Impact of Banking Supervision Enhancement on Banking System Structure: Conclusions from Agent-Based Modeling

Alexey Ponomarenko, *Bank of Russia*

Andrey Sinyakov, *Bank of Russia*

The Bank of Russia's policy for banking sector recovery and elimination of non-viable and unscrupulous banks from it receives experts' attention and their mixed response. Our study, in line with the key points of critique, suggests that this policy can, in the medium term, bring down the level of monopolism in the banking system and improve its efficiency, while weakening medium-sized and small banks' positions in the short term. Overall, long-term benefits from proactive supervision policy may significantly outweigh short-term losses owed to a rise in banking business concentration. To study the implications of proactive banking sector recovery we have constructed an agent-based model of the banking sector and calibrated its key variables using Russia's banking sector data. Based on the model we have compared short-term and long-term effects under two supervision regimes, one more and the other less stringent. Model estimation suggests that short-term effects of proactive supervision policy weaken the positions of medium-sized and small banks, including those complying with supervisory requirements. However, as the banking sector gains in soundness, benefits from heightened confidence in these banks and the entire banking system generally exceed short-term losses. The share of medium-sized and small banks in loans and deposits of the banking system eventually proves to be higher than prior to supervision policy enhancement. The monopolism of the banking sector declines and price competition rises. The banking system becomes a more effective economy financing institution, shedding the excessive risk to individual and systemic stability, with the average risk of financed projects remaining unchanged. Meanwhile, medium-sized and small banks' stability improves. We point out that agent-based models provide a helpful tool for studying a wide range of other issues vital to the Russian banking sector.

Keywords: *banking supervision, banking system cleanup from "bad" banks, agent-based modeling, Russia's banking sector*

JEL: G28, G21, E47, C63

1. Introduction

Proactive policy that the Bank of Russia embarked on in 2013 to secure banking system recovery and its cleanup from fraudulent players had 332 banking licenses withdrawn as of June 2017. Note that a total of just 390 licenses were withdrawn in 2002–2012. The Deposit Insurance Agency's payments to depositors expanded from 0.02% of GDP in 2012 to 0.7% of GDP in 2015.

These drastic measures by the Bank of Russia to straighten things out in the banking sector have however received a mixed public response. The critique generally boils down to the four points below, which have to do with both short-term and long-term effects of proactive supervision policy¹:

- 1) What critics view as the massive license withdrawal is causing depositors' outflow to large and government-controlled banks, damaging smaller, regional banks which stick to fair business practices. In economics this is termed externality², in particular when a "system contagion" by a depositor flight has an adverse effect on the system as a whole³.
- 2) The fall in the number of banks will have an adverse long-term effect on competition in the banking sector. Since it is from private banks that licenses are withdrawn, a risk arises of increasing imbalances in favor of government-controlled banks which may then start to dictate their terms to depositors and borrowers, i.e., offer their services as monopolists at higher prices (higher interest rates on loans and lower rates on deposits).
- 3) Also, it is assumed that the predominance of government-controlled banks will make the banking system more vulnerable to future shocks. As this school of thought sees it, government-controlled banks are less adaptive to shocks but, aware that they will be bailed out in any event, are inclined to assume greater risks⁴, thereby increasing the banking system's vulnerability to crises.
- 4) It is claimed that in the long term this will entail a deterioration in the banking system's efficiency as an institution providing credit to the economy. Less extensive and varied tiers of the banking system and a decrease in the number of market niches where investment projects (borrowers) of various risk levels can find their creditors, may cause a credit shortfall in the economy.

It should be mentioned that economists have yet to reach a clear conclusion as to whether a smaller number of banks adversely affects competition in the banking sector or what the optimal level of this competition is⁵. The impact of banking sector recovery/cleanup on competition, financial intermediation efficiency, and

¹ See, e.g., the Association of Russian Banks' 2017 Annual Report and a review of media comments: <http://expert.ru/2017/03/29/banki/> (in Russian).

² E.g., De Nicolo et al. (2012).

³ In the critics' view, a similar situation was seen in the Republic of Tatarstan after Tatfondbank's license was withdrawn. See media coverage of implications for the republic's banking sector: <http://www.banki.ru/news/columnists/?id=9750266> (in Russian).

⁴ The so-called too-big-to-fail problem.

⁵ See Vives (2016), Vives (2010), Byod and De Nicolo (2005), Keeley (1990).

long-term economic growth is studied in the literature in the context of the effects of proactive banking supervision (see, e.g., Kupiec, et al, 2017)⁶. Studies of the effect of tightening bank capital requirements indirectly suggest arguments for proactive banking supervision⁷. Colliard (2015) examines an optimal banking supervision model and provides a literature review.

In order to analyze the benefits and disadvantages of proactive supervision policy in Russia, we have constructed a formal behavioral model of partial equilibrium for the banking sector, under which each individual bank seeks to maximize profit. The model was constructed using the agent-based modeling technique which is gaining popularity in economics and central banks' policy analysis.⁸ Unlike the widely used DSGE models, this approach makes it technically simpler to model complex economic systems with a large number of agents and their types. In real life, for instance, households are not homogenous but differ in their income levels and tolerance for bank deposit risk, investment projects differ in their default probabilities, while banks are divided into groups by their lending policy types, i.e., the banking sector segmentation is present. Moreover, such models have an important advantage of offering the opportunity to analyze the dynamic interaction of all types of agents and the way independent actions of individual agent types explicitly form a market equilibrium (produce macroeconomic effects).

We calibrated the model against the data of Russia's banking system so as to reflect the degree of concentration and the structure of the banking sector's assets and liabilities from the perspective of how banks were grouped prior to stepping up banking sector recovery (mid-2013). We ran the model thus calibrated to compare the main characteristics of a banking system equilibrium under the two different supervision policy regimes: that of proactive banking sector recovery followed by the maintenance of tough capital requirements and that of loose supervision standards, with a focus on the characteristics of competition and efficiency in the banking sector.

