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# Exploring the conjunction between the structures of deposit and credit markets in the digital economy under information asymmetry

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# Abstract

In the digital economy, customer data becomes particularly valuable. Customer transactions monitored by banks, payment systems, and retail platforms are a useful source of information to assess potential borrowers' credit risk. Thus, a dominant player at a payment or deposit market, behaving strategically, may influence the characteristics of the lending market.

In this article, we show, within the game-theoretic framework, that such dominance can affect the market structure, loan pricing, financial inclusion, and credit risk accumulated on banks' balance sheets. Our results show that specifics of the digital economy set a new link between structures of deposit and credit markets. Information asymmetries allow the dominant player to increase its profits at the expense of the profits gained by other players. At the same time, the accessibility of loans to more risky borrowers reduces while credit risks of banks' loan portfolios decline.

**Key words:** retail payments, banking, market structure, asymmetric information, customer data

**JEL codes:** D43, D82, G21

# Contents

# 1. Introduction

The digitalisation of finance has a strong impact on the nature of financial intermediation and the structure of the financial sector, including the banking sector structure and the role of banks.[1] In the digital economy, at least four effects are playing an important role in profit maximisation: the network effect, economies of scale, economies of scope, and customer data analysis.[2] Players that are successful in exploiting these effects gain significant competitive advantages and can increase their market shares.[3] The last of these effects – the customer data analysis – creates advantages through the formation of information asymmetries for banks, platforms, and payment systems.

In this paper, we investigate the relationship between the deposit/payment markets and the lending market in an environment where a large bank/payment platform enjoys an information asymmetry – greater customer knowledge if compared to other banks.[4] At the same time, the nature of the information asymmetry under consideration differs from that considered in the financial theory traditionally.

In financial theory traditionally the main source of information asymmetries, obtaining more information about the quality of borrowers, is 'learning by lending', as in Arping (2017), Hale, Santos (2008), Hauswald, R. and Marquez, R. (2006), Rajan (1992), and Sharpe (JF'1990), or credit history information, as in Bouckaert, J. and Degryse, H. (2006). As the empirical literature shows, the 'learning by lending' is more relevant in lending to corporates rather than to individuals. This is partly due to the fact that many countries have credit history bureaus to track retail borrowers, which diminishes the information asymmetries generated by the lending process.[5] This in turn encourages banks to find new sources of information advantage.

However, empirical literature finds that information gained from deposits of potential borrowers (current non-borrowers) may be also useful for credit risk evaluation[6]. Moreover, financial intermediation practices in the digital age point to the important role of data in determining the quality (scoring) of potential borrowers, including those who do not provide a credit history[7]. These clients are usually first-time entrants to the credit

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[1] FSB (Oct. 2020), Stulz, R. M. (2019), Carstens, A. (2018), Crémer et al. 2019.
[2] For more information, see Restoy (2021), OECD (2018), Crémer et al. (2019), Shapiro et al. 1998.
[3] See Garratt, R., & Lee, M. J. (2020)
[4] This could also be a large payment system, retail platform, or ecosystem decided to enter the lending market.
[5] Undoubtedly, in this case, lenders try, wherever possible, to act strategically and ration the information transmitted to credit history bureaus, which, for example, is the focus of the article by Bouckaert, J. and Degryse, H. (2006). However, regulators are countering this by standardising the information transmitted to credit history bureaus.
[6] See Yang (2021) who showed that information from deposits of non-borrowers may be an important source of credit risk-evaluation for borrowers applying for information-sensitive loans and representing the same county as that of the depositors. For earlier empirical evidence see Jimenez et al. (2009), Mester et al. (2006), Norden and Weber (2010).
[7] See Shumovskaia, et al. (2021), Huang et al. (2020), including for a review of the latest literature and examples (stylised facts). Experts write about this: 'Consumer technology's access to data is another variable that will separate them [retail platforms] from traditional lenders. Over 90% of the data in all of mankind has been generated in the last 2–3 years, and it's not the traditional financial institutions but consumer technology platforms that cumulatively have access to a large part of this big data. Their ability

market, such as young people or self-employed individuals who lack good reporting records. Transaction data from the bank's payment system, e-commerce platform, or ecosystem make up the major part of these data, together with, to a lesser but developing extent, social media data on potential borrowers. As shown by Tobback, E. and Martens, D. (2019), user transaction information is a useful and promising source to use in household (retail) lending decision-making.[8] This is equally true for lending decision-making by Russia banks.[9]

Thus, financial intermediaries with large and developed payment systems serving households, and hence, with large deposit bases, are able to 'learn by users'/depositors' transactions' when making lending decisions.[10] In doing so, they have the potential to use this knowledge for strategic behaviour on the lending market and to maximise their profits in the lending market.[11]

The goal of our paper is not just to explore how another source of information asymmetry can explain banks' strategic behaviour in loan pricing or the desire of banks to monetise their customer knowledge, should such customers apply for loans. Our goal is to investigate the relationship between the deposit and credit markets, assuming there is a dominant player in the deposit market that can accrue information useful in the lending market. We focus on how dominance in the deposit/payment market (or a concentrated market structure in the payment market) may affect the lending market's characteristics: loan volumes and prices, financial inclusion, borrowers' discrimination, and the level of credit risks accepted by financial intermediaries. As Arping (2017) notes, this issue has not yet been sufficiently explored empirically or theoretically in the literature.

For Russia, this area of research is relevant due to the traditional domination of the deposit/payment market by large state banks, as well as the recently announced plans of a major Russian bank to create an ecosystem.[12]

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to use this data meaningfully through deep learning, modern computing power, and AI can be a complete game-changer in the delivery of retail credit.' (Article 'More than banks, consumer platforms can fill the retail credit gap', https://www.financialexpress.com/money/more-than-banks-consumer-platforms-can-fill-the-retail-credit-gap/2052688/). On the usefulness of payment data for making production and marketing decisions, see Garratt and Lee, (2020).

[8] On the usefulness of transaction data, see Agarwal et al. (2019), Fang, B. and Zhang, P. (2016). Similarly, for applicability to default prediction, see Kvamme et al. (2018), Chen, N., Ribeiro, B., and Chen, A. (2016), Khandani, et al. 2010.

[9] See Shumovskaia, et al. (2021), Babaev, et al. (2019).

[10] Hereinafter, for the sake of simplicity, we will say 'deposit market', referring to the deposit market (term-deposits) or the payment market (demand deposits, salary and payment accounts). Even the deposit market, which traditionally refers to term deposits, can be informative in making loan decisions. Although, in practice, people who have term deposits on a stable basis are less likely to apply for a loan. In applying for a loan, they may prove to be better borrowers, as their track record indicates a high propensity to save and prudent financial behaviour.

[11] Additionally, the presence of strong information asymmetries through 'learning by users'/depositors' transactions' creates incentives for ecosystems and digital platforms not previously involved in the lending business to enter the lending market. In practice, this development has been so successful that it has forced central banks to restrict the lending activity of such platforms (see article 'Ant ordered to restructure by Chinese regulators', FT.com, 12 April 2021, on how Chinese regulators are restricting the lending business of one of China's largest ecosystems, developed on the basis of user transaction services).

[12] https://www.sberbank.com/ru/about/strategy

The main contribution of our paper is theoretical in nature. We show that the market structure of the deposit/payment market, under a rather special but typical a digital economy assumption, can affect important characteristics of the credit market. The importance of these characteristics is explained by their role for the transmission of monetary policy, the level of financial inclusion, and financial stability. We consider the following characteristics of the credit market:

– The market shares of individual financial institutions (market structure of the credit market), including the allocation of available borrowers according to their riskiness to the dominant bank or to the rest of the market.

We show that a dominant position in the payment/deposit market, which is typical of the digital age of finance and provides the basis for strategic behaviour in the credit market, predetermines dominance in the lending market . Hence, the market structure of the payment/transaction/deposit market turns out to be relevant.

– Accessibility of credits to borrowers (financial inclusion).

We show that a large bank with its information advantage may select good borrowers and push other borrowers out as unknown borrowers to other banks, thereby worsening the distribution of borrowers available to the rest of the credit market.

– loan pricing: the level of interest rates; their structure in terms of borrowers' riskiness and structure in terms of financial institutions; as well as, price discrimination of borrowers differentiated by level of their credit risk.

We show that a dominant player of the payment market distorts the overall number and structure of borrowers in the credit market. Behaving strategically, the player distorts both the pricing process and the resulting loan rates. The increasing dominance of such large players in the lending market may have its own undesirable effects on competition in these markets (which makes some regulators feel anxious).

By establishing a relationship between the deposit and credit markets, we thus offer yet another explanation as to why the principle of 'separability' of the deposit and credit markets may be violated – why it may not be desirable for financial institutions to adhere to this concept. This is important in the light of the fact that the principle is actively used in practice in asset-liability management at banks and in macroeconomic modelling.[13]

The principle of 'separability' assumes that a bank's decisions on the funding/deposit side and its decisions on the lending side are separate or independent. In making lending decisions, bank owners compare the return on the loan without taking into account the risk premium over alternative risk-free returns. This alternative is the market rate in the interbank market or yield of federal government bonds of the corresponding maturity. In adhering to this concept, the sectoral structure of the lending market, even if it influences the funding rates of the bank, is irrelevant to loan rates, for which the only benchmark is the alternative market rate of investments. The deposit rate

[13] This is the so-called Klein-Monti approach: see Result 3.4 in Freixas, Rochet (2008) and Chiappori, et al. 1995. The principle is used in macroeconomic modelling (Gerali et al. 2010) and in modern asset and liability management at banks (ALM), see Grant (2011).

and the structure of the funding market, however, play no role in loan price decisions. In other words, the deposit and credit markets are separate. The market structure of the deposit market appears to be irrelevant to the market structure of the lending market.

At the same time, there are several alternative theories that explain the failure of the principle of separability in practice, which are based on certain form of a market imperfection: funding market imperfections, information asymmetries due to learning by lending, and fragmentation of financial markets (see the literature review section below for more details on references).

We obtain our result only on the assumption of the usefulness of transactional data as a source of information asymmetry, which is a key property of the digital economy. In particular, if the structure of the deposit or payment market is highly concentrated and the dominant player may or may not have stable funding, this may still lead to a market structure in the lending market and a level and structure of lending rates that differ from the market structure and lending rates in less concentrated deposit markets.[14]

We use a game-theoretic model along the lines of Dell'Ariccia (2001), Di Patti, E. B. and Dell'Ariccia, G. (2004).

The paper is structured as follows. Section 2 provides a review of the relevant literature and explains our contribution to the literature. In Section 3, we describe the game-theoretic model that we use to analyse market equilibrium in the lending market (rates, market shares, credit risks) under the assumption of information asymmetries when a dominant player doesn't internalize her market dominance (standard Nash equilibrium) and when she internalizes it (Nash equilibrium with a market leader and competitive fringe). In Section 4, we describe the solution of the model – market equilibria and optimal strategies for all players. In Section 5, we analyse the robustness of the results to changes in the parameters of the model, showing that the results remain valid over a wide range of parameters. The last section, the Conclusion, provides a summary of the main results and some suggestions on policy implications.

## 2. Relationship with the literature

First of all, our paper refers to the literature examining the relationship between the deposit/payment and credit markets.[15] We explore this relationship by making an

[14] Given that deposits are created in the lending process (McLeay, et al. (2014)) and that, in servicing loans issued, the bank performs transactions with these deposits, one may ask: how does our explanation differ from the case where banks, when issuing loans, create deposits and, while observing client transactions with those deposits, obtain information advantages? That is, how does this differ from 'learning by lending'? Our only assumption is that the transactions of the bank's or digital platform's clients are a source of information about the quality of the clients as bank borrowers (collaborating with the digital platform). We do not assume any preliminary lending for such transactions. Our assumption is supported by the digital transformation observed in finance and trading, which made it possible to analyse large amounts of transactional data to assess credit risks. See Tobback, E. and Martens, D. 2019. In other words, we do not assume that those who already lend a lot have an information advantage. We assume that those who service many transactions or who have many depositors create such advantages.

[15] While studies of the relationship between the deposit and loan markets predominate, studies of the relationship between the payment and loan markets mostly focus on our main assumption: the analysis of

assumption, natural for the digital economy, of the production of information for the lending market on the side of the deposit market.[16] In particular, we investigate the impact of the market structure of the deposit/payment market, which determines the efficiency of such 'production', on the following characteristics of the lending market:[17]

– The market shares of individual financial institutions (market structure of the credit market),

– financial inclusion,

– loan pricing.

Among recent studies, similar questions in the theoretical model are posed by Arping (2017). In particular, the author is interested in the following ussies: How does competition in the deposit market affect the credit market? Do higher deposit rates due to stronger competition in the deposit market lead to higher credit rates? How does competition in the deposit market affect the risk profile of credits? The author points out that the effect of competition in the deposit market on credit interest rates is not obvious due to the principle of 'separability' (Klenti-Monti approach), and proposes a model based on agency friction which establishes this relationship between the deposit and credit markets.[18]

The author theoretically establishes a hump-shaped relationship between market power in the deposit market and banks' NPLs (as a result of more risk taking) – an important aspect of financial stability in the banking sector. This relationship also depends on the strength of competition in the lending market. More competition in the deposit market makes banks more likely to accept credit risk. However, depending on the extent of competition in the credit market, a more risky profile of lending may be combined with a smaller volume or number of loans. For similar reasons, there is no clear relationship between competition in the deposit market and credit availability.

Second, our results regarding the impact of the structure of the deposit/payment market on the distribution of borrowers by their credit risk, are relevant to the literature on financial stability and financial inclusion implications of a given market structure in the deposit/credit market: Allen, F. and Gale, D. (2004), Boyd, De Nicolo, Smith (2004), Beck (2008).[19]

Third, as our model is based on the assumption of the importance of the deposit/payment market in producing information useful for lending market decisions, we also draw on the literature that explores the nature of information asymmetries in the

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the usefulness of user transaction information in making lending decisions. As in, for example, Tobback, E. and Martens, D. (2019), Tounsi et al. (2017), Óskarsdóttir et al. 2019.

[16] Restoy, F. (2021) Fintech regulation: how to achieve a level playing field, FSI Occasional Papers BIS; Petralia, K, T Philippon, T Rice and N Véron (2019): 'Banking disrupted. Financial intermediation in an era of transformational technology', General Report on the World Economy, CEPR.

[17] Empirical studies of such interplay include De Graeve, F., De Jonghe, O., and Vennet, R.V. 2007. For Russia: Fungáčová, Z. and Weill, L. (2013), Mamonov M. 2016.

