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Sequential Models of Bertrand Competition for Deposits and Loans under Asymmetric Information

by

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Date September 2002

Abstract This paper analyzes sequential games of double-sided Bertrand competition in the deposit and credit markets, when banks are free to reject customers and cannot distinguish among borrowers. The timing of competition is crucial when customers apply once. Interest rates are pushed upwards when the deposit market is the first to be visited, whereas rates are submitted to downward pressures otherwise. With multiple applications, the order of competition does not matter. Multiple applications in one market weaken competition in that market and generate outcomes similar to the case when this market is visited in a second stage in the single-application framework.

Keywords Financial intermediation; Bertrand competition; Dual competition; Adverse selection; Credit rationing

J.E.L. Class D43, D82, G21, L13

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1 Introduction

In financial markets, banks operate as intermediaries between borrowers and suppliers of funds, and as such have to compete in two markets: for collecting deposits on the one hand and for attracting loan applicants on the other. In addition to this dual nature, largely overlooked in the literature on credit markets, competition in the banking industry is characterized by an oligopolistic structure, with a small number of firms controlling a large part of the activities. This situation, resulting from intensive mergers in the last two decades, suggests that strategic interactions between banks would need to be accounted for, which is again rarely the case in the literature on credit and deposit markets.[1] In particular, the modeling of competition in the deposit market either is ignored,[2] or takes the extreme forms of perfect or monopoly competition. Besides its dual and oligopolistic competitive features, financial markets are also characterized by asymmetric information. Despite banks' expertise in assessing the quality of borrowers and in monitoring them, there still remain problems of adverse selection and moral hazard in the credit market.

The present paper incorporates the three important features described above, by modelling double-sided oligopolistic competition among banks in the deposit and credit market, with adverse selection in the loan market. We analyze different versions of a model of dual Bertrand competition - in which banks choose both their credit and deposit interest rates - with homogenous deposits and loans among banks. The main objective of this paper is to contribute to a theory of interest rates determination with financial intermediation when double-sided Bertrand competition prevails. The dual nature of competition raises a specific problem as it potentially generates two opposite mechanisms: Bertrand competition in the credit market alone would imply an undercutting war, with the loan rate falling to the deposit rate, whereas price competition in the deposit market would push the deposit interest rate up to the loan rate. The question is to determine which credit and deposit rates will then result from these two opposing forces.

[1]For an overview of the different forms of competition in banking theory, see Bhattacharya and Thakor [1] and Freixas and Rochet [4].

[2]Many papers assume that banks collect an exogenous amount of deposits (see, eg, the review of reserve management and portfolio models by Santomero [8]) or face an infinite supply of funds at a given deposit rate.

This paper follows Repullo [7] and Yanelle [14] in assuming double-sided Bertrand competition in the banking sector. Both have analyzed simultaneous competition in the deposit and the credit markets under the assumption that banks are compelled to accept and remunerate all deposits supplied by the public. In this paper we relax the assumption of simultaneous competition, on the grounds that the timing of a game could affect its outcome. The paper therefore raises the specific question of the determination of interest rates with regard to the timing of competition in the two markets: does the order of competition matter? To answer that question we carry out the analysis for games in which competition is not simultaneous in both markets, contrary to Repullo [7] and Yanelle [14], but takes place at different stages: banks commit themselves to the rates on one market before competing in the other market. We develop two sequential games, respectively called the 'Deposits-first' and 'Loans-first' games, depending on whether intermediaries compete first for depositors or for loan applicants.

This two-stage competition is familiar from goods market intermediation theory, as developed by Stahl [10].[3] Stahl's framework has been adapted to financial intermediation by Freixas and Rochet [4], who kept all the assumptions of the original paper by assuming homogeneous goods (here homogeneous deposits and homogeneous loans among banks) and a winner-take-it-all sharing rule.[4] In Stahl [10] and Freixas and Rochet [4] intermediaries commit to the quantities offered (or demanded) by the customers in the first market visited. We believe that this commitment to quantity is actually the force that drives the prices, rather than the sequence in price-setting. In order to isolate the effects due to the commitment to the prices, the present paper assumes that, although banks commit themselves to the rates posted in the first market, they do not take any decision with respect to the quantity they trade before competing in the second market and they can possibly reject some customers from the first market. This non-commitment to quantity represents the distinctive feature of our model with respect to the original model, and also departs from Repullo [7] and Yanelle [14], which impose the acceptance of all deposits by banks as an assumption. We prefer to endogeneise this feature as the consequence of credit rationing at equi-

[3] See Spulber [9] for a review of the intermediation theory of the firm.

[4] Among the extensions of the original model, let us mention Toolselma [12], which introduces reserve requirement in the Freixas and Rochet's framework, or Gottardi and Yanelle [5], which models financial innovations as spatial competition.

librium. Another important difference in our modelling is the possibility for customers to reapply to another intermediary if rejected, an aspect which could not be captured in the other papers due to their assumption of acceptation of all customers.

In this new framework, our main result is that timing of competition matters when borrowers and depositors can apply at most to one bank, whereas it does not have any effect and is equivalent to simultaneous competition in the case of multiple applications, which we believe is a more realistic case.

In the single-application framework analyzed in the first part of the paper, the difference in the timing of moves turns out to be important, generating two different polar outcomes. The first market visited is also the market in which competition is fierce, as the banks which do not manage to capture customers in the first stage will eventually be out of business. The timing therefore determines which force drives the deposit and loan rates. When banks make their deposit rate offer before their credit rate offer ('Deposits-first' game), the Subgame Perfect Nash equilibrium is located at the highest deposit rate compatible with banks' profitability. For lower deposit rates, any bank would have an incentive to offer a deposit rate higher than its competitors in order to get a monopoly rent in the credit market. At the opposite, when credit rate offers are made before deposit rate offers ('Loans-first' game), competition drives the credit rate and the deposit rate down to their lowest value compatible with banking activity.

When multiple applications by borrowers and depositors are introduced into the game, as is the case in the second part of the paper, the two polar outcomes still apply but are not sensitive to the timing in competition. Indeed, even with different orderings in the visits to the markets by banks ('Deposits-first' or 'Loans-first'), games characterized by the same assumptions for the mobility of depositors and borrowers converge to the same outcome, one of the polar equilibrium derived in the first part of the paper. The possibility for multiple applications in one market weakens competition in that market in favour of competition in the other market. If borrowers are the only agents to be allowed to apply elsewhere when rejected, or if they reapply before depositors, Bertrand competition in deposit and credit markets, regardless of the timing, gives the outcome of our 'Deposits-first' game in the single application framework, which drives the deposit rate up to its highest value. Even when the credit market is visited first, competition in the loan market is not fierce anymore, as banks can get borrowers later in the game and can even be more aggressive in the deposit market later if they have posted a larger credit rate. When a bank manages to capture all deposits in the second market, it is guaranteed to get all borrowers even with a non-attractive price, simply through the rejection process by competitors without lending capacities. Competition in the deposit market therefore becomes crucial and drives the interest rates upwards. If, on the contrary, depositors are the only agents to be allowed to move from bank to bank, or if they can reapply before borrowers, double-sided Bertrand competition gives the outcome of the 'Loans-first' game in a single-application framework, and the interest rates are driven down to their lowest value, regardless the sequence of competition.

In this paper we assume that the loan market displays adverse selection as in Stiglitz and Weiss [11]. This is captured by a non-monotonic relationship between loan rate and the expected rate of return of a bank. Adverse selection therefore provides a justification for an upper bound on the deposit rate that banks can post. It is important to note that this assumption of asymmetric information is not essential for the theory of determination of interest rates in dual competition that we develop in this paper. In particular, adverse selection does not have any specific interaction with the double Bertrand competition process that we model here. Our motivation is simply to illustrate, with the case of Stiglitz and Weiss' framework of adverse selection, how the modelling of dual competition can shed a new light on existing results in the literature on credit markets. We show that Stiglitz and Weiss' result on credit rationing indeed depends on a specific characterization of competition, where competition in the deposit market is the driving force.

Credit rationing may emerge in both types of equilibria that we have derived but the phenomenon is much more likely to occur and at a larger scale in the game in which the credit market competition is fiercer, i.e., either when the credit market is the first market to be visited in the single-application framework, or when depositors can reapply to another bank before borrowers. More interestingly, explaining credit rationing thanks to adverse selection – as Stiglitz and Weiss do in their paper – may not always be relevant when oligopolistic competition in the deposit market is explicitly taken into account. Credit rationing can be traced back to asymmetric information only in games for which deposit competition dominates (as in the 'Deposits-first' game with single application). When competition in the credit market is fierce, a credit rationing of another nature emerges which has no connection with imperfect information at all.

The paper is organized as follows. Section 2 briefly presents the model. In Section 3, we develop sequential games within a single-application framework. We analyze the game in which banks compete first for funds and then for projects ('Deposits-first' game) in Section 3.1. The reverse order of moves ('Loans-first' game) is studied in Section 3.2. A discussion of the single-application results takes place in Section 3.3. Section 4 is dedicated to the framework with multiple applications by depositors and borrowers, with an analysis of a rationing scheme which enhances the competition in the credit market in Section 4.1. Another rationing scheme, stimulating competition in the deposit market, is analysed in Section 4.2 and Section 4.3 discusses our results and relates them to the existing literature. We summarize our results in Section 5. All proofs are relegated to the appendix.