Of course, we cannot claim that this approach to calibration allows an accurate quantitative assessment of results achieved by toughening supervision policy. Also, we have no reason to suggest that assumptions we use are realistic and comprehensively reflect the impact of supervision policy on the banking system⁹. We did not aim to pinpoint the most vital problems and realistic premises. Although this study takes account of financial intermediation's fundamental

⁶ For arguments for and against banking sector recovery policy, see, e.g., Speech by Dr Raghuram Rajan, Governor of the Reserve Bank of India, at the Confederation of Indian Industry's (CII) first Banking Summit, Mumbai, 11 February 2016.

⁷ Broke et al. (2015), Buch and Prieto (2014), Angelini et al. (2015).

⁸ See, e.g., the section outlining the experience and areas of application of this approach by the Bank of England: Turrell (2016).

⁹ In particular, we do not believe that toughening supervision policy will affect the probability of emergence of new (scrupulous) banks.

features, such as information asymmetry in the loan and deposit markets, the possibility of a depositor flight or a bank run, including the possibility of the liquidity problem (depositor flight) turning into that of capital shortage (insolvency), we do not touch upon a wide range of issues, including moral hazard and risks to financial stability caused by banking system consolidation (too big to fail), the probability and implications of zombie-banks emergence¹⁰, the viability of bailing out banks at the taxpayers' expense¹¹, a balance between supervision and insurance as factors of market discipline, and the accent of supervisory activities on certain bank types¹².

Empirical studies suggest that explanations for processes developing in the banking system probably exaggerate the role of supervision policy¹³. However, our approach allows illustrating a wider range of hypothetical effects which may potentially arise as supervision is enhanced.

The main results that we have obtained are as follows.

Short-run consequences. In the short run, the vigorous cleanup of the banking sector from “bad” banks stems from a growing perception of risks involved in putting money in all medium-sized and small banks (confidence crisis) and more exacting demands on the size of a bank as an observable and simple test of a bank's risk of failure. As a result, a deposit outflow to large federal banks and, to a certain extent, even an outflow of funds from the banking system in general (for example into cash or foreign currency) are seen. This is how the negative externality of proactive supervision materializes. This results in the higher average deposit rate on the balance sheets of medium-sized and small banks, depressing their profit from liabilities management, as they earn this profit through obtaining liabilities at a lower price than a central bank's key rate (rate curve) or the money market rate (rate curve). The profit contraction on the liabilities side results in a low level of medium-sized and small banks' capital, preventing their lending growth. Because of the medium-sized and small banks' capital replenishment problems, this group of banks faces greater financial vulnerability in the short term. The major federal banks find themselves in the opposite situation, expanding their capital thanks to a deposit influx and a lower cost of liabilities, which helps expand lending. As estimates suggest, this will eventually boost the share of the major banks in the banking system's total deposits and loans. A rise in concentration

¹⁰ See, e.g., the description of Japan's economic situation, Koo (2011).

¹¹ This study did not aim to quantify direct public losses, while the given model specification takes into account such direct public losses. Indeed, from the macroeconomic perspective (general equilibrium) bank depositors are also the owners of firms as well as banks themselves. As we charge bank losses to the capital of other banks which can absorb such losses, we actually recognize depositors' direct losses.

¹² The last two questions may become the subject of a further study as part of this model class.

¹³ See, e.g., paper by A. Kruglova and Yu. Ushakova ‘Impact of banking sector recovery policy on dynamics, competition and development sustainability’, Bank of Russia's Working Paper Series, 2017.

is also captured by the increasing Herfindahl index¹⁴, often used as its measure. Competition weakening in the banking sector is adequately reflected by the increasing heterogeneity (dispersion of deposit rates across banks): as the role of a bank's size grows, price competition recedes into the background, and the major banks earn extra profits owing to the abundance and low cost of liabilities. These profits are actually redistributed to them from smaller banks and from depositors. Another important short-term implication of recovery is a deterioration in the efficiency of the banking sector's operation, as shown by a drop in the bank's average risk exposure. Although the maximum loan risk exposure declines owing to the exit of "bad" banks which used to assume such risks most often, the segment of average-risk investment projects receives less resources. This happens because medium-sized banks catering to this segment are unable to provide loans due to their problems with capital caused by the depositor outflows.

Long-term implications. Many of the above effects are not only reversed upon the completion of the banking system cleanup period and the subsequent retention of proactive policy by the regulator but the banking sector's performance in the key areas improves compared with an equilibrium found in the absence of a banking sector cleanup:

- A. **Medium-sized and small banks' deposit base expands compared with a long-run equilibrium seen in the absence of banking system recovery policy, painful in the short-term.** The share of deposits in large banks not only returns to the previous (prior to stepping up supervision) equilibrium, but declines lower – medium-sized and small banks enjoy a higher long-term depositors inflow as compared with the equilibrium under loose policy by the regulator. A reduction in the number of banks with negative capital enhances depositor confidence in medium-sized and small banks and the banking system in general. Having become generally more reliable and jettisoned the ballast of "bad" banks, the medium-sized and small banks shows a greater appeal to depositors than in the absence of banking system recovery by the regulator. As a result, the share of deposits in large banks dwindles in the long term.
- B. **Medium-sized and small banks strengthen their capital positions, thereby boosting lending.** The share of medium-sized and small banks in new total lending grows. The key implication of depositors reversing their flow back to responsible medium-sized and small banks is their profit growth and hence recapitalization. Medium-sized banks' rising potential to earn profit from liabilities translates into their growing ability to make profit

¹⁴ See, e.g., the World Bank overview at:
<http://www.worldbank.org/en/publication/gfdr/background/banking-competition>

on the assets side. This enables nonfederal banks to boost lending to investment projects (facing capital constraints more rarely). **Similarly to deposits, capital and lending expansion by medium-sized and small banks in a new long-term equilibrium surpasses levels seen in an equilibrium under loose policy by the regulator.**

