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Abstract

This dissertation studies the effect of bank equity on banks' rationing behavior. I reveal that the distribution of bank equity is essential: Banks with high equity offer cheap loans and reject superfluous loan applicants, whom banks with low equity then offer expensive loans. The expensive loans yield a higher expected return than the cheap loans. The results are well-suited for analyzing the evolution of bank equity in an environment with credit rationing and heterogeneous banks.

Secondly, this dissertation is the first to analyze equilibrium credit rationing in double-sided Bertrand competition with market side switching. Credit rationing may occur if adverse selection due to borrowers' informational advantage leads to a non-monotonic expected return on loans. Considering a model, in which borrowers and lenders are able to switch market sides, makes the analysis considerably more complex because the expected return on loans then depends on both, the loan rate and the deposit rate.

Thirdly, this dissertation is the first to formally analyze the process of acceptance and rejection of loan applicants in a separate stage of the double-sided Bertrand game. I show that for fixed chosen interest rates, the deposit and loan volumes of all banks in a subgame perfect Nash equilibrium of the resource allocation game are uniquely determined.

Motivation

For decades economists have thought that credit rationing in financial markets only occurs as a short-lived phenomenon that resolves itself in the medium term. Classic economic theory suggests that if loan demand exceeds loan supply, banks charge higher interest rates until loan demand equals loan supply. The seminal contribution "Credit Rationing in Markets with Imperfect Information" by Stiglitz and Weiss (1981) gained attention by claiming that low loan rates and credit rationing can indeed be stable. Stiglitz and Weiss (1981) explained why a bank with excess loan demand does not necessarily raise its loan rate. They argued that a bank only increases its loan rate if this increases the expected return on loans.

If, by contrast, the expected return on loans decreases in the loan rate, banks have no incentive to raise their loan rate. Instead, they have an incentive to offer low interest rates and simply ration superfluous loan applicants.

Why can the expected return on loans decrease if the loan rate increases? If borrowers undertake risky investment projects, they may fail on their loans. Hence, on average, borrowers repay less than their contractual repayments. The higher the likelihood of default, the lower the expected repayment.

No matter which screening devices banks apply, borrowers typically have an informational advantage because they can assess their projects' riskiness more precisely than banks. Stiglitz and Weiss (1981) considered an economy in which borrowers could undertake heterogeneous investment projects with the same expected outcome that differed in their riskiness. All loan applicants were offered the same contract since the banks could not distinguish between safe and risky projects.

An increase in the loan rate has a positive direct effect on bank return. However, indirect effects may produce the opposite result. If the loan rate increases, moral hazard can lead borrowers to assume more risk. Moreover, safe borrowers may leave the market, an effect known as adverse selection.

Both moral hazard and adverse selection increase the average default probability of a bank's borrowers. Thus, the slope of expected return on loans with respect to the loan rate is ambiguous and depends on whether the direct or the indirect effects dominate.

Classic economic theory suggests that banks offer the Walrasian loan rate. With this, loan demand equals deposit supply if the banks pay the expected return on loans as the deposit interest. Stiglitz and Weiss (1981), however, distinguished three scenarios:

Firstly, if all loan rates below the Walrasian rate yield lower expected returns on loan, then banks offer the Walrasian rate.

Secondly, Stiglitz and Weiss (1981) claimed that if the expected return on loans is maximal at a loan rate below the Walrasian rate, all banks offer that loan rate. Some loan applicants receive no loan since loan demand exceeds loan supply. Coco (1997), Arnold and Riley (2009) and Su and Zhang (2017) show that this case only occurs if risky projects have lower expected output than safe projects.

Thirdly, imagine that a lower loan rate than the Walrasian one yields a higher expected return on loans, but a higher loan rate than the Walrasian one yields the maximal expected return on loans. In that case, Stiglitz and Weiss (1981) claimed that while some banks offer the loan rate below the Walrasian rate with the highest expected return, other banks charge a higher rate than the Walrasian one with the same expected return. Hence, there are banks offering cheap loans and banks offering expensive loans, and the equilibrium is asymmetric. At the cheap rate, loan demand exceeds loan supply, and at the expensive rate, loan supply exceeds loan demand. Consequently, cheap banks must reject some loan applicants, and all rejected loan applicants willing to pay the expensive rate receive loans.