2 The model

Section 2 briefly presents the main assumptions of the model. The paper considers an intermediated credit market where funds holders can only lend to borrowers through banks.[5] Banks are modelled in a stylized way that captures the essence of financial intermediation: they collect funds through 'deposits' that are remunerated and use these funds by making 'loans' that provide them with a revenue. As the paper does not focus on problems of maturity transformation, we assume for simplicity that the liabilities and the assets in the banks' balance sheet have the same maturity. The market structure is an oligopoly and takes the form of N (≥ 2) banks i $(i \in B = \{1, 2, ..., N\})$ that play strategically. Banks are assumed to be risk neutral and compete à la Bertrand on both the credit market and the deposit market. Since this double-sided Bertrand competition is really the core of this paper and takes various forms, a precise description of the game and the players' moves is given for each new model. Let us simply point out here the traditional assumption underlying any Bertrand competition

[5] For models where customers can choose between intermediaries and direct finance, see Yanelle [16].

analysis. Banks prefer activity, even if it leads to a zero expected profit, to no activity at all.

Borrowers are assumed to be atomless and are not strategic players in the market. We assume that they are myopic and simply apply to the bank that offers the most attractive price. Although it is not necessary for our theory of determination of interest rates, we assume that the expected return which banks get from their loans, ER, is not a monotonous increasing function of the posted credit rate, r_L. We assume that the expected return is a hump-shaped curve, with a peak at the credit interest rate $\tilde{r}_L$ as illustrated in Figure 1. The characteristics of ER can be explained by assuming heterogeneous borrowers and asymmetric information, as in Stiglitz and Weiss [11]. Borrowers have different probabilities of project success and hence loan repayment. Information is asymmetric, as banks are unable to distinguish different borrowers and therefore must treat them equally. The borrowers with a higher probability of success have a smaller expected profit as they repay their loan with a greater probability and thus must leave the credit market for a lower credit rate. This characteristic is the core of the well-known adverse selection phenomenon, by which an increase in the posted credit rate deteriorates the quality of the applicant pool as the best customers leave the market first. After a certain credit rate, denoted $\tilde{r}_L$ in Figure 1, the deterioration in the quality offsets the beneficial effect of the increase in the payments, hence a decrease in ER and a general hump shape for the curve. At r_L^{max}, the worst borrowers leave the credit market and for larger credit rate, there is no applicants for loan.

[FIGURE 1 ABOUT HERE]

The demand for credit is a monotonic decreasing function of the credit rate. However, the demand for credit is represented as a backward bending curve when drawn with respect to ER. See Figure 2 for an illustration. Depositors are also atomless and are not strategic players in the game. We assume that they are myopic and simply apply to the bank that offers the most attractive price. They are assumed to be endowed with only one unit of funds. They have different reservation values, so that the aggregate supply of funds to the banking sector, S_D, is an increasing function of the deposit rate r_D. Below the smallest reservation value, r_D^{min}, the supply of deposits is zero.[6] See Figure 2 for an illustration of two possible configurations for the aggregate supply of funds.

[FIGURE 2 ABOUT HERE]

The Walrasian equilibrium is either on the upward slope of the expected return as for $S_D^{'}$ or on the downward slope of ER as illustrated for the supply curve $S_D^{''}$.

The following sections consider sequential competition in a single-application framework (Section 3) and in a multiple-application framework (Section 4).

3 Sequential competition in a single-application framework

In section 3.1 competition for deposits will take place before loans whereas in section 3.2 the reverse will happen. We discuss our results derived in a single-application framework in section 3.3.

3.1 'Deposits-first' game: Competition for deposits before competition for borrowers

a. Description of the 'Deposits-first' game

In this section we consider the following game:

Stage 1. Banks compete for deposits. Each bank i offers a deposit rate r_D^i, which cannot be revised later in the game.

Stage 2. Depositors observe all banks' price offers. Each depositor can apply to one bank at most. These offers are registered by banks which retain the right to accept or to reject them later.

Stage 3. Banks observe all gross deposit rates r_D^i and all depositors' actions. Banks, if provided with funds holders applicants, then compete for loan applicants by making a price offer. Bank i posts the credit rate r_L^i, which cannot be revised later in the game.

[6] r_D^{min} can also be interpreted as an outside option available to all depositors.

Stage 4. Borrowers observe all banks' price offers and each applies to one bank at most.

Stage 5. Each bank i then uses the following rationing rule: the amount borrowed from depositors and lent to the borrowers, L^i, is the minimum between the deposits that bank i can attract, S_D^i, and the demand for credit it faces, D_L^i. Borrowers or depositors who registered an offer necessarily carry out their plan if the bank accepts their offer. Agents in excess (either depositors or borrowers) are rejected at random by banks and we assume for the time being that they cannot reapply to another bank.

Although banks compete in the deposit market first and commit themselves to the deposit rates posted, they do not take any decision with respect to the amount of deposits they accept before competing in the loan market: the decision by banks to reject some agents takes place after both markets have been visited. This aspect of the game is a key difference from Stahl's [10] model of intermediation in the goods market and from the Freixas and Rochet [4] model of financial intermediation, where all customers in the first market are accepted.

Note that no additional price offers are made to these rejected agents. Notice also that banks without deposits after stage 2 do not make any price offer at stage 3. This seems a reasonable assumption given that there is no way to get funds later in the game. This assumption will be discussed in section 3.3 and relaxed later when rejected depositors are allowed to move to another bank (section 4).

Throughout the paper we assume that borrowers and depositors are atomless and myopic agents who systematically apply for the most attractive rate, regardless of their probability of being rejected. This is the standard assumption made in the literature on Bertrand-Edgeworth competition. [7] In addition, when depositors or borrowers are indifferent between applying to one bank or another, they distribute themselves so that there is an "equal split" of depositors or borrowers among all banks posting the same rate.[8]

[7] See Vives[13] chapter 5 for a review of models of Bertrand and Edgeworth.

[8] One can object that unless there is a centralised system, the choice of a bank even made at random will not lead to an equal split of customers among banks. Nevertheless, banks have no choice but reasoning on average, and in average terms there is an equal split for price tie.

Consequently, the supply of deposits S^j_D that a bank j faces when posting a deposit rate r^j_D is characterized as follows:

$S^j_D = \frac{S_D(r^j_D)}{K}$ if $r^j_D \geq r^i_D$ with $K = \{i \in B; r^j_D = r^i_D\}$

and where S_D is the aggregate supply of deposits;

$S^j_D = 0$ otherwise.

The demand for loans D^j_L that a bank j faces when posting a credit rate r^j_L is characterized as follows:

$D^j_L = \frac{D_L(r^j_L)}{H}$ if $r^j_L \leq r^i_L$ with $H = \{i \in B; r^j_L = r^i_L\}$

and where D_L is the aggregate demand for loans;

$D^j_D = 0$ otherwise.

As only banks with lending capacities have access to the loan market, a key feature of the game is that whenever one bank posts the highest deposit rate, it captures all deposits and gets a monopoly position in the credit market.

The expected profit of a bank i which posts the rates r^i_L and r^i_D , when the competitors post r^j_L and r^j_D, can be written as

$$E\pi^i(r^i_L, r^i_D, r^j_L, r^j_D) = \left[ER(r^i_L) - (1 + r^i_D)\right] L^i(r^i_L, r^i_D, r^j_L, r^j_D) \tag{1}$$

where

$$L^i = \min\{S^i_D, D^i_L\}. \tag{2}$$

The competition which we model is definitely not pure Bertrand competition: in one-sided pure Bertrand competition the price-setting firm is assumed to be able to satisfy the whole demand whereas in our approach the amount of loans in the credit market is constrained by the amount of deposits collected by the bank, so that the demand for credit may be rationed. Consequently, in our models there is a sort of capacity constraint due to the deposit constraint which makes the type of competition analyzed here closer to Edgeworth-Bertrand competition. However, contrary to the standard literature on Edgeworth-Bertrand competition, capacities here are not exogenously given.

Given that banks observe the constellation of deposit rates at stage 3, a bank' strategy is composed of one deposit rate and a set of credit rates, one for each possible deposit-rate constellation. The game exhibits subgames corresponding to banks' intervention in the credit market and the related applications by the borrowers. The game is solved by backward induction and our objective is to characterize the subgame perfect Nash equilibria (hereafter SPNE) of the game: we first consider the banks' credit rate offers at stage 3 for each possible combination of deposit rates (and the associated supplies of deposits resulting from the optimal decision of depositors) when the banks anticipate the optimal decision by borrowers. The following step is the study of banks' deposit rate offers at stage 1, taking into account the equilibria we will have found for the credit market subgames.

b. Stage 3: The credit market subgame

Here we analyze only the two relevant configurations: the first where all banks offer the same deposit rate and thus have an equal share of funds; the second is a situation in which one bank offers a deposit rate higher than the other banks.[9]The deposit rate r_D – the highest posted rate – leads to an aggregate deposit supply $S_D(r_D)$, which is either split equally among all banks if they post the same deposit rate, or captured entirely by the bank with the highest rate. When one bank captures all deposits, this bank becomes a monopolist in the loan market and charges the monopolist credit rate. In the case where all banks post the same deposit rate, the following subgames are typically situations à la Edgeworth, i.e., Bertrand competition in the credit market with capacity constraints (each bank having an equal share of the funds) and constant marginal cost (equal to the deposit rate). Let us denote by r_L^{MC} (where the superscript MC stands for "market clearing") the gross credit rate which would clear the credit market for a supply of credit equal to the funds provided at r_D . This means that $S_D(r_D) = D_L(r_L^{MC})$. The higher the deposit factor, the lower the market-clearing credit rate. Let us denote by r_L^{ZUP} the lowest credit factor leading to a zero unit profit (hence the superscript ZUP): $ER(r_L^{ZUP}) = 1 + r_D$. As r_L^{ZUP} is located on the upward-sloping portion of ER, the higher the deposit rate, the higher the zero unit profit credit rate.

[9]We present only these two configurations for the following reasons. An equilibrium happens to be a constellation in which all banks offer the same deposit rate. The constellations in which one bank offers a deposit rate higher than all the others (the latter being equal) will be useful for analyzing the deviations. They will help to show which constellation, among those displaying identical rates, will be the equilibrium.

