On equilibria in the model of deposit markets with exogenous switching costs of depositors

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Abstract

We model the deposit market, where commercial banks compete using deposit interest rates, and depositors initially distributed among banks, when switching to another bank, bear the exogenous switching costs associated with a lack of information and money transfer fee. We consider both discrete and continuous distribution of depositors over switching costs and find equilibria in pure strategies.

1 Introduction

It can be seen in Figs. 1 that there is no law of one price in the deposit market. It is empirically confirmed that bigger banks offer lower deposit rates, Penikas (2021); Schoors et al. (2019). Amounts of deposits in banks seem to be persistent from year to year, see Fig. 2, that suggests so called lock-in of consumers effect. One can

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Figure 1: Saving deposits of individuals in Russian banks in April 2023 (left) and in April 2024 (right) corresponding to their weighted average deposit interest rates. Vertical red line depicts the interest rate of the central bank.

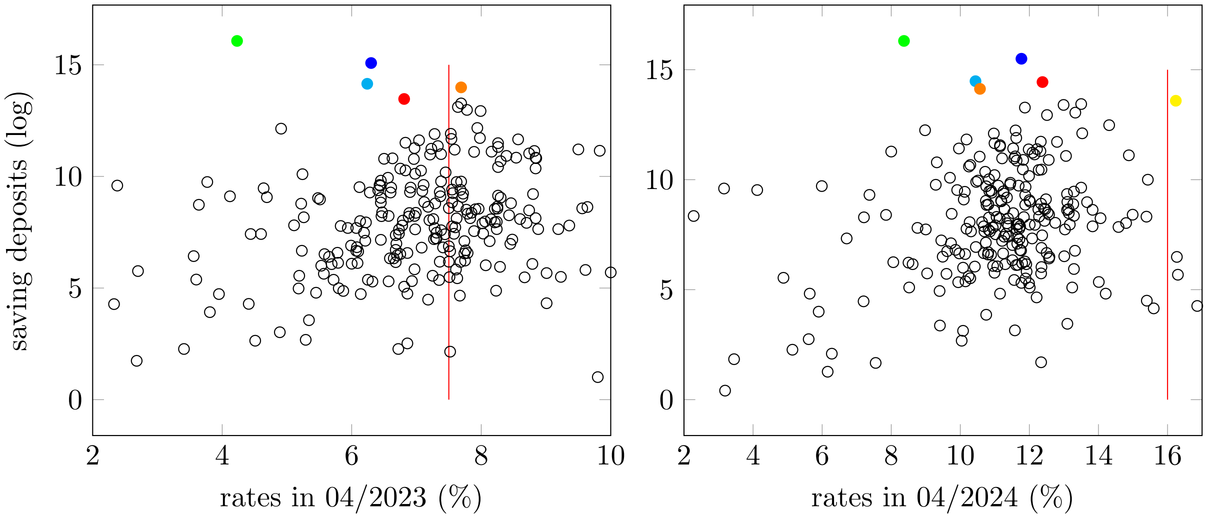
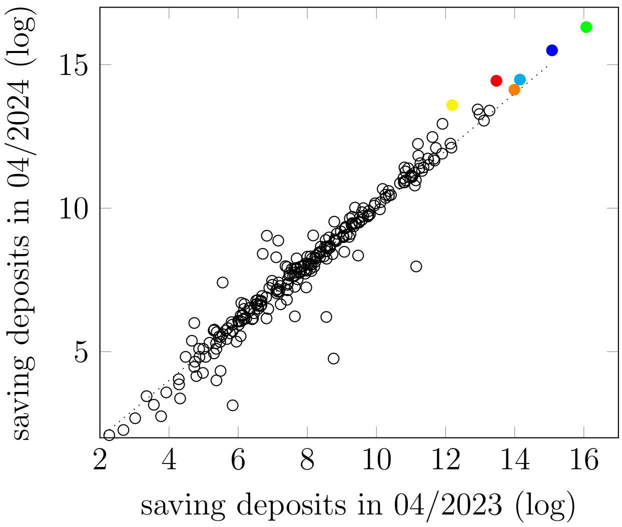


Figure 2: Saving deposits of individuals in Russian banks in April 2024 versus April 2023.