- C. **The major banks' monopolism decreases compared with a long-term equilibrium under loose supervision policy: profit is redistributed from the major banks to medium-sized and small ones.** A long-term rise in confidence in medium-sized and small banks driven by a vigorous cleanup of the banking system diminishes the role of a bank's size as an important factor in choosing a bank for opening a deposit account. It is price competition and the quality of services that come to the fore. As medium-sized and small banks join this competition for depositors (from the position of "equality" with large banks) competition strengthens, leading to higher average rates on deposits in the banking system and more homogenous interest rates across banks. The Herfindahl index showing the concentration of the deposit and loan market drops by half.
- D. **The banking system becomes a more readily available economy financing institution: excessive (frequently associated with asset stripping) credit risks are driven out of the system, while the share of bank-financed investment projects showing a moderate level of risk increases. Meanwhile, the system's average credit risk remains unchanged.** Since medium-sized banks of the model on average pursue a softer lending policy than that of the major banks, the expansion of their share in total lending means greater availability of loans in the banking system, where minimum-risk borrowers, which as a rule implement the largest investment projects, are not the only ones that enjoy the opportunity to raise financial resources.
- E. **Financial stability of the medium-sized and small bank group improves.** The share of banks with negative capital is reduced to zero in the long run, whereas it permanently remains unchanged under loose policy¹⁵. The system sheds the overhang of "bad" banks that used to persist previously, threatening to spark a domino effect and a massive crisis of confidence in scrupulous small banks as well as in the entire banking system even upon a minor shock. Medium-sized and small banks strengthen their capital positions and gain a fairer (more competitive) access to the deposit and

¹⁵ The model's implicit estimate stands at 8% of banks at each moment in time. Note that it is not an aggregate total, because banks which have negative capital at a specific moment in time may subsequently recover if circumstances are favorable.

loan markets. The system as a whole becomes more sound than it would have been if there had been no cleanup of the banking system.

Further presentation of the paper is structured as follows. We will first provide a description of the model, setting rules of behavior for each of the four groups of agents, i.e., households, enterprises, banks, and the regulator (central bank). We will then report the main results of simulation of the model and, finally, will set out our conclusions regarding central bank policy.

2. The model and its calibration

This section presents only a brief description of the logic and structure of the model. A detailed description of the model and parameters calibrated is provided in the Annex.

We need to point out that the model makes use of agent-based modeling which economics took over from natural sciences. For the employment of agent-based models in economics and finance, including in central banks' policy analysis, and their benefits and drawbacks, see Turrel in the Bank of England Quarterly Bulletin (2016) and Fagiolo & Roventini (2017).

The agent-based modeling requires the behavior of various types of the model's economic agents to be defined, i.e., the way they make decisions in various situations (households or firms) – on a bank for opening a deposit account; banks – on whether or not to provide a loan to a company). This process aims to achieve the approximation of the behavior thus described to agents' behavior in real life. Rules of behavior are therefore set for each individual agent in the model. Agents, on their part, vary in parameters, and agents' heterogeneity is thus modeled. These parameters are assigned to agents as random values from a distribution with given characteristics. Agents' emergence and default, the occurrence of various shocks, with which agents have to cope, are governed by probability laws. As a result their behavior patterns are studied via a multitude of simulations in which the law of large numbers manifests itself.

Our model constitutes a basic description of the loan and deposit markets in which banks operate. It can be regarded as a simplified version of the banking sector model presented in Chan-Lau (2017). Non-banking sectors are not however modeled, while demand for loans and deposits is determined by exogenous processes. The overall chart of the banking sector model is presented in Figure 1. In each period, agents act in the following order:

- 1) Borrowers declare default.
- 2) Banks with negative capital have their licenses withdrawn and are taken over by other banks.
- 3) Banks go over deposit rates and decide on their optimal level.

Figure 1. Flow chart of agent-based model for the banking sector

Note: The names of the bank groups are notional. Banks from the above groups differ in their readiness to provide loans to borrowers with a high risk of defaults and their willingness to comply with the capital adequacy requirements. It was assumed as an initial condition that the banks from the third group (which pursue a riskier lending policy and do not try to comply with the capital adequacy requirements) are smaller in size. However, banks from every group could change in size with time.

- 4) Depositors update their characteristics and make deposit placement decisions.
- 5) Interest on loans and deposits is paid and loan principals are repaid.
- 6) New projects are generated. Banks offer financing and add new loans to their loan portfolios.
- 7) Interest on interbank market liabilities is paid.
- 8) New banks are established.

We will consider agent types in the model and their operation in more detail below.

2.1. Banks

The key block of the model comprises **banks** which take deposits from households and firms and provide loans to companies showing various levels of return and matching default probabilities. We identify two sources of profit for the banks of the model: taking deposits at a lower than the key rate and providing loans at a higher than the key rate. Meanwhile, decisions on liabilities management in the model are generally not related to banks' decisions on assets management. This reflects the idea that to obtain liquidity for issuing loans, banks can always go to the interbank market or turn to the central bank, but they need deposits only if these are less expensive than funding from the interbank market or from the central bank¹⁶. The only constraint on lending expansion by the banks in the

¹⁶ That said, we disregard the interest risk issue, as we believe that the central bank's policy is transparent enough and enjoys enough market participants' confidence for all participants' interest rate expectations to be anchored to the same shape of the interest rate curve.

model, if such new loans are in line with the bank's lending policy regarding the risk level, is compliance with the capital adequacy requirement (an analog of H1). We therefore disregard the liquidity management issues.

Banks differ in the size of their capital (and, accordingly, assets) and lending policy types. It is assumed that at the initial point in time the small banks group has the loosest lending standards¹⁷, issuing loans to high-risk projects. One feature of the model with respect to this third group of banks is that these banks continue issuing loans even upon attaining compliance with the capital adequacy requirements or breaking them.

