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Will banks introduce negative interest rates to household deposits?
A game-theoretical model

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Abstract

This paper presents a game-theoretical model to assess whether banks will introduce negative interest rates to household deposits. This is modelled as a game of incomplete information between two banks which can decrease their interest rates to enhance their interest margins. Savers can decide to stay at their bank, switch to another bank against switching costs, or to use their savings alternatively, such as for investments. We find that banks are more likely to decrease their interest rates if switching costs are higher and the alternatives for savings accounts are less attractive. Surprisingly, we also find that higher switching costs and less attractive alternatives are not necessarily beneficial for banks' profitability. High switching costs hinder banks to attract savers from competitors and unattractive alternatives may lead to an expensive war of attrition between banks.

Keywords

Retail banking, Bank interest margin, Low interest rate environment, Bank profitability, Switching behavior, Bank competition

JEL Classification

D14, G21, L11

1. Introduction

After the global financial crisis of 2008, interest rates fell to historical low levels. Central banks in developed countries adopted monetary policies that decreased interest rates to boost economic growth by stimulating lending and investing. For instance, central banks started quantitative easing and decreased their deposit facility rate, the interest rate banks receive for depositing funds at central banks overnight. This latter was even brought below zero, for the first time by the Swedish central bank in July 2009, followed by Denmark (July 2012), the ECB (June 2014), Switzerland (January 2015) and Japan (January 2016). As a result, interest rates on a wide range of financial products such as government bonds and loans to businesses decreased substantially.

The low interest rate environment helps economies, but decreases the profitability of banks (Eisenschmidt and Smets 2018; Sääskilahti 2018). Interest margins are squeezed as interest rates on the revenue-side are affected differently than interest rates on the funding-side. The interest rates on the revenue-side keep decreasing, but some interest rates on the funding-side do not decrease further. Banks decreased the interest rate on household deposits to 0%, but are hesitant to decrease them below zero (see e.g. Eisenschmidt and Smets 2018; Demiralp et al. 2019). Accordingly, banks face the following trade-off. If a bank maintains a positive interest rate, savers stay, but profitability may be (too) low. If a bank decreases its interest rate below zero, it can enhance its profitability, but savers may withdraw their savings. This paper focuses on this trade-off.

This trade-off is a relevant issue for banks for four reasons. First, household deposits represent 28% of the balance sheet of the average bank in the European Union (EU), whereas percentages around 80% are not uncommon for some individual banks (Eisenschmidt and Smets 2018; EBA 2020a). Second, net interest income accounts for 60% of the profits of banks in the EU (EBA, 2020a). Third, until January 2021, no bank has introduced negative interest rates to household deposits below €100,000. Around 50% of the banks in the EU fear reputational issues when implementing negative interest rate and 20% the competition from other banks and non-banks (EBA 2020b). Fourth, more than 50% of the banks in the EU do not believe that their overall profitability will improve soon (EBA 2020b). Additionally, the IMF warns that profits are likely to come under further pressure and argues that substantial action is needed to improve the profitability (IMF 2020).

This paper assesses how banks will solve the trade-off. We address the following questions. Will banks introduce negative interest rates to household deposits? When and under which conditions? What will savers do if negative interest rates are introduced to their savings? How do banks take into account the behavior of savers and competitor banks? And how is the profitability of banks affected? This paper presents a theoretical framework to answer these questions. Our game-theoretical model finds that the outcome of the trade-off depends on switching costs (*how simple can savers switch between banks?*), the attractiveness of alternatives (*do savers prefer alternatives over a savings account?*) and the competition between banks (*how profitable are competing banks?*).

In our model, banks can increase their profitability by decreasing the interest rate on household deposits. Savers can 1) tolerate this decrease and do nothing, 2) move the savings to another bank, or 3) move the savings to an alternative to a savings account, such as investing, spending or keeping the savings at home. We alter the decision of savers in different scenarios. We find that interest rate decreases may occur in all scenarios, but are more likely if switching costs are higher and alternatives are less attractive. Surprisingly, we find that the two forms of market power (i.e. high switching costs and unattractive alternatives) do not necessarily increase the profits of banks, as unattractive alternatives may lead to an expensive *war of attrition* between banks and high switching costs may hinder banks to attract savers from competitors. This nuances the literature that finds that market power is beneficial for banks (Berger and Hannan 1989; Neumark and Sharpe 1992; Molyneux et al. 2019). In a war of attrition, the banks maintain unprofitable high interest rates for a certain amount of time waiting for other banks to decrease their interest rate first.

We contribute to the literature in two ways. First, we provide a theoretical framework to consider the interest rate strategies of banks in the low interest rate environment. Recent literature assumes that banks will avoid to introduce negative interest rates to household deposits, but do not present extensive and comprehensive theoretical argumentation (see e.g. Eisenschmidt and Smets 2018; IMF 2020). Second, we provide a novel theoretical framework on the behavior of savers, taking into account switching between banks and non-bank alternatives. Theoretical frameworks on deposit holder decisions take into account either switching between banks (e.g. Sharpe 1997; Shy 2002) or moving to non-bank alternatives (Hutchison 1995), but not both. Moreover, there are no theoretical frameworks that offer predictions how savers would react to negative interest rates (Efendic et al. 2019).

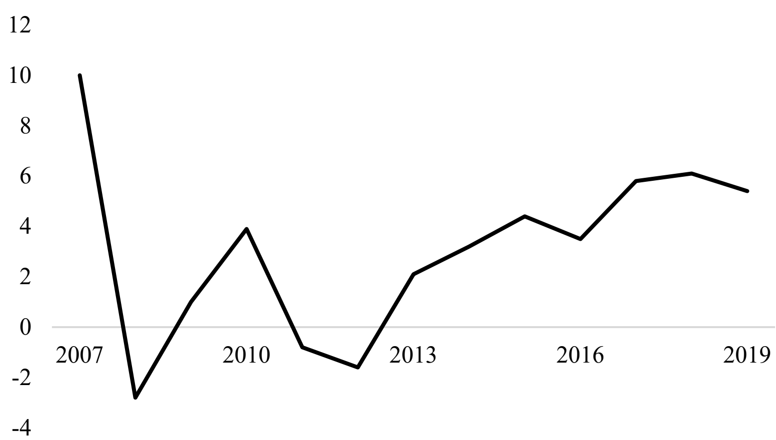
This paper is structured as follows. In section 2 we illustrate the pressure banks face to increase their profitability and how banks aim to do this. Section 3 shows how tolerant savers are towards negative interest rates and which alternatives they consider. Section 4 provides the setup of our game-theoretical model and section 5 the scenarios. Section 6 derives the equilibria and section 7 presents the results. We discuss our findings in section 8.