Three cases must be analyzed for the subgames, as they give rise to different Nash equilibrium (henceforth NE) outcomes in the credit market. They are distinct from each other with respect to the relative position of r_L^{ZUP}, r_L^{MC} and $\tilde{r}_L$.

Proposition 1 *('Deposits-first' game: Equilibria in Credit Market Subgames)*

1. *When all banks post the same deposit rate r_D lower than or equal to $ER(\tilde{r}_L) - 1$,*

   (i) *if $r_L^{MC} > \tilde{r}_L$, the continuum of NE in the subgame is the interval $\left[r_L^{ZUP}, \tilde{r}_L\right]$. The bank profit maximizing NE is $\tilde{r}_L$ and is characterized by credit rationing;*

   (ii) *if $r_L^{MC} \leq \tilde{r}_L$ and $ER(r_L^{MC}) \geq 1 + r_D$, the continuum of NE in the subgame is the interval $\left[r_L^{ZUP}, r_L^{MC}\right]$. The bank profit maximizing NE is r_L^{MC} and is characterized by credit market clearing;*

   (iii) *if $r_L^{MC} < \tilde{r}_L$ and $ER(r_L^{MC}) < 1 + r_D$, the unique NE in the subgame is r_L^{ZUP}, which gives rise to deposit rationing.*

2. *When one bank offers a deposit rate higher than its competitors', the equilibrium of the subgame is the monopolistic credit rate, which is $\tilde{r}_L$ with credit rationing in configuration (i), a rate between r_L^{MC} and $\tilde{r}_L$ generating deposit rationing in configuration (ii), and a rate between r_L^{ZUP} and $\tilde{r}_L$ in configuration (iii) with deposit rationing.*

The Nash equilibria are characterized by non-negative expected profit (credit rate larger or equal to r_L^{ZUP}), are located on the upward-sloping portion of ER and cannot exhibit both deposit rationing and positive expected profit. Equilibria can be characterized by positive expected profit if credit is rationed. Indeed Bertrand competition in the credit market does not always result in an incentive for any bank to undercut its competitors' prices. Here, due to the capacity constraint represented by the deposit endowment inherited from the first two stages of the game, a positive profit (as in cases (i) and (ii)) can be the outcome of the credit market subgame. It is indeed unprofitable for a bank to attract borrowers through a cut in its credit rate if it has no funds available to face the additional demand. This is the usual result in an Edgeworth-Bertrand framework.[10] In contrast, this decrease in the credit rate is always profitable when there is initially an excess of deposits with positive expected profit.

Among the range of all possible NE for cases (i) and (ii), the highest credit rate is profit maximizing for banks, as it provides all banks with the highest expected return, for the same amount of loans (equal to the binding supply of funds).

When the deposit rate posted by all banks increases, r_L^{ZUP} increases too whereas r_L^{MC} decreases. For the highest deposit rate compatible with banking activities, $r_D = \widetilde{ER}(r_L) - 1$, all cases give the same unique NE $r_L^{ZUP} = \tilde{r}_L$ which can exhibit either credit or deposit rationing. Let now refer to the two configurations illustrated in Figure 2. One can see that with a deposit supply curve like S'_D, the credit market is successively switching from case (i) to case (ii) and then from case (ii) to case (iii) with the increase in the deposit rate. With S''_D, although the deposit rate increases, the credit market remains always in case (i), even for the highest deposit rate $r_D = \widetilde{ER}(r_L) - 1$.

c. Stage 1: Competition for funds

We now consider the first two stages of the game, using the outcomes of the credit market subgames analyzed in the previous subsection. What is the outcome of competition for deposits among banks, when they anticipate the related outcome in the credit market? The following proposition states that the banks must post the highest possible deposit rate.

Proposition 2 *(SPNE in 'Deposits-first' game) The SPNE are characterized by all banks posting the same deposit rate equal to* $ER(\tilde{r}_L) - 1$ *and the same credit rate* $\tilde{r}_L$*. For off-equilibrium subgames, credit rates are defined as in Proposition 1. This SPNE can lead to credit rationing, deposit rationing, or (very fortuitously) to credit market clearing.*

As there is a continuum of NE in off-equilibrium subgames, there is also a continuum of SPNE in the game. However they are all characterized by the same outcome at equilibrium.

[10] Notice that we do not face any problem of existence of equilibrium as in the traditional Edgeworth framework because borrowers rejected by a bank here cannot move to another one, so that a deviation through an increase in the credit rate is never profitable.

Competition in the deposit market drives the deposit rate up to its highest value, compatible with profitability. Indeed if the deposit rate were not at this highest level, any bank would then have the incentive to offer a slightly higher deposit rate in order to capture the whole deposit market and then reach a monopoly position in the credit market.An equilibrium must consequently display a deposit rate so high that this mechanism of pushing the rate up cannot operate any longer. As the top of ER constitutes a ceiling for the deposit rate, this is the level at which the deposit rate will be set at equilibrium.[11]

Proposition 2 predicts the emergence of deposit rationing for $S_D^{'}$, as Bertrand competition drives the deposit rate above the Walrasian level. In the double-sided Bertrand competition, a deviation through an increase in the deposit rate can never be made unprofitable because of a binding demand for credit. Indeed, the increase in the deposit rate raises not only the amount of funds available to the deviating bank but also the demand for credit that it faces, due to the monopoly position.

Credit rationing is a possible outcome of the game, when $S_D^{"}$ prevails. The case with credit rationing is illustrated in Figure 3.

[FIGURE 3 ABOUT HERE]

Among the borrowers rejected because of a lack of funds, most of them would have been strictly better off with the loan.

3.2 'Loans-first' game: Competition for borrowers before competition for funds

a. The description of the 'Loans-first' game

In this section we consider a game which reverses the order of banks' intervention in the deposit and credit markets. At stage 1, banks compete for loans applicants and borrowers apply at stage 2. At stage 3, banks with loan applicants compete in the deposit market and depositors apply at stage 4. The other characteristics of the game such as the sharing and rationing

[11]Through the rationing scheme, the amount of deposits remunerated by the banks is always equal to the amount of loans they supply. The deposit factor can thus be driven up to $\widetilde{ER}$ without violating the condition of a non-negative total expected profit.

rules remain unchanged. Given that banks observe the constellation of credit rates at stage 3, a bank' strategy is composed of one credit rate and a set of deposit rates, one for each possible credit rates constellation.

Given the access condition to the deposit market, a bank which manages to capture all borrowers at stage 2 gets a monopoly position in the deposit market.

b. Stage 3: The funds market subgame

Here we only analyze two configurations: one in which all banks offer the same credit rate and thus get an equal share of loan applicants, and a second one where one bank posts a lower credit rate than its competitors and captures the whole market. Let us assume that all banks (or the most attractive bank if one bank charges a credit rate lower than its competitors) post r_L lower than r_L^{max} in order to guarantee a positive demand for credit. The credit rate r_L leads to the aggregate credit demand $D_L(r_L)$. Let us denote by r_D^{MC} the deposit rate which, if posted by all banks, would clear the deposit market: $S_D(r_D^{MC}) = D_L(r_L)$. Let us denote r_D^{ZUP} the deposit factor which leads to a zero unit profit: $r_D^{ZUP} = ER(r_L) - 1$. The lower the credit rate, the higher the market-clearing deposit rate and the lower the zero unit profit deposit rate (on the upward-sloping portion).

The NE in the deposit subgames depend on the relative magnitude of r_D^{MC} and r_D^{ZUP}. In the following proposition we define the Nash equilibria of the subgames.

Proposition 3 *('Loans-first' game: Equilibria in Deposit Market Subgames)*

1. *For subgames where all posted credit rates r_L are the same, lower than r_L^{max} with $ER(r_L) > 1 + r_D^{min}$*

   (i) *If $r_D^{MC} \leq r_D^{ZUP}$, the NE of the subgame is the interval $\left[r_D^{MC}, r_D^{ZUP}\right]$. The bank profit maximizing NE is r_D^{MC} and the market clears.*

   (ii) *If $r_D^{MC} > r_D^{ZUP}$, the NE of the subgame is r_D^{ZUP}. This amounts to credit rationing.*

2. *In the configuration where one bank offers a credit rate lower than the one charged by its competitors, the equilibrium deposit rate is the monopolistic one, which is a rate between r_D^{min} and r_D^{MC} in case (i), and between r_D^{min} and r_D^{ZUP} in case (ii).*

Credit rationing combined with a positive expected profit is ruled out as NE since it would be profitable for any bank to increase the deposit rate in order to collect more funds and to lent more. Credit rationing could survive only if the increase in the deposit rate would lead to a negative expected profit. Notice again that Bertrand competition in the deposit market does not result in an incentive for any bank to overbid its competitors' prices. A positive profit (as in case (i)) can be the outcome of the game, because the demand for credit acts as a constraint.

c. Stage 1: Competition for loan applicants

We now consider the first two stages of the game, using the outcomes of the deposit market subgames analyzed in the previous subsection. Competition in the credit market drives the credit rate down to its lowest value compatible with banking activity.

Proposition 4 *(SPNE in 'Loans-first' game) The SPNE are composed of a deposit rate* r_D^{min} *and a credit rate on the upward-sloping portion of* ER *such that* $ER(r_L) = 1 + r_D^{min}$*. The off-equilibrium-path deposit rates are defined as in Proposition 3. This SPNE can lead to credit rationing, to deposit rationing, or (very fortuitously) to market clearing.*

Again due to a continuum of NE in off-equilibrium subgames, there is also a continuum of SPNE in the game. However they all are characterized by the same outcome at equilibrium.

The case with credit rationing is illustrated in Figure 4.