Banks are modeled as follows. The economy contains a population comprised of j banks where each individual bank belongs to one of three subgroups. A bank's balance sheet looks as follows:

Assets	Liabilities
Loans	Deposits
	Net interbank liabilities
	Capital

A bank earns interest on its assets and pays interest on its liabilities. The spread between these flows makes up its profit and capital increase. At each moment in time banks maximize profit, which is derived from the two sources below:

- 1) Profit from transactions in liabilities. A bank takes household deposits and places these funds in the interbank market (in a central bank), earning a spread between the key rate and a rate on deposits.
- 2) Profit from transactions in assets. A bank issues loans, obtaining liquidity for them in the interbank market (from a central bank). The profit is formed from the spread between a rate on the loan and the key rate.

The size of a bank is defined as a share of its assets in the total assets of the entire banking system. A rate on net interbank liabilities corresponds to the i . A bank sets rates on its products as follows:

- Loan rate variation is determined based solely on the risk level f_m of a project and is determined as $i + \gamma_0 + \gamma_1 f_m$.
- In offering its rate on deposits, a bank seeks to outplay its competitors, bearing in mind that, other things being equal, a lower rate triggers a depositor outflow, while a higher one deprives a bank of a proportion of profit. The profit maximization by a bank on loan and deposit rates is modeled as an iterative process. When, in the first step, a bank has the opportunity to model its decision on the rates, it tests one of five strategies (running values in the range from low to high rates on deposits). Each

¹⁷ This condition holds only for the initial distribution of banks. In equilibrium, the initial bank size and its lending policy are not correlated as much: small banks have a chance of growing into large ones, while large banks may, under adverse circumstances, lose assets and become small even if they pursue prudent lending policy. We decided on classification by bank size rather than by lending policy, because, unlike the portfolio risk, size is an observable characteristic which helps depositors to make a decision.

bank offers a deposit rate from the $(i - \xi_i, i)$ range, which, given the current characteristics of other banks' depositors and deposit rates would secure it a maximum profit.

As regards risk exposure and compliance with capital requirements, all the banks in the model are divided into three groups:

- 1) Large federal banks;
- 2) Medium-sized federal and regional banks;
- 3) Small regional banks.

The main difference between these groups of banks lies in their lending policies¹⁸. At the initial point in time, banks differ in size and their maximum tolerable default risk exposure for a borrower receiving loan, f_j^* . Note that the characteristic of size can change depending on a bank's performance, while risk tolerance of its lending policy remains unchanged.

The major federal banks are assumed to be the least inclined to finance high-risk investment projects, selecting only low-risk projects. As the model parameters were calibrated, roughly the top-ten banks were attributed to this group.

The banks from the second group are less particular in selecting investment projects and show a higher tolerance for project risks. In calibrating the model, the top-100 banks, excluding the top ten ones, fell under this category. The banks from the third group are prepared to finance any investment projects, regardless of their risk levels. These third-group banks are distinguished by their willingness to continue financing companies despite breaching the capital requirement (or even negative capital). These banks are found outside the top-100 group in the model.

Therefore, banks within each of these groups vary in size (that of assets and capital), while groups themselves are also different in terms of the size of banks within them. At the initial point in time, the banks from the first group are the largest ones, the second group includes smaller banks and the third group is represented by small banks. In calibrating the banks groups we included the top-ten Russian banks (operating a large nation-wide branch network) in the first group, the second group comprised top-100 banks, excluding top-10 institutions, the third group was made up of banks outside the top-100.

Apart from grouping banks by their lending policies, we assume that the loan market is segmented, meaning that not every bank can vie for lending to any emerging project. To reflect this effect, it is assumed that a bank can only offer financing to a newly emerged borrower with a probability of P^L .

A bank ceases lending if its capital to loans ratio falls below the rr threshold. If a bank's capital becomes negative, it loses its license with a P^B probability (determined by the sternness of supervision policy) and will stop operating (its balance sheet will be merged with that of another, randomly selected, bank

¹⁸ We note that this premise is not crucial to the general conclusion about the impact of supervision policy enhancement on competition. For details see Appendix 2.

unless this merger causes this new bank to fail to comply with the capital adequacy requirement).

At each moment in time, a new bank emerges in the system. The probability of an emergence of a third-group bank depends on the sternness of the regulator's policy (the probability of the regulator visiting this bank for supervision). The tougher the policy, the lower the probability of new third-type banks emerging and the higher the probability that banks of the second type will emerge. Thus, in every period, a new bank of subgroup II is established with a P^{S1} probability and a new bank from subgroup III emerges with a $P^{S2} - \delta_1 \times P^B$ probability. Random K deposits are invested in their capital, and net interbank liabilities appear on the assets side of their balance sheets.

2.2. Deposit market

On the liabilities side, banks compete for **depositors**, trying to attract them with the most lucrative rates (as long as these remain lower than the key rate). Depositors, on their part, differ as regards their risk tolerance. Risk-tolerant depositors place lower demands on a bank's size (as an observable test of a deposit risk) than those less risk-tolerant. A key feature of such depositors' behavior is that the news of a bank's failure (its license withdrawal) heightens demands on a bank's size and lowers confidence in the banking system¹⁹. License withdrawal therefore triggers both deposit migration to other banks and deposit flight from the banking system (to alternative asset types outside the banking system, such as ruble or dollar cash), if demands on banks' size increase substantially.

Formal modeling is performed in the following manner. There are n depositors on the deposit market, households or firms under the model²⁰. At each moment in time, depositors have options as follows:

- 1) Put money in the bank provided that at least one bank offers higher than required return in terms of rubles and the bank meets their minimum requirement for its size as shown by the size of its assets²¹. The bank's size is in this case an observable measure of this bank's deposit risk²². In this manner, all depositors are implicitly subdivided into two groups: risk-tolerant and risk-averse ones. Risk-averse depositors' minimum requirement for a bank size will be higher (their goal is money safety rather than income).

