Den)^3} > 0\right.$$

$(B.6.3)$ $$\left\{\frac{\partial \alpha_{i1}^*}{\partial \mu_{i2}} = \frac{2AVPSL_{i2}\cdot \left(\overline{L}_i\right)\cdot (\omega_{i2})\cdot (Den - Num)}{(Den)^2} > 0\right.$$

$(B.6.4)$ $$\left\{\frac{\partial \alpha_{i1}^*}{\partial^2 \mu_{i2}} = \frac{-\left(2AVPSL_{i2}\cdot \left(\overline{L}_i\right)\cdot (\omega_{i2})\right)^2 \cdot (Den - Num)}{(Den)^3} < 0\right.$$

B.7 The interest rate in bank i in sector 1

From the interest rate function, we obtain:

$(B.7.1)$ $$\frac{\partial r_{i1}}{\partial \beta_{i1}} > 0;\ \frac{\partial r_{i1}}{\partial \omega_{i1}} < 0;\ \frac{\partial r_{i1}}{\partial \mu_{i1}} < 0$$

We know from equations B.4.1, B.4.3, B.5.1, B.5.3, B.6.1 and B.6.3 that:

$$\frac{\partial \alpha_{i1}^*}{\partial \beta_{i1}} > 0; \frac{\partial \alpha_{i1}^*}{\partial \beta_{i1}} < 0;\ \frac{\partial \alpha_{i1}^*}{\partial \omega_{i1}} < 0;\ \frac{\partial \alpha_{i1}^*}{\partial \omega_{i2}} > 0; \frac{\partial \alpha_{i1}^*}{\partial \mu_{i1}} < 0; \frac{\partial \alpha_{i1}^*}{\partial \mu_{i2}} > 0$$

So, we obtain:

$(B.7.2)$ $$\frac{\partial \alpha_{i1}^*}{\partial r_{i1}} > 0; \frac{\partial \alpha_{i1}^*}{\partial r_{i2}} < 0$$

B.8 Coefficient in the switching cost function

$$(B.8.1) \qquad \begin{cases} \dfrac{\partial \alpha_{i1}^*}{\partial tc_i} = \dfrac{4\overline{L}_i \cdot \left(\alpha_{i1}^p \cdot Den - Num\right)}{\left(Den\right)^2} = \dfrac{4\overline{L}_i \cdot Den \cdot \left(\alpha_{i1}^p - \alpha_{i1}^*\right)}{Den} < 0 \\ \text{if } \alpha_{i1}^p < \alpha_{i1}^* \end{cases}$$

$$(B.8.2) \qquad \begin{cases} \dfrac{\partial \alpha_{i1}^*}{\partial tc_i} = -\dfrac{16 \cdot \left(\overline{L}_i\right)^2 \cdot Den \cdot \left(\alpha_{i1}^p - \alpha_{i1}^*\right)}{\left(Den\right)^3} > 0 \\ \text{if } \alpha_{i1}^p < \alpha_{i1}^* \end{cases}$$

B.9 Allocation of the bank's loan portfolio to sector 1 in the previous period

$$(B.9.1) \qquad \frac{\partial \alpha_{i1}^*}{\partial \alpha_{i1}^p} = \frac{4sc_i \cdot \overline{L}_i}{Den} > 0 \ ;(B.9.2) \qquad \frac{\partial \alpha_{i1}^*}{\partial^2 \alpha_{i1}^p} = 0$$

B.10 The market power of bank i in sectors 1 and 2.

In section 4 (4.1), we show by simulation that: $\left\{ \dfrac{\partial \alpha_{i1}^*}{\partial PSL_{i1}(s)} > 0, \dfrac{\partial \alpha_{i1}^*}{\partial PSL_{i2}(s)} < 0 \right\}$

From equations B.4.1, B.4.3, B.5.1, B.5.3, we prove that:

$$\left\{ \frac{\partial \alpha_{i1}^*}{\partial \beta_{i1}} > 0, \frac{\partial \alpha_{i1}^*}{\partial \beta_{i2}} < 0 \right\}; \left\{ \frac{\partial \alpha_{i1}^*}{\partial w_{i1}} < 0, \frac{\partial \alpha_{i1}^*}{\partial w_{i2}} > 0 \right\}$$