[18] At the same time, Arping (2017) notes: '*To my knowledge, the empirical literature has not yet tackled the question of how changes in deposit market (or loan market) power causally affect loan pricing. Indeed, we know surprisingly little about how bank market power in funding markets shapes loan pricing*.'

[19] Empirical research on the effects of market structure on financial stability is explored, for example, by Pawlowska, M. (2016), Berger et al. (2017), Egan et al. (2017). A more general review on the role of the structure of financing on financial stability is presented in Bats, J. V. and Houben, A. C. (2020).

lending market (why some banks know more about potential borrowers than others) and the effects of these asymmetries on the structural characteristics of the lending market. Such papers include those similar to ours by Dell'Ariccia (2001), Di Patti and Dell'Ariccia (2004), Pagano and Jappelli (1993), although the nature of information asymmetry differs in these works and in ours ('learning by lending' vs 'learning by transacting'). Another group of papers empirically finds that information from deposits of non-borrowers may be useful for credit-risk evaluation and become a source of information asymmetries between banks. Yang (2021) showed that information from deposits of non-borrowers may be an important source of credit risk-evaluation for borrowers applying for information-sensitive loans and representing the same county as that of the depositors. Earlier empirical evidence focused on information content of deposits of potential borrowers to evaluate their own credit risks: Jimenez et al. (2009), Mester et al. (2006), Norden and Weber (2010).

Fourth, since information asymmetries opens the door for strategic behaviour, we also refer to the literature describing the strategic behaviour of banks, including the disclosure of information about borrowers to other market participants. In our model, banks value low-risk clients who decide to become borrowers and push high-risk borrowers out into the rest of the market by setting high interest rates. In a similar article, Bouckaert, J. and Degryse, H. (2006) consider the strategic decisions of banks to disclose information about borrowers' credit histories. It appears to be advantageous for banks not to disclose all information about borrowers in order to narrow the market entry opportunities for new banks. In particular, it is beneficial to disclose more information about good borrowers, but not to disclose anything about bad borrowers. This forces incoming competing banks not to compete for these borrowers and allows existing banks to serve these borrowers at a monopoly premium. It is also advantageous to make information about good borrowers not entirely accurate (e.g. by withholding information about early loan repayments), so as not to provoke strong competition for these borrowers as well. In the authors' model, disclosure improves the profitability of all banks and reduces loss-generating 'moves' of bad borrowers from bank to bank. Banks that have an information advantage, according to Bouckaert, J. and Degryse, H. (2006), are banks with a long history of lending, extensive experience and which can compete with banks entering the market. That is, banks already dominate in the lending market and counteract new banks. In our model, by default, all banks can be considered new banks, which are inherently on an equal footing with respect to potential clients.

Hale and Santos (2008) show that, acting strategically, banks assign lower loan rates to borrowers who have previously issued bonds in the market.

Fifth, as we focus on examining the effects of the deposit market on the credit market, we inevitably come across literature that explicitly or implicitly explains why the concept of 'separability' of banks' decision-making in the deposit and credit markets may in some cases be violated in practice. The mechanics of the concept is described in

Freixas, Rochet (2008),[20] Chiappori, et al. (1995). The principle is the basis for modern banks' practices in asset-liability management (ALM) (Grant, 2011) and is applied in macroeconomic models that include the banking sector, as in Gerali et al. (2010). The principle of 'separability' plays an important role in describing monetary policy transmission. According to this concept, financial institutions' decisions on the asset-liability side, if such decisions are optimal, should be independent. When deciding on a loan price, banks are guided only by the value of alternative investments of similar maturity and risk – the market interest rate curve, which in a modern economy depends on the current and expected decisions of the central bank. Neither the concentration of the deposit/funding market (much less the payment market) nor the funding costs have any influence on banks' actions in the credit market or on the pricing process in the credit market. Accordingly, the market structure of the lending market also appears to be independent of the structure of the funding market.

There are several theories that imply market imperfections leading to violations of the principle of 'separability' in practice.[21]

One such theory explaining the connection between the deposit and credit markets assumes imperfections in the interbank lending market and the incompleteness of central bank tools, with the result that banks need 'stable funding' to issue loans. This theory is described in Disyatatat (2011), Dermine (2013), DeYoung and Jang (2016), and Duijm and Wierts (2016). For example, Li et al. (2019) empirically show that a bank's dominance in the deposit market helps it issue longer-term loans. Such stable funding is represented by the minimum balances of the bank's clients in their current/settlement accounts and time deposits. According to this theory, the more such stable deposits a bank has, including when the bank has a dominant market position, the lower the risk of funding loans. This makes it possible to set lower interest rates (to win more market share or to take more risks and profits) or to issue longer-term loans. The main market imperfection in this case is the bank's inability to hedge against the interest rate risk, which arises from a mismatch between the maturity of the loan issued and the maturity of the underlying funding (the need to refinance it on a daily basis). Liquidity risk may not arise in the case of central bank policy of interest rate targeting. Stable funding must be taken into account in practice in the management of assets and liabilities (this is known as the FTP 2.0 approach). Unlike this literature, our focus is not on the role of deposits as sources of 'stable funding', but on the role of deposits/payments as sources of information asymmetries. Moreover, the more transactions banks' clients carry out, i.e. the less stable deposits are, the more logical it is to expect stronger information asymmetries about banks' clients to be generated by those transactions. That is, in this

[20] See Section 3.4

[21] Empirical research finds either mixed results for the principle of 'separability', as in De Graeve et al. (2007), De Bondt (2002, 2005), Sørensen and Werner (2006), Gambacorta (2008), ECB (2009), Kwapil and Sharler (2010), Kopecky and Van Hoose (JMCB'2012),
or does not support the principle in practice at all: Illes, et al (BIS WP'2015), Eickmeier et al (2015) – WACL.
Illes, et al (BIS WP'2015): 'All in all, this suggests it is no longer valid practice to take a policy rate, a short-term wholesale market rate or a sovereign bond yield as a proxy for bank funding costs'

paper we are looking at another aspect of the deposit market, not its ability to provide 'stability' for funding or to serve as a source of additional income for banks.

The second group of explanations for the relationship between the deposit and credit markets focuses on agency frictions and moral hazard. Allen and Repullo (2004) and Boyd and De Nicolo (2005) show that stronger competition in the funding (deposit) market leads to lower profits on the liability side. This prompts bank managers to accept more risk, which in particular is reflected in lower interest rates: that is, there is more competition for borrowers in the lending market. Arping (JBF'2017) proposed an even more complex explanation, called "a double-moral-hazard problem". Lower lending rates lead to the self-selection of better quality borrowers, thereby reducing risk appetite. This has a beneficial effect on banks' credit risks, further increasing risk appetite.

Our paper lacks the key relationship between the deposit and credit markets inherent in this group of studies – we abstract away from funding costs and, consequently, profits on the liabilities/deposits side. However, strategic behaviour in our competitive fringe model and the use of differential pricing lead to the self-selection of borrowers with a given credit risk. Finally, the strategic behaviour of a large bank with an information advantage results in an allocation of borrowers by risk intensity, which is different from the allocation resulting from pricing in a more competitive credit market.

A third group of explanations for the relationship between the deposit and credit markets, as we have noted earlier, deals with what is called "relationship lending". Berlin and Mester (1999) showed that there is a connection between relationship lending and a bank's funding structure: a higher share for the core deposits base (stable client deposit base) encourages banks to conduct relationship lending, including by offering these clients more stable interest rates, which in turn works in the opposite direction, helping stabilise the deposit base. As shown by Sharpe (JF'1990), Rajan (1992), Hauswald, R., and Marquez, R. (2006), relationship lending can also be a source of information asymmetry (information production on the lending side) and thereby influence lending conditions and the positions of particular banks in the credit market. In our research, we draw attention to the importance of another process that explains the relationship between the deposit and credit markets: information production on the payment/transaction side, which role will only increase in the digital economy. Yan, et al (FinInnov'2015), Lyer et al (2011) have shown how retail platforms can produce information for P2P lending platforms.

Finally, less frequently mentioned in the literature and more specific alternative explanations for the absence of the principle of separability of the deposit and credit markets in practice relate to market fragmentation (as in the Eurozone in episode of the sovereign debt crisis in 2011–2012) or to a zero lower bound on bond interest rates as the base of the transfer curve, with a non-zero limit for deposits, as in Iles et al. (2015). In this case, the structure of the deposit market also affects the pricing in the credit market, the structure and level of interest rates, and the structure of the lending market.

In our paper, we offer an alternative explanation of the relationship between the deposit and credit markets with a minimum of assumptions, the most important of which takes into account a basic feature of finance in the digital age: the role of customer transactions data and the analysis of this data in assessing credit risk.

# 3. Modelling framework

## 3.1 Background

There are N small identical banks and one large bank in the market. Banks' clients are households which use bank services to make payments (receive their salaries/other income in bank accounts and make transactions with this money) and to borrow money. The large bank is the bank that services the payments (transactions) on current and settlement accounts, and deposits of a large share of the households and on this basis has additional information about the quality of its clients as potential borrowers.[22] In other words, we assume that such bank has information about share $A, A \in (0,1)$ of all households. Small banks divide the remaining share of clients $(1-A)/N$ equally (clients randomly choose the appropriate bank to service their accounts). All households are divided into 'good' (which, as borrowers, repay loans with a probability of 1) and 'bad' (which, as borrowers, default with a probability of *pd*). By 'information about clients', we mean that a bank knows the type of a given client. Each bank has transaction information (and therefore credit risk information) only about its clients. Information about the clients of other banks is not available to the bank[23]. At the same time, information about each client is known only to one bank, and there are no unknown borrowers[24].

[22] Transactions are a useful source of information, as they help identify a consumer's consumption habits, risk appetite, and propensity to save. Anecdotal evidence shows, for example, that people who buy red cars are less risk-averse and are therefore less reliable as borrowers. Information about transactions on clients' accounts, their purchases, consumer habits, and propensity to save will be most useful to a bank in characterising its clients when such transactions are made in shops that share detailed transaction information with the bank. This is particularly the case when the bank is part of an ecosystem that includes financial and non-financial services. Operationally, to apply such information in scoring, the bank need not even have a probability-of-default assessment model (PD model) estimated from a sample of past borrowers of that bank or other banks (based on borrower quality information from a credit history bureau). The bank need not use a formal model (the optimal mapping of borrower characteristics to the level of credit risk). In practice, the bank/payment system may observe the transactions of a particular client and assign scores to the client on the basis of characteristics of these transactions. The more scores, the more credibility the client has. In terms of the PD model, we assume that clients with a very low probability of default will be categorised as 'good' by the bank.

[23] To focus on the issue of information asymmetry due to dominance of deposit/payment market we assume that deposit/payment information is the only source of information used to assess credit quality. Banks may more sources of information for that. In such a case optimizing its profits a bank may decide to sacrifice its information asymmetry in one source of information to gain more asymmetry in some other source. Modelling such a complex behavior is an interesting avenue for future research.
If a signal derived by banks from analysis of financial transactions is not perfect regarding credit quality assessment, our results will be still valid qualitatively, but may correct quantitatively (banks still maximize expected profits when a signal is non-biased)

[24] Note, that under such assumption, "bad" borrowers cannot signal as if they were "good" (classic example of such signaling includes Cho and Kreps (1987). Data on transactions is the objective characteristics of the client's credit risk that cannot be manipulated (bad borrowers cannot get large salaries to spend more to signal that they are good)

### Banks

Banks compete by setting loan rates for three types of loans: for known 'good' client applicants, for known 'bad' client applicants, and for unknown client applicants[25]. Every bank's rates are known to all clients who decide to take out loans, as well as to other banks. We, following the market leader/competitive fringe model, assume that the small banks use uniform rates for each type of borrower, which may differ from the rates of the large bank.[26] We define the rates as follows:

$i_{g,A}$ $(i_g)$ – large (small) bank's rate for known 'good' borrowers,

$i_{u,A}$ $(i_u)$ – large (small) bank's rate for unknown borrowers,

$i_{b,A}$ $(i_b)$ – large (small) bank's rate for known 'bad' borrowers,

We also set restrictions on the rates on the assumption that a bank will not offer a better rate to an unknown borrower than to a known 'good' borrower, nor will it offer a known 'bad' borrower a lower rate than it offers to an unknown one.

$$i_{g,A} \leq i_{u,A} \leq i_{b,A} \text{ and } i_g \leq i_u \leq i_b \qquad (1)$$

At every time point, a full lending cycle takes place, that is the banks offer rates, borrowers choose banks for lending, take out and repay the loan, and the banks make their profit. At the next time point, the game starts again. There is no learning process from the previous period through 'learning by lending'[27]. At the same time, the share of known borrowers for each bank does not change over time and the proportions determining the quality of borrowers are also known and remain unchanged in population. The objective of any bank's operation in each cycle is to maximise its profit.

### Borrowers

Borrowers apply or not for a loan based on minimising its cost. They are more willing to take a loan from a bank with the lowest rate available to them. They may also take out a loan at a higher rate, but not more than $x$ above the minimum rate. We assume that the share of borrowers willing to demand loans at higher rates (relative to the minimum rates available to them) decreases according to a linear law. In addition to the rates offered by various banks, borrowers are guided by a standard rate $i^*$,

[25] We assume that the system doesn't have a memory. It is not enough observe a client's transactions once to discover her type forever. As the financial position of the households can change, financial old transactional data may become irrelevant to correctly assess the credit quality of a borrower that once was a client of the bank.

[26] The assumption of equal rates for the same type of borrowers set by identical banks under perfect competition relies on extensive use in the literature, e.g. in Freixas, Rochet (2008), Dell'Ariccia (2001). Nevertheless, in Annex 5, we illustrate the limitations of this approach.

[27] Dell'Ariccia, G. (2001) notes that "learning by lending" as a source of information asymmetries on lending side needs more specific assumptions to realize. They mention that 'learning by lending' stimulates borrowers to borrow from different banks to signal their type to these banks. As a result, in a dynamic setting, information asymmetry disappears in the longer run. To keep it, specific assumptions are needed: either borrowers quickly leave the credit market or credit histories quickly devalues as a source of information on credit quality. Our two assumptions in the paper are less specific: "Deposit/ payment information is useful for assessing credit quality" and "there is a market player, that dominates the payment/deposit market".

which characterises the loan cost level in the economy as a whole[28]. If the banks' rates are lower than the standard rate, the demand for loans increases, while otherwise it falls. This is reflected in the fact that more households apply for a loan or the average amount of the requested loan grows.

