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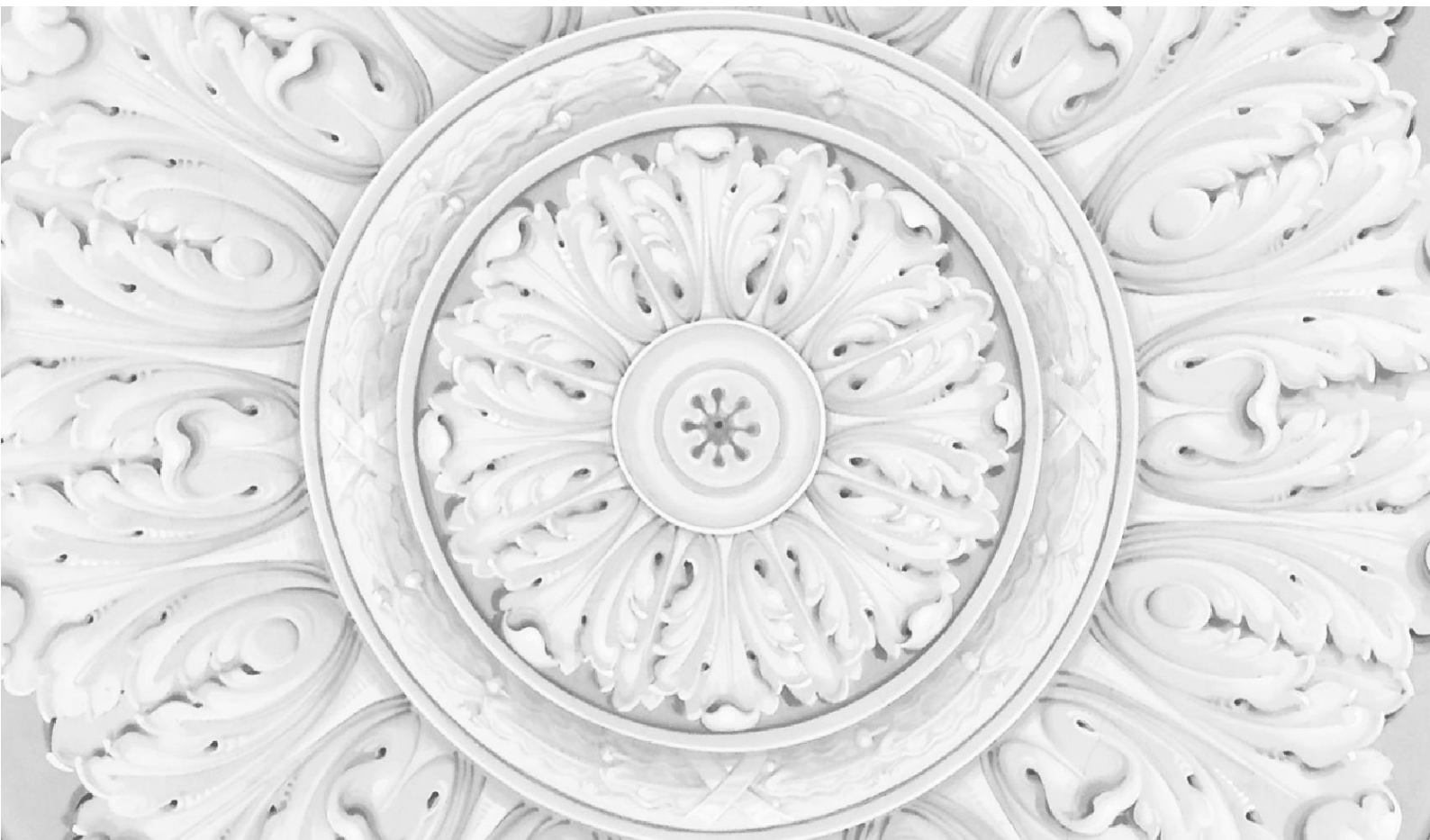
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WORKING PAPER SERIES

Impact of Banking Supervision
Enhancement on Banking System
Structure: Conclusions Delivered by
Agent-Based Modelling

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Summary

The Bank of Russia's policy for banking sector rehabilitation and clearance of nonviable and mala-fide banks attracts attention and receives controversial judgments of experts. Our research shows that, in the medium term, such a policy reduces monopolism and raises efficiency of the banking system. Yet, it has an adverse effect on small and medium-sized banks over the short term. All in all, the long-term benefits of proactive supervisory policy might significantly outweigh the short-term negative effects from a temporary increase in banking business concentration. In order to examine the effects of proactive banking sector resolution, we have constructed an agent-based model of the banking sector and calibrated its key variables using Russian banking sector data. On the basis of the model, we compare the short- and long-term effects of two supervisory policies with different degrees of tightness. The results of model simulation show that in the short-term a proactive supervisory policy adversely affects small and medium-sized banks, including those complying with supervisory requirements. Yet, as the banking sector rehabilitates, the benefits from increasing trust in such banks and the banking system in general outweigh the short-term losses. Eventually, the share of small and medium-sized banks in loan and deposit markets turns out to be greater compared to the period prior to the supervisory policy being made stricter. Monopolism in the banking sector decreases and price competition improves. The banking system efficiently creates credit and gets rid of the excessive risk to individual and systemic sustainability, while preserving the average credit risk of projects. At that, financial sustainability of small and medium-sized banks improves.

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INTRODUCTION

The Bank of Russia's proactive policy on banking system rehabilitation and clearance from mala-fide players initiated in 2013 resulted in the revocation of 332 licences by June 2017. For reference, the number licences withdrawn in 2002–2012 was about 390. The Deposit Insurance Agency payments to depositors grew from 0.02% GDP in 2012 to 0.7% GDP in 2015.

Yet, such vigorous efforts by the Bank of Russia aimed at bringing discipline to the banking sector received controversial public feedback. In general, the criticism boils down to four key points associated with both short- and long-term consequences of the proactive supervisory policy[1]:

1. In the critics' view, large-scale revocation of licences results in depositors draining to major banks and partially state-owned banks. Small and regional, however bona-fide, banks suffer from this process. Economics call such a phenomenon 'externality'[2], specifically, when system spillovers caused by deposit flight produce an adverse effect on the system as a whole[3].

2. A reduction in the number of banks will have long-term negative consequences for banking sector competition. Since the ones that lose licences are mainly private banks, there evolves a risk of the equilibrium being increasingly tilted towards state-owned banks, which might start dictating their terms to depositors and borrowers, thus providing services from monopolistic positions at higher prices (higher credit rates and lower deposit rates).

3. In addition, it is believed that a predominance of state-owned banks will make the banking system more vulnerable to future crises. According to this vision, state-owned banks are less adaptive to shocks but tend to assume greater risks, as they realise they will be rescued anyway[4], so the banking system exposure to crises increases.

4. It is argued that the efficiency of the banking system's functioning in terms of ensuring credit availability will subside in the long term. Reduction in banking system tiers and the number of market niches where investment projects (borrowers) of different risk levels can find their creditors will result in insufficient credit creation.

Let us remark here that economic science still has no clear judgment on the negative consequences of the reduced number of banks on competition in the banking sector, nor on the

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[1] See, for example, ARB 2017 Annual Report, as well as the review of media feedback at http://expert.ru/2017/03/29/banki/

[2] For instance, De Nicolo, Gianni, Favara, Giovanni and Ratnovski, Lev, (2012), Externalities and Macroprudential Policy, No 12/05, IMF Staff Discussion Notes, International Monetary Fund.

[3] According to the critics of proactive supervision, a similar situation apparently occurred in the Republic of Tatarstan after the Tatfondbank licence had been revoked. See media coverage of the situation with an account of consequences for the Tatarstan banking sector at: http://www.banki.ru/news/columnists/?id=9750266

[4] The so-called 'too big to fail' problem.

optimal level of competition in this sector[5]. In their publications, economists examine the impact of the banking sector's resolution process (rehabilitation/clearance) on competition, effectiveness of financial intermediation and long-term economic growth in the context of the effect of proactive banking supervision; see, for instance, Kupiec, et al (2017)[6]. Research on the effects of strengthening requirements for bank capital indirectly makes a stand for the proactive supervisory policy[7]. An optimal banking supervision model with a literature review is set out in J.-E. Colliard (2015).