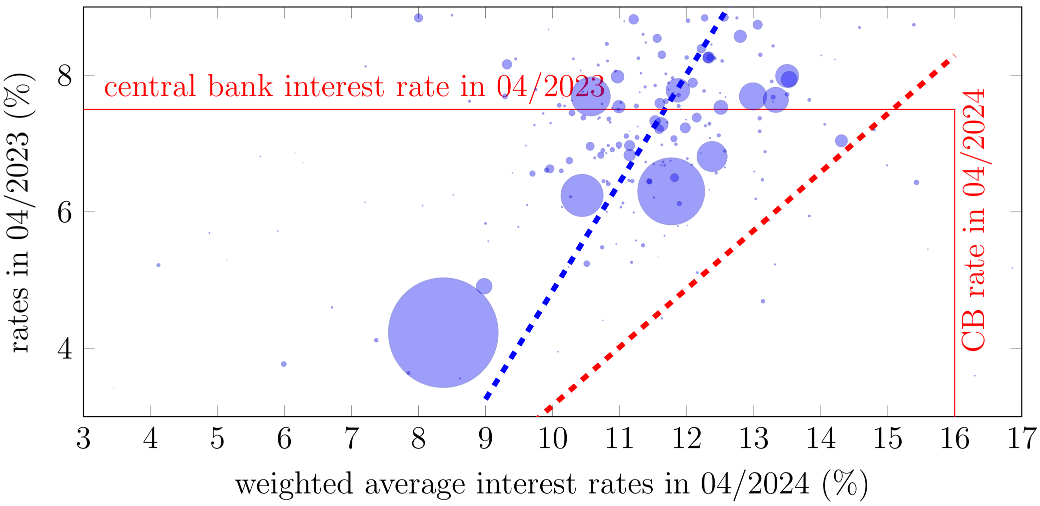


Figure 3: Saving deposits of individuals in Russian banks in April 2023 proportional to the size of corresponding circles (forms 0409101 and 0409102).
Averaged saving rates in April 2024 are related to averaged rates in April 2023 (blue dashed line estimated for 40 largest banks).
New deposit averaged saving rates in April 2024 and April 2023 are also related (red dashed line estimated for 40 largest banks, form 0409129).

argue that persistent deposit interest rate heterogeneity, see Fig 3, can be addressed to the fact that some banks are more reliable than others. But in Russia the absolute majority of credit institutions are included in deposit insurance, and the risks of many depositors losing their savings are practically leveled. Large banks may provide better liquidity services than small banks, offering more convenient online banking, see d'Avernas et al. (2023). The other explanation is the existence of switching costs for depositors, when changing their bank.

The literature on price competition with endogenous switching costs resulting in lock-in of consumers effects is vast. To mention a few on deposit market in Zephirin (1994) endogenous switching costs are considered as a trade-off between service quality and the interest rate faced by a depositor who values the services provided by banks. In Sharpe (1997) there is a generalization of the theory in Klemperer (1987) to a world with arbitrary market structure and empirical test with panel data on bank retail deposit interest rates. The economics of switching costs and network effects became popular in the last three decades, see e.g. Farrell and Klemperer (2007) and references there in.

We believe that a deposit market can be studied with rather simple model with exogenous switching costs of depositors, who do not behave strategically being initially distributed among banks and switching to another bank only when its deposit interest rate is so high that it compensates money transfer fee and other associated costs. We do not assume free entry of new banks, although some of our results could fit for this assumption too.

We consider a two stage game. At the first stage, banks choose deposit rates simultaneously. At the second stage, depositors, knowing the rates, can switch bank if it is profitable for them, after which banks receive money from depositors and put the money in the central bank, thus making profit. At the first stage, each bank sets such a rate so that its profit at the end of the second stage is maximized, considering the rates of competing banks given, but knowing how depositors could redistribute among banks at the second stage. We assume that depositors can keep cash without additional costs. Equilibrium is such a distribution of depositors among banks and such bank rates that no depositor will change his bank and no bank will want to change its rate unilaterally.

If it is possible for depositors to freely switch from bank to bank, the deposit market can be approximated by a price competition model, where the price role is played by the difference between the central bank's rate, under which a private bank can allocate funds, and the private bank's rate on deposits. If the marginal costs of servicing depositors for banks are the same and practically zero, then the "Bertrand paradox" takes place, when even in duopoly, the equilibrium price should be equal to the marginal costs. Therefore, the rates of banks should coincide with the rate of the central bank, so that banks practically do not have market power and receive zero profit. This is the best outcome for public welfare, as shown in the Appendix.

However, if depositors bear non-zero costs when switching to another bank, such as the commission for transferring money or the cost of finding another bank and understanding its conditions, then banks receive some market power and can lower rates without fear that depositors will switch to a competing bank. With sufficiently high switching costs, it can happen that each commercial bank assigns a rate significantly lower than the central bank's rate, as if the commercial bank had monopoly power over its depositors, allowing for a symmetric equilibrium.