## 3.2 Model

In this section, we build a model that determines the optimal strategies for banks and, as a result, the equilibrium rates. To do this, we first assess the allocation of borrowers among banks at different rate combinations. Next, we construct demand functions for different types of borrowers and determine the profits of the large and small banks. We then find the standard Nash equilibrium and show that, under certain conditions, the large bank can increase its profit by using a 'leader' strategy under conditions of asymmetric information.

### *3.2.1. Allocation of borrowers known to the large bank*

Earlier, we agreed that information about every borrower present in the market is known to *only* one of the banks. At the same time, the large bank has information about a significant share of potential borrowers and can therefore distinguish between those who will definitely pay back a loan – 'good' borrowers – and those who, with a probability of *pd*, will not pay back the loan – 'bad' borrowers. Let us first determine how 'good' borrowers will be distributed among banks depending on the ratio of interest rates offered to them.

#### *3.2.1.1. Allocation of 'good' borrowers known to the large bank among banks*

Let us determine the share of 'good' borrowers known to the large bank who would prefer to take a loan from the large bank. In this market segment, there will be competition between the large bank, offering rate $i_g A$, and the small banks, with rate $i_u$, as every borrower known to the large bank is unknown to any small bank. Suppose the share of 'good' borrowers taking a loan from the large bank varies linearly with an increase in the rate difference:

$$GAA = \alpha + \beta(i_u - i_{g,A}), \tag{2}$$

where

$GAA$ – the share of 'good' borrowers known to the large bank who take a loan from the large bank

$i_{g,A}$ – the large bank's rate for known 'good' borrowers,

$i_u$ – a small bank's rate for unknown borrowers,

$\alpha, \beta$ – coefficients which are determined from the boundary conditions.

[28] In practice, it is associated with the key policy rate and its expectations.

$\alpha, \beta$ are to be found.

Let $i_{g,A} \leq i_u$. Then, if all banks offer borrowers of the type under consideration equal rates $i_u = i_{g,A}$, then borrowers do not care which bank they get their loans from. They will be uniformly distributed among all the banks and the large bank's share will be $\frac{1}{N+1}$ ($N$ – the number of small banks)

$$GAA = \alpha + \beta * 0 = \frac{1}{N+1} \rightarrow \alpha = \frac{1}{N+1}$$

If a small bank's rate reaches $i_u = i_{g,A} + x$ ($x$ is the maximum possible rate difference at which borrowers agree to borrow), then all borrowers will borrow from the large bank.

$$GAA = \frac{1}{N+1} + \beta * x = 1 \rightarrow \beta = \frac{N}{N+1} \cdot \frac{1}{x}$$

Thus, applying the equations for the coefficients in (2), we find that the share of 'good' borrowers known to the large bank who would prefer to borrow from the large bank is described by the following function.

$$GAA = \begin{cases} \frac{1}{N+1}\left(1 + N\frac{i_u - i_{g,A}}{x}\right), i_{g,A} \leq i_u \leq i_{g,A} + x \\ 1, i_u > i_{g,A} + x \end{cases} \quad (3)$$

Considering the alternative case, when small banks offer lower rates than the large bank, i.e. $i_u \leq i_{g,A}$, function $GAA$ takes the following form (see Annex 1 for the derivation of the equation).

$$GAA = \begin{cases} \frac{1}{N+1}\left(1 + N\frac{\min(i_u, i_{g,A} + x) - i_{g,A}}{x}\right), i_{g,A} \leq i_u \\ \frac{1}{N+1}\left(1 - \frac{\min(i_{g,A}, i_u + x) - i_u}{x}\right), i_u \leq i_{g,A} \end{cases} \quad (4)$$

Part of 'good' borrowers known to the large bank will take loans from the small banks, and their share at each small bank will be:

$$GAbi = \frac{1 - GAA}{N} \quad (5)$$

The allocation of 'good' borrowers known to the large bank as described by formulas (4) and (5) can be illustrated in a graph (see Figure 2.1 in Annex 2). Let us now find an expression for the distribution of bad borrowers.

#### *3.2.1.2. Allocation of 'bad' borrowers known to the large bank among banks*

Similarly, we can write a function to determine the share of 'bad' borrowers known to the large bank who take loans from the large bank, $BAA$, and from each of the small banks, $BAbi$. The boundary conditions for deriving the formula are provided in Annex 1.

$$BAA = \begin{cases} \frac{1}{N+1}\left(1 - \frac{\min(i_{b,A}, i_u + x) - i_u}{x}\right), i_u \leq i_{b,A} \\ \frac{1}{N+1}\left(1 + N\frac{\min(i_u, i_{b,A} + x) - i_{b,A}}{x}\right), i_{b,A} \leq i_u \end{cases} \quad (6)$$

$$BAbi = \frac{(1 - BAA)}{N} \quad (7)$$

The structure of the allocation of loans to 'bad' borrowers known to the large bank is illustrated in Figure 2.2 in Annex 2.

#### *3.2.2. Allocation of borrowers known to a small bank*

Each client known to a small bank faces a choice of three rates. First, a small bank that has client information will offer rate $i_g$ if, in the bank's opinion, the client is 'good' as a borrower, and rate $i_b$ if the client is a 'bad' borrower. Second, such a borrower can take out a loan at rate $i_u$ from another small bank, being unknown to it. Third, the borrower has the option of borrowing from the large bank at rate $i_{u,A}$, also being unknown to the large bank.

##### *3.2.2.1. Allocation of 'good' borrowers known to a small bank*

Let us take a closer look at the case of 'good' borrowers known to a some small bank $bi$. Assume that, as before, the shares of borrowers are allocated between banks in a linear relationship to the bank's deviation from the lowest rate offered to a given borrower. First, suppose the lowest rate is $i_g$, offered by a small bank to borrowers known to it: $i_g \le i_u$ and $i_g \le i_{u,A}$. Then, the shares are allocated as follows.

$$\begin{gathered} Gbibi = \alpha_1 + \beta_1(i_u - i_g) + \gamma_1(i_{u,A} - i_g) \\ Gbibj = \alpha_2 + \beta_2(i_u - i_g) + \gamma_2(i_{u,A} - i_g) \\ GbiA = \alpha_3 + \beta_3(i_u - i_g) + \gamma_3(i_{u,A} - i_g) \end{gathered} \tag{8}$$

where

$Gbibi$ – The share of 'good' borrowers known to small bank $bi$ who will take loans from small bank $bi$,

$Gbibj$ – The share of 'good' borrowers known to small bank $bi$ who will take loans from each of remaining small banks $bj$ (in total there are $N-1$ such banks),

$GbiA$ – the share of 'good' borrowers known to small bank $bi$ who will take loans from large bank $A$,

$\alpha_1, \alpha_2, \alpha_3, \beta_1, \beta_2, \beta_3, \gamma_1, \gamma_2, \gamma_3$ – Coefficients.

**Table 1.** Conditions for constructing functions that determine the allocation among banks of 'good' borrowers known to a small bank when $i_g \le i_u$ and $i_g \le i_{u,A}$

| No. | Constraints and their interpretation | $Gbibi$ | $Gbibj$ | $GbiA$ |
|---|---|---|---|---|
| 1. | $i_g = i_u = i_{u,A}$<br>condition of indifference: borrowers will be uniformly distributed among banks | $\frac{1}{N+1}$ | $\frac{1}{N+1}$ | $\frac{1}{N+1}$ |
| 2. | $i_g = i_{u,A}$ and $i_u \ge i_g + x$<br>half of the borrowers will take loans from the large bank, and the other half from bank $bi$ | $\frac{1}{2}$ | 0 | $\frac{1}{2}$ |
| 3. | $i_g = i_u$ and $i_{u,A} \ge i_g + x$<br>borrowers will be uniformly distributed among the small banks and will not take loans from the large bank | $\frac{1}{N}$ | $\frac{1}{N}$ | 0 |
| 4. | $i_u \ge i_g + x$ and $i_{u,A} \ge i_g + x$<br>all borrowers will prefer to take loans from bank $bi$ | 1 | 0 | 0 |

Coefficients $\alpha_1, \alpha_2, \alpha_3, \beta_1, \beta_2, \beta_3, \gamma_1, \gamma_2, \gamma_3$ can be calculated using the boundary conditions presented in Table 1 and the normalisation condition $Gbibi + (N-1)Gbibj + GbiA = 1$. Besides, we took into account that if $i_u = i_{u,A}$, the reallocation of borrowers occurs according to a linear law, as if banks with two rates competed in the market: small bank $bi$ with rate $i_g$ and all other banks with rate $i_u = i_{u,A}$. The processes of reallocation of borrowers among banks that occur when $i_u \leq i_{u,A}$ and $i_u \geq i_{u,A}$ are described by different formulas. **Annex 2** provides a rationale with a graphical interpretation.

The function for the allocation of 'good' borrowers known to a small bank upon different combinations of rates is ultimately defined as follows (here $i_g \leq i_u$ and $i_g \leq i_{u,A}$).

If $i_g \leq i_u \leq i_{u,A}$

$$Gbibi = \frac{1}{N+1} + \frac{N-1}{N} \cdot \frac{\min(i_u, i_g + x) - i_g}{x} + \frac{1}{N(N+1)} \cdot \frac{\min(i_{u,A}, i_g + x) - i_g}{x} \quad (9)$$

$$Gbibj = \frac{1}{N+1} - \frac{1}{N} \cdot \frac{\min(i_u, i_g + x) - i_g}{x} + \frac{1}{N(N+1)} \cdot \frac{\min(i_{u,A}, i_g + x) - i_g}{x} \quad (10)$$

$$GbiA = \frac{1}{N+1} - \frac{1}{N+1} \cdot \frac{\min(i_{u,A}, i_g + x) - i_g}{x} \quad (11)$$

If $i_g \leq i_{u,A} \leq i_u$

$$Gbibi = \frac{1}{N+1} + \frac{N-1}{2(N+1)} \cdot \frac{\min(i_u, i_g + x) - i_g}{x} + \frac{1}{2} \cdot \frac{\min(i_{u,A}, i_g + x) - i_g}{x} \quad (12)$$

$$Gbibj = \frac{1}{N+1} - \frac{1}{N+1} \cdot \frac{\min(i_u, i_g + x) - i_g}{x} \quad (13)$$

$$GbiA = \frac{1}{N+1} + \frac{N-1}{2(N+1)} \cdot \frac{\min(i_u, i_g + x) - i_g}{x} - \frac{1}{2} \cdot \frac{\min(i_{u,A}, i_g + x) - i_g}{x} \quad (14)$$

Under alternative assumption the large bank will seek to attract as many lenders as possible and will offer its lowest rate $i_{u,A}$ to this category of borrowers, such that $i_{u,A} \leq i_g$ and $i_{u,A} \leq i_u$. Note also that, based on the initial assumptions in (1), we consider only those cases in which $i_g \leq i_u$. Then, to determine the boundary conditions, it is enough to restrict ourselves to three conditions (see Table 2), and the functions themselves are described by a fragment of one plane and take the following form.

If $i_{u,A} \leq i_g \leq i_u$

$$Gbibi = \frac{1}{N+1} + \frac{N-1}{2(N+1)} \cdot \frac{\min(i_u, i_{u,A} + x) - i_{u,A}}{x} - \frac{1}{2} \cdot \frac{\min(i_g, i_{u,A} + x) - i_{u,A}}{x} \quad (15)$$

$$Gbibj = \frac{1}{N+1} - \frac{1}{N+1} \cdot \frac{\min(i_u, i_{u,A} + x) - i_{u,A}}{x} \quad (16)$$

$$GbiA = \frac{1}{N+1} + \frac{N-1}{2(N+1)} \cdot \frac{\min(i_u, i_{u,A} + x) - i_{u,A}}{x} + \frac{1}{2} \cdot \frac{\min(i_g, i_{u,A} + x) - i_{u,A}}{x} \quad (17)$$

**Table 2.** Conditions for constructing functions that determine the allocation among banks of 'good' borrowers known to a small bank when $i_{u,A} \leq i_g \leq i_u$

| No. | Constraints and their interpretation | $Gbibi$ | $Gbibj$ | $GbiA$ |
|---|---|---|---|---|
| 1. | $i_g = i_u = i_{u,A}$<br>condition of indifference: borrowers will be uniformly distributed among banks | $\frac{1}{N+1}$ | $\frac{1}{N+1}$ | $\frac{1}{N+1}$ |
| 2. | $i_{u,A} = i_g$ and $i_u \geq i_{u,A} + x$<br>half of the borrowers will take loans from the large bank, and the other half from bank $bi$ | $\frac{1}{2}$ | 0 | $\frac{1}{2}$ |
| 3. | $i_u \geq i_{u,A} + x$ and $i_g \geq i_{u,A} + x$<br>all borrowers will prefer to take loans from the large bank | 0 | 0 | 1 |

### *3.2.2.2. Allocation of 'bad' borrowers known to a small bank*

Repeating the previous reasoning, let us consider the case of 'bad' borrowers known to small bank $bi$. When deciding on a loan, they are faced with a choice between banks offering them rates $i_b, i_u$ and $i_{u,A}$. Recall that, in accordance with (1), $i_u \leq i_b$. The form of the function for the allocation of the shares of 'bad' borrowers, as before, is determined linearly with respect to the rates difference. The functions for calculating the shares are given below separately for each domain of definition (see the conditions for boundary points in Annex 3).