¹⁹ This assumption reflects not only a negative news flow from license withdrawals but also depositors' concern that their bank may also have its license withdrawn. As a result, they would have to spend time to recover their money from the Deposit Insurance Agency, and what is more, less than the entire amount of the deposit with accrued interest.

²⁰ As a result, since households are firm owners and transactions in goods and services eventually place money in their hands, we can only refer to household deposits. To separate independent decisions by household in their respective capacities of depositors and firm-owning borrowers, the model separately examines households and companies — investment projects.

²¹ A bank's capital in another version of the model.

²² Depositors thus take into account the lower probability of larger banks' failure. Relying for instance on the adage "too big to fail".

- 2) Use alternative investment opportunities (investments outside the banking system, including in cash)²³.

Every depositor has two characteristics:

- The minimum desired interest rate on deposits i_n^D .
- The minimum desired bank size S_n^* .

One important feature of the model is that depositors' demands on a bank's size depend on their level of confidence in banking system stability. In the model, bank failures (or license withdrawals) play a role of negative signals coordinating agents' behavior. The stronger the signal (the more extensively bank failures occur), the lower the level of confidence in the banking system and the higher depositors' demands on banks' size. This mechanism allows modeling actually occurring migration of depositors from smaller to larger banks (from small regional to large regional banks and from large regional to federal banks) and out of the banking system (if a minimum desired interest rate at a bank of required size happens to be insufficient. This migration proves to be an important channel for bank failures to influence the liquidity situation and profitability, and hence compliance with the capital requirement at all banks of the same group by size. The cleanup of the banking system and declining occurrence of failures in turn improve confidence in banks and bring down demands on bank size, so there are increasingly more depositors willing to put their money in small banks offering high interest rates.

In each period, the parameter of the minimum desired bank size is adjusted to take account of the negative news flow D_t , which depends on the number of banking licenses withdrawn over period L_t . As a result, the current minimum desired bank's size $s_{n,t}$ is determined as:

$$s_{n,t} = s_n^* + \alpha_1 D_t$$

$$D_t = L_t + \alpha_2 D_{t-1}$$

At each moment in time, bank deposits change owners so that the model could reflect transactions occurring in the real economy. Since the lending process automatically creates deposits, lending to companies increases household deposits in the model. This also aims to reflect the use of loans by companies in real life to pay for goods and services, with these funds eventually making their way onto household deposits (including salary deposits). In this context, to reflect the change of deposit holders in each period, parameters i_n^D и s_n^* are chosen randomly from the relevant distribution.

In each period, depositors with a P^D probability revise their choice of a bank to hold their deposits. In this case they choose a bank with the highest interest rate from banks of a larger size than $s_{n,t}$. If this rate does not exceed i_n^D , the depositor decides to hold its money in foreign currency cash.

²³ We do not look at investments in foreign currency, assuming that in an equilibrium adjusted for exchange rate movements returns prove to be equal.

A bank which has expanded (reduced) its deposits as a result of this deposit migration, proportionally decreases (increases) its net interbank liabilities.

The initial equilibrium (under a loose supervision policy) of depositors among the above banks groups was selected so as to match the distribution from the actual Russian banking system data prior to the supervision enhancement (the 2011–2013 average). As a result, we received the 55-35-10 distribution which reflects the share of household and corporate deposits in the Top 10 banks, the Top 100 banks excluding the Top 10 banks, and the rest of the banks by asset size as of March 2013.

2.3. Loan market

On the assets side, banks make a decision on whether to approve or decline loan requests from **projects** with various levels of return and a matching level of risk (which all the banks are able to observe). To simplify estimation, it is assumed that all the banks assess risk accurately. We disregard banks' competition on the loan market via interest rates, simply assuming that a bank charges a rate on a loan which it approves. The rate is positively correlated with the level of risk (return) for this borrower's investment project. This assumption aims to simplify computations without substantively changing the results. The important feature of the model, which brings it close to reality, is that loans issued by the banks are transformed into deposits. The model therefore reflects the economy's money transactions to buy goods and services, in the course of which money changes owners within the banking system.

Formal modeling of the loan market is performed as follows:

Every company presents a risky investment project financed via bank loans. In each period, there appear m investment projects for which borrowers want to get loans. Of these, m_1 projects are low-risk and m_2 projects are high-risk ones.

Projects have two characteristics, their distribution varying depending on the project category.

The first is the probability of default f_m . At each subsequent step, there is such a probability of the borrower's default, which would result in the relevant drop in a bank's loan portfolio and capital. A high project default probability does not necessarily imply default. In the event of default, a bank fails to receive return on investment and the loan is not repaid. The value of collateral is assumed to be equal to zero and the entire loss is charged to the capital of the bank that financed the project²⁴.

The second characteristic is the project rate of return i_m^l . If there is no default, the company repays the loan and pays interest rate which the bank charged on the loan as it was provided.

²⁴ This assumption only emphasizes that the lending process is not risk-free, the value of collateral cannot compensate a loan loss. Losses will still be impossible to avoid, even bearing in mind that compensation is possible for a certain percentage of loans.

The amount is determined as a share (β_1) of the current money supply (the sum of all deposits and currency in circulation). The loan maturity is equal to 30 periods.

A borrower chooses a bank to finance the project randomly (with a probability proportional to the bank size) among banks willing to provide the loan (this is determined by the market segmentation and the bank's risk tolerance). If the rate charged by the bank is above i_m^L , no loan is issued and the project ceases to exist.

When a loan is provided, the size of a randomly chosen deposit increases by the relevant amount (for money supply creation through lending, see McLeay et al., 2014). The bank providing the loan increases its net interbank liabilities, while the bank receiving a newly-created deposit reduces them.