It is sufficient for the existence of pure strategy Nash equilibrium that there are at least two banks on the market with zero switching costs of depositors. In equilibrium, zero switching cost banks, competing with each other, will set rates at the level of the central bank rate, and banks with positive costs will set the lowest rates of those at which their depositors will not go to banks offering a rate at the central bank level. Banks with zero switching costs of depositors actually create a so-called *competitive fringe* for banks with market power, whose depositors have positive costs of switching to other banks. A virtual bank without depositors with zero profit could also play the role of a competitive fringe, setting the interest rate at the level of the central bank's rate, thus threatening other banks to poach their depositors if banks lower rates too much. There is no need in any competitive fringe if we consider equilibrium in *secure strategies*, see Iskakov et al. (2018); Iskakov (2005), a more general concept, than that of Nash, that avoids *threats*, when it is profitable for one bank to worsen the situation of another.

It is worth emphasizing that since depositors do not change banks in equilibrium and do not bear the associated costs, the costs of switching from bank to bank affect social welfare only via lower rates of commercial banks. To encourage banks to increase rates, their risk of losing depositors should be increased, reducing the cost of switching from bank to bank. Moreover, these transition costs can be both a personal characteristic of the depositor (financial literacy) and the specific bank in which he is serviced (fee for the money transfer).

2 Discrete distribution of depositors over switching costs

2.1 Competition with homogeneous switching costs

Banks set the deposit rates at the same time, maximizing profits

$$\Pi_i(r) = Q_i(r_i, r_{-i})\,(R - r_i) \to \max_{r_i \geq 1},$$

where R is the gross rate of the central bank, r_{-i} is the gross rate of the other bank, and $r = (r_i, r_{-i})$ is the strategy profile of interest rates.

Let us start with two banks $i \in \{1, 2\}$. The bank i attracts D_{-i} depositors of the other bank if the transfer covers the costs $z > 0$ including interest, $r_i - r_i z > r_{-i}$, see Section 6.1, otherwise banks have their initial depositors $D_1 \geq 0$ and $D_2 \geq 0$. Thus, the demand functions for banks have the following form

$$Q_i = \begin{cases} D_i + (1-z)\,D_{-i}, & \frac{r_i}{r_{-i}} > \frac{1}{1-z} \\ D_i, & \frac{r_i}{r_{-i}} \in [1-z, \frac{1}{1-z}] \\ 0, & \frac{r_i}{r_{-i}} < 1-z \text{ or } r_i < 1 \end{cases},$$

There could be two types of equilibria depending on the switching costs:

- symmetric $r_1 = r_2 = 1$, with $D_i \geq D_{-i}\left(\frac{1}{z} - 1\right)(R(1-z) - 1)$ only if[1] $z \geq$

[1]Banks do not poach depositors from each other if $D_i\,(R-1) \geq (D_i + (1-z)\,D_{-i})\,(R - r_i)\,, \forall r_i > \frac{1}{1-z}$, which is fulfilled if $D_i\,(R-1) \geq (D_i + (1-z)\,D_{-i})\left(R - \frac{1}{1-z}\right)$, where we set $r_i = \frac{1}{1-z}$. After grouping we get $D_i \geq D_{-i}\left(\frac{1}{z} - 1\right)(R(1-z) - 1)$, that is true for both banks, i.e. $D_{-i} \geq D_i\left(\frac{1}{z} - 1\right)(R(1-z) - 1)$ also holds, only if $\left(\frac{1}{z} - 1\right)(R(1-z) - 1) \leq 1 \Rightarrow R \leq \frac{1}{(1-z)^2}$. If $D_i > 0$, $r_i \geq r_{-i}$ and $r_i > 1$, the bank i can reduce r_i retaining depositors.

$1-\frac{1}{\sqrt{R}}$,
for example $z \geq 1-\frac{1}{\sqrt{R}} = 1-\frac{1}{\sqrt{1.16}} \approx 0.07 = 7\%$ of the deposits.

- asymmetric $D_1 = 0$, $r_1 = R$, $D_2 > 0$ $r_2 = \max\{1, R(1-z)\}$, for all $z \geq 0$ for example: $z = 1 - \frac{r_j}{R} = 1 - \frac{1.15}{1.16} \approx 0.009 = 0.9\%$ of the deposit.

2.2 Competition with heterogeneous switching costs

When there are both zero and positive switching cost for depositors, there is no equilibria with strictly positive number of depositors of two banks. This is the same result as for firms with informed and uninformed customers in Varian (1980), see, e.g., Chapter 7 in Belleflamme and Peitz (2015).