In order to analyse the pros and cons of the proactive supervisory policy in Russia, we construct a formal behavioural model of individual equilibrium for the banking sector, where each bank seeks to maximize its profit. It is driven by the agent-based modelling approach that has been gaining popularity in economics and central bank policy analysis recently[8]. Unlike the commonly used DSGE models, this approach makes it technically easier to model complex economic systems with large numbers of both agents and their types. In real life, for instance, households are not homogeneous – they vary by income level and appetite for bank deposit risk; investment projects have different default probability and banks split into groups by type of credit policy, i.e. the banking sector is segmented. Another important advantage of these models is that they analyse dynamic interactions between all types of agents, as well as the way individual independent actions of certain types of agents explicitly shape the market equilibrium (produce macroeconomic effects).

We have calibrated the model using Russian banking system data so that it reflects the degree of concentration and the structure of banking sector liabilities and assets in terms of its division into various groups of banks prior to proactive banking sector rehabilitation (mid-2013). As a result of calculations in such a calibrated model, we have compared the key characteristics of banking system equilibrium under two central bank supervision policy scenarios: 1) proactive rehabilitation of the banking sector with subsequent enforcement of strict requirements for compliance with capital ratios, and 2) a 'soft' supervision requirements regime. Special attention was paid to competition and banking sector efficiency characteristics.

Our key findings are as follows:

Short-term consequences. Over the short-term perspective, proactive withdrawal of bad banks from the banking sector boosts the perceived risks of keeping deposits in all small and medium-sized banks (crisis of confidence), as well as the requirements for bank size as an

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5 For a review, see Xavier Vives, Competition and Stability in Banking: The Role of Regulation and Competition Policy, Princeton University Press, 2016, as well as Xavier Vives, 2010. "Competition and Stability in Banking," CESifo Working Paper Series 3050, CESifo Group Munich.

6 Pros and cons of the banking sector resolution policy are outlined, for instance, in the 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, Prieto (2014), Angelini, et al. (2015)

8 See, for example, the chapter of the Bank of England Quarterly Bulletin 2016 describing the experience and areas of practical application of this approach by the Bank of England. Turrell, Arthur, Agent-Based Models: Understanding the Economy from the Bottom Up (December 16, 2016). Bank of England Quarterly Bulletin 2016 Q4.

observable and simple indicator of bank bankruptcy risk. This results in the migration of deposits to larger banks and, to some extent, even funds drain from the banking system (for instance, into cash or foreign currency). This is a demonstration of the negative externality of the proactive supervision. Eventually, the average deposit rate on the balance sheet of small and medium-sized banks goes up, thereby reducing their profit from liability management, which rests upon the attraction of cheaper liabilities at rates below the Bank of Russia key rate (rates curve) or the money market rate (rates curve). Decline in profit on the liability side results in capital shortages among small and medium-sized banks, which prevents them from expanding lending. Due to the problems with capital replenishment experienced by small and medium-sized banks, this whole group becomes more financially vulnerable in the short term. The opposite is observed for larger banks, which build up their capital and can afford to expand lending thanks to the deposit inflow and decreased liability value. As a result, the share of larger banks in aggregate banking system deposits and in aggregate credits is projected to expand. Increase in concentration is also registered by the growing Herfindahl index[9] often used to measure it. Reduced competition in the banking sector is well evidenced by an upsurge in the heterogeneity (variation among banks) of deposit rates: as a result of the increasing role of bank size, price competition goes into the background, while larger banks earn additional profits amid abundant and cheap liabilities. This profit actually shifts to them from smaller banks and from depositors. Another important short-term effect of rehabilitation is the declining efficiency of banking sector operation, manifested in the reduction of average credit risk assumed by banks. Although the maximum risk of approved loans goes down on the back of the withdrawal of 'bad' banks, which are usually inclined to assume it, the investment project segment (characterised by mid-level risks) gets less resources. This occurs because of the inability of bona-fide medium-sized banks targeting this segment to issue loans due to the problems with capital induced by depositor churn.

Long-term consequences. Completion of the banking system clearance period and the regulator's on-going proactive policy not merely reverse most of the above effects but, in fact, improve the banking sector parameters in key areas compared to the equilibrium situation without banking sector rehabilitation measures:

A. **Deposit base of small and medium-sized banks expands compared to the long-term equilibrium values without the short-term painful effects caused by the banking system resolution regime.** The share of deposits in larger banks not only falls back to the levels prior to the regulator's policy tightening but even goes below that: depositor inflow into small and medium-sized banks grows over the long-term horizon compared to the equilibrium in the context of a soft policy conducted by the regulator. Decline in the number of banks with negative capital enhances depositors' trust in small and medium-sized banks and the banking system in general. After

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[9] See, for example, the World Bank overview at: http://www.worldbank.org/en/publication/gfdr/background/banking-competition.

getting more reliable in general and doing away with the ballast of 'bad' banks, small and medium-sized banks become more attractive in the eyes of potential depositors than what they would have been otherwise without the regulator's resolution measures for the banking system. As a result, the share of deposits in larger banks shrinks in the long term.

B. **Small and medium-sized banks reinforce their positions in terms of capital, which allows them to expand their loan provision activity. The share of these banks in credit creation is growing.** As a key consequence of depositors returning to bona-fide small and medium-sized banks, these banks build up their profits and increase capital levels. The improved capability of medium-sized banks to earn on liabilities translates into the development of their capability to make profit on the assets side. This enables non-federal banks to build up loan provision to investment projects (as they are less constrained by capital requirements). **As in the case of deposits, capital build-up and credit creation by small and medium-sized banks are higher in the context of the new long-term equilibrium compared to the equilibrium amid the soft policy of the regulator.**

C. **The monopoly of larger banks is weakening compared to the period of soft supervisory policy and profits are shifting from larger banks to small and medium-sized ones.** The long-term growth of confidence in small and medium-sized banks in the event of proactive banking system clearance results in a decreased role of bank size as a factor critical for depositors' choice of bank for placing their deposits. Price competition, coupled with competition in service quality, moves to the forefront. Active involvement of small and medium-sized banks in the competition for depositors on a par with major banks leads to the escalation of competition and, consequently, first, to an increase in average deposit rates in the banking system and, second, to the greater homogeneity of bank rates. The Herfindahl indices of deposit and credit market concentration halve.

D. **The banking system becomes more accessible for the purposes of economy financing: excessive (often associated with asset stripping) credit risks are forced out of the system, whereas the share of financing that goes to investment projects with moderate risks is growing. Meanwhile, the average credit risk of the system remains unchanged.** Since medium-sized banks generally pursue a milder credit policy compared to major banks in our model, the growth of their share in the aggregate credit creation is also indicative of the growing availability of credit in the banking system, where eligible borrowers for crediting are not limited to borrowers with minimal risk (these typically implement major investment projects).

E. **Financial sustainability of the group comprising small and medium-sized banks improves**. In the long term, the share of banks with negative capital reduces to zero, while,

without resolution measures, it remains unchanged[10]. The formerly permanent share of bad banks posing a threat of a domino effect and large-scale crisis of confidence in bona-fide banks and the entire banking system in response to any, even minor, shock, is eliminated. Small and medium-sized banks reinforce their positions in terms of capital, obtain fairer (more competitive) access to deposit and credit markets. The overall system becomes healthier compared to that without banking system clearance of problem banks.

Further on, the discussion will be organised as follows: we will first provide a description of the model, outlining the behaviours of each of the four types of agents. These are: households, firms, banks and the regulator (the central bank). Then, we will present the key results of calculations accomplished using the model. Finally, we will deliver our conclusions pertaining to the central bank's policy.

1. THE MODEL AND ITS CALIBRATION

This section provides just a very brief description of the model's logic and structure. See Annex for a more detailed description of the model and calibrated parameters.

It should be noted that the model has been constructed using the agent-based modelling approach that economic science took over from biology. For advantages and disadvantages, as well as the applications of agent-based models in economics and finance, including in analysing central bank policies, see the article by Turrell in the Bank of England Quarterly Bulletin 2016, and Fagiolo & Roventini (2017). An outlook on the banking sector and inter-bank market model can be found in the article by ECB economists: Wolski, et al. (2016).