2. Banks: Interest margins and profitability

2.1 Persistent low profitability

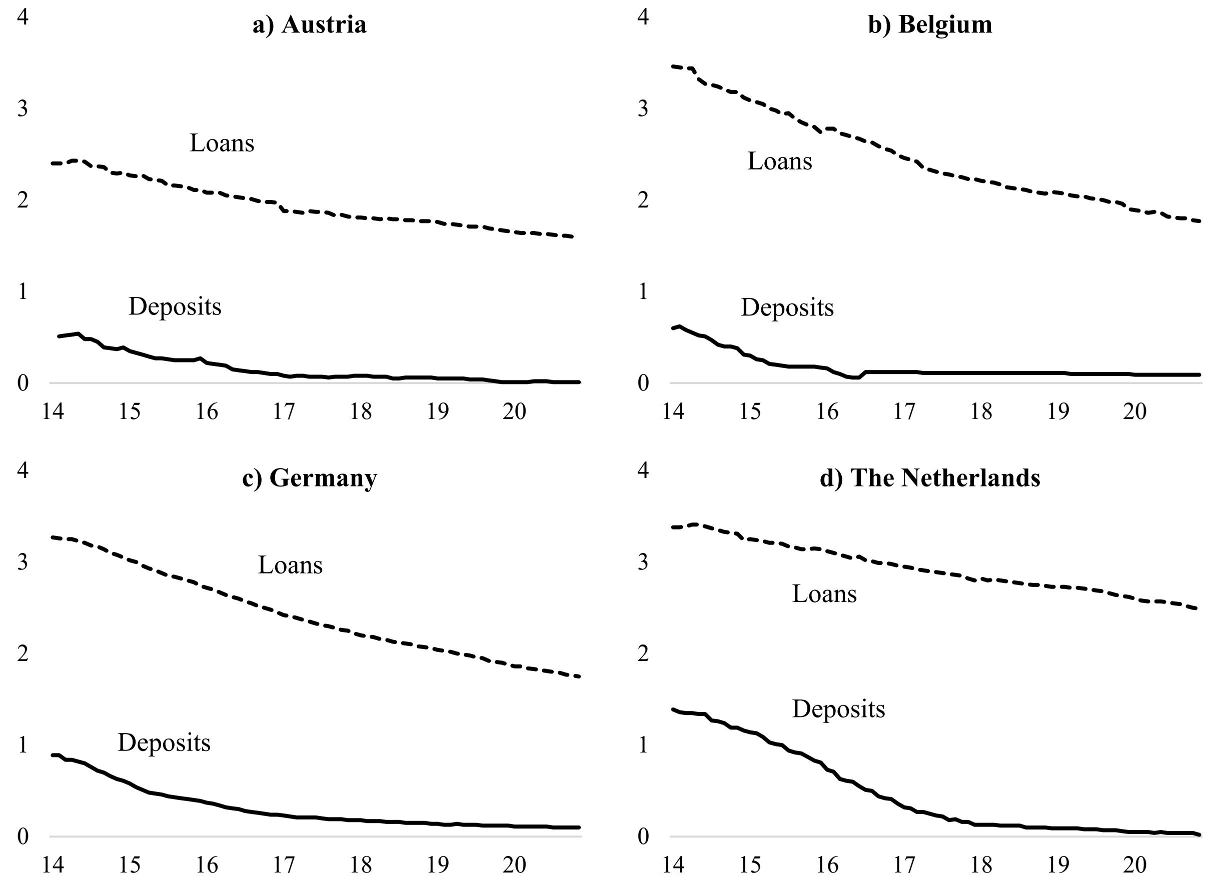
Since the global financial crisis, the profitability of banks in the EU is under pressure. Figure 1 shows that the average return on equity of banks in the EU decreased from 10.0% in 2007 to 5.4% in 2019. During the financial and sovereign debt crisis, return on equity was even negative, but the profitability recovered slightly since 2013. However, the return on equity remains suppressed and 2019 figures in some individual countries such as Germany (1.7%), Italy (4.8%) and the UK (4.9%) are exceptionally low. By contrast, the averages in countries with central banks that did not introduced negative interest rates, such as Hungary (15.9%), Romania (15.2%) and Czech Republic (12.5%), are much higher. The COVID-19 pandemic is expected to decrease the return on equity further.

Fig. 1 The return on equity (%) of banks in the EU-28 (ECB 2021)



There is ample empirical evidence that the low interest rate environment decreased the profitability of banks (see Eisenschmidt and Smets (2018) for a review of the literature). On the revenue-side, the interest rates that banks receive on loans to businesses or households decrease steadily, while interest rates on the funding-side stagnated around 0%. Figure 2 shows this development for banks in some individual countries. For the Netherlands, for instance, figure 2d shows that interest rates on loans decreased persistently from 3.4% in 2014 to 2.5% in 2020, while the decrease of household deposit rates flattened in 2018, when the 0% was reached. Indeed, the three largest banks of the Netherlands adopted household deposit rates around 0%: ABN AMRO Bank (0.0%), ING Bank (0.01%) and the Rabobank (0.01%). Figure 2 shows similar developments in other EU countries.

Fig. 2 Interest rates (%) on loans to non-financial corporations[1] and deposits of households[2] (ECB 2021)



Note: Negative interest rates on household deposits are not allowed by law in Belgium.

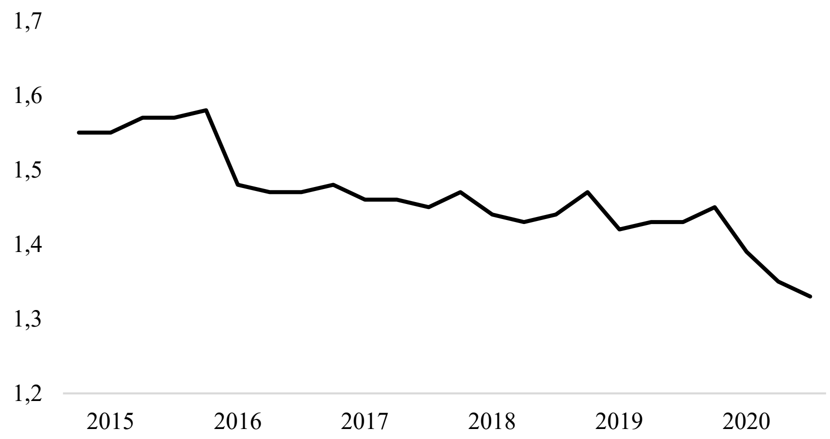
2.2 The trade-off

When the 0% on household deposits is reached, banks are unwilling to decrease this interest rate further (Eisenschmidt and Smets 2018; EBA 2019). It is uncertain how savers would react to negative interest rates, but deposit outflows are likely (see section 3). To decrease their funding costs while avoiding deposit outflows, banks introduced negative interest rates to some specific segments, such as households deposits above €100,000 or deposits of non-financial corporations. Only around 3% of the banks in the

[1] Loans to non-financial corporations with an original maturity of over 5 years.
[2] Deposits of households and non-profit institutions serving households redeemable at notice with a period of notice of up to 3 months.

EU charge negative rates on household deposits, and around 22% on deposits of non-financial corporations (EBA 2019a). These measures seem insufficient, as interest margins remain low. Figure 3 shows that the average net interest margin of banks in the EU decreased from 1.58% in 2015 to 1.33% in 2020 (EBA 2020a). Figure 3 shows that this decrease was already ongoing before the COVID-19 pandemic. There are substantial decreases in Sweden (-0.6%), Germany (-0.5%) and France (-0.4%) (IMF 2020).

Fig. 3 The net interest margin (%) of banks in the EU-28 (EBA 2020a)



Banks face a difficult trade-off. Positive interest rates on household deposits maintain the number of savers, but are expensive, while negative interest rates can increase the interest margin, but may trigger deposit outflows. Given the low profitability, however, banks may not have much time to work on a solution. Only 32% of the banks indicated that they can operate on a longer-term basis with a return on equity lower than 8% (EBA 2020b). If profitability is too low, it becomes difficult for banks to re-invest profits, rather than paying dividends (DNB 2016). Banks may sustain the current situation for some time, but there will be a “tipping point” at which banks cannot tolerate the squeezed interest margins anymore (Bech and Malkhozov 2016; Eisenschmidt and Smets 2018). Therefore, substantial action will be needed to fill the earnings shortfall (IMF 2020).

2.3 Can negative interest rates be avoided?

Banks aim to increase their profitability without introducing negative interest rates. It is shown that banks recently make riskier investments to increase their interest revenue (Hong and Kandarac 2018; Demiralp et al. 2019; Heider et al. 2019), enhance the net fee and commission income (Eggertsson et al. 2017; Madaschi and Nuevo 2017; Basten and Mariathasan 2018), decrease operational costs (Scheiber et al. 2016; IMF 2020), or increase the share of wholesale funding (Turk 2016). Especially the reduction of operational expenses is a popular measure among European banks. In EBA’s Risk Assessment Questionnaire, banks earmarked cutting operational expenses as most popular measure to enhance the profitability in the next months, followed by increasing net fees and commission income (EBA 2020b). However, it remains uncertain whether these measures will be sufficient to avoid negative interest rates.

For some banks the pressure to take action is higher than for others. The low interest rate environment particularly decreases the profitability of banks that rely more on deposit funding (Heider et al. 2019; Lopez et al. 2020) and that are specialized in real estate mortgages (Molyneux et al. 2019). Moreover, for some banks it is harder to take action. For instance, banks that are more deposit-funded face more problems to charge negative interest rates, smaller banks with less wholesale experience will have more difficulties to change their funding structure and for smaller banks it is harder to switch from interest to non-interest oriented business models (EBA 2019; Molyneux et al. 2019).

In line with the context outlined above, banks in our model can increase their interest margins by decreasing the interest rate on household deposits. Our model distinguishes two types of banks. A 'competitive' bank has, all other things equal, a higher interest margin than an 'uncompetitive' bank. This can be interpreted as if the competitive bank successfully took measures to enhance its profitability in other ways than decreasing its interest rate on household deposits, such as by cost reduction. A competitive bank is therefore profitable without decreasing its interest rate to households, unlike an uncompetitive bank.