If $i_{u,A} \leq i_u \leq i_b$

$$Bbibi = \frac{1}{N+1} - \frac{1}{N+1} \cdot \frac{\min(i_b, i_{u,A}+x) - i_{u,A}}{x} \tag{18}$$

$$Bbibj = \frac{1}{N+1} + \frac{1}{N(N+1)} \cdot \frac{\min(i_b, i_{u,A}+x) - i_{u,A}}{x} - \frac{1}{N} \cdot \frac{\min(i_u, i_{u,A}+x) - i_{u,A}}{x} \tag{19}$$

$$BbiA = \frac{1}{N+1} + \frac{1}{N(N+1)} \cdot \frac{\min(i_b, i_{u,A}+x) - i_{u,A}}{x} + \frac{N-1}{N} \cdot \frac{\min(i_u, i_{u,A}+x) - i_{u,A}}{x} \tag{20}$$

If $i_u \leq i_{u,A} \leq i_b$

$$Bbibi = \frac{1}{N+1} - \frac{1}{N+1} \cdot \frac{\min(i_b, i_u+x) - i_u}{x} \tag{21}$$

$$Bbibj = \frac{1}{N+1} + \frac{1}{N(N+1)} \cdot \frac{\min(i_b, i_u+x) - i_u}{x} + \frac{1}{N(N-1)} \cdot \frac{\min(i_{u,A}, i_u+x) - i_u}{x} \tag{22}$$

$$BbiA = \frac{1}{N+1} + \frac{1}{N(N+1)} \cdot \frac{\min(i_b, i_u+x) - i_u}{x} - \frac{1}{N} \cdot \frac{\min(i_{u,A}, i_u+x) - i_u}{x} \tag{23}$$

If $i_u \leq i_b \leq i_{u,A}$

$$Bbibi = \frac{1}{N+1} - \frac{1}{N} \cdot \frac{\min(i_b, i_u+x) - i_u}{x} + \frac{1}{N(N+1)} \cdot \frac{\min(i_{u,A}, i_u+x) - i_u}{x} \tag{24}$$

$$Bbibj = \frac{1}{N+1} + \frac{1}{N(N-1)} \cdot \frac{\min(i_b, i_u+x) - i_u}{x} + \frac{1}{N(N+1)} \cdot \frac{\min(i_{u,A}, i_u+x) - i_u}{x} \tag{25}$$

$$BbiA = \frac{1}{N+1} - \frac{1}{N+1} \cdot \frac{\min(i_{u,A}, i_u+x) - i_u}{x} \tag{26}$$

Three-dimensional illustrations corresponding to (9) – (14) and (21) – (26) are presented in Figures 2.5–2.6 in Annex 2.

### *3.2.3. Function of demand for loans from bank clients*

The demand for loans from borrowers in our model is determined not only by the difference in the rates set by the banks, but also by how expensive lending can be considered as a whole. For this, we introduce the concept of standard rate $i^*$, which can be associated, for example, with the central bank's key rate (corresponding to the maturity of the loan) or with the rate on long-term government bonds. The lower (higher) the rate offered by a bank in comparison with the standard rate, the greater (lower) the demand for a loan shown by a borrower. In addition, we must take into account the ratios that have developed between 'good' and 'bad' borrowers, as well as the awareness of banks about their clients. The demand functions are as follows:

$$\begin{aligned}
D_{GAA} &= GAA \cdot M \cdot A \cdot good \cdot (1 + c \cdot (i^* - i_{g,A})) \\
D_{GAbi} &= GAbi \cdot M \cdot A \cdot good \cdot \big(1 + c \cdot (i^* - i_u)\big) \\
D_{Gbibi} &= Gbibi \cdot M \cdot (1 - A) \cdot good \cdot \Big(1 + c \cdot \big(i^* - i_g\big)\Big) \\
D_{Gbibj} &= Gbibj \cdot M \cdot (1 - A) \cdot good \cdot \big(1 + c \cdot (i^* - i_u)\big) \\
D_{GbiA} &= GbiA \cdot M \cdot (1 - A) \cdot good \cdot \Big(1 + c \cdot \big(i^* - i_{u,A}\big)\Big) \\
D_{BAA} &= BAA \cdot M \cdot A \cdot (1 - good) \cdot (1 + c \cdot (i^* - i_{b,A})) \\
D_{BAbi} &= BAbi \cdot M \cdot A \cdot (1 - good) \cdot (1 + c \cdot (i^* - i_u)) \\
D_{Bbibi} &= Bbibi \cdot M \cdot (1 - A) \cdot (1 - good) \cdot \big(1 + c \cdot (i^* - i_b)\big) \\
D_{Bbibj} &= Bbibj \cdot M \cdot (1 - A) \cdot (1 - good) \cdot \big(1 + c \cdot (i^* - i_u)\big) \\
D_{BbiA} &= BbiA \cdot M \cdot (1 - A) \cdot (1 - good) \cdot \Big(1 + c \cdot \big(i^* - i_{u,A}\big)\Big)
\end{aligned} \tag{27}$$

where $D_{GAA}, D_{GAbi}, \dots D_{BbiA}$ – demand for loans from categories of borrowers whose shares are $GAA, GAbi, \dots BbiA$ respectively, $M$ – the number of bank clients ($M \gg N$), $A$ – the share of borrowers about which information is known to the large bank, $good$ – the share of 'good' borrowers, $c$ – elasticity of demand for loans on the deviation of the loan rate from the standard rate.

As a result, market demand for loans $D$ is equal to:

$$\begin{aligned}
D = D_{GAA} + N \cdot D_{GAbi} + N \cdot (D_{Gbibi} + (N - 1) \cdot D_{Gbibj} + D_{GbiA}) + D_{BAA} + N \cdot D_{BAbi} \\
+ N \cdot (D_{Bbibi} + (N - 1) \cdot D_{Bbibj} + D_{BbiA})
\end{aligned}$$

### *3.2.4. Banks' profits*

The profit of each bank can be calculated as the difference between the total profit from all categories of borrowers and the losses from loans outstanding to 'bad' borrowers.[29] Using the loan demand formulas obtained in (27), let us write down the profit functions of the large and small banks.

$$\begin{aligned}
Profit_A = D_{GAA} * i_{g,A} + D_{BAA} * i_{b,A} * (1 - pd) + N * D_{Gbi\,A} * i_{u,A} + N * D_{BbiA} * i_{u,A} * (1 \\
- pd) - (D_{BAA} + N * D_{BbiA}) * pd
\end{aligned} \tag{28}$$

$$\begin{aligned}
Profit_bi = D_{GAbi} * i_u + D_{BAbi} * i_u * (1 - pd) + D_{Gbibi} * i_g + D_{Bbibi} * i_b * (1 - pd) \\
+ (N - 1) * D_{Gbibj} * i_u + (N - 1) * D_{Bbibj} * i_u * (1 - pd) \\
- \big(D_{BAbi} + D_{Bbibi} + (N - 1) * D_{Bbibj}\big) * pd
\end{aligned} \tag{29}$$

[29] Banks' costs are not considered

Where $Profit\_A$ and $Profit\_bi$ – the profits of the large and small banks, respectively, $pd$ – the probability of default on loans by 'bad' borrowers..

# 4. Solution of the model

## 4.1 The approach to finding equilibrium rates

All banks compete with each other to maximise their profits. The three types of rates for different categories of borrowers is the only tool they use. At the same time, the large bank makes decisions independently and sets rates $i_{g,A}, i_{u,A}, i_{b,A}$ for different types of borrowers. Individual small banks cannot pursue independent policy: their rates $i_g, i_u, i_b$ vary by borrowers' type, but are indistinguishable between banks. We will solve our model, that is, find the optimal rates for the banks, using the methods of game theory (for example, Gibbons (1992), and Freixas and Rochet (2008)).

Let us consider a game with asymmetric information and two players: a large bank and small banks. We will consider the small banks to be one player, since they are all the same. They operate in the same environment with perfect competition among them relative to one another. The large bank has information about a significant number of potential borrowers, namely, it can distinguish between 'good' and 'bad' borrowers in a large share of the market. There are many small banks, and the remaining clients are distributed among them in equal shares. Accordingly, they have information about the quality of potential borrowers from their client group. By changing their lending rates, the players try to maximise their profits.

Making assumptions about the strategy behind one another's behaviour, the large and small banks decide on the size of their rates independently and simultaneously. It has become standard in the game theory consider such games as a sequential games, taking into account the fact that the players act rationally. At each step, the player, making an assumption about the previous move of the other player, can correctly calculate it. Both players, acting in turn, arrive at the equilibrium rates, which in the end will be played at the same time.

At the beginning of the game, we set the banks' rates randomly. The first player, for example, the large bank, tries to increase its profit by changing its rates, subject to the fixed rates of the small banks. The small banks assume the rates that the large bank can set and decide to change their rates in order to maximise their profits. The next move is made by the large bank, based on the same reasoning, and so on. The game continues until, at the next step, no player can increase its profit by changing its rates, with the other player's rates fixed, i.e. until the standard Nash equilibrium is reached.

Under information advantages, the large bank can make decisions strategically, taking into account the fact that it is large, i.e. it has a large amount of information about potential borrowers. Therefore, at the next stage of the game, the large bank seeks to use this advantage and act as a 'leader', while the small banks play the role of 'followers'.[30] The main question we are interested in is whether the 'leader' benefits from the information asymmetry. To answer this question, we conduct an experiment and compare two equilibria: the standard Nash equilibrium and the equilibrium resulting from the 'leader'-'follower' game.

## 4.2 Equilibria with information asymmetries: an example

For the purpose of the experiment, we simulated artificial data. To do so, we set the model parameters (see Table 3), randomly set the rates $i_{g,A}, i_{u,A}, i_{b,A}$ of the large bank and $i_g, i_u, i_b$ of the small banks[31] and calculated the profits of the large and small banks using formulas (28) and (29), respectively. The banks take turns maximising profits, as described in Paragraph 4.1, and arriving at the equilibrium rates, i.e. the rates at which the players cannot increase their profits by deviating from set rates, provided the rates of the other player remain unchanged – the Nash equilibrium.[32]

**Table 3**. Model parameters

| | | |
|---|---|---|
| $M$ | 400 | number of bank clients |
| $good$ | 0.5 | share of 'good' borrowers |
| $N$ | 49 | number of small banks |
| $A$ | 0.5 | share of borrowers known to the large bank |
| $pd$ | 0.1 | the probability of default of 'bad' borrowers |
| $i^*$ | 8 | standard rate |
| $c$ | 0.2 | elasticity of demand |
| $x$ | 8 | spread between the minimum and higher rate within which borrowers do not refuse to take loans at a higher rate |

In the second stage of the simulations, we allowed the rates of the large bank – the 'leader' – to deviate from the equilibrium rates. In this case, the 'leader' does not pursue the goal of increasing profits right at this step. It chooses its rates in such a way as to force the 'follower' to optimise its rates too (the small banks, being in equilibrium,

[30] This type of interaction between players is conceptually similar to the Stackelberg model (H. von Stackelberg, Market Structure and Equilibrium: 1st Edition Translation into English, Bazin, Urch & Hill, Springer 2011, XIV, 134 p.), but the tool to achieve the goal is not a firm's production, but the banks' rates, i.e., price categories.

[31] We assume that the initial allocation of rates is uniform over the range from 0% to 17% and satisfies the constraints of (1).

[32] The search for the extremum of a bank's profit function was carried out using the *fmincon* optimisation procedure in Matlab, which is designed to find the local minimum of a nonlinear function of many variables with constraints. The target functions for optimisation are the profit functions of the large and small banks in accordance with formulas (28) and (29). The optimisation arguments are the rates of the bank which profit is maximised at this step. Constraints are imposed on the ratio between the rates (1) and their range of definition from 0% to 17%. Starting from different points, generally speaking, different equilibrium positions can be attained. We have chosen one of them. Alternative calculations were performed using the *csminwel* function and similar results were obtained.

can change their rates only to maximise profits in response to the actions of the large bank). Having the opportunity to predict the behaviour of the ‘follower’, the ‘leader’ tries at its step to select rates such that, after the ‘follower’ responds, it can make a profit greater than in the standard Nash equilibrium.[33] This is where the game ends (see the results of the game in Table 4). The ‘leader’ can continue to increase its profit, but will not make the next move. It knows that after the move, the ‘follower’ will be interested in changing its rates again, and if the game continues, the ‘leader’ will not be able to maintain the advantage achieved.

**Table 4.** Results of the ‘leader’-‘follower’ game, %

| | **Large bank** | | **Small bank** | |
|---|---|---|---|---|
| | $i_g =$ 5.48 | $i_g =$ 4.37 | $i_g =$ 5.48 | $i_g =$ 4.37 |
| | $i_u =$ 9.15 | $i_u =$ 12.37 | $i_u =$ 9.15 | $i_u =$ 12.37 |
| | $i_b =$ 11.26 | $i_b =$ *14.95* | $i_b =$ 11.26 | $i_b =$ *14.95* |
| $i_{g,A} =$ *3.57*<br>$i_{u,A} =$ *8.08*<br>$i_{b,A} =$ 11.97 | 100 | 149.7 | 100 | 86.8 |
| $i_{g,A} =$ 2.41<br>$i_{u,A} =$ 8.83<br>$i_{b,A} =$ 15.54 | 89.8 | 120.5 | 88.7 | 92.4 |

Table 4 is structured as follows. It consists of two payoff matrices that reflect the state of the profits of the large bank (left) and the small banks (right) in the ‘leader’-‘follower’ game. To the left of the matrices are the rates of the large bank, and above the matrices are the rates of the small bank for each position of the game. For 100%, we use the profits of the large bank (in the left matrix) and of the small bank (in the right matrix) in the standard Nash equilibrium.

The first move is made by the large bank that changes its rates. This corresponds to going from the top to the bottom left cell in each matrix. It can be seen that the large bank is forced, in changing its rates at the first step, to reduce its profit. The small banks also lose profits. In the second move, the small banks change their rates in an attempt to improve the situation. The game moves to the lower right position of the matrices. Table 4 shows that the ‘follower’ is interested in moving into this position. It increases its profit from 88.7% to 92.4%, but fails to restore it to the standard Nash equilibrium level. At the same time, the ‘leader’ achieves its goal and gets a 20.5 percentage point increase over its original position. We can see that by bringing its rates back, the large bank can continue to increase its profit to 149.7% (top right cell of the matrix), but in this case, the small banks will also be interested in returning their rates, and the game will return to the

[33] First, we added a random variable uniformly distributed over the interval from -2 to +2 to the equilibrium rates of the ‘leader’. Then, using the *fmincon* function, we maximised the profit of the ‘leader’ after the response of the ‘follower’ and received new rates from both players. We repeated this procedure 100 times and chose the variation in which the ‘leader’s’ profit was maximised.