For example, let bank 2 attract depositors of bank 1 without switching costs, $z_1 = 0$, and let bank 1 attract depositors of bank 2 if their strictly positive switching costs $z_2 = z > 0$ are covered including not received interest. Otherwise banks have their original depositors $D_1, D_2 > 0$. Demand functions for the banks have the following forms

$$Q_1 = \begin{cases} D_1 + D_2(1-z), & \frac{r_1}{r_2} > \frac{1}{1-z} \\ D_1 & , \frac{r_1}{r_2} \in [1, \frac{1}{1-z}] \\ 0 & , r_1 < r_2 \text{ or } r_1 < 1 \end{cases},$$

$$Q_2 = \begin{cases} D_1 + D_2, & r_2 > r_1 \\ D_2 & , \frac{r_2}{r_1} \in [1-z, 1] \\ 0 & , \frac{r_2}{r_1} < 1-z \text{ or } r_2 < 1 \end{cases}.$$

Neither there is an asymmetric equilibrium, if $r_1 < r_2$ or $r_1 > r_2$, then bank 1 or 2 can increase its profit choosing $r_1 = r_2$ retaining its depositors, nor there is a symmetric equilibrium $r_1 = r_2$, because if $r_1 = r_2 > 1$, then bank 2 can choose $r_2 = \max\{1, (1-z)r_1\}$ increasing its profit, and if $r_1 = r_2 < R$, then bank 2 by infinitesimal increase of r_2 attracts all depositors with zero switching costs form bank 1.

Notice that case $D_1 = 0$ is equivalent to homogeneous switching cost situation considered in the previous section, while case $D_2 = 0$ is equivalent to zero switching cost environment subject to Bertrand competition.

More asymmetric equilibria can be found in a more general case of $N > 2$ banks with different switching costs of depositors, where the demand functions of banks have the following form

$$Q_i(r_i, r_{-i}) = \begin{cases} D_i + \sum_{j \neq i, r_i < \frac{r_j}{1-z_j}} (1-z_j) D_j, & r_i \geq (1-z_i)\max_{j\neq i} r_j \text{ and } r_i \geq 1 \\ 0 & , r_i < (1-z_i)\max_{j \neq i} r_j \text{ or } r_i < 1 \end{cases}.$$

In addition to the previously described asymmetric equilibrium

$$r_1 = R, \quad D_1 = 0, \quad r_{i>1} = \max\{1, R\,(1 - z_i)\}, \quad \forall\ D_{i>1} \geq 0,$$

with strictly positive switching costs $z_i > 0$ of all banks, there are also asymmetric equilibria

$$r_i = \max\{1, R\,(1 - z_i)\}, \quad \forall\ D_i \geq 0. \tag{1}$$

when depositors of at least two banks have only zero switching costs $z_1 = z_2 = 0$. These is a Bertrand competition between these two banks resulting to $r_1 = r_2 = R$, thus providing competitive fringe for other banks.

3 Equilibria in secure strategies

There is a more general than that of Nash concept of equilibrium, see Iskakov et al. (2018); Iskakov (2005), that would look one step further to avoid *threats*, which are the situations when it is profitable for one bank to worsen the situation of another.

Definition 1. *A* threat *of bank i against bank j at strategy profile $\boldsymbol{r}$ is a deviation r_i' such that $\Pi_i(r_i', r_{-i}) > \Pi_i(\boldsymbol{r})$ and $\Pi_j(r_i', r_{-i}) < \Pi_j(\boldsymbol{r})$.*

It is easy to show that for any $z_i \geq 0$ and any $D_i \geq 0$ gross interest rates in (1) are *a secure strategies* composing *a secure profile* defined as follows.

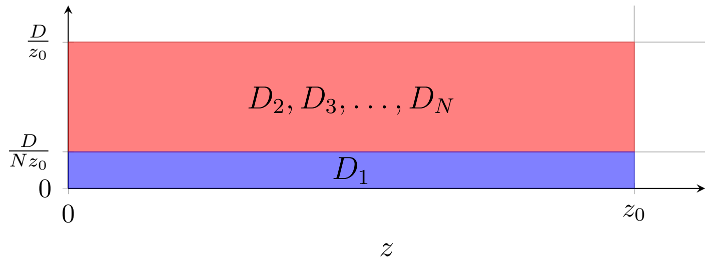
Definition 2. *A strategy r_i of bank i is* a secure strategy *at strategy profile $\boldsymbol{r}$ if no bank $j \neq i$ has a threat against bank i at $\boldsymbol{r}$. A strategy profile $\boldsymbol{r}$ is* a secure profile*, if all banks' strategies are secure.*

The concept provides fewer equilibria than we would find in repeated games and includes all pure strategy Nash equilibria.

4 Continuous distribution of depositors over switching costs

So far we considered situation when each bank have depositors with the same switching costs. The more general case we will study in continuous setup.

Figure 4: Distribution of depositors among banks in symmetric equilibrium



4.1 Symmetric equilibrium

Consider symmetric equilibrium with the same gross interest rates $r_i = r$ and same uniform continuous distributions of depositors over switching costs $z \in [0, z_0]$ in N banks, see Fig. 4.