Agent-based models explain the behaviour of a system by simulating the behaviour of each individual 'agent' within it. In our case, these are households and firms choosing banks for placing deposits and banks deciding whether or not to issue loans to firms. At that the same time, it is necessary to make sure that the modelled behaviour is an approximation of the real behaviour observed in practice, so there are certain behavioural patterns in the model for each of the agents. The agents themselves vary in behaviour parameters, so heterogeneity of agents is also modelled. Those parameters are assigned to agents as random values from a distribution with pre-set characteristics. Emergence and default of agents, and occurrence of various shocks that the agents have to handle, are governed by the laws of probability. The behavioural patterns are explored through a large number of simulations where the law of large numbers comes in. Figure 1 shows the overall design of the model.

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[10] According to implicit model estimate, it is 8% of banks at any specific time. It should be noted that this is not a cumulative estimate, because banks that have negative capital at a specific time may subsequently stabilise if the circumstances are favourable.

Figure 1. Banking sector agent-based model flow chart
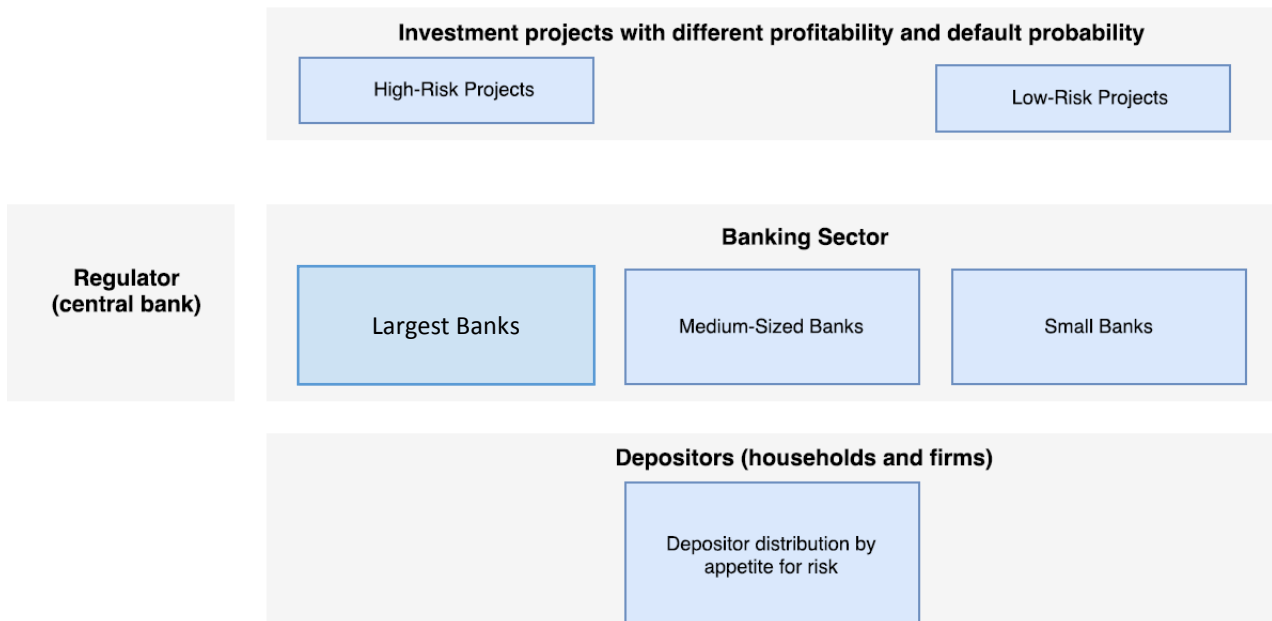
*Note: Denomination of bank groups is nominal. Banks from different groups vary in their readiness to credit borrowers with high default probability and in their adherence to the capital adequacy requirement. It was assumed that, **initially**, Group 3 banks (that pursue the most risky lending policy and do not seek to maintain capital adequacy) are smaller in size. Yet, over time, the size of banks in all groups might change.*

The key block of the model is represented by **banks** taking deposits from households and firms and issuing loans to companies at different interest rates and with respective default probability levels. We identify two sources of bank profits in the model: deposits at a rate below the key interest rate and loans at a rate above the key interest rate. Meanwhile, liability management decisions in the model are generally independent of the banks' asset management decisions. This reflects the idea that, in order to get liquidity to be able to issue loans, banks can always turn to the inter-bank market or the central bank, so they need deposits only if those happen to be cheaper than inter-bank or central bank funding[11]. The only limitation for banks in expanding their lending, if such new loans are in line with the bank's credit policy in terms of risk level, is compliance with the capital adequacy requirement (N1 analogue). This way, we abstract from the issues of liquidity management.

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[11] That said, abstracting from the interest risk issue and assuming that the central bank policy is transparent enough and trusted by market players, so that the interest rate expectations of all agents are anchored at the same interest rate curve.

Banks vary in the size of capital (and hence assets) and the type of credit policy pursued. It is presumed that, initially, the small-banks group has the softest lending terms[12]. These banks provide loans to highly risky projects. The specificity of the model, as far as the banks of this group are concerned, consists in the fact that these banks keep issuing loans even when the capital adequacy ratio is reached or even surpassed.

On the liability side, banks compete for **depositors**, trying to attract them by more favourable interest rates (as long as the latter remain below the key interest rate). The depositors vary in their appetite for risk. Risk-tolerant depositors have more modest requirements in terms of bank size (as an observable indicator of the risk of placing deposits with a bank) compared to more risk-averse depositors. A key characteristic of depositors is that news about bankruptcy of a bank (its licence revocation) results in an increase in the requirements for bank size and a decline in the confidence in the banking system[13]. Thus, licence revocation contributes to both deposit migration to other banks and to deposit flight from the banking system (to alternative asset types outside the banking system, e.g. ruble or dollar cash), if the minimal bank size requirements rise materially.

On the asset side, banks decide to approve or disapprove loan applications received from **projects** with various profitability and respective risk levels (which all banks can study). To simplify calculations, it is assumed that all banks assess risks properly. Here we abstract from bank competition on the credit market by means of rates, simply assuming that banks set rates for applying borrowers if they decide to issue loans to them. The interest rate positively depends on the risk level (profitability) of the investment project for which the loan is approved. This assumption is aimed at simplifying calculations without altering the essence of the results. An important feature of the model, which brings it closer to the reality, is that loans issued by banks turn into deposits. In this way, the model reflects the process of transactions in cash associated with the purchasing of goods and services, as a result of which cash moves around the banking system.

Finally, there is a **central bank** in the model, which conducts bank inspections with a pre-set probability. It is assumed that the regulator revokes a licence from a bank with negative capital. After that, all assets and liabilities of such bank migrate to another (randomly picked) bank with

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[12] This assumption is valid only for the initial distribution of banks. In equilibrium, the initial size of the bank and its credit policy do not correlate very much any more: small banks may grow into big ones, while larger banks, in unfavourable circumstances, might lose their assets and become small, irrespective of their careful credit policy. We have chosen to classify banks by size, not by their credit policy, because size, unlike portfolio risk, is an observable property that underpins depositors' decision-making.

[13] This assumption reflects not only the negative media coverage associated with licence revocation, but also the depositors' concerns that their bank might also lose its licence. If this happens, they will have to spend time to recover their money via the Deposit Insurance Agency (DIA) and, most probably, will be unable to get their deposits in full with accrued interest.

sufficient capital to take up the loss[14]. A small number of banks emerge in the system at any given moment. When setting up a new bank, its organiser realises that the tighter the regulator's policy is, the shorter the bank's life cycle will be if it fails to comply with the capital adequacy requirement. Consequently, in the proactive supervision scenario, the chance of spawning Group 3 bank (the worst type) is smaller.

Specific parameters are attributed to every agent randomly from the pre-set distributions. The key calibrated parameters of the model are provided in the Annex. The choice of model parameter calibration was designed to ensure that, in a large number of simulations, we obtain equilibrium parameters of the banking sector structure that are close to those actually observed in the Russian banking sector before supervision enhancement, that is to say, in the first half of 2013. The following structural parameters are meant here: distribution of deposits/loans by bank group and the Herfindahl index values for the assessment of the degree of concentration for the credit and deposit market (see Annex 1). Such calibration approach clearly prevents us from accurately estimating the results of the tightening of supervisory policy in quantitative terms. Even so, it does illustrate the presence of a wide range of hypothetical effects that might stem from it.

Since the model is stochastic, the results of different simulations will vary. However, according to the law of large numbers, with a great number of simulations, the systemic equilibrium outcome is observable by averaging various effects. It is the comparison of such averaged systemic effects under two policy scenarios that will constitute our results.

We have accomplished two series of 100 simulations each, and compared the key characteristics of banking system equilibrium under two central bank policy scenarios using our calibrated model. These scenarios are as follows.