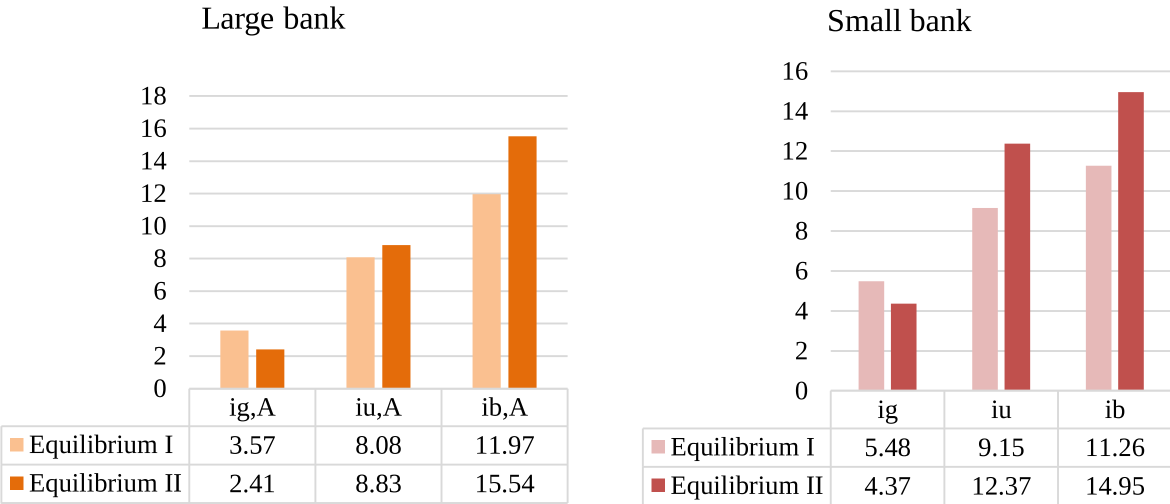
standard Nash equilibrium. Knowing this, the large bank will not make the next move and will remain in the bottom right position.[34]

## 4.3 Allocation of profit and borrower demand

**Banks**

In this section we consider the large bank's mechanism for realising its information advantage in more detail. Figure 1 demonstrates, using our experimental example, that in the course of the game, the banks reduce the rates offered to known 'good' borrowers and raise the rates offered to 'bad' and unknown borrowers. Equilibrium I in Figure 1 (and further in Figures 2–7) corresponds to the standard Nash equilibrium, and Equilibrium II corresponds to equilibrium in the 'leader'-'follower' game.

**Figure 1.** Comparison of the rates of the large and small banks in the 'leader'-'follower' game




Large bank

| | ig,A | iu,A | ib,A |
|---|---|---|---|
| Equilibrium I | 3.57 | 8.08 | 11.97 |
| Equilibrium II | 2.41 | 8.83 | 15.54 |

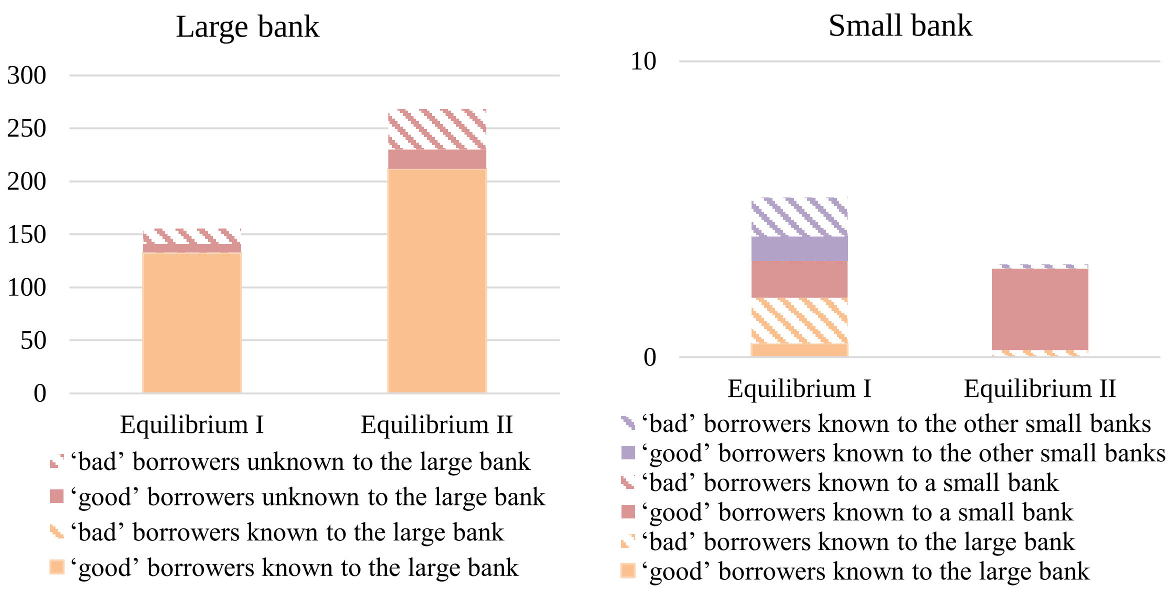
Small bank

| | ig | iu | ib |
|---|---|---|---|
| Equilibrium I | 5.48 | 9.15 | 11.26 |
| Equilibrium II | 4.37 | 12.37 | 14.95 |

In response to the rate movements, borrowers reallocate their demand for loans between the banks as shown in Figure 2. The mechanism of profit variation for the large and small banks in the 'leader'-'follower' game is illustrated in Figure 3.

**Figure 2.** Allocation of demand of different types of borrowers among banks in the 'leader'-'follower' game

[34] In addition to the strategy described, the 'leader' has another opportunity to increase its profit: to increase all its rates. In response to this, the 'follower' also raises its rates. Calculations for this strategy are presented in Annex 4.



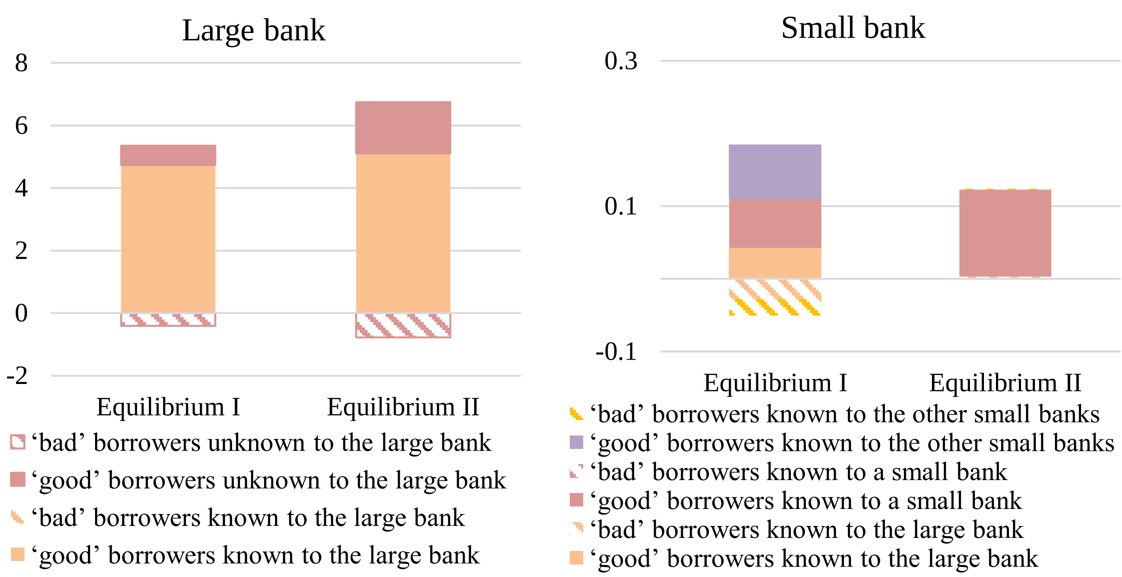

As a result of the reduced rate $i_{g,A}$, the large bank manages to increase its profit due to a significant influx of known 'good' borrowers through two channels.

First, the large bank minimises the share of 'good' borrowers known to it who would like to choose another bank through an increase in rate spread $i_u - i_{g,A}$. Second, the demand for loans grows following an increase in the attractiveness of the rate offered compared to the standard rate, i.e. due to the growth of $i^* - i_{g,A}$.

At the same time, due to a moderate increase in rate $i_{u,A}$ against a background of sharper increases in rates $i_u$ and $i_b$ by the small banks, the large bank accumulates an additional number of unknown borrowers. They exert pressures on profits, but the losses from the attraction of new unknown 'bad' borrowers are ultimately lower than the additional profit from the unknown new 'good' borrowers. Overall, the large bank increases its profit in the 'leader'-'follower' game, as shown in Figure 3.

In response to the actions of the large bank in the 'leader'-'follower' game, the small bank addresses two main issues: it gets rid of losses caused by 'bad' borrowers, and attracts the largest possible number of known 'good' borrowers. By getting rid of unknown 'bad' borrowers, the small bank sharply raises rate $i_u$, at the same time losing unknown 'good' borrowers who, in the standard Nash equilibrium, brought a significant part of the profit, not only because of their tangible share among the customers of the small bank, but also because they demanded loans at the initially high enough rate $i_u$. The remaining 'bad' borrowers unknown to the small bank begin to bring it approximately zero profit, since the income from the high rate $i_u$ now balances the losses from defaults. Demand from 'good' borrowers known to the small bank increases due to the transfer of clients from other small banks with an increase in the gap between $i_u$and $i_g$ and from the decline in $i_g$ compared to standard rate $i^*$. If, in response to the actions of the 'leader', the small banks had not lowered rates $i_g$, then they would have lost some of the 'good' borrowers, namely, those who respond to the improvement of lending conditions (the difference between $i_g$ and $i^*$ would not have changed), and those who choose between the small and large banks. The small bank has balanced rates $i_g$ and $i_u$ at such a level that all ‘good’ borrowers known to it have left other small banks and eagerly borrowed from it rather than from the large bank. Further reduction of $i_g$ is unprofitable, as it leads to reduced profits. In general, in the ‘leader’-‘follower’ game, as shown in Figure 3 and Table 4, the small bank loses profit compared to the initial equilibrium.

**Figure 3.** Reallocation of the banks’ profits in the ‘leader’-‘follower’ game




Thus, we have shown that the presence of information asymmetry enables a bank that has an information advantage to increase its profit by acting strategically as a ‘leader’. In this game, the ‘follower’ takes a loss.

In addition, it should be noted that in the ‘leader’-‘follower’ game, the risks of loan defaults are generally reduced, and the price of higher profits for the large bank is taking on some more credit risks (see Figure 4 and Figure 4a).

**Figure 4.** Weighted average probability of default, %

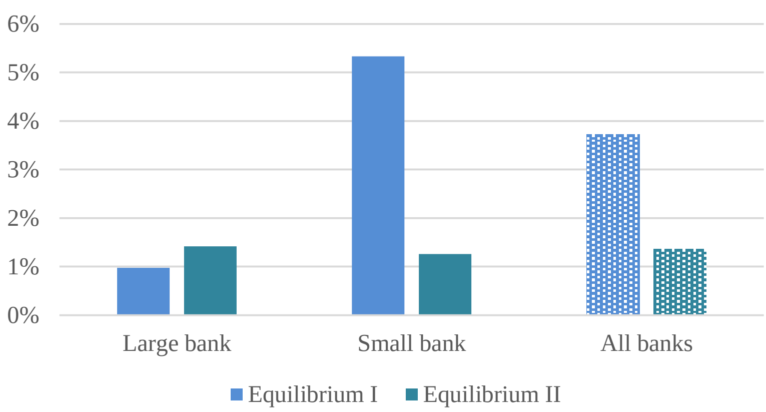
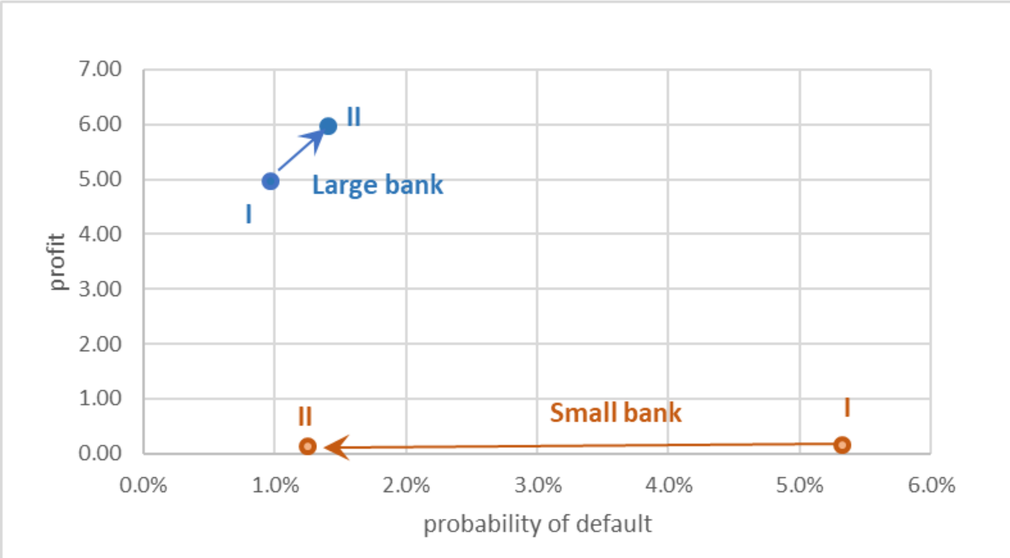


**Figure 4a.** Changes in the loan portfolio composition (in terms of return and risk) of the large and small banks in two equilibriums




**Borrowers**

It should be noted that there are also non-strategic participants in this game. These are borrowers. They do not directly participate in the competition, but benefit or suffer losses in the course of the game. The diagram in Figure 5 (or Figure 5a) shows the change in lending volumes for different categories of borrowers. It can be seen that 'good' borrowers benefit. They increase the loan they take out and, at the same time, benefit from lower rates, as shown in Figure 6 (or Figure 6a).