3. Savers: Negative interest rates and switching costs

Although negative interest rates have not been applied to household deposits below €100,000 yet, the potential reaction of savers affects the interest rate decisions of banks. Therefore, it is important to consider how savers would react to negative interest rates. Would they tolerate the negative interest rates? Or would they withdraw (part of) their savings and look for alternatives? Consumer surveys have been conducted to answer these questions. The surveys indicate that 1) there is some tolerance towards negative interest rates, but not much and it depends on several factors, and 2) investing seems the most popular alternative to savings accounts. However, the possibility to switch between banks is understudied. Below we elaborate more on the surveys.

3.1 How tolerant are savers towards negative interest rates?

There are several reasons why savers may hold their savings at the bank against negative interest rates (see Efendic et al. 2019; Corneille et al. 2020). First, saving allows people to delay spending to match future needs. Second, stalling savings at the bank is safer than keeping them at home or elsewhere. Outside the bank, savings may get stolen or lost, while digital savings at a bank are safely preserved. Even if banks go bankrupt, deposit guarantee schemes ensure that savers will not lose their savings. Third, holding savings at the bank is also more practical in a cashless world in which online payments are increasingly popular. Accordingly, savers value a bank account for its convenience and are willing to pay for this service.

Consumer surveys confirm that savers have some tolerance towards negative interest rates. For instance, 23% of the respondents in ING (2015) would tolerate negative interest rates, against 40% of the respondents in Efendic et al. (2019), 21% to 55% of the respondents in Corneille et al. (2020) and 30% to 50% in Baars et al. (2020). However, we need to be careful to draw conclusions from these surveys, as respondents were often offered only one alternative to tolerating negative interest rates: To spend the entire amount (Corneille et al. 2020), to take all savings out of the bank (Efendic et al. 2020) or to invest (Baars et al. 2020). This may give a biased view on the tolerance towards negative interest rates.

Studies find that the tolerance differs per saver and context. For instance, the tolerance decreases if the interest rate is lower (Efendic et al. 2019) and if the duration is longer (Corneille et al. 2020). This is economically rational as both make saving more costly. Also the saving amount matters, but findings are ambiguous. Corneille et al. (2020) and Efendic et al. (2019) find that respondents are more tolerant towards negative interest rates if the saving amount is lower, but in another experiment, Efendic et al. (2019) find the opposite effect. Furthermore, older people are less tolerant for negative interest rates (Efendic et al. 2019), whereas ING (2015) finds that the tolerance differs between countries. For instance, 31% of the savers in the UK would do nothing if negative interest rates were introduced, against 16% in Luxembourg. This may be the result of political or cultural factors, such as the perception of fairness or the perceived role of banks in society.

3.2 Which alternatives do savers consider?

ING (2015) and Efendic et al. (2019) find that investing the savings is the most popular alternative to tolerating negative interest rates. About 33% of the respondents in the ING survey would invest their savings when negative interest rates are introduced, against 41% of the respondents in Efendic et al. (2019). This is in line with Baars et al. (2020) who find that 61% to 63% of their respondents prefer risky investment over a risk-free interest rate of -1%. The percentages in Baars et al. (2020) are higher than in ING (2015) and Efendic et al. (2019) probably because respondents could choose only between saving and investing. Other popular alternatives identified by the surveys are keeping the savings at home or at a safe place, paying off debt (such as mortgages) or spending more than normal (ING 2015; Efendic et al. 2019; De Volksbank 2020). Both ING (2015) and Efendic et al. (2019) found that spending the savings is the least popular alternative.

The preferred alternative differs per individual and context. De Volksbank (2020) assessed under 3,000 savers in the Netherlands whether the preferred alternatives depend on the saving amount. Under savers with low saving amounts (< €10,000), the most preferred alternative is to transfer the savings to their payment account. Under savers with medium (€10,000 - €50,000) and high (> €50,000) saving amounts, the most preferred alternative is to contact the bank and discuss the possibilities. Spending or keeping the savings at home are less popular alternatives under savers with higher saving amounts, while respondents with higher saving amounts are more inclined to invest their savings. ING (2015) finds that investing is the most preferred alternative under savers in the United States, Australia and Turkey, whereas withdrawing the savings to keep them at a safe place is more popular in European countries.

3.3 Switching between banks

As the surveys mentioned above do not cover the possibility that savers may switch between banks in the event of negative interest rates, we consider whether savers are likely to do so. Other surveys have been conducted to define the annual switching rate for bank accounts: The percentage of account holders that switched between banks in a given year. In the UK, the Competition and Markets Authority (2015) finds a switching rate of 3% for current accounts. For EU member states, the European Commission (2018a) finds a switching rate of 7% in 2017 for current accounts, against 10% in 2011 (European Commission 2013). In Australia, Deloitte (2019) finds a switching rate of 11% in 2019 for savings accounts. For a set of 28 developed countries, Accenture (2020) finds a switching rate of 4% in 2019 for primary accounts. In short, between 3% and 11% of account holders switch annually between banks, without banks having introduced negative interest rates yet.

Financial factors are an important reason for deposit holders to switch between banks. Accenture (2020) finds that the most important reason to switch between banks is "*competitive pricing*", whereas Deloitte (2019) finds "*better value*". Focusing on interest rates, Van der Cruijsen and Diepstraten (2017) find that 45% of respondents would switch between banks if another bank offers a 1% higher interest rate. Gerritsen and Bikker (2020) find that savers in the Netherlands transfer between 2.9% and 6.1% of their savings to another bank for each percentage point interest rate difference. The large difference between the results of Van der Cruijsen and Diepstraten (2017) and Gerritsen and Bikker (2020) may result from the focus on intended behavior (the former) in contrast to actual behavior (the latter).

However, customers with the intention to switch between banks do not always actually switch. Deloitte (2019) finds that only 10% of the customers who have searched for information about other banks ultimately switched. Customers face barriers to switch between banks, which are referred to as "switching costs" in the literature (see e.g. Sharpe 1997). Burnham, Frels and Mahajan (2003) distinguish three types of switching costs. First, procedural switching costs involve the time and effort to evaluate alternative service providers and initiate a relationship with a new provider. Second, financial switching costs involve the loss of benefits of staying at the current provider, such as losing accumulated points in loyalty programs, but also one-time initiation fees or deposits for new customers. Third, relational switching costs include the loss of personal relationships customers have with employees and the brand relationship loss, such as the identity customers derive from the provider.

Van der Cruijsen and Diepstraten (2017) find that savers are especially concerned about the procedural switching costs. They asked 744 customers about their barriers to change savings accounts. Procedural switching costs were important factors, as "*I cannot keep my account number(s)*" ranked 3rd and "*it is a hassle to switch*" ranked 4th. The answers that ranked 1st and 2nd were related to people that did not have the intention to switch[3]. Relational switching costs ("*I am customer of this/these bank(s) for a long time*") ranked 5th and financial switching costs ("*It costs a lot of money to switch*") only 9th. Some literature aimed to quantify the switching costs in the banking sector based on the number of clients and prices of banks, among others (see for instance Shy 2002; Ho 2015; Egarius and Weill 2016; Takalo 2019). These switching costs range between 0 and 1400 euros, depending on the year, country and bank.

In short, consumer surveys find that there is some tolerance for negative interest rates among savers, but the tolerance is limited and varies per situation. Also the preferred alternative varies per individual. From these surveys it is unclear how negative interest rates affect switching behavior, but other research shows that between 3% and 11% of account holders switch banks annually and that switchers often have financial motives. In our model, savers can tolerate an interest rate decrease, switch to another bank or choose for an alternative. We impose that the relative size of switching costs and the attractiveness of alternatives determine the decisions of savers.

4. The model

We present a game-theoretical model with incomplete information focusing on the decision of banks to decrease their interest rate on household deposits. The savers in our model are initially allocated over two banks. This is a common feature in theoretical models on banks deposits (see e.g. Sharpe 1997; Shy 2002). The banks offer the same (high) interest rate, but can decrease their interest rate in subsequent periods to reduce their costs. We assume for simplicity that banks can only set two different interest rates: The high interest rate (i_H) and the low interest rate (i_L). A decrease from high to low can be interpreted as reducing the interest rate from positive to negative, but we refer to a 'high' and 'low' interest rate to maintain generality.

There are Q savers. They decide each period 1) to let their savings at their bank, 2) to move the savings to the other bank, or 3) to withdraw the savings from the bank and choose for 'the alternative'. This alternative can be anything, such as investing, spending or keeping the savings at home. This is in line with the theoretical model of Hutchison (1995), for instance, in which savers can alternatively consume or invest in corporate shares. All savers have an equal amount of savings and cannot spread their savings over multiple banks. Like in Klemperer (1995), we assume a finite time horizon, as the game has four

[3] The most popular answers were "*I am satisfied with the current situation*" and "*there is not much benefit from switching*".

periods. At the beginning of each period only one bank can decrease its interest rate and banks alternate these turns. Once a bank decreased its interest rate, it cannot increase it again in a later period.