Gross interest rate $r_i \leq r$ would keep depositors with switching costs $z \geq 1 - \frac{r_i}{r}$ at bank i. Gross interest rate $r_i > r$ would attract all depositors with switching costs $z < 1 - \frac{r}{r_i}$ and deposits $1 - z \in [0, \frac{r}{r_i})$ form other banks to bank i of total amount $(N-1)\int_0^{1-\frac{r}{r_i}} (1-z)\, dz = (N-1)\left(z - \frac{z^2}{2}\right)\Big|_0^{1-\frac{r}{r_i}} = (N-1)\frac{1-\left(\frac{r}{r_i}\right)^2}{2}$. The demand function of bank i has the form

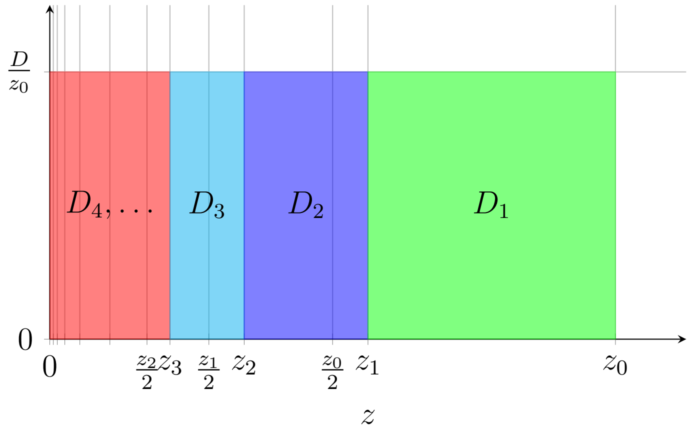
$$Q_i(r_i, r) = \frac{D}{z_0 N} \times \begin{cases} z_0 - (1 - \frac{r_i}{r}) & , \quad r_i \leq r \\ z_0 + (N-1)\frac{1-\left(\frac{r}{r_i}\right)^2}{2}, & r_i > r \end{cases},$$

where D is the total mass of depositors equally distributes among $N > 1$ banks. Its profit $\pi_i(r_i, r) = Q_i(r_i, r)\,(R - r_i)$ for $r_i \leq r$ has decreasing w.r.t. r_i derivative $\frac{\partial}{\partial r_i}\pi_i(r_i, r) = \frac{R}{r} - \frac{2r_i}{r} - z_0 + 1 \geq \frac{R}{r} - 1 - z_0$, which is not negative iff $r \leq \frac{R}{1+z_0}$. For $r_i > r$ the derivative w.r.t. r_i is decreasing $\frac{\partial}{\partial r_i}\pi_i(r_i, r) = (N-1)\, r^2\left(\frac{R}{r_i^3} - \frac{1}{2r_i^2}\right) - z_0 - \frac{N-1}{2} \leq (N-1)\left(\frac{R}{r} - 1\right) - z_0$, which is not positive iff $r \geq \frac{R}{1+\frac{z_0}{N-1}}$. Inequalities $\frac{R}{1+\frac{z_0}{N-1}} \leq r \leq \frac{R}{1+z_0}$ compatible only if $N = 2$. Thus there is a symmetric equilibrium only with two banks and $r = \frac{R}{1+z_0}$.

Same result holds for any differentiable cumulative distribution $F(z)$ of depositors over their switching costs, such that $F(0) = 0$, $F(z_0) = 1$, $F'(0) > 0$. The demand function of bank i has the form

$$Q_i(r_i, r) = \frac{D}{N} \times \begin{cases} 1 - F(z) & , \quad z = 1 - \frac{r_i}{r} \geq 0 \\ 1 + (N-1)\int_0^{\tilde{z}} (1-z)\, dF(z), & \tilde{z} = 1 - \frac{r}{r_i} > 0 \end{cases},$$

Figure 5: Distribution of depositors among infinite number of banks in asymmetric equilibria, where banks set gross interest rates $r_i = R\,(1 - z_i)$



and its profit $\pi_i(r_i, r) = Q_i(r_i, r)\,(R - r_i)$

$$\pi_i(r_i, r) = \frac{D}{N} \times \begin{cases} (1 - F(z))\,(R - r + rz) & , \quad z = 1 - \frac{r_i}{r} \geq 0 \\ \left(1 + (N-1)\int_0^{\tilde{z}} (1 - z)\,dF(z)\right)\left(R - \frac{r}{1 - \tilde{z}}\right), & \tilde{z} = 1 - \frac{r}{r_i} > 0 \end{cases} .$$