**Figure 5.** Change in volume of loans by borrower category

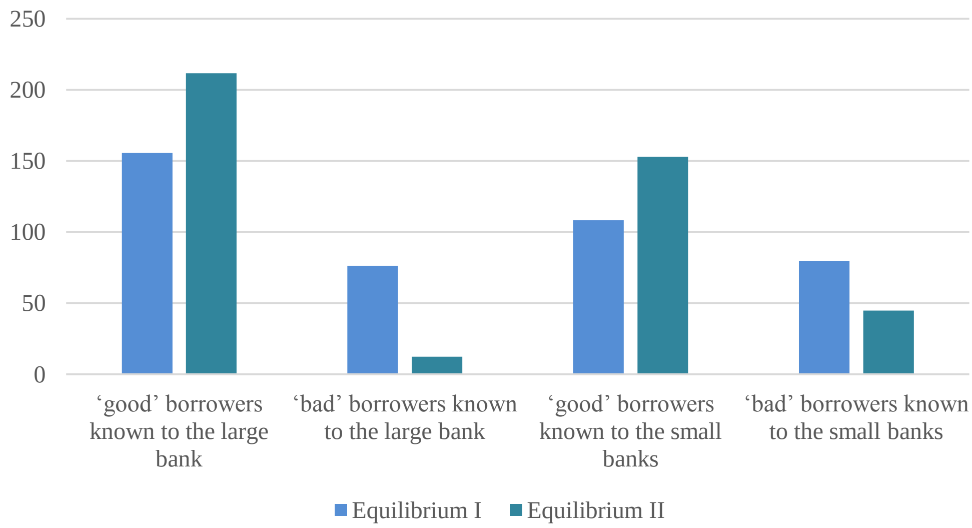
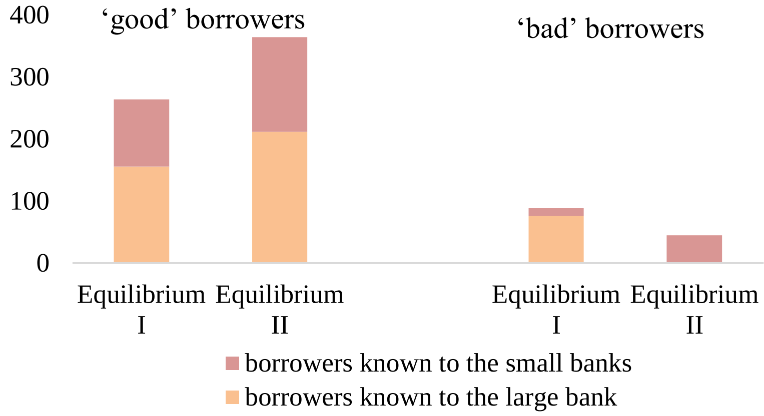


**Figure 5a.** Change in volume of loans by borrower category




'Bad' borrowers known to the large bank almost completely lose their opportunity to get loans due to an increase of rates $i_{b,A}$ and $i_u$. We can interpret this change as a reduction of financial inclusion. Indeed, interest rates for 'bad' borrowers are higher comparing with that in the first equilibrium, so they face worse financial conditions. The situation of 'bad' borrowers of the small banks is not so dire. They do not lose so much in the volume of loans, since they still have the opportunity to take out loans from the large bank at moderate rate $i_{u,A}$, leaving the small banks.

**Figure 6.** Change in average rates by borrower category

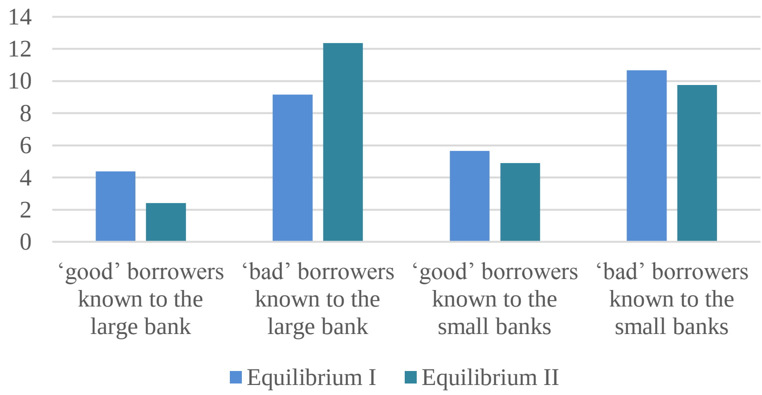
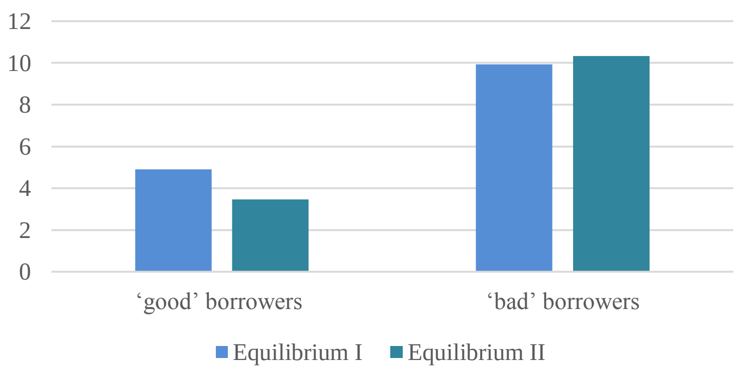



**Figure 6a.** Change in average rates by borrower category



# 5. Robustness check to alternatives

In this section we check how the 'leader's' gain changes with variations in the model parameters. Figure 7 contains three figures, each showing the ratio of the large bank's profit in the 'leader'-'follower' game to its profits in the standard Nash equilibrium depending on changes in the three main parameters of the model: the share of information available to the 'leader' about borrowers, the share of 'good' borrowers in the population and the maximum rate difference.

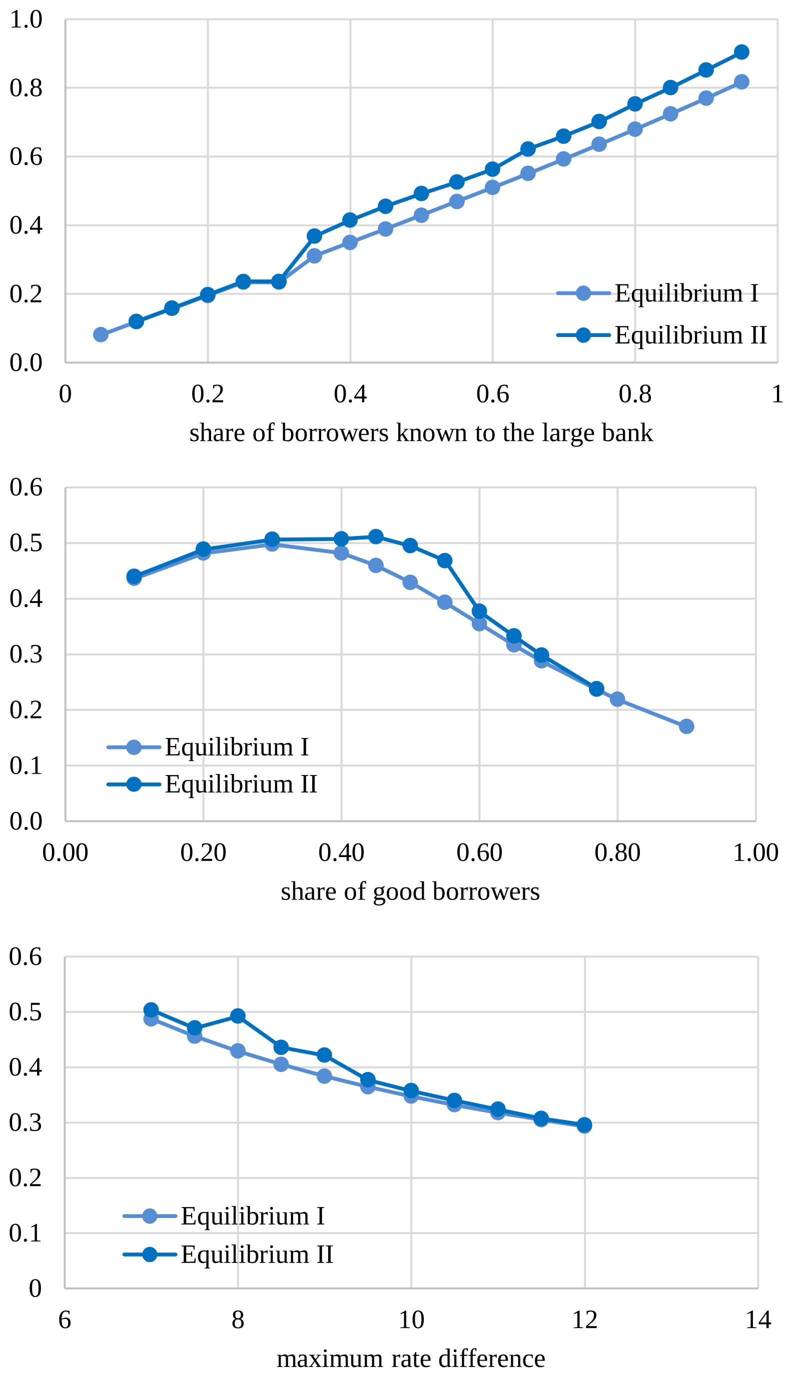
The results confirm that the 'leader's' advantage can be realised only if the information asymmetry is large enough (the share of borrowers known to the large bank must exceed 0.3 in order for it to be able to move to an equilibrium different from the standard Nash equilibrium).

As larger clients' base strengthens information asymmetry of a dominant bank, it creates stimulus to increase market share on the deposit/payment markets as a precondition to increase profits on the lending market. For example, a bank may charge higher (then optimal or market) deposit rates to attract more clients and increase profits on the credit markets under information asymmetry to compensate losses on the deposit market. To prevent such behaviour the regulator may use mechanisms of information sharing (most likely through credit bureaus)[35]. In our model, information symmetry excludes possibility for the large player to benefit from the strategic behavior.

At the same time, the 'leader' will not always be able to use its information advantage over the 'follower'. For this to happen, the shares of 'good' and 'bad' borrowers must be comparable (otherwise the rates offered to unknown small bank borrowers will initially be close to those offered to 'good' or 'bad' borrowers and will not be sensitive to the actions of the large bank). It should also be noted that a prerequisite for the strategic behaviour of the large bank is the moderate sensitivity of borrowers to differences in the rates offered to them. Too sensitive demand, when clients agree to take out a loan only at minimum rates, leads to market fragmentation: low rates are set by banks for known 'good' borrowers with high rates set for everyone else, since there are no 'good' borrowers left among unknown borrowers. As a result, borrowers receive loans only from those banks where they have deposits. On the other hand, with low sensitivity to differences in rates, borrowers are uniformly distributed among banks, and the 'leader' loses the ability to influence clients' decisions.

[35] We discuss policy implications in more detail in Conclusion.

**Figure 7.** Share of the large bank's profit in equilibria I and II



# Conclusion

Using a simple, but highly relevant to the digital economy, assumption, we obtain the following results:

First, a dominant position in the payment/deposit market, which is typical of the digital age of finance, provides the basis for strategic behaviour in the credit market and predetermines dominance in the lending market. Hence, the market structure of the payment/transaction/deposit market turns out to be relevant for the market structure of the credit market

We show that a large bank with its information advantage may select good borrowers and push other borrowers out as unknown borrowers to other banks, thereby worsening the distribution of borrowers available to the rest of the credit market.

Second, loan pricing plays an important role in the implementation of the dominant bank's strategy. The large bank raises the rates offered to known bad borrowers and raises rates slightly for unknown borrowers, pushing them out into the rest of the market, worsening the allocation of borrowers available to the small banks. At the same time, it lowers the rates offered to known good borrowers. The small banks, faced with an influx of borrowers unknown to them, also raise their rates, thus pushing some of their unknown good (and bad) borrowers away to the large bank. In general, the structure of small banks' borrowers deteriorates.

As a result, known good borrowers get lower rates and known bad borrowers get higher rates. The strategic behaviour of a large player leads to greater differentiation of rates in the market. At the same time, interest rates offered to unknown borrowers increase.

Third, higher rates for unknown borrowers and for bad borrowers known to banks results in a decrease in the demand in these categories of borrowers – inclusiveness of the lending market goes down. At the same time, bad borrowers of the large bank suffer the most. Bad borrowers of the small banks can improve their position as unknown borrowers of the large bank by switching to this bank.

Fourth, the weighted average risk on the balance sheet of the banking sector is reduced by the small banks' narrowing their customer base. For the large bank, it is strategically more profitable to accept some additional risk of an increase in the number of borrowers, which is offset by an increase in profits.

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# APPENDIX 1

Let us continue the derivation of the formula for the share of 'good' borrowers known to the large bank who will take loans from the large bank. Now let $i_u \leq i_{g,A}$. Then, if these rates are equal, borrowers, as before, will be uniformly distributed among banks and they will take $GAA = \frac{1}{N+1}$ loans from the large bank. If $i_{g,A} = i_u + x$, no one will take loans from the large bank: $GAA = 0$. Substituting these conditions into a linear function, we get the formula.

$$GAA = \begin{cases} \frac{1}{N+1}\left(1 - \frac{i_{g,A} - i_u}{x}\right), i_u \leq i_{g,A} \leq i_u + x \\ 0\ , i_{g,A} > i_u + x \end{cases}$$

To find the share of 'bad' borrowers known to the large bank who will take loans from the large bank $BAA$, let us define the following boundary conditions and substitute them into a linear function.

If $i_u \leq i_{b,A}$, then when

$$i_{b,A} = i_u \rightarrow BAA = \frac{1}{N+1}$$

$$i_{b,A} = i_u + x \rightarrow BAA = 0$$

consequently

$$BAA = \begin{cases} \frac{1}{N+1}\left(1 - \frac{i_{b,A} - i_u}{x}\right), i_u \leq i_{b,A} \leq i_u + x \\ 0\ , i_{b,A} > i_u + x \end{cases}$$

If $i_{b,A} \leq i_u$, then when

$$i_u = i_{b,A} \rightarrow BAA = \frac{1}{N+1}$$

$$i_u = i_{b,A} + x \rightarrow BAA = 1$$

consequently

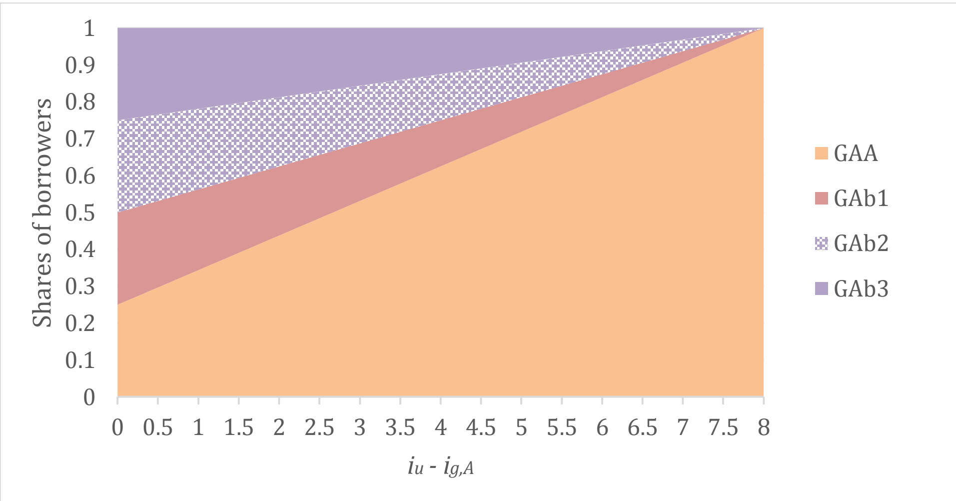
$$BAA = \begin{cases} \frac{1}{N+1}\left(1 + N\frac{i_u - i_{b,A}}{x}\right), i_{b,A} \leq i_u \leq i_{b,A} + x \\ 1\ , i_u > i_{b,A} + x \end{cases}$$

# APPENDIX 2

**'Good' borrowers known to the large bank**

It is possible to illustrate in a graph the allocation of the shares of 'good' borrowers known to the large bank among banks of the economy we have described as a function of rate differential $i_u - i_{g,A}$. Figure 1 shows the cumulative allocation of borrowers among four banks[36] when $i_{g,A} \leq i_u$. It can be seen that, in the case of the equality of rates $i_u - i_{g,A} = 0$, borrowers will be uniformly distributed among the four banks and their share in each bank will be 0.25. With an increase in rates $i_u$, the shares of small banks $GAbi$ will decrease and reach zero at $i_u - i_{g,A} = x$ ($x = 8$ in this example). All borrowers will then take loans from the large bank, and its share $GAA$ will amount to 1.