The first scenario was the proactive rehabilitation of the banking sector with subsequent pursuance of a proactive supervisory policy and tight requirements for compliance with capital ratios. This was implemented by setting a high probability of inspection of a specific bank and identification of problems there, if any.

The second scenario was preservation of a soft supervisory policy, manifested in a low probability of bank inspection. This is synonymous to the low probability of violations being detected, even if such violations exist. This is the regime that was presumably in place until mid-2013.

On every simulation, after entering initial conditions and starting the system dynamics, we allow the system to 'live' its own life in two scenarios – soft or proactive regulator's policy. The entire 'life' of the system consists of 150 periods (owing to the specifics of our calibration, it is impossible

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[14] Preservation of bad assets on the DIA balance is to some extent equivalent to this.

to say whether those are months, quarters or years). The system 'lives' the first 50 periods in the soft scenario, so that its persistent systemic features might become evident, while accidental effects induced by certain initial conditions (like specific selective distribution of projects by risk level) could be neutralised. Then, starting from the 51st period, the policy changes and proactive banking sector rehabilitation starts (see Figure 2), whereupon the system 'lives' another 100 periods, the first 30-50 of which can be viewed as a short term, and the following 50–70 as a long term.

Comparison of the median in the two policy scenarios following a large number of simulations reveals systemic differences. We have chosen to run 100 simulations, which – as judged by the computational stability – is sufficient for the law of large numbers to kick in.

2. RESULTS

Figures 2–11 depict averaged developments of key system indicators prior to the launching of banking sector rehabilitation and the dynamics of those indicators after the introduction of the proactive policy. Short-term and long-term periods are additionally highlighted. The short-term period is the time interval from the 50th period (the time when the banking supervision enhancement is launched) to the 80–100th. Subsequent effects through the 150th period are already viewed as long-term consequences of banking sector rehabilitation and attributed to the situation when the banking sector would have fully adapted to the new regulator's policy. At the same time, we have marked the 25% and 75% percentiles of indicated characteristics distribution in all the simulations as the confidence intervals. The results of simulations without proactive supervisory policy are shown in blue, while the results with the changed policy are shown in red.

Hereinafter, we will distinguish between short-term and long-term effects. Short-term consequences for the banking sector will be described first.

Short-term effects of supervision enhancement

As can be seen from Figures 2 and 3, more active supervision leads to rather quick clearance of the banking system of mala-fide banks, in our case, banks with negative capital.

Figure 2. Share of banks with their licences revoked over the four periods, in the total initial number of banks
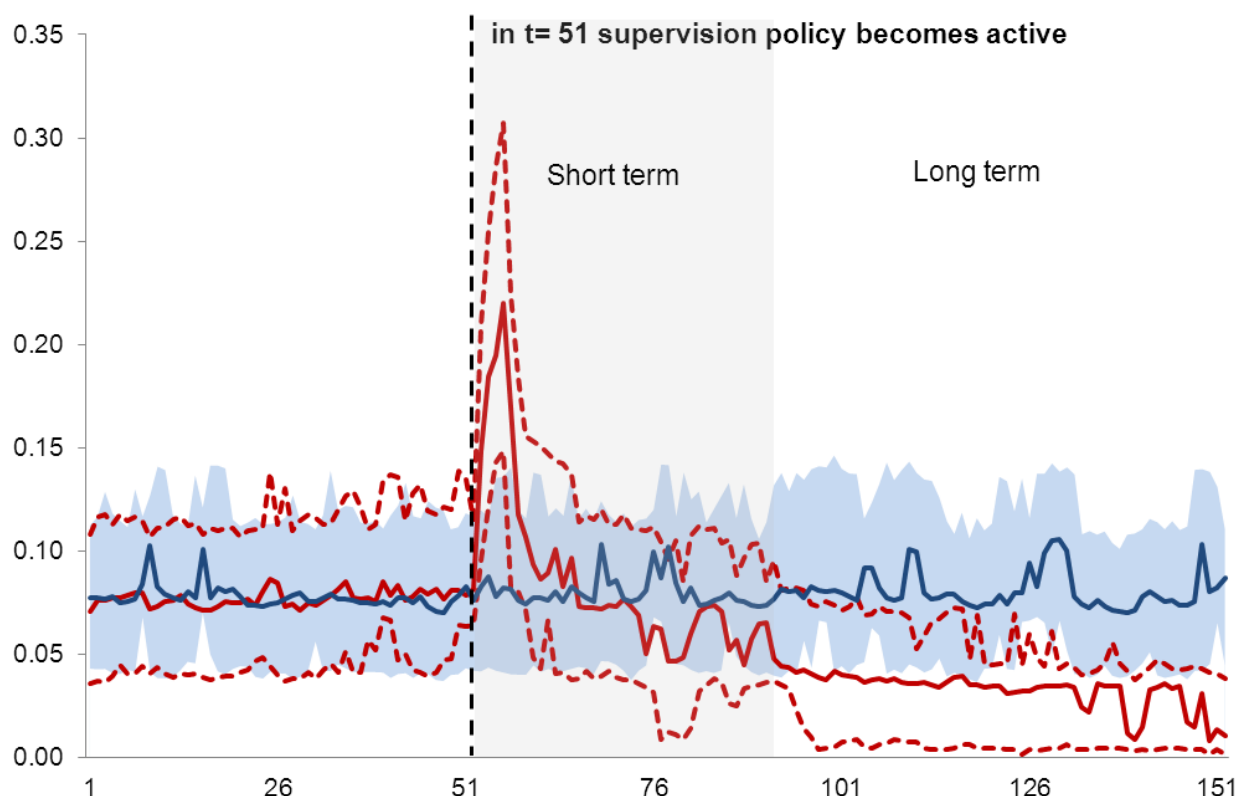

Source: hereinafter, authors' calculations

Perceived risks of keeping deposits in all small and medium-sized banks grow over the short term, as do the requirements for bank size as an observable and simple indicator of bank bankruptcy risk. This results in a migration of deposits to larger banks and, to some extent, even funds drain from the banking system, for instance, into cash or foreign currency. As a consequence of this, the average deposit rate on the balance sheet of small and medium-sized banks goes up, which reduces their profit from liability management[15]. Reduced profit results in a lower capital of small and medium-sized banks, which prevents them from expanding lending. Due to the problems with capital replenishment experienced by small and medium-sized banks, which

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[15] This profit is earned by attracting cheaper liabilities below the Bank of Russia key rate (rates curve) or the money market rate (rates curve).

in the model, generally pursue a more risky policy compared to larger banks, this group becomes altogether more financially vulnerable over the short-term horizon. The opposite is observed for larger banks, which build up their capital and can afford to expand lending thanks to the deposit inflow and decreased liability value.