Banks are profit maximizers. A bank's profit per period is its number of savers q multiplied by its interest margin $r - i$. Its interest margin is its return on investment r minus the interest rate it pays to its savers i. The return on investment is exogenously determined, in which we distinguish two types of banks. With probability σ, a bank is "competitive" (C) and has a high return on investment (r_H). Its profit in period t is:

(1) $$V_t^C = q(r_H - i_{L,H})$$

With probability $1 - \sigma$, a bank is "uncompetitive" (U) and has a low return on investment (r_L). Its profit per period is:

(2) $$V_t^U = q(r_L - i_{L,H})$$

We assume that $r_H > i_H > r_L > i_L$, which means that a competitive bank has a positive interest margin under both the low and high interest rate, but that the uncompetitive bank only has a positive interest margin under the low interest rate. A bank knows its type, but not the type of the other bank.

The utility of savers is based on Shy (2002), in which a saver's utility in period t is the interest rate he receives from his bank minus switching costs c if he decides to switch between banks. We add to this setup that a saver can also withdraw his savings from the bank and choose for the alternative. The alternative yields the saver k per period, whereas the saver does not incur switching costs if he moves to the alternative[4]. We commit savers to a fixed strategy depending on the relative size of s and k, as captured by the scenarios outlined in the next section. Table 1 depicts the sequence of events.

Table 1 The sequence of events

Period 1	1. Bank 1 decreases its interest rate or not. 2. Savers stay at their bank, switch banks or move to the alternative.
Period 2	3. Bank 2 decreases its interest rate or not. 4. Savers stay at their bank, switch banks or move to the alternative.
Period 3	5. Bank 1 decreases its interest rate or not. 6. Savers stay at their bank, switch banks or move to the alternative.
Period 4	7. Bank 2 decreases its interest rate or not. 8. Savers stay at their bank, switch banks or move to the alternative.

5. The scenarios

The scenarios are based on different assumptions on the utility and behavior of savers. Savers have three possible actions. They can stay at their bank, switch between banks, or go to the alternative. As a result, savers can have different utilities per period, which are depicted in table 2.

Table 2 Possible actions and corresponding utility of savers per period

[4] A saver who chooses to move its saving amount to the alternative may also incur some kind of switching costs. We assume that these costs are included in the fixed utility k savers gain from the alternative.

Possible action		Utility
1.	Stay at the current bank, while this bank maintained the high interest rate i_H.	i_H
2.	Stay at the current bank, while this bank decreased the interest rate to i_L.	i_L
3.	Switch to a bank with the high interest rate i_H and incur switching costs s.	$i_H - s$
4.	Withdraw the saving amount from the bank and move it to the alternative.	k
5.	Switch to a bank with the low interest rate i_L and incur switching costs s.	$i_L - s$

Each scenario assumes a different ranking of these utilities, as there are different assumptions possible on the values of s and k. To derive the different rankings, first consider the following assumptions. First, $i_H > i_L$, which means that receiving a high interest rate is more beneficial than a low interest rate. Second, $i_H > i_H - s$ and $i_L > i_L - s$, as we assume positive switching costs. This means that savers have no incentive to switch between banks if the interest rate is not higher at the other bank. This also means that we can exclude action 5 as rational action.

Table 3 Overview of scenarios based on the relative size of s and k

Switching costs (s)	*Low*	*Medium*	*High*	*Very high*
High	$1 > 2 > 3 > 4$ No competition	1 > 2 > 4 > 3 No competition	1 > 4 > 2 > 3 Competition only with the alternative	4 > 1 > 2 > 3 No place for banks
Low	1 > 3 > 2 > 4 Competition only between banks	1 > 3 > 4 > 2 Competition between banks and with the alternative	1 > 4 > 3 > 2 Competition only with the alternative	4 > 1 > 3 > 2 No place for banks

Attractiveness of the alternative (k)

Note: Under a high s, switching from i_L to i_H is unbeneficial, while under a low s, switching from i_L to i_H is beneficial. Under a very high k, the alternative is the most attractive action, under 'high' the alternative ranks second as attractive action, under 'medium' as third, and under 'low' as least attractive action.

Given these assumptions, the values of s and k determine the ranking of the utilities of the possible actions. This results in the following five scenarios, which are also outlined in table 3:

1. *No competition*. The high switching costs and low or medium attractiveness of the alternative make it unattractive for savers to leave their bank. They prefer a low interest rate over switching banks to receive a higher interest rate. Moreover, they also prefer the low interest rate over the alternative. This means that savers will stay at their banks, regardless of the interest rate their banks offer.
2. *Competition only between banks.* The low switching costs induce savers to switch between banks if their bank decreases its interest rate. Due to the low attractiveness of the alternative, savers prefer a

low interest rate over the alternative. This means that banks have no competition from the alternative.
3. *Competition between banks and with the alternative*. The low switching costs cause savers to switch banks if the other bank offers a higher interest rate. Moreover, the alternative is sufficiently attractive for savers to leave their bank if no bank offers a high interest rate.
4. *Competition only with the alternative*. The high attractiveness of the alternative induces savers to go to the alternative if their bank decreases the interest rate. Although the switching costs are low, savers do not switch between banks as the alternative is more beneficial than $i_H - s$.
5. *No place for banks*. As the alternative is more attractive for savers than receiving a high interest rate at a bank, savers go to the alternative directly in period 1.

6. The equilibria

6.1 The *no competition* scenario

Savers. Savers keep their savings at their bank regardless of the interest rate the bank offers, as savers gain more from i_L than from switching between banks or the alternative.

Banks. As all savers stay at their bank regardless of the interest rate banks offer, banks have no incentive to maintain i_H. If banks decrease i, the interest margin increases, while the savers stay anyway. Hence, if bank 1 decreases i in period 1, its total profits become $2Q(r_{L,H} - i_L)$. This is higher than maintaining i_H, which gives a total profit of $2Q(r_{L,H} - i_H)$. The same holds for bank 2. If bank 2 decreases i in period 2, its profit for periods 2-4 are $1.5Q(r_{L,H} - i_L)$. If it maintains i_H, its profit is $1.5Q(r_{L,H} - i_H)$, which is lower than the former. Therefore, banks decrease i as soon as possible, regardless of their type. Lemma 1 summarizes the equilibrium strategies and utilities.

Lemma 1 Equilibrium strategies and utilities (*No competition*)

Actor	Equilibrium strategies	Equilibrium utilities
Bank 1		
If competitive	Decreases i in period 1.	$2Q(r_H - i_L)$
If uncompetitive	Decreases i in period 1.	$2Q(r_L - i_L)$
Bank 2		
If competitive	Decreases i in period 2.	$0.5Q(r_H - i_H) + 1.5Q(r_H - i_L)$
If uncompetitive	Decreases i in period 2.	$0.5Q(r_L - i_H) + 1.5Q(r_L - i_L)$

6.2 The *competition only between banks* scenario

Savers. Savers move to the other bank if the other bank offers a higher interest rate. However, if a bank decreases i, while the other bank offers i_L already, savers stay at this bank, as savers gain more from receiving i_L than from the alternative.

Banks. Appendix A derives the full equilibrium. Table 4 summarizes the equilibrium outcomes under the possible types of banks. We discuss the most important equilibrium outcomes below.

First, a competitive bank never decreases i before the other bank. Therefore, if there are two competitive banks, both banks maintain i_H. Second, an uncompetitive bank never maintains i_H in all periods. We find that an uncompetitive bank decreases i as soon as possible or waits for the other bank to decrease i first. For the latter equilibrium, consider the following.

We find that an uncompetitive bank 1 may maintain i_H in period 1 waiting for bank 2 to decrease i first. We refer to this equilibrium as a "war of attrition". The uncompetitive bank 1 only wins the war of attrition if bank 2 is also uncompetitive and decreases i in period 2. Then, bank 1 attracts all savers in period 2 and decreases i in period 3. In both periods 3 and 4, bank 1 is profitable. By contrast, bank 1 loses the war of attrition if bank 2 is competitive and does not decrease i in period 2. Then, bank 1 decreases i only in period 3. All savers go to bank 2 and bank 1 does not make any profit in period 3 and 4. In the results section we discuss the war of attrition further.

Definition (*The war of attrition*)

There is a war of attrition if an uncompetitive bank 1 maintains i_H in period 1 and waits for bank 2 to decrease i first.