Figure 2.1. Structure of the allocation of 'good' borrowers known to the large bank (cumulative share)

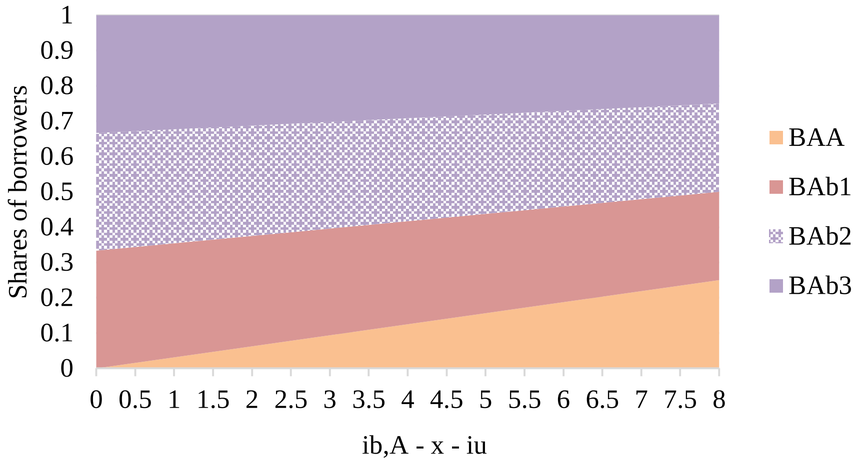



**'Bad' borrowers known to the large bank**

For the case of $i_u \leq i_{b,A}$ and the system of 4 banks (rate $i_u$ takes values from $i_{b,A} - x$ to $i_{b,A}$). Figure 2.2 shows that, with a sufficiently large difference in rates $i_{b,A} - x - i_u = 0$, 'bad' borrowers will not take out loans from the large bank, but will be uniformly distributed among small banks, 1/3 in each. When $i_u = i_{b,A}$ (the value on the axis is 8), borrowers will take loans from all four banks in equal proportions of 0.25.

Figure 2.2. Structure of the allocation of 'bad' borrowers known to the large bank (cumulative share)

[36] Here and further in Annex 2, when constructing graphs of the borrower allocation structure, for clarity, we will limit the number of banks to three small banks and one large bank

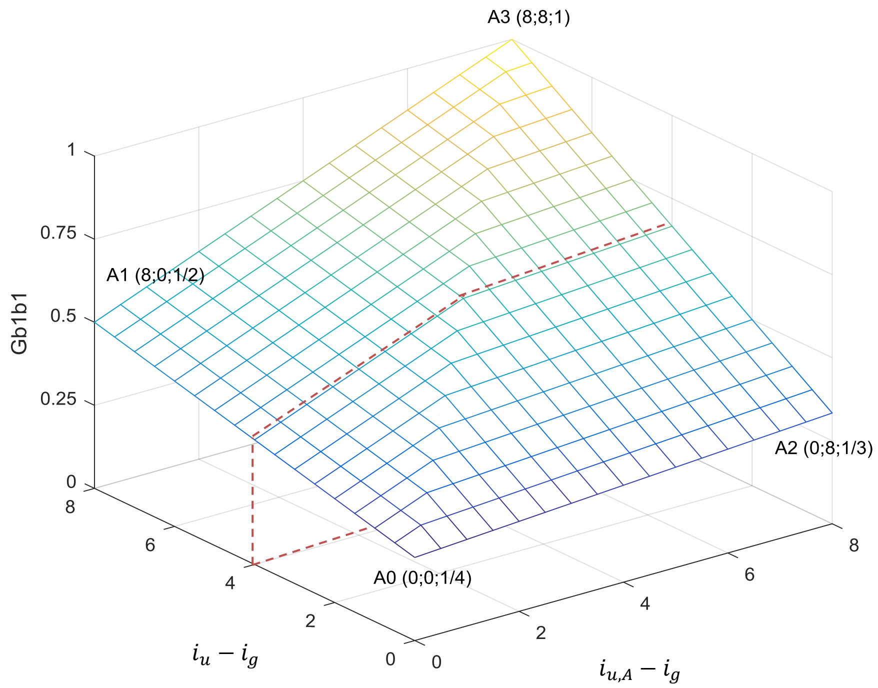



**‘Good’ borrowers known to a small bank**

A graphical representation of the desired dependence can be helpful to formally determine coefficients $\alpha_1, \alpha_2, \alpha_3, \beta_1, \beta_2, \beta_3, \gamma_1, \gamma_2, \gamma_3$ in the relations of (8). As suggested earlier, we will narrow the number of banks to four and make the following assumptions. We will fix the minimum of rates $i_g, i_u, i_{u,A}$, which is likely considered as the most attractive one by borrowers. Let it be rate $i_g$ of bank $b1$. How much rates $i_{u,A}$ and $i_u$ exceed rate $i_g$ determines borrowers’ choices ($i_u$ and $i_{u,A}$ vary from $i_g$ to $i_g + x$). Then function $Gb1b1$, which determines the share of ‘good’ borrowers known to small bank $b1$ who take a loan from it, is a function of two variables and can be plotted in three-dimensional space in the form of a surface (see Figure 2.3). The constraints introduced in Table 1 of the main text are made at points A0, A1, A2, and A3 (subject to strict equality). Since we assume a linear dependence on the difference in rates, in three-dimensional space this surface is a plane or a composition of several planes. It is easy to show that a single plane cannot pass through points A0, A1, A2, and A3.[37] Therefore, we construct the required surface in the form of two half-planes connected along a straight line passing through A0 and A3, where the condition of the equality of rates is satisfied $i_u$=$i_{u,A}$. This line characterises a case similar to that considered in two-dimensional space, when one of the banks (in this case, bank $b1$) sets lower rates $i_g$ for borrowers known to it, and for all the rest, sets another higher rate $i_u$=$i_{u,A}$ (similar to (3) and Figure 2.1).

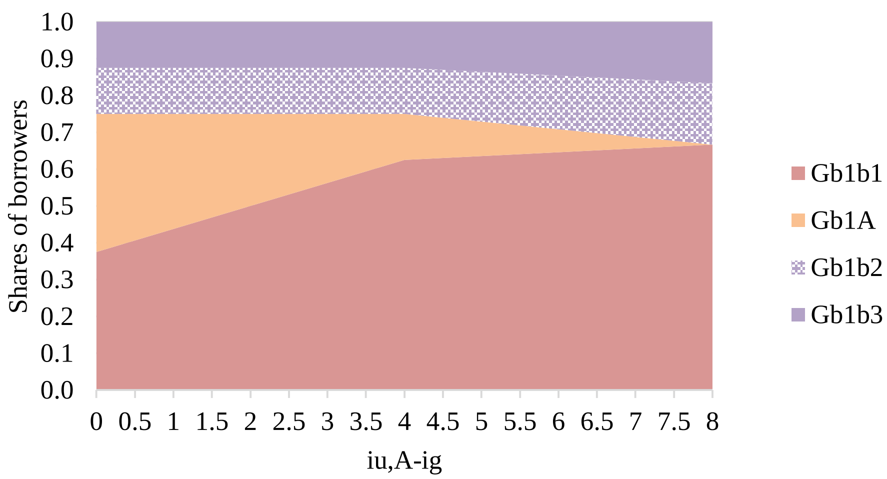
Figure 2.3. Share of ‘good’ borrowers known to a small bank who will take loans from the small bank that knows them

[37] Segments A0A1, A1A3, A3A2, and A2A0 limit the part of the space that is the domain of the definition of function $Gb1b1$.



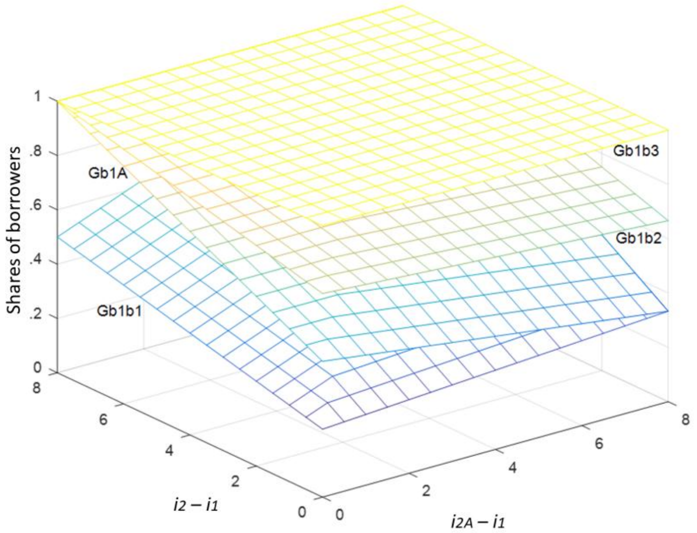

The existence of the junction of the planes can be explained. To do this, we will fix rate $i_u$ at, for example, $i_u = i_g + x/2$, and gradually increase rate $i_{u,A}$ from $i_g$ to $i_g + x$. This will be a section of surface Gb1b1 with plane $i_u - i_g = 4$, which is shown in Figure 2.3 as a red dotted line and as a polyline in Figure 2.4. In addition to $Gb1b1$, for clarity, Figure 2.4 is supplemented by the allocation of borrowers among all other banks. We see that at values of $i_{u,A}$ close to $i_g$, an increase in rate $i_{u,A}$ causes a rapid flow of borrowers from the large bank to small bank $b1$. This continues as long as $i_{u,A} < i_u$. A further increase in $i_{u,A}$ is accompanied by a lower rate of growth in the share of borrowers of bank $b1$, as each borrower leaving the large bank begins to consider not only bank $b1$ but also other small banks as lenders, seeing that their rates $i_u$ are also becoming attractive.

Figure 2.4. Structure of the allocation of 'good' borrowers known to a small bank at fixed rate $i_u = i_g + x/2$ (cumulatively in shares)



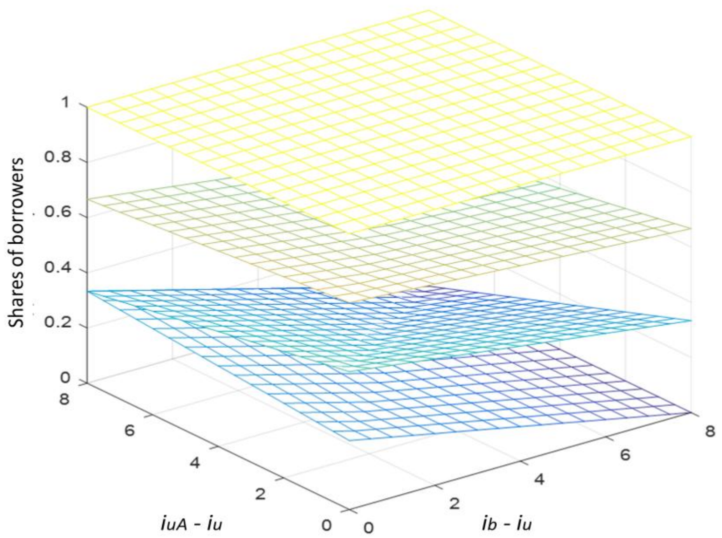
The three-dimensional allocation of the shares of 'good' and 'bad' borrowers known to a small bank is shown in Figures 2.5 and 2.6, respectively.

Figure 2.5. Structure of the allocation of 'good' borrowers known to a small bank when $i_g \le i_u$ and $i_g \le i_{u,A}$ (cumulatively in shares)




**'Bad' borrowers known to a small bank**

Figure 2.6. Structure of the allocation of 'bad' borrowers known to a small bank when $i_u \le i_b$ and $i_u \le i_{u,A}$ (cumulatively in shares)



# Appendix 3

Table 2.1. Conditions for constructing functions that determine the allocation among banks of 'bad' borrowers known to a small bank when $i_{u,A} \leq i_u \leq i_b$

| No. | Constraints and their interpretation | $Gbibi$ | $Gbibj$ | $GbiA$ |
|---|---|---|---|---|
| 1. | $i_{u,A} = i_u = i_b$<br>condition of indifference: borrowers will be uniformly distributed among banks | $\frac{1}{N+1}$ | $\frac{1}{N+1}$ | $\frac{1}{N+1}$ |
| 2. | $i_{u,A} = i_u$ and $i_b \geq i_{u,A} + x$<br>borrowers will be uniformly distributed among the large bank and small banks, except for $bi$ | 0 | $\frac{1}{N}$ | $\frac{1}{N}$ |
| 3. | $i_u \geq i_{u,A} + x$ and $i_b \geq i_{u,A} + x$<br>all borrowers will prefer to take loans from the large bank | 0 | 0 | 1 |