Necessary conditions for $r_i = r$ being the best response are the following inequalities

$$\frac{\partial}{\partial z}\,(1 - F(z))\,(R - r + rz)\bigg|_{z=0} \leq 0,$$

$$\frac{\partial}{\partial z}\left(1 + (N-1)\int_0^{\tilde{z}} (1 - z)\,dF(z)\right)\left(R - \frac{r}{1 - \tilde{z}}\right)\bigg|_{\tilde{z}=0} \leq 0,$$

which result into the chain of inequalities

$$\frac{R}{1 + \frac{1}{F'(0)(N-1)}} \leq r \leq \frac{R}{1 + \frac{1}{F'(0)}},$$

compatible only when $N = 2$ and unique $r = \frac{R}{1 + \frac{1}{F'(0)}}$.

4.2 Asymmetric equilibria

Consider uniform distribution of depositors over switching costs from 0 to $z_0 \in \left(0, 1 - \frac{1}{R}\right)$, see Fig 5. It is easy to show that there is the following asymmetric equilibrium including intervals $(z_i, z_{i-1}]$ of all depositors distribution that are

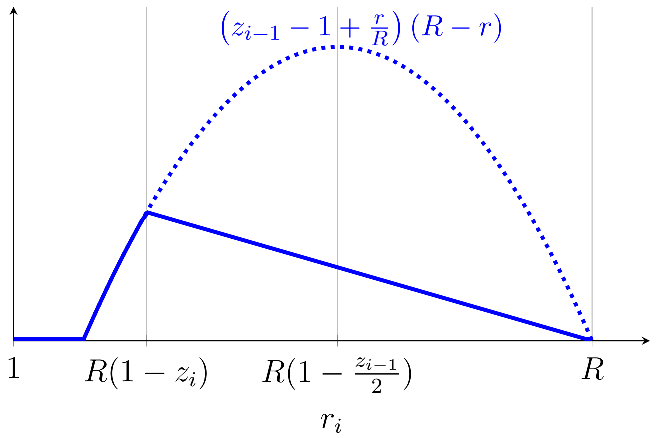


Figure 6: Profit (solid blue line) of bank i having depositors with switching costs in $(z_i, z_{i-1}]$ reaches maximal value at $r_i = R(1-z_i)$, because we require $z_i \geq \frac{z_{i-1}}{2} \iff r_i \leq \frac{r_{i-1}+R}{2}$.

clients of bank i, so that

$$D_i = D\,\frac{z_{i-1}-z_i}{z_0}, \quad r_i = R\,(1-z_i)\,,$$

where $z_i \in [\frac{z_{i-1}}{2}, z_{i-1}]$ and $\lim_{i\to\infty} r_i = R$ with infinite number of banks. Indeed, $r_i = R\,(1-z_i)$ is the optimal response maximizing profit[2], see Fig. 6.

$$r_i \in \arg\max_{r\geq 1} \left\{0, \left(z_{i-1} - \max\left\{z_i, 1-\frac{r}{R}\right\}\right)\right\}(R-r).$$

Similar equilibria exist for finite number of banks $N>1$, when depositors are uniformly distributed over switching cost $[\underline{z}, z_0]$ staring form positive value $\underline{z}>0$:

$$D_i = D\,\frac{z_{i-1}-z_i}{z_0-\underline{z}}, \quad r_i = R\,(1-z_i)\,, \quad \forall\, i<N$$

where $z_i \in [\frac{z_{i-1}}{2}, z_{i-1}]$ and $r_N = R$, $D_N = 0$, so that $z_{N-1} = \underline{z}$ see Fig. 7.

Similar result holds for any differentiable cumulative distribution $F(z)$ of depositors over their switching costs with the following profit function of bank i

$$D\,R\,\max\{0, (F(z_{i-1}) - \max\{F(z_i), F(z)\})\}\,z \to \max_z$$

if the derivative of the profit is negative for all $z \in [z_i, z_{i-1}]$:

$$F(z_{i-1}) - F(z) - z\,F'(z) < 0.$$

[2]Function $\left(z_{i-1}-1+\frac{r}{R}\right)(R-r)$ is concave with maximum at $r = R\left(1-\frac{z_{i-1}}{2}\right) \geq R\,(1-z_i)$ due to $z_i \geq \frac{z_{i-1}}{2}$.