[FIGURE 4 ABOUT HERE]

The core of the argument is that if banks post a credit rate higher than $ER^{-1}(1 + r_D^{min})$, any bank would have an incentive to offer a slightly lower credit rate to capture the whole loan market and be a monopolist in the deposit market.

Credit rationing appears as a more likely outcome for this game than for the previous one. Indeed, for a given demand-for-credit function and a given supply-of-deposit function, the equilibrium in this game is necessarily characterized by lower credit and deposit rates than in 'Deposits-first' game.

This implies that the demand for credit is larger than for the other game whereas the supply of deposits is smaller. The gap between demand for credit and supply of deposits is necessarily larger at the equilibrium of the present game, giving credit rationing a higher chance to occur. As an illustration, notice that with S'_D credit rationing emerges in 'Loans-first' game but not in 'Deposits-first' game.

Notice that credit rationing is now compatible with the application of all borrowers in the credit market, in contrast to the previous game: if r_D^{min} is low enough, the equilibrium loan rate may be lower than the reservation value of the best borrowers, which guarantees that all types of borrowers apply for a loan. In any case, the pool of loan applicants is always larger and of better quality in this game than in 'Deposits-first' game.

3.3 Discussion and implications of the single-application framework

a. The role of the sequence of price-setting

We have shown in the previous sections that the two games in a single-application framework generate two polar outcomes, illustrating that the sequence in the price-setting, regardless the commitment in quantity in the first market, is crucial. Competition in the first market is fierce because posting the best price in that market guarantees a monopolistic position in the second market. In order to better understand the contribution of a sequential game, let us briefly describe the outcome which would have emerged if offers had been made simultaneously, in a framework where borrowers again cannot apply to another bank if rejected. When there is no mobility at all, Nash equilibria are all pairs (r_D, r_L) characterized by a zero unit profit on the positive slope of ER between $r_D = r_D^{min}$ and $r_D = \widetilde{ER} - 1$.[12] The multiplicity of equilibria is due to the fact that a profitable deviation requires a more attractive interest rates in both markets, which becomes impossible as long as the expected unit profit is zero. In sequential games with a single application, a more attractive interest rate in the first market is sufficient

[12] A positive profit is not possible at equilibrium since a simultaneous increase of the deposit rate and decrease of the credit rate allows the deviating bank to capture all deposits and all borrowers, so that there is necessarily a discrete jump in the quantities which more than offsets the decrease in the unit profit.

for a bank to deviate, regardless of the other price. Deviating is therefore made easier and only one outcome at equilibrium survives.

b. The access condition

The reader may wonder if the access condition that we have imposed to the second market - a bank deprived of applicants on the first market cannot make a price offer on the second market - is not directly responsible for our result. We now discuss this point. At first sight, the assumption of an access condition to the second market is quite reasonable in a framework where a bank without customers after the first two stages have no way to capture applicants later in the game. However, one cannot deny that the banks without customers could decide to adopt a form of retaliation policy, consisting in being very competitive in the second market. In subgames where one bank captures all customers in the first market one bank without applicants could post a credit rate such that it gives an ER lower than the highest deposit rate, driving the bank with all customers to no activity. The deviations through a better price being disactivated in this way, both games have a multiplicity of SPNE, consisting in all vectors with identical rates for the first market. The associated prices in the second market are then defined as in Proposition 1 (for 'Deposits-first' game) or Proposition 3 (for 'Loans-first' game). Some SPNE would then admit a strictly positive expected profit. For a proof of this result, see Bracoud [3].[13] The introduction of more rational customers in the second market nevertheless could justify the results that we have derived in the previous sections, even in the absence of an access condition to the second market. If banks without customers after the first two stages of the game post a better price in the second market, as part of a retaliation policy, customers in the second market may realize that going for the best rate would imply being rejected with probability one. They may therefore decide rationally to go for the bank with all customers after the first two stages of the game, even if the price posted by that intermediary in the second market is less attractive. From that perspective, our results described in Proposition 2 and 4 are robust to the removal of the access condition to the second market.

[13] One could consider, in particular, that the collusion outcome of the game could be sustained by such retaliatory policies from competitors.

c. Credit rationing and asymmetric information

In Figure 3 and 4, we have illustrated that both games could generate credit rationing. A major difference however between the two models is that asymmetric information plays no role in generating the credit rationing result in the second game, whereas it was essential in the first one.

Asymmetric information is directly responsible for credit rationing, when this phenomenon happens in 'Deposits-first' game. In a symmetric framework such a rationing would be ruled out. When banks can distinguish among borrowers, the expected return for each type of borrower is monotonically increasing in the credit rate charged to this type, up to the point where this type of borrower decides to leave the credit market because his investment becomes unprofitable. Competition in the deposit market at the first stage of the game would drive the deposit rate to its maximum value, i.e. at the highest value of ER. Under Stiglitz and Weiss' assumption of common expected return for all project, this corresponds to the ER at which all borrowers are indifferent between applying for a loan and leaving the market. In such a context even a shortage of funds cannot be interpreted as credit rationing as loan applicants at this rate do not suffer from being rejected.

In contrast in the loans-first game, even if the expected return were a strictly increasing function of the credit rate resulting from symmetric information, we would still get credit rationing. Competition in the credit market in the first stage of the game compels the banks to post the lowest possible credit rate for every given type. The lowest credit rate for each type of borrowers compatible with profitable banking activities necessarily corresponds to an expected return equal to r_D^{min}. The 'loans-first' game therefore suggests that credit rationing could be approached from a totally different perspective, independently of informational problems. Credit rationing could be the result of a tough Bertrand competition on the credit market, rather than the consequence of asymmetric information.

Remark 1 *(Credit rationing and adverse selection) In Stiglitz and Weiss's [11] framework, asymmetric information in the loan market is necessary to generate credit rationing if and only if Bertrand competition in the deposit market drives the interest rates. When Bertrand competition in the credit market is the driving force, credit rationing may emerge without adverse selection.*

4 Multiple applications for borrowers and/or depositors

In section 3 we assumed that a borrower or a depositor could apply at most to one bank. Now we consider multiple applications by borrowers or depositors (equivalently referred to as 'mobility' hereafter), which we believe is a more realistic assumption. At stage 2 or stage 4 of the game, the depositors and/or the borrowers choose a list of banks whose order reflects the sequence that agents will respect when they visit banks at stage 5 after being rejected. We assume that depositors and/or borrowers can visit all banks at no additional cost. The discussion on multiple applications requires that we allow all banks to make a price offer in the second market regardless their performance in the first one, as they can capture customers later in the game.

In our multiple-application framework, the same polar outcomes as in the single-application framework prevail. However, our major finding is that the timing in the competition for deposits and loans is not the key element any longer in explaining the emergence of one equilibrium rather than the other. What really matters now is the specification of the mobility of the customers and the rationing scheme. The outcome will depend on who among borrowers or depositors can reapply after being rejected, and if both can, the crucial element will be the timing in the rejection of excess depositors or excess borrowers.

The possibility for multiple applications affects the banks' behaviour as a less attractive price can now attract a positive demand (or supply) from rejected customers. The mobility of customers in only one market weakens the competition in that market in favour of the competition in the other market, regardless of the timing in competition. Put differently, multiple applications in one market are equivalent, in terms of competition pressure, to the case where competition on this market took place at a second stage in the single-application framework. Competition in the market where there is no mobility is fierce as there is no way to catch these customers later, and the capacity built up on that market may influence the ability to get customers from the other market. When both depositors and borrowers can reapply after rejection, the outcome depends on the specification of the rationing scheme, in particular the timing in the rejection process. When rejection takes place in two different stages for borrowers and depositors, reapplication by those in the second group would be totally inoperative and superfluous since they are bound to be subsequently rejected by all other banks. This implies that in the following analysis of multiple applications we only need to consider the mobility of the first group to be rejected.

4.1 Multiple applications with excess depositors rejected first

To begin with, let us assume that excess depositors are the only to be rejected or are rejected first at stage 5 of the games and have the possibility to apply to other banks in accordance with the list of banks selected in stage 2 (Deposits-first game) or at stage 4 (Loans-first game). We maintain the assumption that depositors are myopic so that the order in which they visit the banks simply reflects the banks' price attractiveness: rejected depositors visit the banks offering the next more attractive price, and so on, up to the point where depositors are finally accepted or have no new bank to visit. We assume that the rationing scheme in stage 5 is the following: depositors in excess (with respect to the quantity of borrowers attracted by banks' price offers) are rejected first and once depositors have finished their movements from bank to bank as specified in the list, borrowers can in turn be rejected, on the basis of the banks' definitive amount of deposits. As already explained even though they may be allowed to reapply this is meaningless as they will necessarily be rejected by all the subsequent banks.

Depositors and borrowers are rejected through the so-called proportional rationing scheme: banks select the rejected customers at random, so that each agent has exactly the same probability of being rejected.

The multiple successive applications by depositors necessarily affect the sharing rules for deposits in 'Deposits-first' and 'Loans-first' games. Here is the case of two banks:

$$S_D^j = S_D(r_D^j) \text{ if } r_D^j > r_D^i$$

$$S_D^j = \max\left\{0; \left(\frac{S_D(r_D^i) - D_L^i(r_L^i)}{S_D(r_D^i)}\right) S_D(r_D^j)\right\} \text{ if } r_D^j < r_D^i.$$

$$S_D^j = \max\left\{\frac{S_D(r_D)}{2}; S_D(r_D) - D_L^i(r_L^i)\right\} \text{ if } r_D^j = r_D^i = r_D.$$

In the second case, although bank j offers a less attractive price, it can expect a positive amount of deposits, given that bank i with the most attractive price may reject some depositors.

Due to the dual nature of Bertrand competition in this game, if a bank captures all borrowers it can eventually collect all deposits as well, regardless the attractiveness of its deposit rate offer.[14] This feature was also the key characteristic of 'Loans-first' game in a single-application framework and it is therefore not surprising that the outcome is similar.