Figure 3. Share of banks with negative capital
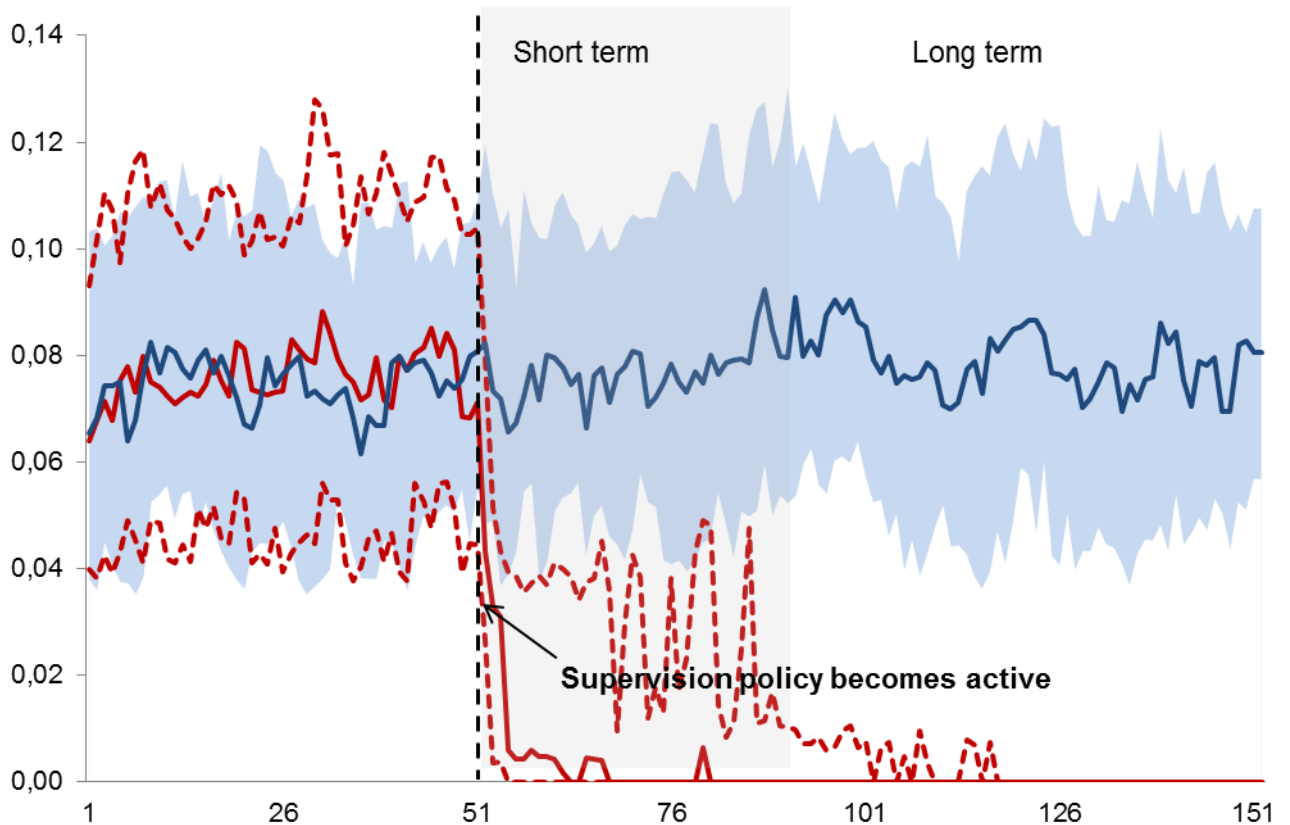
Note: equilibrium share of 8% is the model assessment. It indicates that there are around 8% of banks with negative capital in the system at any specific time, but those are not necessarily the same banks in two different moments of time.

Eventually, the share of larger banks in aggregate banking system deposits (Figure 4) and in aggregate credits (Figure 5) is projected to increase.

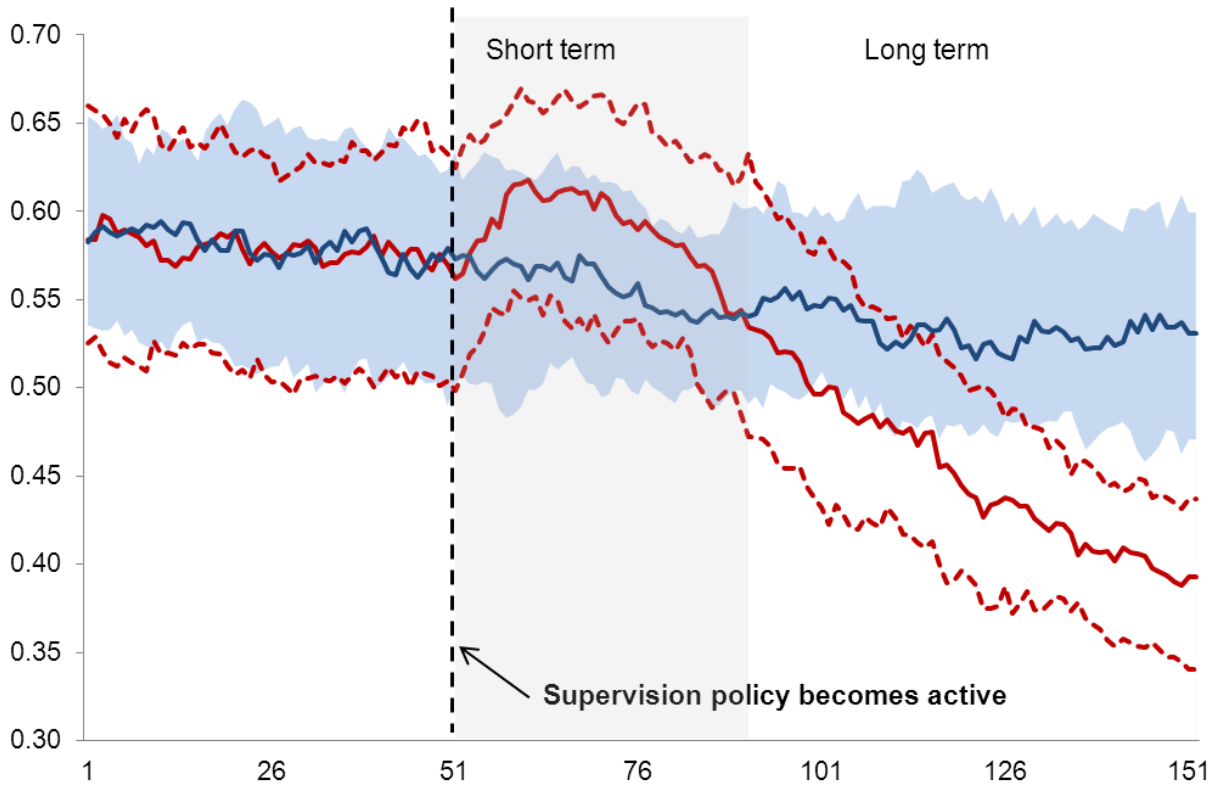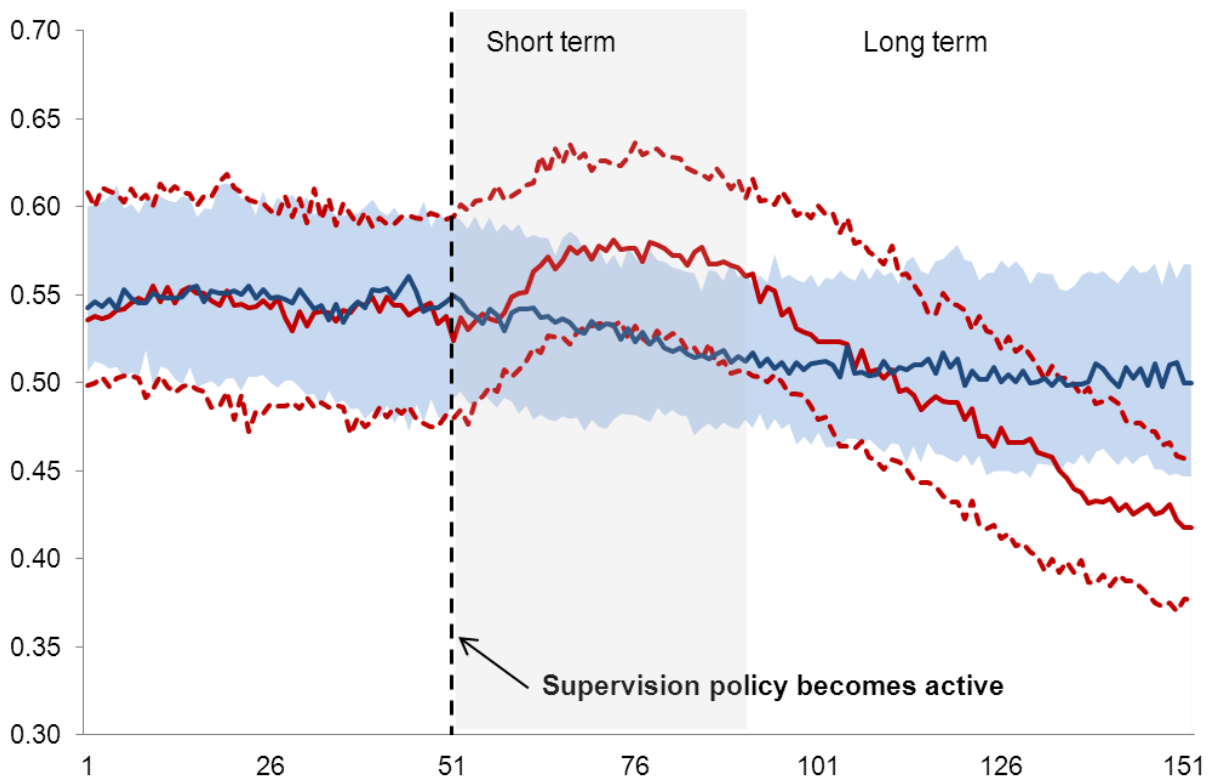**Figure 4.** Share of deposits in Group I banks (larger banks)

Figure 5. Share of credit in Group I banks (larger Banks)

Greater concentration is also registered by the growing Herfindahl index often used to measure it (Figures 6–7 for deposit and loan markets). Reduced competition for depositors is expressed in a lower deposit rate in the banking system (Figure 8).