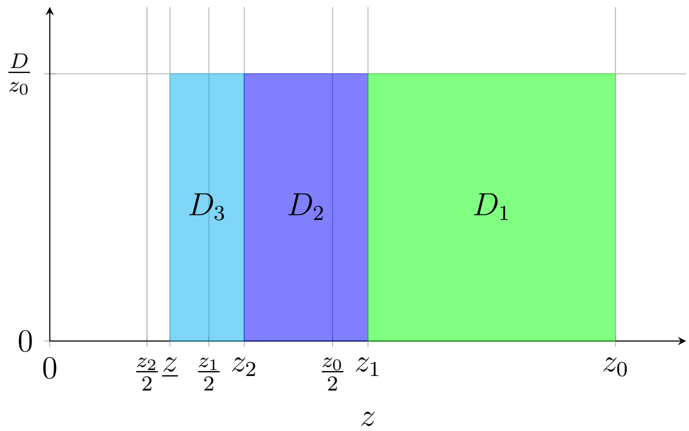


Figure 7: Distribution of depositors among banks in asymmetric equilibria, where $r_1 = R(1 - z_1) \geq R\left(1 - \frac{z_0}{2}\right)$, $r_2 = R(1 - z_2) \geq R\left(1 - \frac{z_1}{2}\right)$, $r_3 = R(1 - \underline{z})$, $D_3 = 0$, $r_4 = R$, $D_4 = 0$

5 Market power of banks and policy

We measure market power of banks by the Lerner index

$$L_i = \frac{R - r_i}{R} = z_i,$$

that for equilibrium (1) is the switching cost, and the market power in the market as the average Lerner index (weighted by market shares)

$$L = \sum_{i=1}^{N} L_i \frac{D_i}{D} = \frac{\sum_{i=1}^{N} z_i D_i}{D},$$

which is the average switching cost.

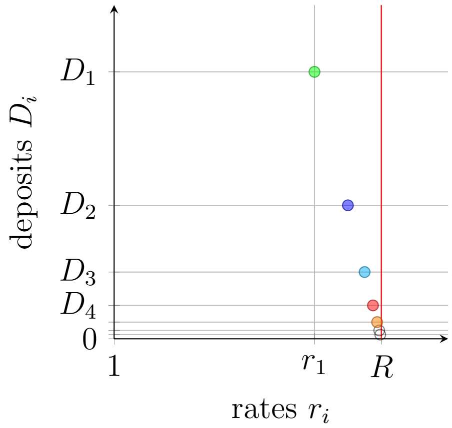
There are many asymmetric equilibria in section 4.2, depending on distribution of depositors among banks satisfying condition $z_i \in [\frac{z_{i-1}}{2}, z_{i-1}]$ so that bank market power is not necessarily related to the number of its depositors. But we can outline a natural distribution appearing if banks emerge consequently so that initially all depositors with $z \in [0, z_0]$ were at the first bank. When the second bank emerges the first bank keeps only $(z_0/2, z_0]$ setting $r_1 = R\left(1 - \frac{z_0}{2}\right)$. The second bank keeps $(z_0/4, z_0/2]$ setting $r_2 = R\left(1 - \frac{z_0}{4}\right)$, when the third bank emerges, and so on. The resulting equilibrium would be

$$r_i = R\left(1 - \frac{z_0}{2^i}\right), \quad D_i = \frac{D}{2^i}, \quad i = 1, 2, 3, \ldots \quad \Rightarrow \quad L_i = \frac{z_0}{2^i}.$$

So it looks like there is a negative relation

$$r_i = R\left(1 - \frac{z_0}{D} D_i\right)$$

Figure 8: Relation between amounts and interest rates of bank deposits in a historically plausible equilibrium.



between sizes D_i and interest rates r_i of banks, see Fig. 8, but this is just one equilibrium of many, although historically plausible and having the smallest average Lerner index among all asymmetric equilibra

$$L = \sum_{i=1}^{N} L_i \frac{D_i}{D} = z_0 \sum_{i=1}^{\infty} \frac{1}{2^i} \frac{1}{2^i} = \frac{z_0}{3}.$$

under assumption that banks do not discriminate their depositors over switching costs. When banks can discriminate as if each depositor is at separate bank, we have maximal market power

$$L = \int_0^{z_0} z \, dF(z) = \int_0^{z_0} z \, d\frac{z}{z_0} = \frac{z_0}{2}.$$

Thus smaller market concentration results to higher market power.[3] That is why policy that divides big banks cannot decrease the market power, Figs. 9, 10.

6 Conclusions

In almost all settings of switching costs, there are asymmetric equilibria, when banks set different interest rates, having a kind of competitive fringe, where for example, one bank without depositors sets the central bank rate, or at least two

[3] This is because there is a price competition rather than quantity competition, where the market power directly proportional to the market concentration (measured, e.g., by Herfindahl-Hirschman index).

Figure 9: New banks will set the same rate $\tilde{r}_1 = \tilde{\tilde{r}}_1 = R(1 - z_1) = r_1$.