Proposition 5 *(SPNE with multiple applications and depositors first rejected) The mobility of depositors, combined with the assumption that depositors are rationed by banks before borrowers, makes 'Deposits-first' and 'Loans-first' games converge on the same SPNE* $(r_D^{min}, ER^{-1}(1 + r_D^{min}))$*. The off-equilibrium-path rates are unique and different for the two games. In the 'Deposits-first' game, the NE in the credit subgames is* $r_L^{ZUP}(r_D)$*. In the 'Loans-first' game, the NE in the deposit subgames, if it exists, is* $r_D^{MC}(r_L)$ *in case (i), and* $r_D^{ZUP}(r_L)$ *in case (ii).*[15]

Multiple applications by depositors who are rejected first weaken competition on the deposit market, even in the case where the deposit market is the first market to be visited. In that case, not fighting on the deposit market is even the best strategy in order to be able to lead a more attractive price policy on the credit market: a lower deposit rate allows to post a lower credit rate. At the opposite, competition on the credit market becomes really decisive since a bank which has succeeded in attracting all borrowers can expect to collect all deposits rejected by competitors.

Note that we could have derived the same results with a parallel rationing scheme, where the depositors with the highest valuation are served first. When $S_D^j = \max\left\{0; S_D(r_D^j) - D_L^i(r_L^i)\right\}$ if $r_D^j < r_D^i$ then a bank getting all the demand for credit is guaranteed to get all the deposit supply.

4.2 Multiple applications with excess borrowers rejected first

Let us now briefly turn to the case where borrowers can move from bank to bank and are rejected before depositors. The rationing scheme in stage 5 is

[14] With an unattractive interest rate on deposits but all borrowers, the residual supply that a bank can expect is
$S_D^j = \max\left\{0; \left(\frac{S_D(r_D^i)-0}{S_D(r_D^i)}\right) S_D(r_D^j)\right\} = S_D(r_D^j)$.
With the same interest rate on deposits but all borrowers, the residual supply that a bank can expect is
$S_D^j = \max\left\{\frac{S_D(r_D)}{2}; S_D(r_D) - 0\right\} = S_D(r_D^j)$.
[15] The cases refer to Proposition 3.

the following: borrowers in excess (with respect to the quantity of depositors attracted by banks' price offers) are rejected first and once borrowers have finished their movements from bank to bank as specified in the list, depositors can in turn be rejected, on the basis of the banks' definitive amount of borrowers. Notice that in our imperfect information environment, the proportional rationing scheme is the only way for the banks to proceed, since they cannot distinguish among borrowers.

Quite straightforwardly,

$$D_L^j = D_L(r_L^j) \text{ if } r_L^j < r_L^i$$

$$D_L^j = \max\left\{0; \left(\frac{D_L(r_L^i) - S_D(r_D^i)}{D_L(r_L^i)}\right) D_L(r_L^j)\right\} \text{ if } r_L^j > r_L^i$$

$$D_L^j = \max\left\{\frac{D_L(r_L)}{2}; D_L(r_L) - S_D(r_D^i)\right\} \text{ if } r_L^j = r_L^i = r_L$$

Competition in the credit market is significantly weakened (even in the game where the credit market is the first market to be visited), since a non-attractive price in the credit market can be rational: a bank with a non-attractive price can expect to capture borrowers rejected by its competitors. Competition in the deposit market becomes fierce since an attractive price in the deposit market, which provides the bank with all deposits, will be an indirect way to attract all borrowers, whatever the rate posted on loans.

Mechanisms similar to 'Deposits-first' game in a single-application framework lead to the following conclusion:

Proposition 6 *(SPNE with multiple applications and borrowers rejected first) In a framework where borrowers can move from bank to bank and are rejected before depositors, both games converge on the SPNE ($ER(\tilde{r}_L) - 1$, $\tilde{r}_L$). The off-equilibrium-path rates are unique and different for the two games. In the 'Loans-first' game, the NE in the deposit subgames is $r_D^{ZUP}(r_L)$. In the 'Deposits-first' game, the NE in the credit subgames, if it exists, is $\tilde{r}_L$ in case (i), $r_L^{MC}(r_D)$ in case (ii),and $r_L^{ZUP}(r_D)$ in case (iii).*[16]

4.3 Discussion of the multiple-application framework

We have shown that the sequence in the price-setting of interest rates is not the important factor determining in which direction the rates are driven

[16] The cases refer to Proposition 1.

when the model allows multiple applications by borrowers and/or borrowers. We discuss below our results, and relate them to the conclusions in the existing literature.

a. Comparison with simultaneous interest rate offers

The previous section has taught us that the order in which the banks visit the markets is in fact not a key aspect of the games. The two games converge to the same SPNE when we allow for mobility of agents (one market only, or both markets). It is then not surprising that we find here exactly the same conclusions as those we would have reached by developing a game where the credit and deposit rates are simultaneously posted by banks. As already mentioned, when there is no mobility at all in a game with simultaneous offers, Nash equilibria are all pairs (r_D, r_L) characterized by a zero unit profit on the positive slope of ER between $r_D = r_D^{min}$ and $r_D = ER(\tilde{r}_L) - 1$. Let us introduce, in this framework with simultaneous price offers, the possibility for rejected borrowers (rejected before depositors) to apply elsewhere. Starting from any pair (r_D, r_L) (characterized by a zero unit profit on the upward-sloping part of ER) with r_D lower than $ER(\tilde{r}_L) - 1$, there is now an incentive to deviate through an increase in the deposit rate and an increase in the credit rate (while generating a positive unitary profit). The deviating bank collects all deposits and can then capture the borrowers rejected by its competitors, who are totally deprived of funds. The unique NE is $(ER(\tilde{r}_L) - 1, \tilde{r}_L)$. If we allow mobility only for depositors, we select the unique NE $(r_D^{min}, ER^{-1}(1 + r_D^{min}))$. The reason is that now, for a higher deposit rate, it is always profitable to decrease both the credit rate and the deposit rate, since by capturing all borrowers the bank is sure to capture all depositors rejected by its competitors who are totally deprived of loan applicants.

b. The role played by the non-commitment to serve all customers

The major change we have introduced in the modelling of sequential competition is the possibility to reject customers from the first market, whereas in Stahl [10], Freixas and Rochet, and the other models extending the original framework, competition in the first market implies serving all customers in that market. Acceptance of all customers in a market results in a single application by these agents. Therefore, in Stahl [10],and in Freixas and Rochet, intermediaries have to compete fiercely on the first market, simply because the customers in that market are not mobile. The order in the competition matters only because of this commitment to the quantities in the first market. Put differently, if we impose that the middlemen in Stahl's framework always accept to buy the stocks from the producers, we would find that competition in the input market is fierce regardless of the sequence in the price-setting. This is also the reason why by imposing that banks accept all depositors, Repullo [7] and Yanelle [14] have results similar to our 'Deposits-first' game in a single-application framework, although they study a simultaneous competition framework.

In Stahl, the two sequential games eventually converge to the same outcome, the Walrasian equilibrium, and therefore the author concludes that the timing does not really matter. Stalh also shows that price–setting by few middlemen in the input and output markets is equivalent to the case where the price would be fixed by a benevolent auctioneer. However, the acceptance of all customers in the first market generates opposite pressures on the prices in the two models, upwards for the input-first game and downwards for the output-first game. A priori, there is no reason why the two games would converge to the same outcome, as a bank technically can hold more stocks than it can sell (more deposits than loans) but cannot provide more sales than stocks (no more loans than deposits). We understand therefore that if the middlemen commit to serve all consumers, then the downwards pressure on prices stops at the Walrasian equilibrium because the stocks cannot be smaller than the demand. If the middlemen commit to buy all goods from producers, the upwards pressure on the prices could bring the prices beyong the Walrasian equilibrium, and possibly bringing a different outcome from the other game, as stocks can be larger than sales. This does not occur in Stahl because there is no equilibrium in that case. In the present paper, our assumption that banks can reject any excess allows us to push the prices beyond or below the Walrasian equilibrium. We show that price–setting by few financial intermediaires in the deposit and loans markets is not equivalent to the case where the price would be fixed by a benevolent auctioneer.

In Bracoud [3] we carry out the analysis of sequential competition among financial intermediaires when the latter commit to serve all depositors within an imperfect information context, à la Stiglitz and Weiss. This implies that, contrary to Stahl [10], the unit receipt is non-monotonic with respect to the price. The results are interesting as in cases where there is excess of deposits at $(ER(\tilde{r}_L) - 1, \tilde{r}_L)$, the Walrasian outcome will emerge. Indeed, if there is excess deposits at $r_D = \widetilde{ER} - 1$, which used to be the highest deposit rate in our present paper, then the expected profit is negative as the surplus of deposits now has to be remunerated as well. The obligation to pay all deposits, including those which will not be lent, therefore prevents the banks from posting a deposit factor as high as $\widetilde{ER} - 1$, as was the case in 'Deposits-first' game. The Walrasian outcome will emerge instead. However, and not surprisingly, credit rationing can also emerge in this new framework, contrary to Stahl's conclusions. The outcome in that case is the same as in the present paper as the outcome is obviously not affected by the fact that all depositors are accepted. Since no depositor was rejected anyway in the original game, total costs are unaffected, so that the deposit rate can rise as far as before.

5 Conclusion

This paper develops sequential games of Bertrand competition in the deposit and loan markets, where banks can also reject customers from the first market, and depositors and borrowers may be allowed to make multiple applications. Our main conclusion is that the sequence in the price-setting is not the key element to explain the direction in which the interest rates are driven. Generally speaking, in a double Bertrand competition environment, the interest rates are determined by the competition in the market for which customers are less mobile, or for which mobility comes too late.