And from the introduction, we know that[38]:

$$\left\{ \frac{\partial PSL_{ij}(s)}{\partial MP_{ij}} > 0; \frac{\partial w_{ij}}{\partial MP_{ij}} < 0, \frac{\partial \partial \beta_{ij}}{\partial MP_{ij}} > 0 \right\}$$

$$\Rightarrow (B.10.1) \qquad \frac{\partial \alpha_{i1}^*}{\partial MP_{i1}} > 0, \frac{\partial \alpha_{i1}^*}{\partial MP_{i2}} < 0$$

B.11 Relationship banking of bank i in sectors 1 and 2

In section 4 (4.1 and 4.4), we show by simulation that:

$$\left\{ \frac{\partial \alpha_{i1}^*}{\partial PSL_{i1}(s)} > 0, \frac{\partial \alpha_{i1}^*}{\partial PSL_{i2}(s)} < 0 \right\}; \left\{ \frac{\partial \alpha_{i1}^*}{\partial em_{i1}(s)} > 0, \frac{\partial \alpha_{i1}^*}{\partial em_{i2}(s)} < 0 \right\}$$

From equation B.10.1, we prove that: $\left\{ \dfrac{\partial \alpha_{i1}^*}{\partial MP_{i1}} > 0, \dfrac{\partial \alpha_{i1}^*}{\partial MP_{i2}} < 0 \right\}$

And from the introduction, we know that[39]: $\left\{ \dfrac{\partial PSL_{ij}(s)}{\partial RB_{ij}} > 0, \dfrac{\partial MP_{ij}}{\partial RB_{ij}} > 0, \dfrac{\partial em_{ij}(s)}{\partial RB_{ij}} > 0 \right\}$

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[38] See Table 1 – Conclusions IO.3 and IO.2.

$$\Rightarrow (B.11.1) \qquad \frac{\partial \alpha_{i1}^{*}}{\partial RB_{i1}} > 0 \; ; \frac{\partial \alpha_{i1}^{*}}{\partial RB_{i2}} < 0$$

B.12 Bank dependence in sectors 1 and 2

From equations B.4.1, B.4.3, B.5.1, B.5.3, we prove that:

$$\left\{ \frac{\partial \alpha_{i1}^{*}}{\partial \beta_{i1}} > 0, \frac{\partial \alpha_{i1}^{*}}{\partial \beta_{i2}} < 0 \right\}; \left\{ \frac{\partial \alpha_{i1}^{*}}{\partial w_{i1}} < 0, \frac{\partial \alpha_{i1}^{*}}{\partial w_{i2}} > 0 \right\}$$

And from the introduction, we know that[40]:

$$\left\{ \frac{\partial w_{ij}}{\partial BD_{j}} < 0, \frac{\partial \beta_{ij}}{\partial BD_{j}} > 0 \right\}$$

$$\Rightarrow (B.12.1) \qquad \frac{\partial \alpha_{i1}^{*}}{\partial BD_{1}} > 0, \frac{\partial \alpha_{i1}^{*}}{\partial BD_{1}} < 0$$

B.13 Firm bank size ratio in sectors 1 and 2

From equations B.4.1, B.4.3, B.5.1, B.5.3, we prove that:

$$\left\{ \frac{\partial \alpha_{i1}^{*}}{\partial \beta_{i1}} > 0, \frac{\partial \alpha_{i1}^{*}}{\partial \beta_{i2}} < 0 \right\}; \left\{ \frac{\partial \alpha_{i1}^{*}}{\partial w_{i1}} < 0, \frac{\partial \alpha_{i1}^{*}}{\partial w_{i2}} > 0 \right\}$$

And from the introduction, we know that[41]:

$$\left\{ \frac{\partial w_{ij}}{\partial FBS_{ij}} < 0, \frac{\partial \beta_{ij}}{\partial FBS_{ij}} > 0 \right\}$$

$$\Rightarrow (B.13.1) \qquad \frac{\partial \alpha_{i1}^{*}}{\partial FBS_{i1}} > 0, \frac{\partial \alpha_{i1}^{*}}{\partial FBS_{i2}} < 0$$