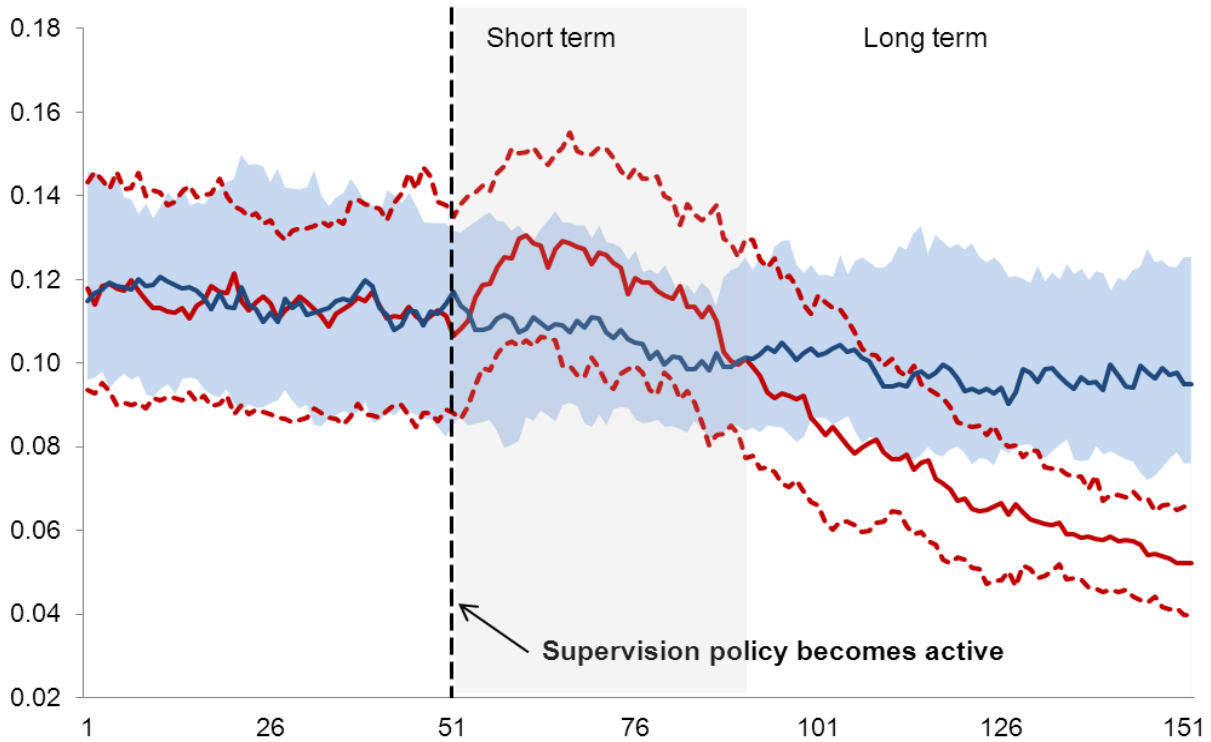**Figure 6.** Herfindahl index for the deposit market
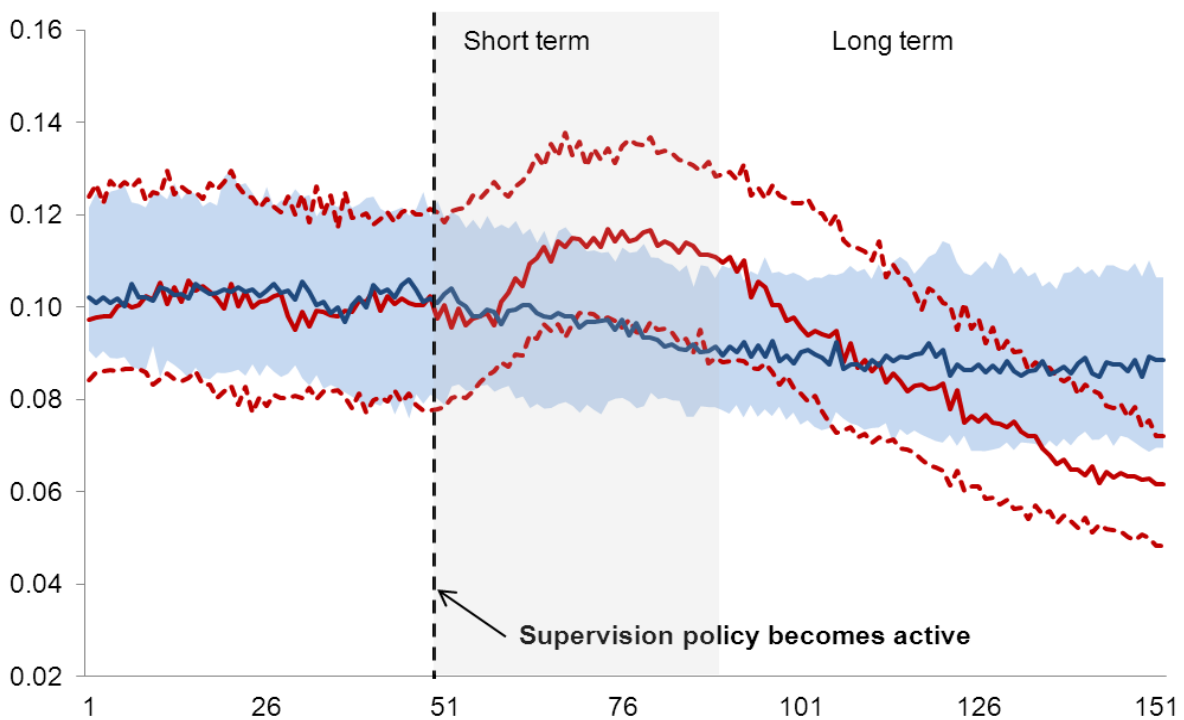

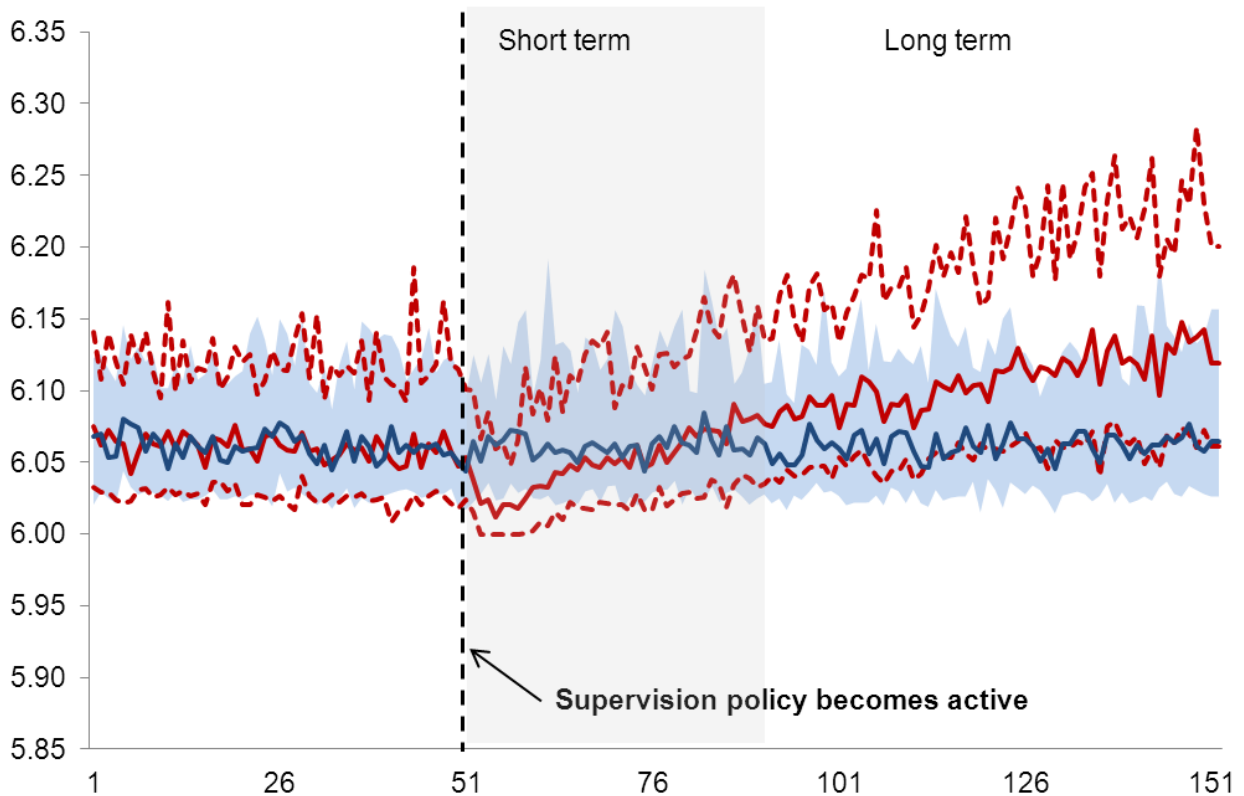**Figure 7.** Herfindahl index for the credit market

Figure 8. Average deposit rate in the banking system, % per annum

Reduced competition in the banking sector first leads to some upsurge in heterogeneity (variation by banks) of deposit rates (Figure 9).