- *Bank 1 wins the war of attrition if bank 2 decreases i in period 2, all savers move to bank 1, and bank 1 decreases i in period 3;*
- *Bank 1 loses the war of attrition if bank 2 maintains i_H in period 2, savers stay equally divided over the banks, bank 1 decreases i in period 3 and loses its savers to bank 2.*

For a war of attrition to occur, two conditions must hold. First, bank 1's profit after winning the war of attrition must be higher than the costs of waiting to decrease i, taking into account the possibility that it may also lose the war of attrition (i.e. condition (4) must hold[5]). Second, it must be unbeneficial for an uncompetitive bank 2 to react tough to a high interest rate of bank 1 and maintain i_H in period 2. (i.e. condition (5) must fail[6]). If one of these conditions fails, bank 1 avoids a war of attrition and decreases i directly in period 1.

Table 4 Equilibrium outcomes under *competition only between banks*

		Uncompetitive (U)	*Competitive (C)*
Bank 1	*C*	If (4) and (5) hold: • No equilibrium Otherwise: • Bank 1 decreases i in period 3. • Bank 2 decreases i in period 2.	Both banks maintain i_H in all periods.
	U	If (4) holds and (5) fails: • Bank 1 decreases i in period 3. • Bank 2 decreases i in period 2. (*War of attrition; Bank 1 wins*) Otherwise: • Bank 1 decreases i in period 1. • Bank 2 decreases i in period 2.	If (4) holds and (5) fails: • Bank 1 decreases i in period 3. • Bank 2 decreases i in period 4. (*War of attrition; Bank 1 loses*) Otherwise: • Bank 1 decreases i in period 1. • Bank 2 decreases i in period 2.

Bank 2

[5] See appendix.

[6] See appendix.

6.3 The *competition between banks and with the alternative* scenario

Savers. Savers move to another bank if the other bank offers a higher interest rate. If both banks offer i_L, savers move to the alternative.

Banks. To find the equilibrium, first consider the incentives of an uncompetitive bank. An uncompetitive bank knows that it cannot make profit under this scenario. An uncompetitive bank can only make profit if it maintains savers while offering i_L. This is impossible under this scenario, as savers move to the other bank or the alternative if the bank decreases i. Therefore, an uncompetitive bank has no incentive to maintain i_H and decreases i as soon as possible to avoid losses.

Second, consider the incentives of a competitive bank. If the competitive bank maintains i_H it gains $0.5Q(r_H - i_H)$ per period if the other bank also maintained i_H and $Q(r_H - i_H)$ if the other bank decreased its i. By contrast, if the competitive bank decreases i it gains 0, which is lower than the possible utilities under maintaining i_H. Therefore, a competitive bank does not have an incentive to decrease i and maintains i_H in all periods. Lemma 2 summarizes the equilibrium strategies and utilities.

Lemma 2 Equilibrium strategies and utilities (*Competition between banks and with the alternative*)

Actor	Equilibrium strategies	Equilibrium utilities
Bank 1		
If competitive	Maintains i_H in all periods.	$[\sigma 2Q + (1-\sigma)3.5Q](r_H - i_H)$
If uncompetitive	Decreases i in period 1.	0
Bank 2		
If competitive	Maintains i_H in all periods.	$[\sigma 2Q + (1-\sigma)4Q](r_H - i_H)$
If uncompetitive	Decreases i in period 2.	$[\sigma 0.5Q + (1-\sigma)Q](r_L - i_H)$

6.4 The *competition only with the alternative* scenario

Savers. Savers move their savings to the alternative if their bank decreases its interest rate to i_L, as savers prefer k over i_L and over switching between banks, as $k > i_H - s$.

Banks. First, an uncompetitive bank cannot make profit under this scenario. It needs to set i_L in order to become profitable, but if it decreases i, savers go to the alternative. Therefore, the uncompetitive bank decreases i as soon as possible.

Second, a competitive bank can be profitable under this scenario, as it can make profit while it offers i_H. If it maintains i_H and keeps its share of savers, its profit per period is $0.5Q(r_H - i_H)$. By contrast, if it decreases i and its savers move to alternative, its profit per period is 0. As the former is higher the latter, a competitive bank maintains i_H to keep its savers. Lemma 3 summarizes the equilibrium strategies and utilities.

Lemma 3 Equilibrium strategies and utilities (*Competition only with the alternative*)

Actor	Equilibrium strategies	Equilibrium utilities
Bank 1		
If competitive	Maintains i_H in all periods.	$2Q(r_H - i_H)$

If uncompetitive	Decreases i in period 1.	0
Bank 2		
If competitive	Maintains i_H in all periods.	$2Q(r_H - i_H)$
If uncompetitive	Decreases i in period 2.	$0.5Q(r_L - i_H)$

6.5 The *no place for banks* scenario

Savers. Savers take their savings out of the bank and move to the alternative as soon as possible, as the alternative is more attractive than any interest rate the bank can offer.

Banks. Both the competitive and uncompetitive bank are indifferent between maintaining the high interest rate or decreasing the interest rate. Savers will leave them in period 1 anyway. Lemma 4 summarizes the equilibrium strategies and utilities.

Lemma 4 Equilibrium strategies and utilities (*No place for banks*)

Actor	Equilibrium strategies	Equilibrium utilities
Bank 1		
If competitive	Decreases i in period 1.	0
If uncompetitive	Decreases i in period 1.	0
Bank 2		
If competitive	Decreases i in period 2.	0
If uncompetitive	Decreases i in period 2.	0

7. Results

7.1 Will banks decrease their interest rates?

We can broadly distinguish three different equilibrium interest rate strategies. First, a bank may adopt a strategy to never decrease its interest rate. This is the equilibrium strategy of a competitive bank under the *competition between banks and with the alternative* scenario and under the *competition only with the alternative* scenario. In these scenarios, the competitive bank would lose its savers after decreasing the interest rate, while it is also profitable under a high interest rate.

Second, a bank may decrease its interest rate as soon as possible. This is the equilibrium strategy of all banks under the *no competition* scenario and of an uncompetitive bank under the *competition only between banks* scenario, the *competition between banks and with the alternative* scenario and the *competition only with the alternative* scenario. In the former case, banks know that they would maintain their savers even under the low interest rate. In the latter case, the uncompetitive bank knows that it cannot become profitable given the scenario.

Third, a bank may decrease its interest rate only after the other bank decreased its interest rate. This is the equilibrium strategy of competitive banks under the *competition only between banks* scenario and of the uncompetitive bank if it starts a war of attrition. By waiting for the other bank to decrease its interest rate first, the bank can attract all savers and decrease its interest rate thereafter. We only refer to a war of attrition if the uncompetitive bank chooses this strategy, as an uncompetitive bank is loss-making while it maintains the high interest rate, in contrast to a competitive bank. Proposition 1 summarizes the equilibrium interest rate strategies. Proposition 2 summarizes the war of attrition.

Proposition 1 (*Equilibrium interest rate strategies*)

Across the scenarios, we can distinguish three equilibrium interest rate strategies:
- *Never decrease the interest rate;*
- *Decrease the interest rate as soon as possible;*
- *Decrease the interest rate only after the other bank decreased its interest rate.*

Proposition 2 (*The war of attrition*)

In a war of attrition, an uncompetitive bank maintains a high interest rate although this is costly. It waits for the other bank to decrease its interest rate first.

We find that interest rate decreases may occur in all five scenarios, and in one scenario with certainty. In the *no competition* scenario, the interest rate is always decreased. In the *competition only between banks* scenario, the interest rate is always decreased unless there are two competitive banks. This means that savers face a probability of $1-\sigma^2$ that their bank decreases the interest rate. In the *competition between banks and with the alternative* scenario and the *competition only with the alternative* scenario only uncompetitive banks decrease their interest rates. This means that savers face a probability of $1-\sigma$ that their bank decreases the interest rate. In the *no place for banks* scenario, banks are indifferent about their interest rate. The findings above mean that interest decreases are more likely if switching costs are higher and the attractiveness of the alternative is lower.

Finally, savers will only hold savings against the low interest rate in the *no competition* scenario and the *competition only between banks* scenario. Under these scenarios, the low or medium attractiveness of the alternative make savers tolerant towards the low interest rate. Proposition 3 summarizes the findings regarding low interest rates.

Proposition 3 (*Low interest rates*)

Interest rate decreases may occur in all five scenarios, and in one of these scenario with certainty. Interest rate decreases are more likely if alternatives are less attractive, switching costs are higher, and if banks are uncompetitive. Only in two scenarios, savers may tolerate the low interest rate.