Stiglitz and Weiss (1981) added valuable economic insight with their paper on credit rationing in equilibrium. However, the model has several unresolved issues. Firstly, the main caveat is that Stiglitz and Weiss (1981) did not model the banking sector explicitly and implicitly assumed that a single bank has no market power. Secondly, there is evidence to suggest that a game-theoretic model only yields the asymmetric equilibrium from Stiglitz and Weiss (1981) under specific model assumptions. Arnold (2012) and Wälde (2011) show that it is possible to replicate the results of Stiglitz and Weiss (1981) gametheoretically. They draw on results from Stahl (1988), who developed the first model of double-sided Bertrand competition for inputs and outputs among firms, and Yanelle (1989, 1997), who observed that Stahl's model could be applied to financial markets.

However, Arnold (2012) and Wälde (2011) have to make the following assumptions: Competition for loans precedes competition for deposits. If several banks offer the same loan rate, allborrowers take loans from one randomly chosen bank. If this bank rations loan applicants, they assume that the rejected applicants will address a bank with a more expensive loan rate even if other banks offer the cheap loan rate as well. As a result, in an asymmetric equilibrium, only two banks are active. One lends at the low interest rate, and one lends at the high interest rate. All other banks are inactive and neither receive deposits nor grant loans.

If the Bank of America and Wells Fargo offer the same contracts, some customers will choose the Bank of America, and others will choose Wells Fargo. Indeed, economists generally assume that firms that offer the same products or services for the same prices serve equal shares of the market. Consider the well-known model of Bertrand competition for one good, in which finitely many sellers of the same good engage in price competition. Buyers address the sellers in ascending order of prices. If two sellers set the same prices, they face the same demand. It is only natural to assume that, in the financial sector, banks that offer the same interest rates receive the same share of loan applications and deposits.

In this dissertation, we analyze an oligopolistic financial sector, in which banks simultaneously compete for loans and deposits. If several banks offer the same loan rate, we assume that each bank receives the same loan application volume and if several banks offer the same deposit rate, they receive the same deposit volume. Contrary to Arnold (2012) and Wälde (2011), in this dissertation, banks offering the same contracts are either all active or all inactive.

This dissertation is the first to incorporate credit rationing into double-sided Bertrand competition with market side switching. So far, in the literature, credit rationing has only been analyzed when deposit suppliers and potential borrowers are distinct. That is, either loan demand and deposit supply functions are given directly as in Bracoud (2007), or distinct pools of borrowers and lenders take borrowing and lending decisions.

In this dissertation, loan demand and deposit supply are generated by a production sector with heterogeneous agents. Potential entrepreneurs can either save their endowments or borrow in order to undertake a risky investment project. That is, they are able to switch market sides as in Gersbach and Wenzelburger (2003, 2008, 2010, 2012).

If the deposit rate increases, saving becomes more attractive, and the opportunity cost of investment increases. Hence, some borrowers switch market sides and decide to save. The deposit volume increases, and the volume of loan applications decreases. If, on the other hand, the loan rate increases, the expected profit of an investor decreases and, thus, saving becomes comparably more favorable. Generally, if any interest rate increases, deposit supply increases, and loan demand decreases. Both loan demand and deposit supply depend on both interest rates.

It follows that not only a change in the loan rate alters the pool of borrowers and their average default possibility, but also a change in the deposit rate. The expected return on loans is a function in both interest rates. This interdependency between the deposit rate and the expected return on loans adds a considerably higher degree of complexity to this dissertation. By contrast, in Stiglitz and Weiss (1981), Arnold (2012) and Wälde (2011), the expected return on loans is independent of the deposit rate.

Gersbach and Wenzelburger (2003, 2008, 2010, 2012) find no credit rationing in equilibrium because they assume that investment projects differ by a quality parameter. A project with high quality yields a better outcome in every possible state of the economy. Therefore, high-quality entrepreneurs are willing to accept more expensive loans than low-quality entrepreneurs. If the loan rate increases, bad borrowers become savers, and the pool of borrowers improves. Hence, while we observe adverse selection in Stiglitz and Weiss (1981), there is *favorable* selection in Gersbach and Wenzelburger (2003, 2008, 2010, 2012). If the loan rate increases, the expected return on loans increases overproportionally. A bank with excess loan demand has a strong incentive to raise its loan rate, and credit rationing resolves itself.