Higher variation of rates reflects heterogeneity of banks in terms of their competitive positions on the deposit market. Thanks to the inflow of depositors, major banks can afford to set lower deposit rates compared to those of other banks. By contrast, due to depositors outflow, small banks are forced to offer higher rates to compensate for risk. As a result of the bank size role coming to the fore, price competition falls by the wayside, while larger banks earn additional profits on the back of abundant and cheap liabilities. This profit actually shifts to them from smaller banks and from depositors. Lack of homogeneity is indicative of some other factors in the banking system, apart from price factors (the deposit rate), that influence depositors' preferences. In a competitive banking system, the role of such non-price factors (e.g., difference in bank size) should be moderate.

Figure 9. Variation (standard deviation) of deposit rates across banks, pp
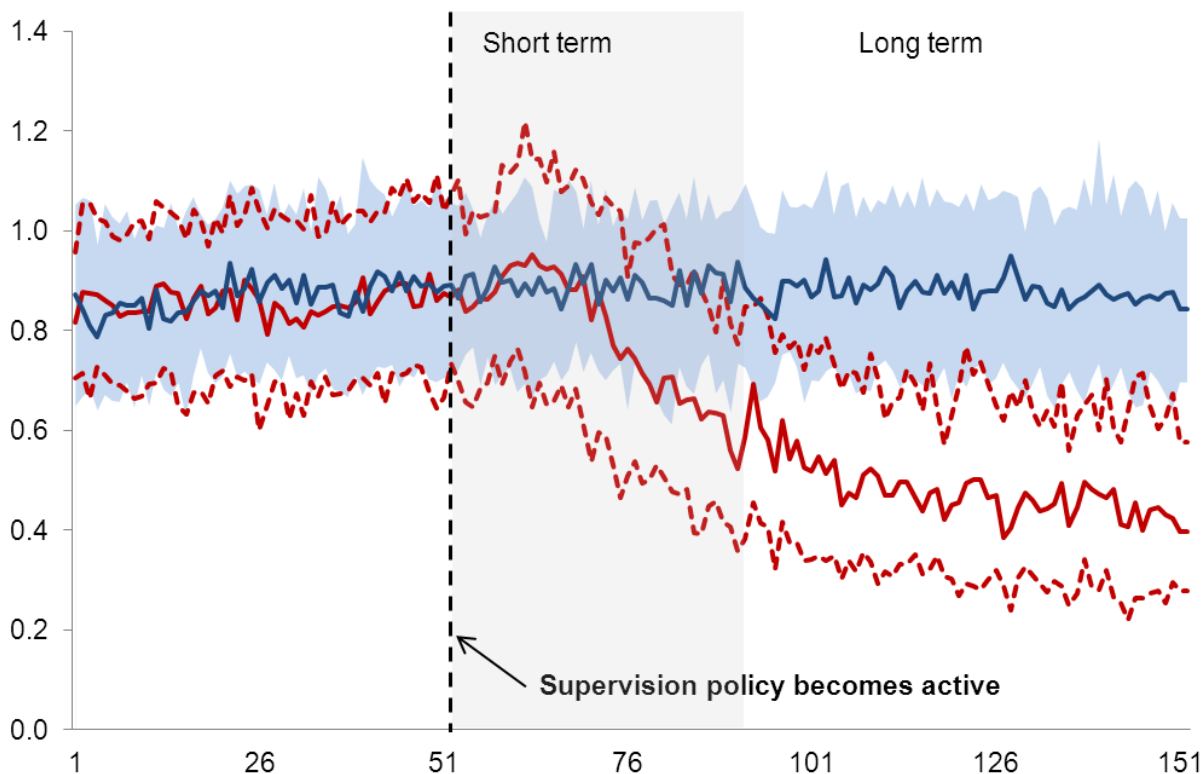
The other short-term effect of proactive supervision is a decrease in the availability of loans for borrowers with relatively high risk of default, manifested in the reduction of the average credit risk assumed by banks (Figure 10) and the maximum risk of approved loans (Figure 11). The reduction of maximum risk is driven by the 'wash-out' of the group of mala-fide banks that used to pursue an extremely soft credit policy. Average risk reduction is also caused by the inability of medium-sized bona-fide banks targeting this segment to provide loans because of problems with capital caused by depositor outflow. Meanwhile, larger banks (according to the modelling assumptions) are less inclined to credit risky projects despite the growing capitalization.