7.2 What is the effect of switching costs on bank profitability?

To assess the effect of switching costs on bank profitability we compare the equilibrium profits under the *no competition* scenario (high s) with the equilibrium profits under the *competition only between banks* scenario (low s) and the *competition between banks and with the alternative* scenario (low s). The switching costs have no impact on the *competition only with the alternative* and *no place for banks* scenarios. The profits of the competitive and uncompetitive banks under each scenario are provided in table 5 and 6, which we use to derive the findings below.

7.2.1 Competitive banks

We find that for a competitive bank, high switching costs are beneficial if the other bank is also competitive. Hence, if the other bank is also competitive, it is impossible to attract more savers, but under the *no competition* scenario (high s) it can at least decrease its interest rates without losing savers.

If the other bank is uncompetitive, there are two cases in which high switching costs are beneficial. First, the *no competition* scenario (high s) is more beneficial than the *competition between banks and with the alternative* scenario (low s) if $(r_H - i_L) > 2(1/3)(r_H - i_H)$ while there is an uncompetitive bank 1, or if $(r_H - i_L) > 1.75(r_H - i_H)$ while there is an uncompetitive bank 2. Under these conditions, it is more beneficial to maintain half of the savers against a low interest rate than to attract all savers against a high interest rate. Second, the *no competition* scenario (high s) is more beneficial than the *competition only between banks* scenario (low s) if an uncompetitive bank 1 starts a war of attrition while $(r_H - i_L) > 3(r_H - i_H)$. Then, the competitive bank has to maintain a high interest rate for three periods. Otherwise, high switching costs are unbeneficial if the other bank is uncompetitive, as it becomes harder to attract savers from the competitor.

7.2.2 Uncompetitive banks

We find that for an uncompetitive bank, high switching costs are beneficial, as high switching costs allow the bank to decrease its interest rate without losing savers to another bank. There is only one case in which high switching costs are unbeneficial for an uncompetitive bank. The *competition only between banks* scenario (low s) is more beneficial than the *no competition* scenario (high s) for an uncompetitive bank 2 if an uncompetitive bank 1 does not start a war of attrition while $(r_L - i_L) > -(1/3)(r_L - i_H)$. Then, the uncompetitive bank 2 attracts all savers in period 1 and can decrease its interest rate.

Proposition 4 (*Switching costs*)

High switching costs are beneficial for a bank if the other bank is competitive. If the other bank is uncompetitive, high switching costs can be beneficial or unbeneficial.

In short, high switching costs can be beneficial as they allow banks to decrease their interest rate without losing savers, and they can prevent a war of attrition. By contrast, low switching costs can be beneficial as they allow banks to attract all savers.

7.3 What is the effect of the attractiveness of the alternative on bank profitability?

To assess the effect of the attractiveness of the alternative on bank profitability, we compare the equilibrium profits under different scenarios. Given high switching costs, we compare the equilibrium profits of the *no competition* scenario (low or medium k), the *competition only with the alternative* scenario (high k) and the *no place for banks* scenario (very high k). Given low switching costs, we compare the equilibrium profits of the *competition only between banks* scenario (low k), the *competition between banks and with the alternative* scenario (medium k), the *competition only with the alternative* scenario (high k) and the *no place for banks* scenario (very high k). We use the profits provided in table 5 and 6.

7.3.1 Competitive banks

We find that for a competitive bank a higher attractiveness of the alternative is unbeneficial, as it becomes harder to attract savers from the other bank. However, there is one exception. For a competitive bank 2, the *competition between banks and with the alternatives* scenario (medium k) can be more beneficial than the *competition only between banks* scenario (low k) if the other bank is uncompetitive. This is the case when the uncompetitive bank 1 starts a war of attrition while $2(r_H - i_H) > (r_H - i_L)$. Due to the low k, the uncompetitive bank 1 knows that it can become profitable by maintaining i_H, while it does not have this incentive under the medium k. Then, the uncompetitive bank would decrease its interest rate directly and savers would move to the competitive bank.

Table 5 Equilibrium profits of competitive banks

a) The equilibrium profits of a competitive bank 1 if bank 2 is also competitive.

<table>
<tr><td rowspan="2">*s*</td><td>*H*</td><td colspan="2">$2Q(r_H - i_L)$
No competition</td><td rowspan="2">$2Q(r_H - i_H)$
Competition only with the alternative</td><td rowspan="2">0
No place for banks</td></tr>
<tr><td>*L*</td><td>$2Q(r_H - i_H)$
Competition only between banks</td><td>$2Q(r_H - i_H)$
Competition between banks and with the alternative</td></tr>
<tr><td></td><td></td><td>*Low*</td><td>*Medium*</td><td>*High*</td><td>*Very high*</td></tr>
<tr><td></td><td></td><td colspan="4">***k***</td></tr>
</table>

b) The equilibrium profits of a competitive bank 1 if bank 2 is uncompetitive.

<table>
<tr><td rowspan="2">*s*</td><td>*H*</td><td colspan="2">$2Q(r_H - i_L)$
No competition</td><td rowspan="2">$2Q(r_H - i_H)$
Competition only with the alternative</td><td rowspan="2">0
No place for banks</td></tr>
<tr><td>*L*</td><td>$1.5Q(r_H - i_H) + 2Q(r_H - i_L)$
Competition only between banks</td><td>$3.5Q(r_H - i_H)$
Competition between banks and with the alternative</td></tr>
<tr><td></td><td></td><td>*Low*</td><td>*Medium*</td><td>*High*</td><td>*Very high*</td></tr>
<tr><td></td><td></td><td colspan="4">***k***</td></tr>
</table>

c) The equilibrium profits of a competitive bank 2 if bank 1 is also competitive.

<table>
<tr><td rowspan="2">*s*</td><td>*H*</td><td colspan="2">$0.5Q(r_H - i_H) + 1.5Q(r_H - i_L)$.
No competition</td><td rowspan="2">$2Q(r_H - i_H)$
Competition only with the alternative</td><td rowspan="2">0
No place for banks</td></tr>
<tr><td>*L*</td><td>$2Q(r_H - i_H)$
Competition only between banks</td><td>$2Q(r_H - i_H)$
Competition between banks and with the alternative</td></tr>
<tr><td></td><td></td><td>*Low*</td><td>*Medium*</td><td>*High*</td><td>*Very high*</td></tr>
<tr><td></td><td></td><td colspan="4">***k***</td></tr>
</table>

d) The equilibrium profits of a competitive bank 2 if bank 1 is uncompetitive.

<table>
<tr><td rowspan="2">*s*</td><td>*H*</td><td colspan="2">$0.5Q(r_H - i_H) + 1.5Q(r_H - i_L)$.
No competition</td><td rowspan="2">$2Q(r_H - i_H)$
Competition only with the alternative</td><td rowspan="2">0
No place for banks</td></tr>
<tr><td>*L*</td><td>$Q(r_H - i_H) + 3Q(r_H - i_L)$ if no WoA
$2Q(r_H - i_H) + Q(r_H - i_L)$ if WoA
Competition only between banks</td><td>$4Q(r_H - i_H)$
Competition between banks and with the alternative</td></tr>
<tr><td></td><td></td><td>*Low*</td><td>*Medium*</td><td>*High*</td><td>*Very high*</td></tr>
<tr><td></td><td></td><td colspan="4">***k***</td></tr>
</table>

Note: WoA refers to 'war of attrition'.

Table 6 Equilibrium profits of uncompetitive banks

a) The equilibrium profits of an uncompetitive bank 1 if bank 2 is competitive.

<table>
<tr><td rowspan="2">*s*</td><td>*H*</td><td colspan="2">$2Q(r_L - i_L)$
No competition</td><td rowspan="2">0
Competition only with the alternative</td><td rowspan="2">0
No place for banks</td></tr>
<tr><td>*L*</td><td>0 if no WoA
$Q(r_L - i_H)$ if WoA
Competition only between banks</td><td>0
Competition between banks and with the alternative</td></tr>
<tr><td></td><td></td><td>*Low*</td><td>*Medium*</td><td>*High*</td><td>*Very high*</td></tr>
<tr><td></td><td></td><td colspan="4">***k***</td></tr>
</table>

b) The equilibrium profits of an uncompetitive bank 1 if bank 2 is also uncompetitive.

<table>
<tr><td rowspan="2">*s*</td><td>*H*</td><td colspan="2">$2Q(r_L - i_L)$
No competition</td><td rowspan="2">0
Competition only with the alternative</td><td rowspan="2">0
No place for banks</td></tr>
<tr><td>*L*</td><td>0 if no WoA
$1.5Q(r_L - i_H) + 2Q(r_L - i_L)$ if WoA
Competition only between banks</td><td>0
Competition between banks and with the alternative</td></tr>
<tr><td></td><td></td><td>*Low*</td><td>*Medium*</td><td>*High*</td><td>*Very high*</td></tr>
<tr><td></td><td></td><td colspan="4">***k***</td></tr>
</table>

c) The equilibrium profits of an uncompetitive bank 2 if bank 1 is competitive.