In this thesis, we introduce positive bank equity at the beginning of the game and allow for distinct equity volumes. This makes the analysis considerably more complex. However, equity is an essential feature of a bank's balance sheet. In fact, it is *the* objective of a firm to maximize equity. It is probably fair to say that models with the simplifying assumption of zero equity are well-suited if one is mainly interested in equilibrium interest rates and wants to analyze their impact on other markets. However, if one studies the banking sector itself, for example, its stability or profitability, then equity is of utmost importance. Legislators impose capital adequacy rules to manage banks' default risk. Therefore, it is only natural to include bank equity in the intermediation model. This allows incorporating the results of this thesis into multi-period models which analyze the evolution of the banking sector and policy measures over time.

It is important to note that bank equity will essentially decide whether and which equilibria exist. Hence, by introducing equity, we make effects visible which do not occur if one assumes zero equity. In particular, we show that in asymmetric equilibria, banks with high equity offer cheap loans with a low expected return, and banks with low equity offer expensive loans with a high expected return. The deposit rate lies between the low expected return on loans and the high expected return on loans and banks offering expensive loans may enjoy a positive intermediation margin in equilibrium.

Furthermore, this dissertation is the first to treat the allocation of loan applicants to banks in double-sided Bertrand competition with market side switching as a rigorous part of the intermediation game. Our intermediation game consists of an interest rate game and a subsequent allocation game. At first, banks simultaneously choose their deposit and loan rates. Then entrepreneurs apply for a loan at different banks until they are successful or switch market sides and save. The acceptance and rationing decision of each bank affects loan applications at other banks later in the game as well as the resources of all banks that offer favorable deposit contracts and attract savers. In this dissertation, loan volumes are the direct result of banks' decisions, while they are the result of a black box allocation mechanism in other literature in this field.

We show that the loan volumes banks choose in the allocation game are always uniquely determined and explicitly compute the equilibrium deposit and loan volumes.

An earlier version of a part of this thesis is available as a joint SSRN paper with my supervisor, Krebs and Wenzelburger (2017). It has similar model assumptions as this thesis and contains some preliminary results from Chapters 2 and 3 for two banks with equal equity.

The remainder of the thesis is organized as follows: We introduce the model and formally define the intermediation game between the banks in Chapter 1. In Chapter 2 we show that the allocation game entails subgame perfect Nash equilibria and derive the equilibrium deposit and loan volumes. In Chapter 3, we analyze symmetric equilibria of the interest rate game in a general setting before we consider an economy with two distinct production projects in Chapter 4.

Contents

1 Intermediation Game

1.1 Model

We consider a two-period model with $n \geq 2$ banks and a continuum of agents indexed by $\theta \in [0, \overline{\theta}]$.

In period 1 agents are endowed with w units of a perishable good. There exists no storage technology and agents want to transfer the good to period 2. Agents are risk-neutral and maximize the expected value of the good in period 2. They are divided into consumers $\theta \in [0, \underline{\theta})$ and potential entrepreneurs $\theta \in [\underline{\theta}, \overline{\theta}]$, where $0 < \underline{\theta} < \overline{\theta}$. Consumers can only deposit their endowments at a bank. We denote their aggregate endowments by $s := \underline{\theta} w$. Entrepreneurs have two possibilities to transfer the good into period 2: They can either deposit their endowments at a bank or undertake a production project in period 1 with a stochastic output in period 2. Necessary funds for an investment into a production project exceed the endowment w, and we assume that all production projects need the same amount of inputs. We denote the additional units of the good an entrepreneur has to borrow in order to invest into her production project by $\ell > 0$.

Production projects are heterogeneous, and every entrepreneur has access to one specific project. There exist a set of project types $\mathcal{T} \subseteq \mathbb{R}$ and a weakly increasing function $t\colon [\underline{\theta}, \overline{\theta}] \to \mathcal{T}$ mapping entrepreneur θ to her project type $t(\theta)$. Each entrepreneur's project type is private information, but the distribution of production types is public knowledge. That is, for every Lebesgue-measurable set of project types $T \subseteq \mathcal{T}$, the Lebesgue-measure $\mu(t^{-1}(T))$ of entrepreneurs with access to projects of a type $\tau \in T$ is public knowledge.[1]

[1] The map t is Lebesgue-measurable since it is increasing. Hence, the measure $\mu(t^{-1}(T))$ exists.

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Production is risky. A macroeconomic shock ξ is realized in period 2, and the outcome of a project $f(\tau, \xi)$ depends both on its type τ and on the macroeconomic shock ξ. The distribution of the macroeconomic shock is public knowledge in period 1 and project outcomes in period 2 are observable. Entrepreneurs are risk-neutral and willing to invest if saving and investing yield the same expected profit.