2.4. Regulator

And, finally, the model comprises a **central bank** which carries out an inspection of a bank with a given probability. It is assumed that upon finding negative capital the regulator withdraws the bank's license. As a result, all the bank's assets and liabilities go to another (randomly selected) bank whose capital allows it to absorb the loss²⁵. At each moment in time, a small number of banks are established in the system. As a new bank is established, its founder is aware that the tougher the regulator's policy, the shorter this bank's life cycle will be should it fail to comply with capital requirements. So proactive supervision diminishes the probability of the newly-established bank being ranked as belonging to a "bad" bank type (the third group of banks).

The model reflects this in the following way. The central bank inspects this bank with a certain probability, which takes two values in the model: 0.2 prior to the autumn of 2013 and 0.8 after the autumn of 2013. The regulator's visit to the bank under supervision enables breaches of capital requirements to be detected with certainty. If negative capital is found, the bank's license is withdrawn and it is taken over by another bank (see above). If capital requirements are complied with, the bank continues operating as previously, while if a breach is discovered and capital is positive, banks from the first and second groups cease lending.

The regulator's role in the model also consists in providing liquidity to banks as part of policy to manage interest rates of the money market (which is in this case identical to the central bank's liquidity management instruments).

2.5. Initial conditions and simulation procedure

The parameters of every agent are drawn randomly from given distributions. The main calibrated parameters of the model can be found in Appendix 1. The

²⁵ The maintenance of "bad" assets on the Deposit Insurance Agency's balance sheet is essentially the same thing.

calibration of the model's parameters was chosen so as to obtain in a large number of simulations equilibrium parameters close to those actually observed in Russia's banking sector prior to stepping up supervision (the first half of 2013). These are the following structural parameters: deposit/loan distribution across the above groups of banks and the Herfindahl index used to assess the degree of concentration of the loan and deposit markets (see Appendix).

Thus, for initial conditions, a population of *NB* banks is generated whereas the calculation of the Herfindahl index assumes that each bank involved is the aggregate of the balance sheets of *nb* banks.

There are *ND* deposits of size *D* and *NL* low-risk loans of size *L* on the balance sheet of each bank. The size of capital is set at *rr0* of total loans. Net interbank liabilities offset the balance sheet.

Also, *NC* depositors are created that hold *C* worth of financial assets in foreign currency cash.

Since the model is stochastic, the results obtained in different simulations will differ. However, with a large number of simulations, as various effects are averaged, systemic characteristics of an equilibrium should emerge in keeping with "the law of large numbers". It is the comparison of these averaged systemic effects under the two different policy regimes that will produce our results.

We ran two 100-simulation series and, based on this calibrated model compared the principal characteristics of a banking system equilibrium under the two different central bank policy regimes.

The first policy regime is that of proactive banking sector recovery followed by the maintenance of proactive supervision policy and tough capital requirements. This implies a high probability of an inspector visiting a specific bank and discovering its problems, if any.

The second regime is the retention of a "loose" supervision regime, maintaining a low probability of a bank being inspected. This is equivalent to a low probability of detecting noncompliance, if any. This regime is assumed to have existed prior to mid-2013.

After setting the initial conditions and the beginning of the system's dynamics in each simulation, we allow the system to "spend its life" in the two modes: under loose or proactive policy by the regulator. The system's life consists of 250 periods (our calibration is so structured that we are unable to say whether these are months, quarters, or years). During the first 100 periods²⁶, the system lives under the loose policy regime so as to let its stable properties become visible and allow the effects owed to the random setting of some initial conditions (for example, a specific sample distribution of projects by the risk level) to fade. Then, in 50 periods, the moment of policy change comes: the period of the banking system's proactive recovery starts (Figure 2), following which the system is allowed to "live" another 100 periods, of which the first 30–50 can be regarded as a short-term period, and the following 50–70 — a long-term one.

In this case, comparison of the median under the two policy regimes based on a large number of simulations shows systemic differences. We set the number of

²⁶ The figures below will present the dynamics of variables based on this set of periods.

simulations to 100, which, judging by the stability of the results, is sufficient for the “law of large numbers” to come into effect.

3. Results

Figures 2–11 present the averaged dynamic trajectories of the system’s key parameters prior to the start of banking sector cleanup and their dynamics after launching this policy. Short-term and long-term periods are presented separately. The short-term period is a time span from the 50th period (the time when banking supervision was stepped up) to the 80th–100th periods. The subsequent effects, until the 150th period, are regarded as long-term consequences of banking sector cleanup emerging in a situation of the banking sector’s adaptation to the regulator’s new policy. Along with them we presented 25-percent and 75-percent percentiles of these parameters’ distribution in the total number of simulations. The results of the simulations without supervision policy stepped up are shown in blue color and those with stepping up supervision — in red color.

Further on, we will make a distinction between short-term and long-term effects. We will first present a description of short-term implications for the banking sector.

3.1. Short-term effects of stepping up supervision

As Figures 2 and 3 show, enhanced supervision secures a fairly fast cleanup of the banking system from unscrupulous banks, which, in our case, are banks with negative capital.

Figure 2. Share of banks with licenses withdrawn over four periods in the total number of banks at the initial point in time

Source: authors' estimates here and further

Figure 3. Share of banks with negative capital

Note: An equilibrium share of 8% is the model's estimate. It suggests that at each point in time there are around 8% of banks with negative capital, but at two different points in time these are not necessarily the same banks.

The short term sees increased risks of placing funds in all medium-sized and small banks with demands heightening on a bank's size as an observable and simple test of bank failure risk. This causes the migration of deposits to large federal banks and, to a certain extent, even an outflow of funds from the banking system, for example, into ruble cash or foreign currency. As a result, the average rates on deposits on the balance sheets of medium-sized and small banks go up, diminishing their profit from liabilities management²⁷. Profit contraction implies a lower level of capital of medium-sized and small banks, preventing their lending growth. Due to the problems with capital replenishment by medium-sized and small banks, which under the model also on average pursue a riskier policy than large federal banks, this group of banks proves to be more financially vulnerable in the short term. The major federal banks find themselves in the opposite situation, expanding their capital thanks to a deposit influx and a lower cost of liabilities, which helps expand lending.