<table>
<tr><td rowspan="2">*s*</td><td>*H*</td><td colspan="2">$0.5Q(r_L - i_H) + 1.5Q(r_L - i_L)$
No competition</td><td rowspan="2">$0.5Q(r_L - i_H)$
Competition only with the alternative</td><td rowspan="2">0
No place for banks</td></tr>
<tr><td>*L*</td><td>$0.5Q(r_L - i_H)$
Competition only between banks</td><td>$0.5Q(r_L - i_H)$
Competition between banks and with the alternative</td></tr>
<tr><td></td><td></td><td>*Low*</td><td>*Medium*</td><td>*High*</td><td>*Very high*</td></tr>
<tr><td></td><td></td><td colspan="4">***k***</td></tr>
</table>

d) The equilibrium profits of an uncompetitive bank 2 if bank 1 is also uncompetitive.

<table>
<tr><td rowspan="2">*s*</td><td>*H*</td><td colspan="2">$0.5Q(r_L - i_H) + 1.5Q(r_L - i_L)$
No competition</td><td rowspan="2">$0.5Q(r_L - i_H)$
Competition only with the alternative</td><td rowspan="2">0
No place for banks</td></tr>
<tr><td>*L*</td><td>$Q(r_L - i_H) + 3Q(r_L - i_L)$ if no WoA
$0.5Q(r_L - i_H)$ if WoA
Competition only between banks</td><td>$Q(r_L - i_H)$
Competition between banks and with the alternative</td></tr>
<tr><td></td><td></td><td>*Low*</td><td>*Medium*</td><td>*High*</td><td>*Very high*</td></tr>
<tr><td></td><td></td><td colspan="4">***k***</td></tr>
</table>

Note: WoA refers to ‘war of attrition’.

Proposition 5 (*Attractiveness of the alternative 1/2*)

For a competitive bank, an attractive alternative is unbeneficial. Only if the other bank is uncompetitive and would start a war of attrition, it is more beneficial to have a higher attractiveness of the alternative.

7.3.2 Uncompetitive banks

We find that for an uncompetitive bank 1 a higher attractiveness of the alternative is unbeneficial. To become profitable, an uncompetitive bank needs a low interest rate, whereas savers move to the alternative if the interest rate is low and the attractiveness of the alternative is higher. Therefore, it is only possible to be profitable under a low or medium k. There is only one case in which a higher attractiveness of the alternative may result in higher profits. It is more beneficial to have the *competition between banks and with the alternative* scenario (medium k) than to start and lose a war of attrition under the *competition only between banks* scenario (low k). However, the decision to start a war of attrition is rational, as it is based on a calculated risk (i.e. condition (4) must hold[7]).

For an uncompetitive bank 2 it is more ambiguous to draw conclusions. On the one hand, it needs a low or medium attractiveness of the alternative in order to become profitable. Hence, the *no competition* scenario (low or medium k) and the *competition only between banks* scenario (low k) are the only scenarios in which it can become profitable. On the other hand, in the scenarios in which it cannot become profitable, a higher attractiveness of the alternative is beneficial, as it is easier to shake off savers. Hence, the *no place for banks* scenario (very high k) is more beneficial than the *competition only with the alternative* scenario (high k). Moreover, if the other bank is also uncompetitive, the *competition only with the alternative* scenario (high k) is more beneficial than the *competition between banks and with the alternative* scenario (medium k).

Proposition 6 (*Attractiveness of the alternative 2/2*)

For an uncompetitive bank an attractive alternative can be beneficial or unbeneficial.

In short, an attractive alternative can be unbeneficial as it hinders to maintain profitable savers, but can be beneficial to avoid a war of attrition or to quickly discharge unprofitable savers.

8. Discussion

8.1 Discussion of our findings

The profitability of banks in developed economies is under pressure since the global financial crisis kicked-off an era of persistent low interest rates. While interest rates on the revenue-side decreased, banks struggled to obtain equivalent decreases on the funding-side. The resistance of banks to bring household deposit rates below zero has reduced interest margins. This paper presents a game-theoretical model to assess whether banks will decrease their household deposit rates further. It assessed this decision under different assumptions on the behavior of savers, captured in five scenarios. The results regarding the interest decisions and profitability of banks can be structured as follows.

First, we find that interest rate decreases are more likely if alternatives to savings accounts are less attractive. When alternatives are less attractive, banks are less afraid that savers move their savings to alternatives after interest rate decreases. This is in line with the positive relationship between the interest

[7] See appendix.

rates on household deposits and market interest rates, as has been found empirically (see e.g. Hannan and Berger 1991; Neumark and Sharpe 1992; Hannan and Liang 1993). Surprisingly, we find that less attractive alternatives are not necessarily beneficial for banks. A war of attrition between banks may occur if alternatives are unappealing for savers. Then, banks may maintain unprofitable high interest rates for a certain amount of time, waiting for other banks to decrease their interest rate first. This also provides a reason for the lag between changes in market interest rates and household deposit interest rates (Neumark and Sharpe 1992).

Second, we find that interest rate decreases are more likely if switching costs are higher. When switching costs are higher, banks are less afraid that savers move to another bank after an interest rate decrease. This finding is in line with Sharpe (1997) and Hannan and Adams (2011), who show empirically that higher switching costs lead to lower interest rates on deposits. Yet, the effect of switching costs on the profitability of banks is ambiguous. On the one hand, high switching costs allow banks to decrease their interest rate on household deposits without losing savers. On the other hand, high switching costs hinder banks to attract savers from their competitors. Klemperer (1995) also finds this trade-off in his theoretical model on competition between service providers with switching costs.

Unattractive alternatives and high switching costs are forms of market power. Our finding that these lead to lower interest rates on household deposits confirms the finding of Berger and Hannan (1989), who provide evidence that banks in less competitive markets offer lower interest rates on household deposits, and Neumark and Sharpe (1992), who show that banks in less competitive markets are faster to decrease their interest rates on household deposits following decreases in the market interest rate. In relation to the current low interest rate environment, Molyneux et al. (2019) find that the profit of banks in countries with low competition decreased less severe. The negative effect that market power can have on profitability, as we surprisingly found, adds a new perspective to this literature. Unattractive alternatives may lead to an expensive war of attrition and high switching costs hinder banks to attract savers from competitors.

8.2 Which scenario applies to the current market for household deposits?

Using our model, we can carefully assess which scenario applies to the current market for household deposits. Since negative interest rates have not been introduced to household deposits under €100,000, we can exclude the *no competition* scenario. Moreover, we can exclude the *no place for banks* scenarios, as savers have not massively withdrawn their savings from banks. It is also unlikely that all banks are ‘competitive’, as only 12% of the banks indicated that they can operate on a longer-term basis with a return on equity lower than 6%, while the EU-average return on equity was 5.4% in 2019 (EBA 2020b; ECB 2021). This makes the *competition between banks and with the alternative* and the *competition only with the alternative* scenarios unlikely, as uncompetitive banks would have decreased their interest rates. By contrast, the current market shows characteristics of the *competition only between banks* scenario in which a war of attrition is ongoing: No bank has introduced negative interest rates yet, while the profitability is alarming low.

Finally, developments may move the market to other scenarios. For instance, online banking environments may have decreased switching costs in the past, while efforts to introduce account number portability may decrease them further (Van der Cruijsen and Diepstraten 2017). In this line, the European Commission (2018b) reports that the ease of switching between banks increased between 2010 and 2017. Also alternatives to savings accounts are changing and may become better accessible. For instance, FinTech solutions lower the barriers for individuals to engage in crowdfunding, peer-to-peer lending and even foreign currency transactions (Lee and Shin 2018). More than 50% of the banks in the EU consider FinTech as a threat for their revenues in the retail branch (EBA 2020c). If alternatives become more attractive, our model predicts that competitive banks are less likely to decrease their interest rates, while survival becomes harder for uncompetitive banks.

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10. Appendix: Derivation of the equilibria under the *competition only between banks* scenario

10.1 A competitive bank

A competitive bank 1 or 2:

- Suppose that both banks maintain i_H and savers stay equally divided over the banks. Then, a competitive bank makes a profit per period of $0.5Q(r_H - i_H)$. By contrast, if it decreases i before the other bank and all savers go to the other bank, its profit per period becomes 0. Therefore, a competitive bank does not decrease i before the other bank.
- Suppose that the other bank decreases i first and all savers go to the competitive bank. Then, the competitive bank gains $Q(r_H - i_H)$ per period if it maintains i_H, and $Q(r_H - i_L)$ per period if it decreases i. Since the latter is higher than the former, it decreases i directly after the other bank decreased i.