1. When depositors and borrowers can only apply to one bank, it becomes crucial for banks to capture customers in the first market to have access to the second market. Competition is then particularly fierce in the first market to be visited, and in that particular case the timing of competition matters. When banks make their deposit rate offer before their credit rate offer ('Deposits-first' game), the Subgame Perfect Nash equilibrium maximizes the banks' expected return and is located at the highest deposit rate compatible with profitability. When credit rate offers are made before deposit rate offers ('Loans-

first' game), competition drives the credit rate (and the deposit rate) down to its lowest value compatible with banking activity.

2. When depositors or borrowers can apply to several banks, the timing in the visits of the markets is no longer the key element. Both games converge to the same outcome when they are characterized by the same assumptions concerning mobility of customers and the rationing scheme. If borrowers are the only agents to be allowed to apply elsewhere when rejected, or if they are rejected before depositors, Bertrand competition in both deposit and credit markets gives the outcome of the 'Deposits-first' game in the single-application framework, the deposit rate being driven up to its highest value. On the other hand, if depositors are the only agents to be allowed to move from bank to bank, or if they are rejected before borrowers, Bertrand competition in both deposit and credit markets generates the outcome of the 'Loans-first' game in a single-application environment, and the credit and the deposit rates are driven down to low levels.

These results show that in the original paper by Stahl [10] on competition among middlemen in the goods market, the prices where not driven by the sequence in the price-setting but simply by the assumption that middlemen commit to serve all customers in the first market.

Even though the timing of the competition is not a key element in the determination of interest rates, the present paper has underlined the existence of two possible alternative equilibria, depending on which side of the market it is more important to capture. We can therefore express some concern that so many papers in the credit maket literature overlook the modelling of competition in the deposit market. This paper has illustrated that the commonly-referred-to result of Stiglitz and Weiss [11] that asymmetric information explains credit rationing could not be derived from just any model with asymmetric information. In order to generate credit rationing due to asymmetric information, competition in the deposit market must be dominant such that an upwards pressure on interest rates takes place. We emphasize that credit rationing might not always be the consequence of asymmetric information, but might sometimes simply result from fierce competition in the credit market.

The present paper contributes to a better understanding of the forces that are in play in an environment of double Bertrand competition. Many other games should be examined in order to gain complete insight into the modelling of Bertrand competition in the deposit and credit markets. For example, it would be interesting to show the influence that strategic borrowers and/or depositors (whom we so far assumed to be myopic and insensitive to the probability to be a victim of rationing) could have on our results. The rationing schemes in this paper are exogenously given and a natural extension would be to endogeneize these schemes. Another possible development would be to introduce the interbank market, which may change the way the model deals with the extreme situation in which a bank has all deposits whereas its competitor has all loans applications. This paper provides a basis for extensions in these directions.

Appendix

Proof of Proposition 1

1. For subgames where the banks post the same deposit rate, lower than or equal to $ER(\tilde{r}_L)-1$,

   - A NE is necessarily composed of identical credit rates. A bank with a larger credit rate would be left without activity and then would have an incentive to decrease its credit rate to attract some borrowers.
   - A NE cannot exhibit a negative expected profit ($ER(r_L) \leq 1 + r_D$). Indeed, one bank with negative expected profit would then have the incentive to increase the credit rate to lose all its borrowers and thus give up banking activities.
   - A credit rate located on the downward-sloping portion of the ER curve cannot be a NE either. A decrease in the credit rate would then raise the expected return ER and would either increase the quantity lent when there was an excess of deposits or leave the quantity unchanged if the deposits were binding. As a result, the expected profit would unambiguously increase.
   - The above arguments leave us with the credit rates located on the upward-sloping portion of ER, and above r_L^{ZUP}. In addition, deposit rationing (i.e., $r_L > r_L^{MC}$) with a strictly positive expected profit cannot be a NE. With an excess of deposits, a bank has an incentive to decrease the posted credit rate to attract all borrowers and can thus significantly increase the quantity lent. The global expected profit of the deviating bank is then increased ($E\Pi(r_L - \epsilon, r_D) > E\Pi(r_L, r_D)$), even if the expected unit profit is slightly decreased ($[ER(r_L - \epsilon) - (1 + r_D)] < [ER(r_L) - (1 + r_D)]$) on the upward-sloping portion of the ER curve. This is due to the discrete jump in the quantities effectively lent (from $\frac{D_L(r_L)}{N}$ to $\min\left\{D_L(r_L - \epsilon); \frac{S_D(r_D)}{N}\right\}$). The only case where it is not possible to deviate from a situation with excess deposits is when the decrease in the credit rate would result in a negative unit profit. This is the case when we start from a zero-profit configuration located on the upward-sloping portion of the ER curve, i.e., r_L^{ZUP}.

- Finally let us show that it is unprofitable to deviate from a situation where credit offers are identical, higher than r_L^{ZUP}, located on the upward-sloping portion of ER, and characterized by credit rationing or market clearing. A decrease in the credit rate would decrease the expected return and the attraction of all borrowers would not raise the quantity of loans since the supply of deposits is binding. Such a deviation would unambiguously be unprofitable. An increase in the credit rate is not profitable either, because the deviating bank would then be deprived of borrowers.

2. Let us now turn to the constellation where one deposit rate is strictly higher than the others. The bank with the most attractive price attracts all deposits and is thus the only one to have access to the credit market. The equilibrium credit rate is then the monopolistic rate. The latter cannot be on the downward-sloping portion of ER, since a decrease in the credit rate raises the unit expected profit and potentially the amount lent if the demand was binding. The monopolistic rate cannot be characterized by credit rationing either: when the supply of funds is binding, the total expected profit is increased through an increase in the credit rate since the amount lent remains the same and the unit expected profit is unambiguously increased on the upward-sloping portion of ER. It follows that the equilibrium in the subgame is $\tilde{r}_L$ in case (i), is located somewhere between r_L^{MC} and $\tilde{r}_L$ in case (ii), and between r_L^{ZUP} and $\tilde{r}_L$ in case (iii). For the last two cases, the equilibrium is the credit rate which equates marginal revenue and marginal cost, taking the demand for credit to be the amount lent.

Proof of Proposition 2

- At equilibrium, it is impossible for a bank to post a deposit rate lower than others'. It would have no funds at all and would be compelled to give up banking activities. It would then have an incentive to deviate by offering the same deposit rate as the most attractive bank.

- It is not possible for banks to post a deposit rate higher than $ER(\tilde{r}_L)-1$ either, as this generates a negative profit. Some bank would then always have an incentive to post a deposit rate lower than the others' to give up lending activities by a lack of funds.

- It is not possible, either, that banks post a deposit rate strictly lower than $ER(\tilde{r}_L) - 1$. Indeed, one bank would then have the incentive to offer a slightly higher deposit rate in order to capture the whole deposit market and reach a monopoly position in the credit market. Even if the deviating bank did not post the monopolistic optimal credit rate at stage 3 but upholds the credit rate which was a NE in the subgame where all banks offered a deposit rate lower than $ER(\tilde{r}_L) - 1$, it could increase its expected profit by simply benefitting from a jump in the quantity lent, which more than offsets the loss due to the infinitesimal increase in the unit cost of funds:

$$\begin{aligned} E\Pi(r_L, r_D + \epsilon) &= [ER(r_L) - (1 + r_D + \epsilon)] \min\{D_L(r_L), S_D(r_D + \epsilon)\} \\ &> \\ E\Pi(r_L, r_D) &= [ER(r_L) - (1 + r_D)] \min\left\{\frac{D_L(r_L)}{N}, \frac{S_D(r_D)}{N}\right\} \end{aligned}$$

With the monopolistic credit rate the increase of the profit would be even larger.

- Let us check, finally, that there is no profitable deviation from $r_D = ER(\tilde{r}_L) - 1$ (with the subgame equilibrium at $r_L = \tilde{r}_L$). An increase in the deposit rate would entail a negative expected profit, whereas a decrease would deprive the deviating bank of its funds.

Proof of Proposition 3

1. We begin the proof with the subgames where all posted credit rates are the same.

    - The deposit offers have to be the same for all banks in a NE. A bank posting a lower deposit rate would be deprived of deposits and would thus have an incentive to raise its deposit rate to have deposits and activity.
    - A deposit rate which would lead to a negative expected profit for the banks, i.e. $r_D > r_D^{ZUP}$, cannot be a NE. One bank would have an incentive to decrease the deposit rate to have no deposits and thus give up banking activities.
    - A deposit rate generating a deposit deficit (i.e., $r_D < r_D^{MC}$) cannot be a NE if associated with a strictly positive unit profit. With

an excess of credit applicants, a bank has an incentive to increase the posted deposit rate so as to attract all depositors and thus significantly increase the quantity lent. The global expected profit of the deviating bank is thus increased, even if the expected unit profit is slightly decreased. The only case where it is not possible to deviate from a situation with a deposit deficit is when we start from a situation with a zero unit profit. The increase in the deposit rate would then result in a negative unit profit.

- Let us now show that there is no profitable deviation from a situation where the deposit rate is higher than the market-clearing one and lower than r_D^{ZUP}. An increase in the deposit rate would be useless since the demand for credit is binding whereas a decrease in the deposit rate would deprive the bank of deposits.

2. Let us now turn to the constellation where one credit rate is lower than the others. All borrowers choose this bank which therefore has a monopolistic position in the deposit market. This bank is thus able to post the monopolistic deposit rate. This rate cannot be characterized by deposit rationing, since an increase in the deposit rate would leave the quantity lent unchanged (since the demand for credit is binding) but would profitably raise the expected return. The rate is chosen in such a way that it equates marginal revenue and marginal cost, taking the supply of deposits to be the quantity lent.