We estimate that eventually the share of the major banks in the banking system's total deposits (Figure 4) and loans (Figure 5) will rise.

A rise in concentration is also captured by the increasing Herfindahl index, often used as a measure of concentration for deposit and loan markets (Figures 6–7). The weakening of competition for depositors is reflected by dropping rates on deposits in the banking system (Figure 8).

²⁷ This profit is earned by obtaining liabilities at a lower cost than the key rate (rate curve) of the central bank or the money market rate (rate curve).

Figure 4. Share of deposits in the first banks group (large banks)

Figure 5. Share of loans in the banks of the first group (large banks)

Figure 6. Herfindahl index for deposit market

Figure 7. Herfindahl index for loan market **Figure 8. Average deposit rate in the banking system, annual %**

The weakening of competition in the banking sector at first causes deposit rate nonhomogeneity (variations across banks) to rise slightly (Figure 9).

A higher rate dispersion reflects banks' heterogeneity as regards their competitive positions on the deposit market. In a situation of depositors' migration, large banks can afford to offer lower rates on deposits than all the others. By contrast, small banks, in the face of depositor outflows, have to offer higher rates as compensation for risk. So the heightening of the role of a bank's size causes price competition to recede into the background, and the largest banks earn extra profit thanks to the abundance and low cost of liabilities. This profit is actually redistributed to them from smaller banks and from depositors. The heterogeneity suggests that in addition to price (a deposit rate) there are some other factors which affect depositors' preferences. In a competitive banking system, these non-price factors (such as differences in banks' size) are supposed to play a minor role.

Figure 9. Variation (standard deviation) in deposit rates across banks, p.p.

Another short-term result of supervision enhancement is lower availability of loans to borrowers with a relatively high default risk, as the banks' average credit risk exposure (Figure 10) and maximum credit risk exposure (Figure 11) decline. The maximum credit risk exposure declines because the group comprised of unscrupulous banks which pursue an extremely soft lending policy is forced out of the market. The average risk drop occurs because medium-sized banks catering to high-risk borrowers are unable to provide loans due to their problems with capital caused by depositor outflows. Meanwhile large banks (based on the model's assumptions) are less inclined to lend to fairly risky projects despite these banks' capitalization growth.

Figure 10. Average loan default risk

Figure 11. Maximum loan default risk

3.2. Long-term implications of supervision enhancement

One important result of proactive supervision is that in the long term the number of license withdrawals falls to virtually zero after the banking system's cleanup versus the persistence of roughly the same number under loose policy (Figure 2). This is not so much a result of proactive policy as that of the system itself getting more sound — the regulator's scope of operation narrows.

Indeed, as proactive supervision policy also hampers the emergence of “bad” banks, the share of banks with negative capital declines to zero in the long term versus its staying permanently at around 8% under a loose policy (Figure 3). The system eventually becomes more sound, shedding the formerly permanent “overhang” of “bad” banks threatening with a domino effect and a massive crisis of confidence in honest small banks and in fact the entire banking system following an even minor news-generated shock. Hence the financial stability of the system as a whole improves.

The drop in the number of banks with negative capital and license withdrawals enhances depositors' confidence in medium-sized and small banks as well as the banking system in general. As a result, depositors' demands on a bank's size (as a test of deposit risk) lessen, with depositors starting to migrate both to the banking system and back to medium-sized and small banks from large ones. This causes the share of deposits in the banks of the first group, i.e., the major banks, to shrink around 15 percentage points (Figure 4). The key result is that the share of deposits in the major banks not only returns to the previous equilibrium but declines lower than it used to be prior to policy toughening, with medium-sized and small banks

enjoying a rising long-term depositor inflow compared with the equilibrium under the regulator's loose policy. Having become more reliable and jettisoned the ballast of "bad" banks, this group of banks shows a greater appeal to depositors compared with a situation where the regulator fails to clean the banking system from unscrupulous participants.

The Herfindahl index shows a similar long-term trend, pointing to a concentration downturn on the deposit side (Figure 6). The deposit market concentration drops practically by half.

The by-effect of depositors reversing their flow back to responsible medium-sized and small banks is these banks' profit growth and hence their capital expansion (recapitalization). Medium-sized banks' rising potential to earn profit from liabilities translates into their growing ability to make profit on the assets side. This enables nonfederal banks to boost lending to investment projects (facing capital constraints more rarely). Similarly to deposits, capital and lending expansion by medium-sized and small banks in a new long-term equilibrium surpasses levels seen in an equilibrium under loose policy by the regulator. As a result, the share of medium-sized and small banks in total lending goes up by around 10 percentage points (Figure 5).

The industry concentration downturn is reflected by the Herfindahl index for the loan market declining below its equilibrium seen in the absence of a vigorous banking sector cleanup (Figure 7).

The long-term confidence growth with respect to medium-sized and small banks as the banking system is cleaned from weak players diminishes the role of a bank's size as an important factor for depositors in choosing a bank for opening a deposit account. Price competition comes to the fore, with the quality of service also taken into account. As medium-sized and small banks join this competition for depositors (from the position of "equality" with large banks) competition toughens, leading to higher average rates on deposits in the banking system (Figure 8).

The banking system becomes more homogenous in the process. The fall in the deposit rate variation across banks is clearly pronounced (Figure 9), with the cross-bank rate dispersion dropping by half. This homogeneity adequately indicates the toughness of price competition, as it shows the low significance of other factors securing advantages for some (large) banks as regards the cost of deposits. The deposit rate increase along with the rise in rate uniformity means that extra (monopolist) profit from the low cost of deposits to large banks, which is typical of an environment where "junk" banks operate, is redistributed in favor of medium-sized and small banks in the new equilibrium emerging after the cleanup of the system.