A competitive bank decreases i *after the other bank decreased* i. *Otherwise, it maintains* i_H.

10.2 An uncompetitive bank

10.2.1 Period 4

An uncompetitive bank 2:

- Suppose that both banks maintained i_H and savers are still equally divided over the banks. If bank 2 decreases i and its savers move to bank 1, it gains 0 in period 4. If it maintains i_H, it gains $0.5Q(r_L - i_H)$, which is lower than 0. Therefore, it decreases i in this situation.
- Suppose that bank 1 decreased i in period 1 or 3 and all savers moved to bank 2. If bank 2 decreases i, it gains $Q(r_L - i_L)$ in period 4. If it maintains i_H, it gains $Q(r_L - i_H)$. As the former is higher than the latter, bank 2 decreases i.

An uncompetitive bank 2 decreases i *in period 4, if it was not decreased already before.*

10.2.2 Period 3

An uncompetitive bank 1:

- Suppose that both banks maintained i_H and savers are still equally divided over the banks. If bank 1 decreases i, it gains 0 in period 3 and 4. By contrast, if it maintains i_H, it gains $(Q/2)(r_L - i_H)$ per period in periods 3 and 4 if the other bank is competitive. If the other bank is uncompetitive, it gains $(Q/2)(r_L - i_H)$ in period 3 and $Q(r_L - i_H)$ in period 4. Since all these profits per period are lower than 0, an uncompetitive bank decreases i in period 3.
- Suppose that bank 2 decreased i in period 2 and all savers moved to bank 1. If bank 1 decreases i in period 3, it gains $Q(r_L - i_L)$ per period in periods 3 and 4. If bank 1 maintains i_H, it gains $Q(r_L - i_H)$ per period in periods 3 and 4. As the former is higher than the latter, the uncompetitive bank 1 decreases i in period 3.

An uncompetitive bank 1 decreases i *in period 3, if it was not decreased already before.*

10.2.3 Period 2

An uncompetitive bank 2:

- Suppose that bank 1 maintained i_H in period 1 and savers are still equally divided over the banks. If bank 2 decreases i in period 2, it gains 0 over periods 2-4. If it maintains i_H, it obtains $Q(r_L - i_H)$ over periods 2-4 if the other bank is competitive and $1.5Q(r_L - i_H) + Q(r_L - i_L)$ if the other bank is uncompetitive. However, bank 2 is uncertain about the other bank's type and it therefore considers the expected utility. If bank 2 assigns probability π that bank 1 is competitive, the expected utility from maintaining i_H is $\pi Q(r_L - i_H) + (1-\pi)[1.5Q(r_L - i_H) + Q(r_L - i_L)]$. This is higher than 0, if:

(3) $\quad (1-\pi)Q(r_L - i_L) > \pi Q(i_H - r_L) + (1-\pi)1.5Q(i_H - r_L)$

If (3) holds, an uncompetitive bank 2 maintains i_H in period 2.

- Suppose that bank 1 decreased i in period 1. If bank 2 decreases i in period 2, it gains $3Q(r_L - i_L)$ in total between period 2-4. If it maintains i_H, it obtains $2Q(r_L - i_H) + Q(r_L - i_L)$ in total between period 2-4. Note that the former is higher than the latter. The uncompetitive bank thus decreases i in period 2 if bank 1 decreased i in period 1.

An uncompetitive bank 2 maintains i_H in period 2 if bank 1 maintained i_H in period 1 and (3) holds. Otherwise, it decreases i in period 2.

10.2.4 Period 1

An uncompetitive bank 1:
- If bank 1 decreases i in period 1, it gains 0 in period 1-4.
- If bank 1 maintains i_H, its profit depends on the other bank's type and strategy. If bank 1 maintains i_H in period 1, it gains $Q(r_L - i_H)$ if bank 2 is competitive, $Q(r_L - i_H)$ if bank 2 is uncompetitive and (3) holds, and $1.5Q(r_L - i_H) + 2Q(r_L - i_L)$ if bank 2 is uncompetitive and (3) fails.

If bank 1 observes that (3) holds, its expected utility from maintaining i_H in period 1 is $Q(r_L - i_H)$. This is lower than 0, and therefore bank 1 decreases i. If bank 1 observes that (3) fails, its expected utility from maintaining i_H in period 1 is $\sigma Q(r_L - i_H) + (1-\sigma)[1.5Q(r_L - i_H) + 2Q(r_L - i_L)]$, which is higher than 0 if:

(4) $\quad (1-\sigma)2Q(r_L - i_L) > \sigma Q(i_H - r_L) + (1-\sigma)1.5Q(i_H - r_L)$

If (4) holds, an uncompetitive bank 1 maintains i_H in period 1.

An uncompetitive bank 1 maintains i_H in period 1 if (3) fails and (4) holds. Otherwise, it decreases i in period 1.

10.2.5 Check and overview

To determine whether the strategies above are an equilibrium, we need to reconsider the incentives of an uncompetitive bank 2 in period 2, given the strategies of bank 1 in period 1. If bank 2 observes that bank 1 maintained i_H in period 1 while (4) failed, then it knows that the other bank is a competitive type. Then, it decreases i in period 2. If it observes that bank 1 maintained i_H in period 1 while (4) holds, then it is uncertain about the other bank's type. It knows with probability σ that the other bank is competitive, so we can substitute π for σ in condition (3):

(5) $\quad (1-\sigma)Q(r_L - i_L) > \sigma Q(i_H - r_L) + (1-\sigma)1.5Q(i_H - r_L)$

If bank 2 observes that bank 1 maintained i_H in period 1 while (4) and (5) hold, it reacts tough and maintains i_H in period 2. By contrast, if (5) fails, it decreases i in period 2.

However, there is no equilibrium if both (4) and (5) hold. If uncompetitive bank 1 observes that (4) and (5) hold, then it knows that bank 2 maintains i_H in period 2. Therefore, it will decrease i in period

1. Then, bank 2 knows that i_H in period 1 results from a competitive bank. As a result, bank 2 will decrease i in period 2. This enhances a feedback loop of changing strategies, which means that there is no equilibrium if (4) and (5) hold.

In short:

- If (4) and (5) hold: There is no equilibrium.
- If (4) holds and (5) fails: An uncompetitive bank 1 maintains i_H in period 1 and an uncompetitive bank 2 decreases i in period 2.
- It is impossible that (4) fails and (5) holds, as the left-hand side of (4) is always larger than the left-hand side of (5).
- If (4) and (5) fail: An uncompetitive bank 1 decreases i in period 1 and bank 2 attracts all savers and decreases i in period 2.

Lemma 5 depicts the equilibrium strategies and utilities.

Lemma 5 Equilibrium strategies and utilities (*Competition only between banks*)

	Equilibrium strategies	Equilibrium utilities
Bank 1		
Competitive	• Decreases i after bank 2 decreased its i.	• $\sigma 2Q(r_H - i_H) + (1-\sigma)[1.5Q(r_H - i_H) + 2Q(r_H - i_L)]$ if (4) and/or (5) fail(s)
Uncompetitive	• Decreases i in period 3 if (4) holds and (5) fails. • Otherwise, it decreases i in period 1.	• $\sigma Q(r_L - i_H) + (1-\sigma)[1.5Q(r_L - i_H) + 2Q(r_L - i_L)]$ if (4) holds and (5) fails • 0 if (4) and (5) fail
Bank 2		
Competitive	• Decreases i after bank 1 decreased its i.	• $\sigma 2Q(r_H - i_H) + (1-\sigma)[2Q(r_H - i_H) + Q(r_H - i_L)]$ if (4) holds and (5) fails • $\sigma 2Q(r_H - i_H) + (1-\sigma)[Q(r_H - i_H) + 3Q(r_H - i_L)]$ if (4) and (5) fail
Uncompetitive	• No equilibrium if (4) and (5) hold. • Otherwise, it decreases i in period 2.	• $0.5Q(r_L - i_H)$ if (4) holds and (5) fails • $\sigma 0.5Q(r_L - i_H) + (1-\sigma)[Q(r_L - i_H) + 3Q(r_L - i_L)]$ if (4) and (5) fail

Note: If at least one of the banks is an uncompetitive type, there is no equilibrium if (4) and (5) hold. It is impossible that (4) fails and (5) holds.

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