B.14 Legal system and firm's average size in sectors 1 and 2

From equations B.4.1 and B.4.3, we prove that:

$$\left\{ \frac{\partial \alpha_{i1}^{*}}{\partial \beta_{i1}} > 0, \frac{\partial \alpha_{i1}^{*}}{\partial \beta_{i2}} < 0 \right\}$$

And from the introduction, we know that:

[39] See Table 1 – Conclusions RB.1 and RB.2

[40] An increase in market power increases the portion of successful loans and the market share of bank i, and decreases the demand sensitivity. See Table 1 – Conclusions IO.3 and IO.2.

[41] An increase in market power increases the portion of successful loans and the market share of bank i, and decreases the demand sensitivity. See Table 1 – Conclusions IO.3 and IO.2.

$$\left\{ ,\frac{\partial \beta_{ij}}{\partial LSFS_{ij}} > 0 \right\}$$

$$\Rightarrow (B.14.1) \qquad \frac{\partial \alpha_{i1}^{*}}{\partial LSFS_{i1}} > 0, \frac{\partial \alpha_{i1}^{*}}{\partial LSFS_{i2}} < 0$$

B.15 Bank ownership and firm's average size in sectors 1 and 2

From equations B.4.1 and B.4.3, we prove that:

$$\left\{ \frac{\partial \alpha_{i1}^{*}}{\partial \beta_{i1}} > 0, \frac{\partial \alpha_{i1}^{*}}{\partial \beta_{i2}} < 0 \right\}$$

And from the introduction, we know that:

$$\left\{ ,\frac{\partial \beta_{ij}}{\partial BOFZ_{ij}} > 0 \right\}$$

$$\Rightarrow (B.15.1) \qquad \frac{\partial \alpha_{i1}^{*}}{\partial BOFZ_{i1}} > 0, \frac{\partial \alpha_{i1}^{*}}{\partial BOFZ_{i2}} < 0$$

B.16 Collateral rate of bank i in sectors 1 and 2

In section 4 (4.1 and 4.3), we show by simulation that:

$$\left\{ \frac{\partial \alpha_{i1}^{*}}{\partial PSL_{i1}(s)} > 0, \frac{\partial \alpha_{i1}^{*}}{\partial PSL_{i2}(s)} < 0 \right\}, \left\{ \frac{\partial \alpha_{i1}^{*}}{\partial \lambda_{i1}(s)} > 0, \frac{\partial \alpha_{i1}^{*}}{\partial \lambda_{i2}(s)} < 0 \right\}$$

From the introduction, we know that[42]: $\left\{ \frac{\partial PSL_{ij}(s)}{\partial CR_{ij}} > 0, \frac{\partial \lambda_{ij}}{\partial MP_{ij}} > 0 \right\}$

We obtain: $(B.16.1) \qquad \frac{\partial \alpha_{i1}^{*}}{\partial CR_{i1}} > 0 \ ; \frac{\partial \alpha_{i1}^{*}}{\partial CR_{i2}} < 0$

And from equations B.4.1 and B.4.3, we prove that: $\left\{ \frac{\partial \alpha_{i1}^{*}}{\partial \beta_{i1}} > 0, \frac{\partial \alpha_{i1}^{*}}{\partial \beta_{i2}} < 0 \right\}$

And from the introduction, we know that: $\left\{ \frac{\partial \beta_{ij}(s)}{\partial CR_{ij}} < 0 \right\}$

We obtain: $(B.16.2) \qquad \frac{\partial \alpha_{i1}^{*}}{\partial CR_{i1}} < 0 \ ; \frac{\partial \alpha_{i1}^{*}}{\partial CR_{i2}} > 0$

[42] The collateral can be used as a screening device; increasing the collateral increases the portion of successful loans and the recovery rate, but reduces the number of borrowers.

We assume that the relation between the share of loans bank i allocates to sector $\left(\alpha_{i1}\right)$ and the average rate of collateral bank i pledges in this sector (CR_{i1}) is non-monotonic; first it increases and then it decreases.