Banks' maximum risk exposure (maximum default probability of all projects approved by banks) stays at a lower level in a long-term equilibrium (Figure 11). This shows that the banking system does not assume excessive risks after the

removal of banks using such practices, with their managers often knowing eventual results (fraud and asset stripping) in advance.

Meanwhile the banks' average risk exposure (weighted average default probability for approved investment projects) is restored to the levels found under loose supervision policy (Figure 10). As banks' maximum risk exposure decreases, this rise in the average risk exposure reflects an increase in the proportion of lending by medium-sized banks which provide loans to projects with a moderate but higher risk than those financed by the major federal banks.

Another important conclusion from Figures 10–11 is that despite the average risk staying on the same level due to the expansion in the share of loans from riskier banks, the regulator's proactive policy protects the system from accumulating financial stability risks (a larger number of banks breaching the capital requirement).

Finally, the fact that the medium-sized banks in our model tend to practice looser lending standards than the largest ones, their increasing share in total lending also means greater availability of lending, where it is not only minimum-risk borrowers that have the vast opportunities to raise financial resources. Excessive risk meanwhile is driven out of the banking system: such projects are rarely approved. Conventional banks are not an important source of financing high-risk projects (venture financing) throughout the world. Hence our result is quite realistic in this respect.

4. Conclusion

We have built up an agent-based model for the banking sector to analyze the impact of proactive policy of the banking sector cleanup on the main characteristics of the banking system, including the parameters of competitive environment. Our general conclusion from the study is as follows:

- 1) The enhancement of banking supervision offers a variety of important long-term benefits. It promotes competition, which eventually benefits scrupulous banks, improving their financial stability. Benefits are enjoyed by both depositors and borrowers, especially small and medium-size enterprises (SMEs).
- 2) To lessen short-term negative effects, banks' negative influence on one another needs to be minimized.
- 3) In light of our findings, it is especially important that during the period of proactive recovery of the system small and medium-sized banks send their customers signals that their respective banks are ranked as "good" rather than "bad", unscrupulous ones. This, in particular, can be achieved through a more open information disclosure by banks relying on fair business practices, their greater willingness to secure transparency, especially regarding compliance with the capital requirements and engagement in financing the real economy.

- 4) Since greater openness does not in itself eliminate the problem of disclosing false information on banks' operation by fraudulent market participants, this places more stringent requirements for rating banks, including by the regulator, in terms of financial reporting quality, followed by public disclosure of this information. The focus should be placed on giving the public unbiased information about credit institutions, without fear that disclosure of this information could entail problems for the banking system or trigger depositor flight from some banks.

This paper does not examine the entire range of potential effects which may accompany proactive supervision policy. In particular, the issues of moral hazard and risks to financial stability stemming from banking system consolidation (too big to fail) and strengthening of banks with government stakes, the acceptability of bailing out banks at taxpayers' expense, a balance between supervision and insurance as factors of market discipline, orientation of supervisory activities to certain bank types, along with issues relating to the origin, spreading and impact (including systemic one) of bank panic. Moreover, this study did not aim to model a great multitude of other, no less important, problems: the influence of the money and foreign exchange markets on banks' operation, change from a liquidity deficit to a liquidity surplus. We show that object-based models can act as a practical and effective tool for studying the issue examined here and other similar subjects.

Appendices are available at:
www.cbr.ru/money-and-finance

5. References

- Angelini, P., Clerc, L., Cúrdia V., Gambacorta, L., Gerali, A., Locarno, A., Motto, R., Roeger, W., Van den Heuvel, S. and Vlček, J. (2015). *BASEL III: Long-term impact on economic performance and fluctuations*. Staff Report, Federal Reserve Bank of New York, № 485.
- Brooke, M., Bush, O., Edwards, R., Ellis, J., Francis, B., Harimohan, R., Neiss, K., Siebert, C. (2015). *Measuring the Macroeconomic Costs and Benefits of Higher UK Bank Capital Requirements*. Bank of England Financial Stability Paper № 35.
- Buch, C. M. and Prieto, E. (2014). Do Better Capitalized Banks Lend Less? Long-Run Panel Evidence from Germany. *International Finance*, 17, pp. 1–23.
- Byod, J., De Nicolo, G. (2005). The theory of bank risk taking and competition revisited. *The Journal of Finance*, 60(3), pp.1329–1343.
- Chan-Lau, J.A. (2017). *ABBA: An Agent-Based Model of the Banking System*. IMF Working Paper WP17/136.
- Colliard, J-E. (2015). *Optimal supervisory architecture and financial integration in a banking union*. Working Paper Series 1786, European Central Bank.
- De Nicolo, G., Favara, G. and Ratnovski, L. (2012). *Externalities and Macroprudential Policy*. IMF Staff Discussion Notes, № 12/05.

- Fagiolo, G. and Roventini, A.** (2017). Macroeconomic Policy in DSGE and Agent-Based Models Redux: New Developments and Challenges Ahead. *Journal of Artificial Societies and Social Simulation*, 20(1).
- Keeley, M.** (1990). Deposit insurance, risk and market power in banking. *American Economic Review*, 80, pp. 1183–1200
- Kupiec, P., Lee Y., Rosenfeld, C.** (2017). Does bank supervision impact bank loan growth? *Journal of Financial Stability*, Volume 28, February 2017, pp. 29–48.
- McLeay, M., Radia, A. and Thomas, R.** (2014). *Money creation in the modern economy*. Bank of England Quarterly Bulletin, 54 (1), pp. 14-27.
- Turrell, A.** (2016). *Agent-Based Models: Understanding the Economy from the Bottom Up*. Bank of England Quarterly Bulletin, Q4.
- Vives, X.** (2010). *Competition and Stability in Banking*. CESifo Working Paper Series, 3050, CESifo Group Munich.
- Vives, X.** (2016). *Competition and Stability in Banking: The Role of Regulation and Competition Policy*. Princeton University Press.