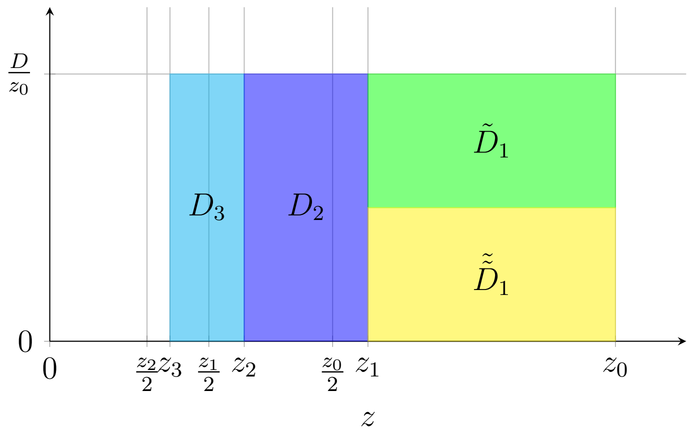
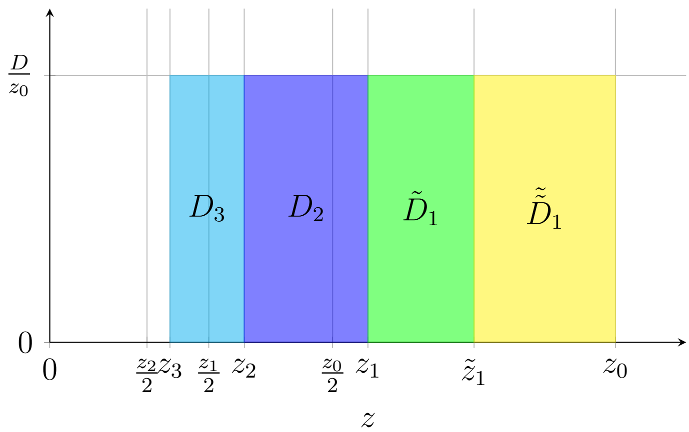


Figure 10: One of the new banks will set a lower rate $\tilde{\tilde{r}}_1 = R(1 - \tilde{z}_1) < \tilde{r}_1 = R(1 - z_1) = r_1$.



banks do the same due to Bertrand competition between them, when their depositors have only zero switching costs. Other banks with positive switching costs set the lowest interest rates at which their depositors still remain with them. Same equilibria in secure strategies exist even without a competitive fringe. These asymmetric equilibria can describe lock-in of consumers effect without difference of banks in their quality of reliability.

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Appendix

Depositor's utility function

Let a depositor change the size of the deposit $x \leq y - c$

$$u(c,x) = r\,x - \frac{\sigma}{1+\sigma}\,(y-c)^{\frac{1+\sigma}{\sigma}} \to \max,$$

choosing consumption c, where $\sigma > 0$, y is income, as well as *bliss point* on consumption for simplicity.

If $x \geq 0$, then $c \leq y$ and the budget constraint is $x = y - c$.

Then the first-order condition is $r - x^{\frac{1}{\sigma}} = 0$ and the size of the deposit

$$x = r^{\sigma}$$

Optimal utility of the depositor has value $u(y - r^{\sigma}, r^{\sigma}) = \frac{r^{1+\sigma}}{1+\sigma}$.

The bank's profit from such a depositor is $r^{\sigma}(R - r)$.

6.1 Condition of non-switching to another bank

When switching to another bank, the budget constraint is $x = y - z - c$ and the demand for deposits is:

$$x = r^{\sigma} - z,$$

where z is the cost of switching to another bank.

Utility $u(y - r^{\sigma}, r^{\sigma} - z) = \frac{r^{1+\sigma}}{1+\sigma} - r\,z$.

The bank's profit from a switching depositor is $(r^{\sigma} - z)\,(R - r)$.

When choosing between his bank i and another bank j with a maximum interest rate of r_j, a depositor with switching costs z will remain in his bank if

$$\frac{r_i^{1+\sigma}}{1+\sigma} \geq \frac{r_j^{1+\sigma}}{1+\sigma} - r_j\,z$$

Note that for $\sigma \to 0$, which we assume for the sake of simplicity, the condition takes the form

$$r_i \geq r_j - r_j z.$$

6.2 Increase in social welfare

The increase in the utility of the depositor

$$\frac{r^{1+\sigma}}{1+\sigma} - \frac{1^{1+\sigma}}{1+\sigma} = \frac{r^{1+\sigma} - 1}{1+\sigma}$$

plus bank's profit

$$r^\sigma(R-r)$$

is the increase in social welfare per depositor:

$$Rr^\sigma - \frac{\sigma r^{1+\sigma}+1}{1+\sigma} > 0 \text{ when } r > 0 \text{ and } \sigma > 0,$$

increasing in r and maximal in $[1, R]$ at $r = R$.