Proof of Proposition 4

- It is not possible, at equilibrium, for one bank to post a higher credit rate than the others. This bank would have no loan applicants at all and would have to give up banking activities. It would thus have an incentive to deviate by offering the same credit rate as the others in order to get activity.

- We are not interested in the case where banks post a credit rate lower than $ER^{-1}\left(1+r_D^{min}\right)$, as associated deposit rate in the subgame would have to be not higher than r_D^{min} (to avoid negative expected profit), implying an absence of funds to finance loans.

- It is not possible, either, for banks to post a credit rate higher than

$ER^{-1}\left(1+r_D^{min}\right)$. Indeed, one bank would have an incentive to offer a slightly lower credit rate to capture the whole loan market and induce a jump in the quantity lent, which more than offsets the loss due to the infinitesimal decrease in the unit return. This is profitable even if the deviating bank does not post the optimal monopolistic deposit rate. This rules out in particular the credit rates on the downward-portion of the expected return ER.

- We now simply apply Proposition 3 to the interest rate r_L^{min}. If r_D^{MC} exists for r_L^{min}, it is necessarily higher than or equal to $r_D^{ZUP} = r_D^{min}$. We are therefore in case (i) or (ii) of Proposition 3 and the optimal deposit rate is r_D^{min}, which entails credit rationing (if $r_D^{MC} > r_D^{min}$) or market clearing (if $r_D^{MC} = r_D^{min}$). This last case is very fortuitous and credit rationing is more likely.

Proof of Proposition 5

Let us begin with **'Deposits-first' game** where the deposit market is the first market to be visited.

1. Credit market subgames

   - The credit subgames where all banks offer the same deposit rate now exhibit only one NE, r_L^{ZUP}, characterized by a zero unit profit, as in the standard Bertrand competition without capacity constraints.

     Let us start from our results in Proposition 1 where we had $\left[r_L^{ZUP}, \tilde{r}_L\right]$ as NE for case (i), $\left[r_L^{ZUP}, r_L^{MC}\right]$ for case (ii), and r_L^{ZUP} for case (iii). We now rule out as equilibria all situations of positive expected profit. Indeed, if we start with a positive profit (i.e., $r_L > r_L^{ZUP}$), any bank has an incentive to post a lower credit rate to attract all borrowers. Although deposits captured by the deviating bank at the beginning of the game are binding before deviation, this bank will eventually capture the depositors rejected by the other bank totally deprived of borrowers and collect all deposits. In a way, the capacity constraint is automatically relaxed and then a discrete jump in the quantities takes place which more than offsets the decrease in ER.

- The credit market subgames where one bank offers a higher deposit rate than its competitor ($r_D > r'_D$) now surprisingly lead to no activity for the most attractive bank, rather than to a monopolistic outcome as previously in Proposition 1. Its competitor always has the opportunity to undercut it on the credit market (as $r_L^{ZUP} > r_L'^{ZUP}$) in order to get all borrowers and then to capture depositors rejected by the most attractive bank: $\left(\frac{S_D(r_D)-0}{S_D(r_D)}\right) S_D(r'_D) = S_D(r'_D)$.
  The bank profit maximizing NE in the subgame is $r_L = r_L^{ZUP}$ and r'_L is the minimum between $r_L^{ZUP} - \epsilon$ and the monopolistic credit rate. The bank with the lowest deposit rate captures both markets and generates a positive profit.

2. Deposit market and SPNE

   Starting from a subgame where all banks post the same deposit rate strictly higher than r_D^{min}, necessarily leading to a zero expected profit since the associated NE credit factor is r_L^{ZUP}, any bank has an incentive to decrease the deposit rate, since this deviation gives a positive profit with all customers. A deviation through an increase in the deposit rate would lead to no activity at all and is consequently not a profitable deviation. The only SPNE is then $(r_D^{min}, ER^{-1}\left(1 + r_D^{min}\right))$. [17]

Let us now turn to **'Loans-first' game**, where the credit market is the first market to be visited.

1. Deposit market subgames

   - Subgames exhibiting the same credit rate for all banks are affected by the mobility of depositors in the sense that now a decrease in the deposit rate may be profitable, since the deviating bank can potentially benefit from the rejection of funds by its competitor. Let us start from the outcomes of Proposition 3, with $\left[r_D^{MC}, r_D^{ZUP}\right]$ for case (i) and r_D^{ZUP} for case (ii). Any situation characterized by deposit rationing ($r_D > r_D^{MC}$) is now challenged

[17] A deviation through a decrease in the deposit rate is not profitable if the competitor always conducts a retaliation policy. In such a limit case, any pair $(r_L; r_D)$ characterized by a zero expected profit is a SPNE.

by a cut in the deposit rate. By choosing a deposit rate such that it remains higher than r_D^{MC}, the deviating bank guarantees that the effective quantity is still given by its demand for credit. Indeed, the residual supply in the case of a proportional rationing scheme is
$S_D(r_D - \epsilon)\left[\frac{S_D(r_D)-(\frac{1}{2})D_L(r_L)}{S_D(r_D)}\right] = S_D(r_D - \epsilon)\left[1 - \frac{1}{2}\frac{D_L(r_L)}{S_D(r_D)}\right]$
As $D_L(r_L)$ is lower than $S_D(r_D)$, $\left[1 - \frac{1}{2}\frac{D_L(r_L)}{S_D(r_D)}\right] > \frac{1}{2}$. This results in the residual supply to be larger than $\frac{1}{2}S_D(r_D - \epsilon)$ and in spite of a less attractive price, the effective quantity lent is still $\frac{1}{2}D_L(r_L)$. As the expected unit profit is unambiguously increased through the fall in the deposit rate, the deviating bank's expected profit rises. In case (i), the only potential NE in the subgame is thus r_D^{MC}. However its existence, as for r_D^{ZUP} in case (ii), is not guaranteed. A decrease in the deposit rate could still threaten them. A deviation through a decrease in the deposit rate from r_D^{MC} leads to a residual supply exactly equal to $\frac{1}{2}S_D(r_D - \epsilon)$ and is the effective quantity the deviating bank can lend. We face two opposite effects: on the one hand a decrease in the quantity lent, and on the other an increase in the expected unit profit through a fall in the deposit rate. If the rise in unit profit more than offsets the decrease in the quantity, the deviation is profitable and r_D^{MC} is not a NE.

- For subgames such that one credit rate is lower than the others, the equilibrium deposit rate is again the monopolistic one, as in the original game. The bank which has captured all the borrowers is not even compelled to post an attractive deposit rate, since it has the guarantee of collecting the deposits from the other banks anyway.

2. Credit market and SPNE

   Starting from a case where all banks post the same credit rate higher than $ER^{-1}\left(1 + r_D^{min}\right)$ and where there exists an equilibrium in the subgame, any bank has an incentive to decrease the credit rate. The only SPNE is thus the same as previously, i.e., $(r_D^{min}, ER^{-1}\left(1 + r_D^{min}\right))$.

Proof of Proposition 6

Let us begin with **'Loans-first' game** where the credit market is the first market to be visited. We give less details than for the previous proposition since the logic of this proof is equivalent to that of 'Deposits-first' game with mobility of depositors.

1. Deposit market subgames

    - The subgames where all banks offer the same credit rate now exhibit only one NE, r_D^{ZUP}, characterized by a zero unit profit. Let us start from the outcomes of Proposition 3, with $\left[r_D^{MC}, r_D^{ZUP}\right]$ for case (i) and r_D^{ZUP} for case (ii). From the continuum of NE, we can now rule out all situations leading to a strictly positive unit profit. Indeed, from a situation of positive unit profit ($r_D < r_D^{ZUP}$) any bank can deviate through an increase in the deposit rate. Although it faces a lack of demand for loans at the beginning of the subgame ($r_D > r_D^{MC}$), the deviating bank will eventually capture the borrowers rejected by the other banks totally deprived of deposits. The consequent jump in the quantity will more than offset the infinitesimal decrease in the expected unit profit.
    - The subgames where one bank offers a lower credit rate than its competitor ($r_L < r'_L$) now surprisingly lead to no activity for the most attractive bank, rather than to a monopolistic outcome as in Proposition 3. Its competitor can always overbid it in the deposit market and gets all deposits and all borrowers. The bank profit maximizing NE in the subgame is $r_D = r_D^{ZUP}$ and r'_D is the minimum between r_D^{ZUP} and the monopolistic deposit rate.

2. Credit market and SPNE

    Starting from a subgame where all banks post the same credit rate, strictly lower than $\tilde{r}_L$, necessarily leading to a zero expected profit since the associated NE deposit factor is r_D^{ZUP}, any bank has an incentive to increase the credit rate, since this deviation always gives a positive profit. The only SPNE is then $(ER(\tilde{r}_L); \tilde{r}_L)$.

Let us now turn to **'Deposits-first' game**, where the deposit market is the first market to be visited.

1. Credit market subgames

   - Subgames exhibiting the same deposit rate for all banks are affected by the mobility of borrowers in the sense that now an increase in the credit rate may be profitable since the deviating bank can potentially benefit from the rejection of loan applicants by its competitor. Let us start from our results in Proposition 1 where we had $\left[r_L^{ZUP}, \tilde{r}_L\right]$ as the NE for case (i), $\left[r_L^{ZUP}, r_L^{MC}\right]$ for case (ii), and r_L^{ZUP} for case (iii). We rule out situations where there is credit rationing since an increase in the credit rate is profitable. In case (i) the only equilibrium is $\tilde{r}_L$. For case (ii) the only potential Nash equilibrium in the subgame is r_L^{MC}, but its existence is not guaranteed. In case (iii) r_L^{ZUP} is the only potential NE but its existence is not guaranteed either.
   - For subgames such that one deposit rate is higher than the other, the Nash equilibrium is again the monopolistic one, as in the original game, regardless of the behaviour of competitor.