The banking sector consists of $n \geq 2$ risk-neutral and profit-maximizing banks, which offer deposit contracts and loan contracts with limited liability of the borrower. Equity e_i of bank $i \in \{1, \ldots, n\}$ at the beginning of period 1 is positive and observable by all other banks. We denote aggregate equity in the banking sector by $e := \sum_{i=1}^{n} e_i$ and assume that there is not enough equity in the banking sector to finance all production projects,

$$e + s < \ell\,(\overline{\theta} - \underline{\theta}). \tag{1.1}$$

At the beginning of period 1 all banks simultaneously offer publicly observable deposit and loan rates. We denote the deposit rate of bank i by $r_i^d > -1$ and the loan rate of bank i by $r_i^l > -1$. A saver who deposits w units of the good at bank i in period 1 is entitled to a repayment of $(1 + r_i^d)w$ units of the good in period 2. Banks are not allowed to reject depositors. If entrepreneurs with positive measure are indifferent between the saving contracts of several banks, then each of these banks receives the same share of depositors.

All loan contracts have the same volume ℓ. An entrepreneur who borrows ℓ units of the good from bank i in period 1 agrees to pay back $(1 + r_i^l)\ell$ units of the good in period 2. If her production outcome $f(t(\theta), \xi)$ is less than $(1 + r_i^l)\ell$, she is liquidated and pays the bank $f(t(\theta), \xi)$. Thus, her repayment obligation in period 2 with limited liability is $\min\{(1 + r_i^l)\ell,\ f(t(\theta), \xi)\}$. If loan applicants with positive measure are indifferent between the loan contracts of several banks, the same share applies at each bank.

Banks can only accept loan applications subject to their resource constraints. If the loan application volume of a bank exceeds its equity and deposits, it has to reject potential borrowers. Banks cannot distinguish between entrepreneurs with different project types. Therefore, we assume that if a bank must ration, the distribution of projects among the entrepreneurs it accepts equals the distribution of projects among its loan applicants. That is, if entrepreneurs $B \subseteq [\underline{\theta}, \overline{\theta}]$ apply for loans at bank i and if bank i accepts applicants $A \subseteq B$, then for every project type $\tau \in \mathcal{T}$,

$$\mu(\{\theta \in A \mid t(\theta) \leq \tau\}) = \frac{\mu(A)}{\mu(B)} \cdot \mu(\{\theta \in B \mid t(\theta) \leq \tau\}), \tag{1.2}$$

where μ is the Lebesgue measure. Neither the entrepreneurs nor the banks themselves take bank failures into account.

1.2 Timing

In period 1 actions take place in the following order: At first all banks simultaneously offer publicly observable interest rates $r_1^d, r_1^l, \ldots, r_n^d, r_n^l$. Then consumers decide at which bank they deposit their endowments and sign saving contracts.

Entrepreneurs apply for loans in n rounds. In round 1 every entrepreneur has two options: Either she saves her endowments, or she applies for a loan at one bank. In the first case, she chooses a bank and immediately signs its deposit contract because she may not be rejected by assumption.

Banks with positive loan demand in round 1 decide which loan applicants they accept. Successful applicants sign loan contracts and do not apply for further contracts in subsequent rounds. Banks that reject loan applicants are not allowed to accept additional borrowers in subsequent rounds.

In round $j \in \{2, \ldots, n\}$, entrepreneurs who have unsuccessfully applied for loans in rounds 1 to $j - 1$ can again decide between saving their endowments and applying for a loan at a different bank that has not yet rejected loan applicants. Banks with positive loan applications in round j decide which entrepreneurs they accept. Successful loan applicants sign loan contracts. Unsuccessful loan applicants decide whether they become savers or apply at a different bank in round $j + 1$.

After n rounds each entrepreneur has either signed a deposit contract, signed a loan contract, or has unsuccessfully applied for credit at all banks. Then the allocation procedure stops and unsuccessful loan applicants must save.

Savers deposit their endowments at the respective banks. Banks pay out the loans. Borrowers undertake their investment projects.

In period 2, the macroeconomic shock is realized. Borrowers collect their production outcomes and meet their repayment obligations with limited liability. Finally, banks pay out the deposits.

1.3 Game-Theoretic Formalization

We formalize the model as a strategic game between the n banks, which we call *intermediation game*. We do not model the agents as strategic players. They are assumed to be myopic in the sense of Gersbach and Wenzelburger (2003, 2008, 2010, 2012). That is, they simply apply for the cheapest loans they can get. In each