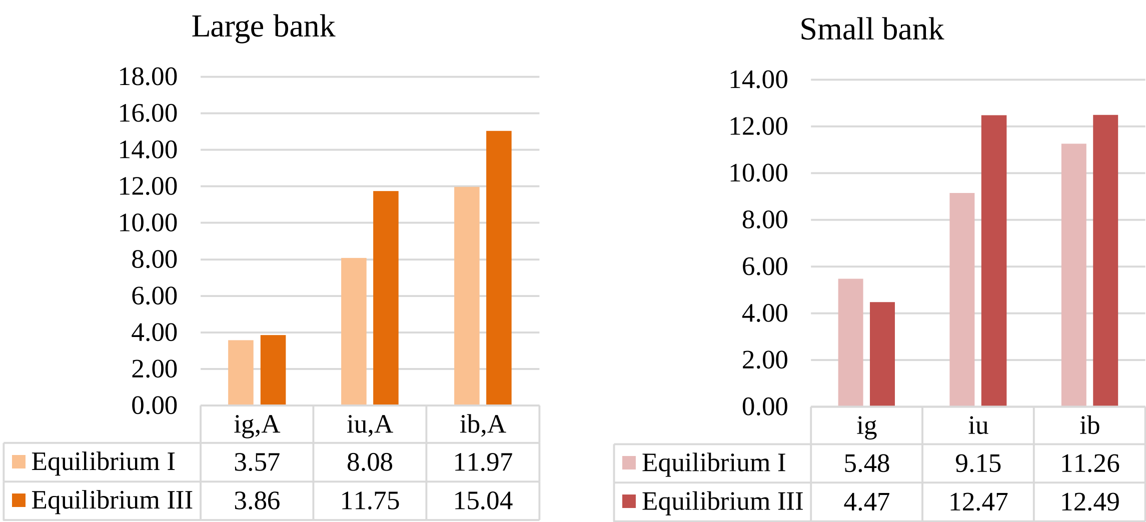
Table 2.2. Conditions for constructing functions that determine the allocation among banks of 'bad' borrowers known to a small bank when $i_u \leq i_{u,A}$ and $i_u \leq i_b$

| No. | Constraints and their interpretation | $Gbibi$ | $Gbibj$ | $GbiA$ |
|---|---|---|---|---|
| 1. | $i_{u,A} = i_u = i_b$<br>condition of indifference: borrowers will be uniformly distributed among banks | $\frac{1}{N+1}$ | $\frac{1}{N+1}$ | $\frac{1}{N+1}$ |
| 2. | $i_u = i_{u,A}$ and $i_b \geq i_u + x$<br>borrowers will be uniformly distributed among the large bank and small banks, except for $bi$ | 0 | $\frac{1}{N}$ | $\frac{1}{N}$ |
| 3. | $i_u = i_b$ and $i_{u,A} \geq i_u + x$<br>borrowers will be uniformly distributed among the small banks and will not take loans from the large bank | $\frac{1}{N}$ | $\frac{1}{N}$ | 0 |
| 4. | $i_b \geq i_u + x$ and $i_{u,A} \geq i_u + x$<br>all borrowers will prefer to take loans from the small banks, but not from bank $bi$ | 0 | $\frac{1}{N-1}$ | 0 |

# Appendix 4

The 'leader'-'follower' game has another acceptable strategy in addition to the one described in the main body of the work. The large bank can raise all of its rates. In response to its actions, the small banks are also interested in changing their rates (we will denote the new state as Equilibrium III). They will raise rates $i_u$ and $i_b$ and lower $i_g$, as shown in Figure 4.1. Adhering to this strategy, both the small and large banks will ultimately receive an additional profit (Figure 4.2).

Figure 4.1. Comparison of the rates of the large and small banks in the 'leader'-'follower' game with the large bank's strategy to raise all rates



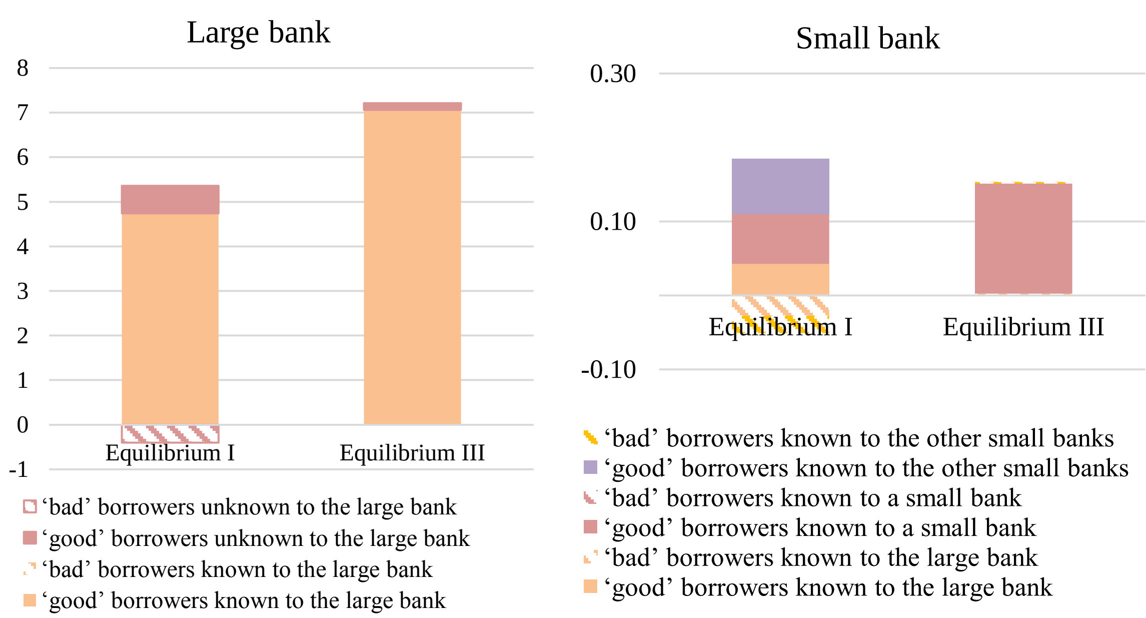

Large bank

| | ig,A | iu,A | ib,A |
|---|---|---|---|
| Equilibrium I | 3.57 | 8.08 | 11.97 |
| Equilibrium III | 3.86 | 11.75 | 15.04 |

Small bank

| | ig | iu | ib |
|---|---|---|---|
| Equilibrium I | 5.48 | 9.15 | 11.26 |
| Equilibrium III | 4.47 | 12.47 | 12.49 |

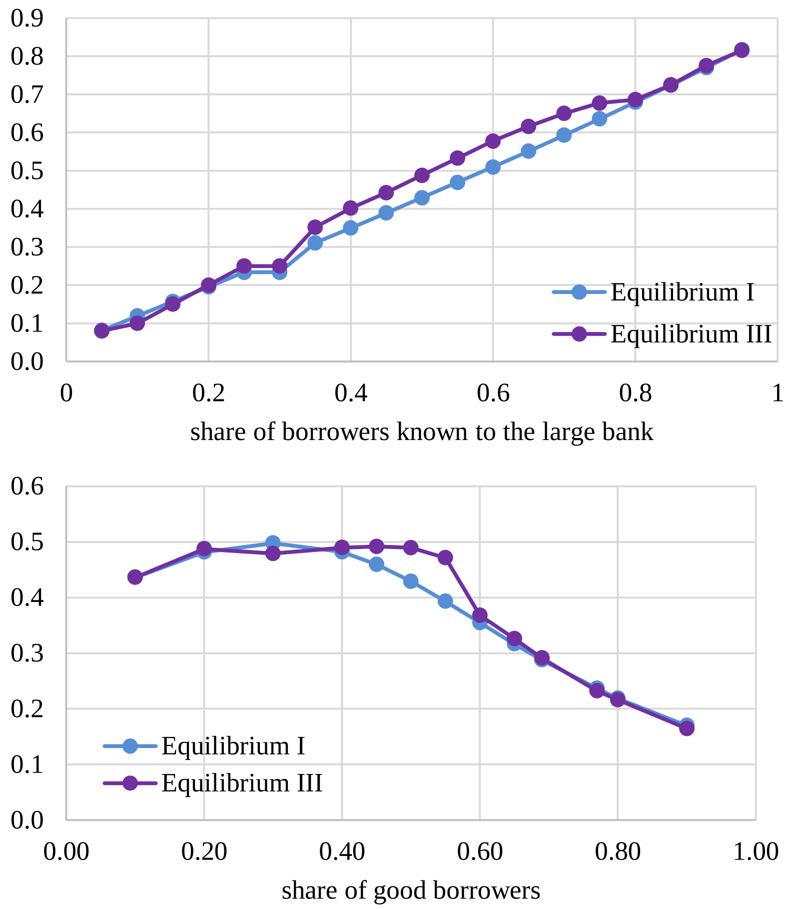
Figure 4.2. Reallocation of the banks' profits in the 'leader'-'follower' game, with the large bank's strategy to raise all rates

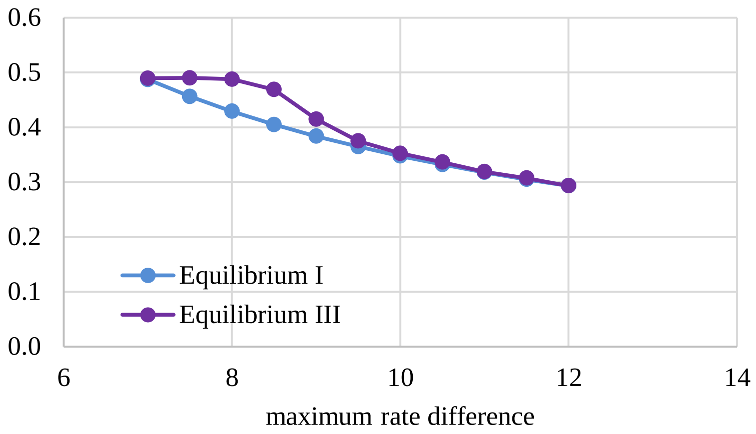


In this strategy, the large bank increases its profit both by expanding the number of 'good' borrowers it knows and by raising rate $i_{g,A}$. Unlike the game version described in the main body of the article, the small banks can win by substantially increasing the share of 'good' borrowers known to them.

As for bank clients, as before, on average, 'good' borrowers have an advantage. Under the influence of a sharp rise in rates for unknown borrowers, they prefer to get loans from those banks that have information about them. At the same time, 'bad' borrowers almost completely lose their ability to take out loans.

Figure 4.3. Share of the large bank's profit in equilibria I and III




0.6
0.5
0.4
0.3
0.2
0.1
0.0
6
8
10
12
14
Equilibrium I
Equilibrium III
maximum rate difference

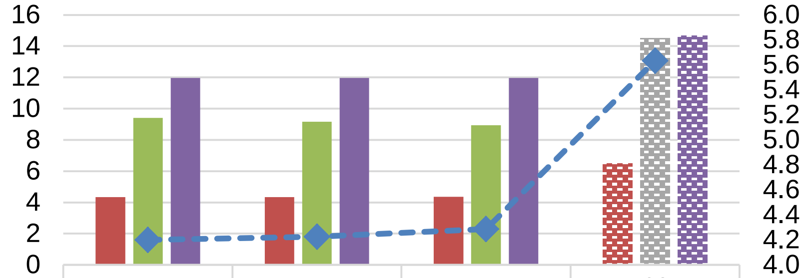
# Appendix 5

One of the key assumptions of our model is the assumption that the rates of the small banks are equal for borrowers of the same type. The small banks have the same amount of information, therefore, having no advantages, they freely compete with each other. The assumption of the equality of rates is widely used in the literature, as, for example, by Freixas, Rochet (2008) and Dell'Ariccia (2001) as part of the development of Salop's model of spatial competition. As a baseline, the authors consider a system of *n* identical banks and a continuum of customers uniformly distributed on a unit circle, with product differentiation by transport costs proportional to the distance from the customer to the bank. From symmetry considerations, it is obvious that rates are equal. Since our model has conceptual differences in comparison with Salop's model, let us show with an example that the assumption of equal rates is acceptable.

Without loss of generality, let us assume that three identical banks are competing in the market. The principles for the construction of the profit functions of each bank are similar to those described in the main body of this paper, and the parameters for the calculation are taken from Table 3 for comparability. Each bank maximises its profit independently of the other banks, by setting, as in the main part of this work, three types of rates: $i_{gj}(i_{bj})$ to known 'good' ('bad') borrowers and $i_{uj}$ to unknown borrowers when inequality (1) $i_{gj} \leq i_{uj} \leq i_{bj}$ is satisfied, where *j=1, 2, 3*. The banks have the same amount of client information. In contrast to the assumptions of the basic model, we assume that each bank can impose its own set of rates, which does not coincide with the sets of rates of the other banks. The banks take turns maximising profits, as described in Paragraph 4.1, and arrive at rates that correspond to the standard Nash equilibrium.

The results of the calculation of the equilibrium rates are shown in Figure 5.1. It can be seen that in the standard Nash equilibrium, the rates of all three banks by borrower group are almost identical. If we assume that the banks agree and set the same rates, maximising aggregate profits, then all rates will rise substantially and the banks will increase their profits (the last group of three columns in Figure 5.1).

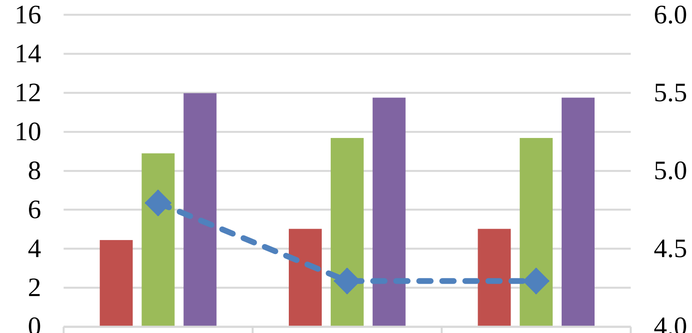
**Figure 5.1.** Comparison of rates in a game with three identical banks under competitive and collusive conditions (standard Nash equilibrium)




| | bank1 | bank2 | bank3 | no competition |
|---|---|---|---|---|
| i1 | 4.33 | 4.34 | 4.37 | 6.50 |
| i2 | 9.40 | 9.16 | 8.95 | 14.50 |
| i3 | 11.97 | 11.97 | 11.97 | 14.67 |
| profit | 4.20 | 4.22 | 4.29 | 5.63 |

In the case that one of the banks (for example, bank1) manages its rates independently and the other two (bank2 and bank3) act together, then, as shown in Figure 5.2, the independent bank will win in comparison with the competitive case, almost without changing its rates, while the other two banks will lose by raising rates for known ‘good’ and unknown borrowers.

**Figure 5.2.** Comparison of rates in a game with three identical banks under one versus two conditions (standard Nash equilibrium)




| | bank1 | bank2 | bank3 |
|---|---|---|---|
| ig | 4.4 | 5.0 | 5.0 |
| iu | 8.9 | 9.7 | 9.7 |
| ib | 12.0 | 11.7 | 11.7 |
| profit | 4.8 | 4.3 | 4.3 |

Thus, we see that in our model, the equality of rates for identical banks is not always preserved. At least in a system with a small number of banks, equality depends on the activity of individual players. However, in the event of free competition, even then the standard Nash equilibrium equalises the rates and profits of identical banks.