2. Deposit market and SPNE

   Starting from a case where all banks post the same deposit rate, lower than $\tilde{r}_D$, and where there exists an equilibrium in the subgame, any bank has an incentive to increase the deposit rate. The only SPNE is thus the same as previously, i.e., $(E(\tilde{r}_L), \tilde{r}_L)$.

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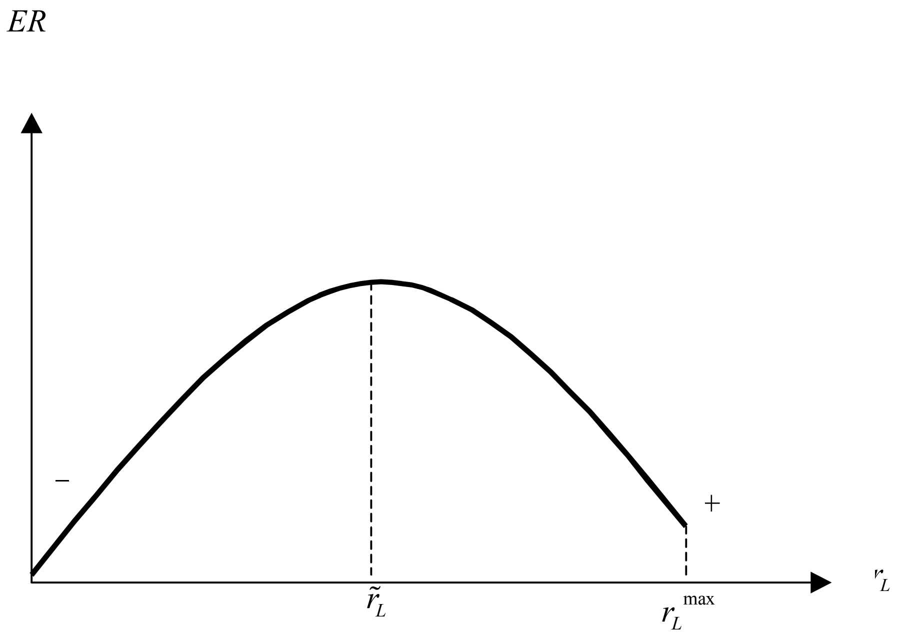

Figure 1: The expected return function

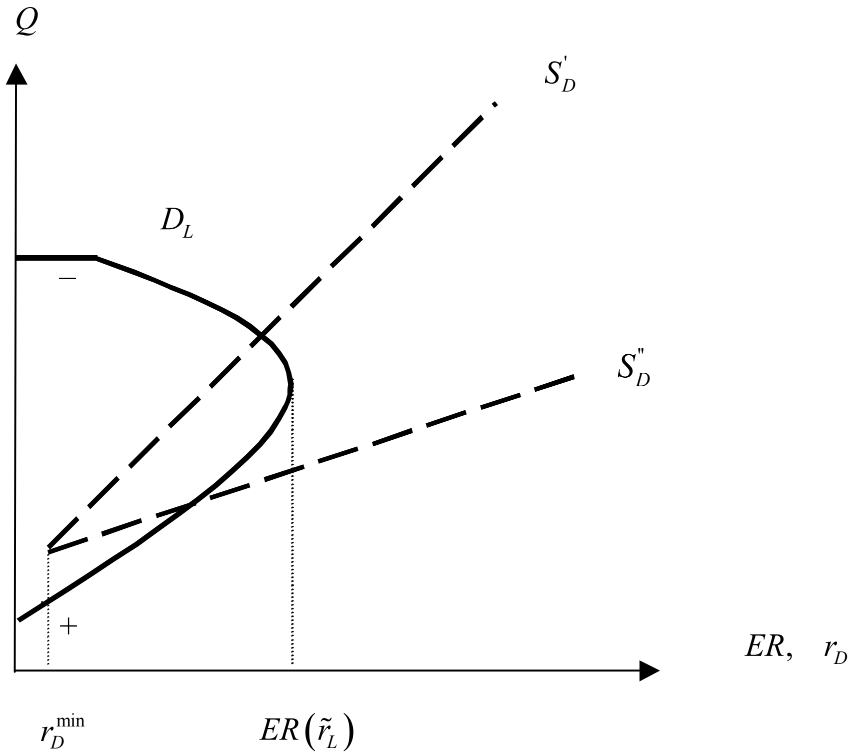

Figure 2: The demand for credit and the supply of deposits

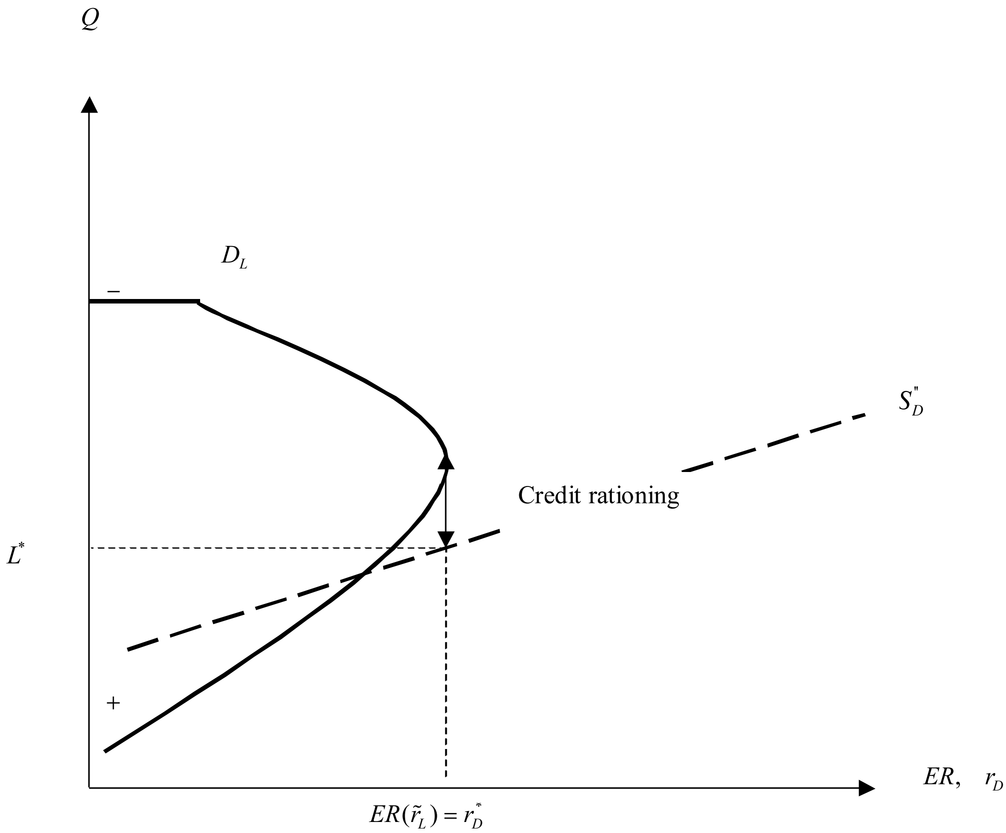

Figure 3: SPNE with credit rationing in the Deposits-first game with single application

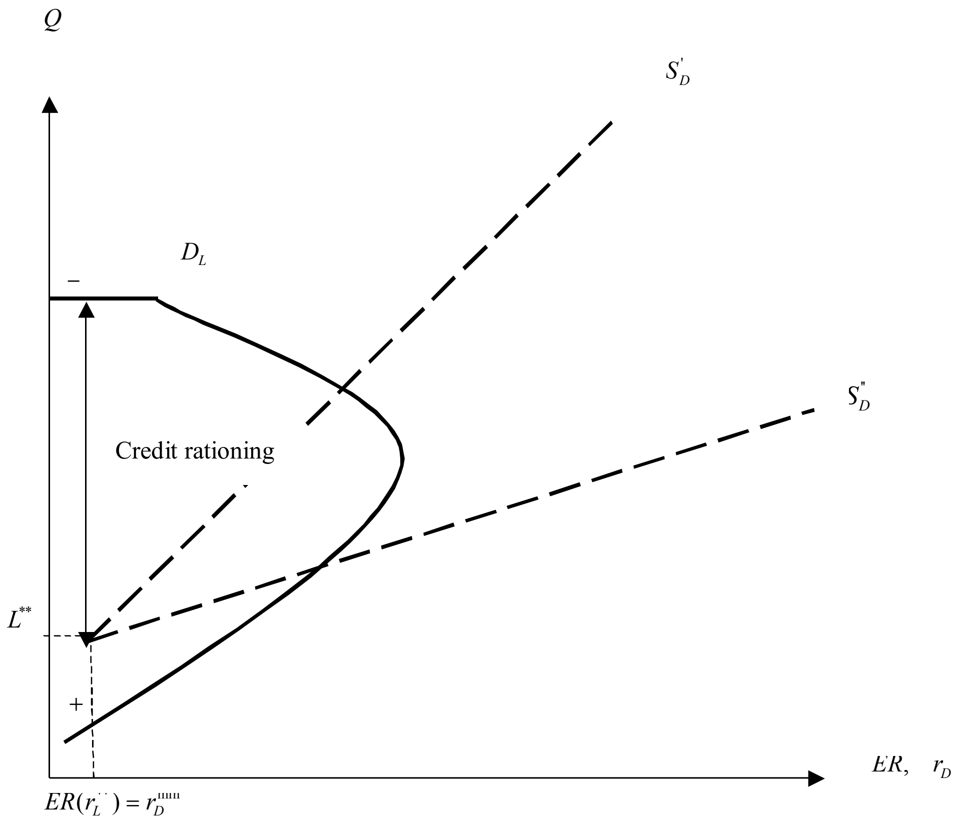

Figure 4: SPNE with credit rationing in the Loans-first game with single application

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