Figure 10. Average risk of credit default
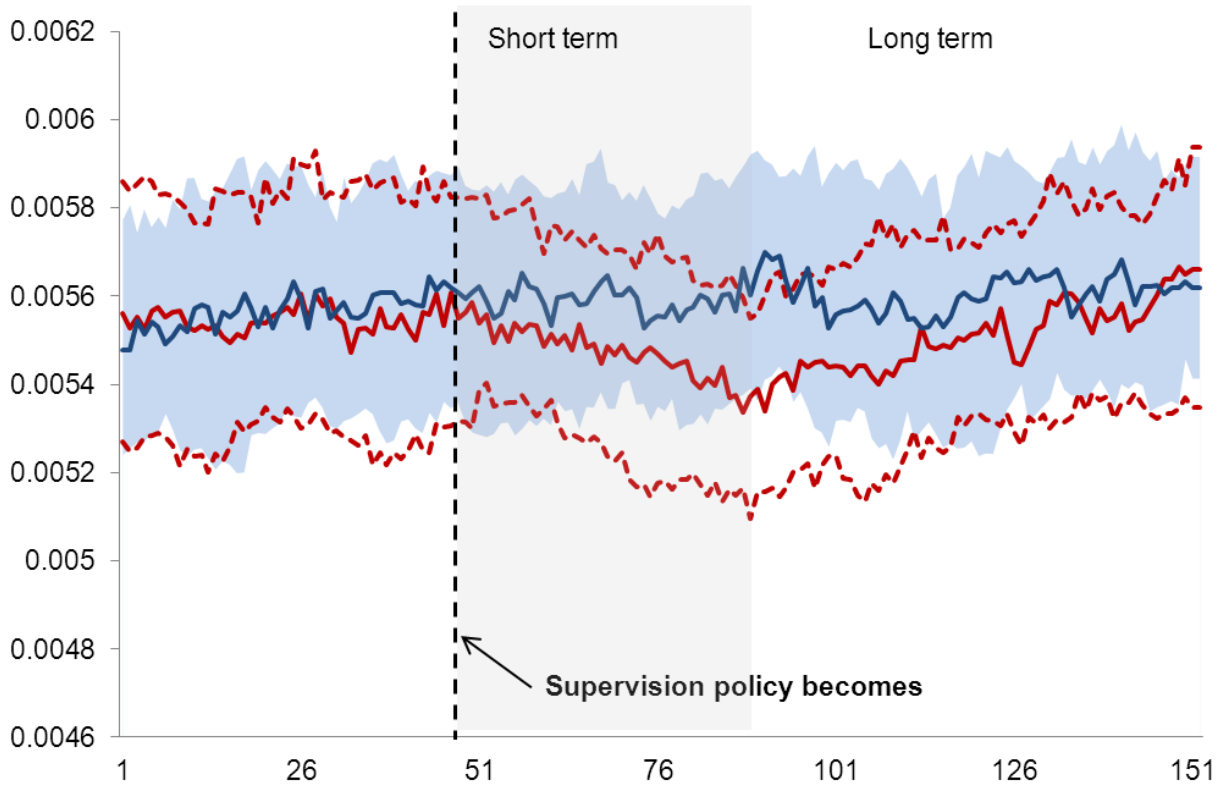
Figure 11. Maximum risk of credit default
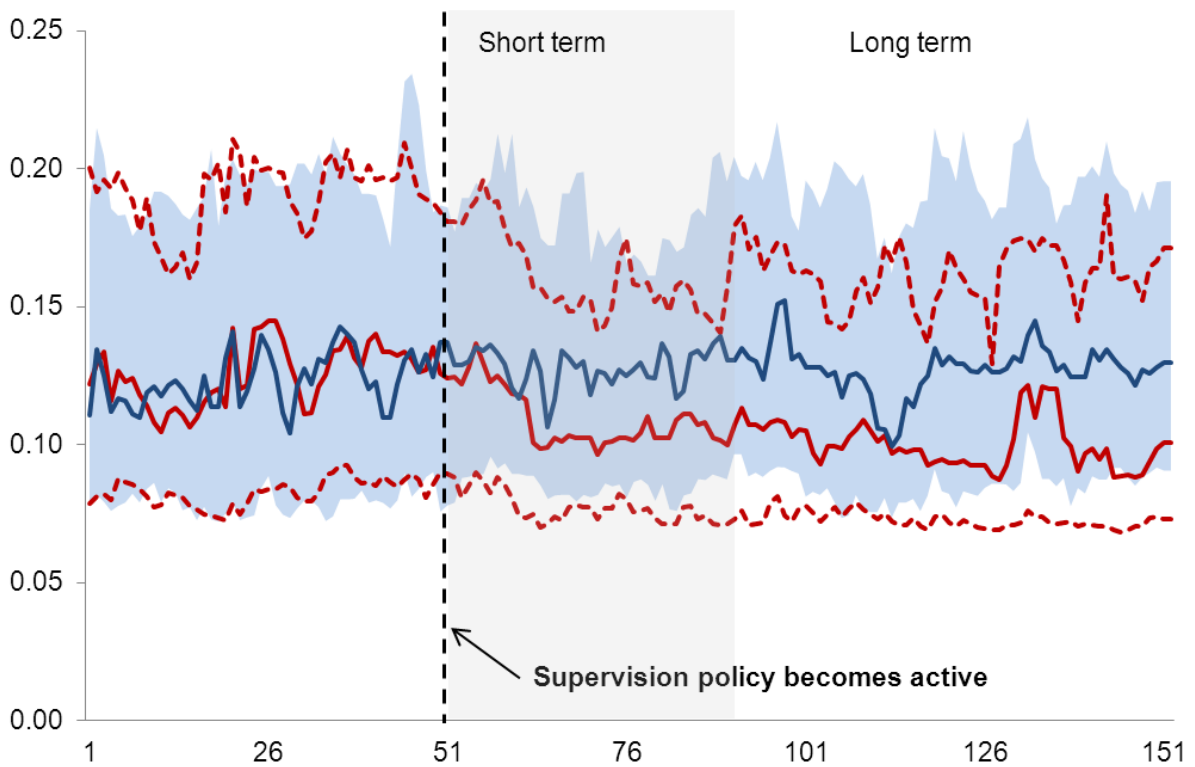
Long-term effects of supervision enhancement

The fact that, in the long term, after the banking system is cleared, the licence revocation rate falls virtually to zero, as opposed to the preservation of a stable rate in the event of an unchanged soft policy (Figure 2), is an important result of proactive supervision. This is not only and not so much a result of the proactive policy as of the rehabilitation of the system itself, which means that the regulator's domain narrows.

In fact, since the proactive supervisory policy also prevents the emergence of bad banks, in the long run, the share of banks with negative capital sets to zero, whereas under the soft policy, it remains persistently unchanged at about 8% (Figure 3). The system becomes healthier as a result. The formerly permanent share of bad banks posing a threat of a domino effect and large-scale crisis of confidence in bona-fide banks and the entire banking system is eliminated. Thus, the system becomes more financially stable in general.

The smaller number of banks with negative capital and the declining licence revocation rate enhance depositors' trust in small and medium-sized banks and the banking system in general. As a result, in the long run, depositors' requirements for bank size (as indicative of deposit risk) go down and depositors start returning to the banking system and migrating from larger to small and medium-sized banks. Consequently, the share of deposits in Group I banks, i.e. larger banks, goes down about 15 pp in the long term (Figure 4). It is critical here that the share of deposits in larger banks not merely gets to the former equilibrium level but even goes beyond that, which means that the depositor inflow into small and medium-sized banks increases compared to the equilibrium observed in the situation with a soft regulatory policy. After getting more reliable in general and doing away with the ballast of 'bad' banks, small and medium-sized banks become more attractive in the eyes of potential depositors than what they would have been otherwise without the regulator's resolution measures for the banking system.

The same is observed over the long term for the Herfindahl index, which is indicative of declining concentration on the deposits side of the industry (Figure 6). Concentration on the deposit market almost halves.

As a side effect of depositors returning to small and medium-sized bona-fide banks, these banks build up their profits and increase capital levels (recapitalisation). The increased capability of medium-sized banks to earn on liabilities translates into the development of their abilities to make profit on the assets side. This enables non-federal banks to build up loans provision to investment projects (as they are less constrained by capital requirements). As in the case of deposits, capital build-up and credit creation by small and medium-sized banks are higher in the

context of the new long-term equilibrium compared to the equilibrium amid the soft policy of the regulator. As a result, the share of small and medium-sized banks in aggregate loans issued goes up by about 10 pp (Figure 5).

Decreased concentration in the industry also leads to a lower Herfindahl index on the credit market below the equilibrium without implementing active clearance of the banking sector (Figure 7).

The long-term growth of trust in small and medium-sized banks given proactive banking system clearance of 'weak' players results in a decreased role of bank size as a critical factor in depositors' choice of bank for placing their deposits. Competition in price, complemented by competition in service quality, moves to the forefront. Engagement of small and medium-sized banks in price competition for depositors on a par with larger banks leads to the escalation of competition and, consequently, to a surge in average deposit rates in the banking system (Figure 8).

Meanwhile, the banking system becomes more homogeneous. Decline in deposit rate variation across banks is more pronounced (Figure 9). The deposit spreads halve. Such homogeneity is a good indicator of price competition intensity, since it reflects low significance of other factors that give advantages to certain (larger) banks in terms of the cost of attracting deposits. The surge in deposit rates together with the growth of rate homogeneity means that the extra (monopolistic) profit earned by larger banks through attracting cheaper deposits, which is typical for the system with 'junk' banks after the introduction of a proactive supervisory policy (implying the system clearance) is redistributed to small and medium-sized banks.

The maximum risk assumed by banks (maximum default probability of all projects approved by banks) remains at a lower level in the long-term equilibrium (Figure 11). This is indicative of the fact that the banking system refrains from assuming excessive risks after the elimination of the banks that pursued such policy, often with the management knowing the future results (fraud and asset stripping) in advance.

That said, over the long-term perspective, the average risk assumed by banks (weighted average default probability of approved investment projects) recovers to the level recorded prior to the introduction of the proactive supervisory policy (Figure 10). On the back of the reduced maximum assumed risk, the rise in the average risk level reflects an increase in the proportion of medium-sized banks in lending. These are the banks that issued loans to projects with moderate, yet higher risk levels, compared to larger banks.

Another important conclusion from Figures 10–11 is that, despite of the average risk remaining at the same level, by increasing the share of loans issued by more risky banks, the regulator's

proactive policy protects the system from accumulating risks to financial stability (a large number of banks not observing capital adequacy requirements).

Finally, the fact that medium-sized banks in the model pursue a softer lending policy than larger banks and that their proportion in aggregate loan provision goes up also means that credit becomes more available, so that not only borrowers with minimum risk have a chance to attract financing. At the same time, excessive risk is pushed out of the banking system, as such projects are seldom approved. Conventional banks worldwide do not constitute any significant sources of lending for high-risk projects (venture financing), so our results are quite realistic in this context.

3. CONCLUSIONS

We have constructed an agent-based model of the banking sector to analyse the impact of a proactive policy of banking sector resolution on the key banking system characteristics, including the competitive environment parameters. Our general conclusion is as follows.

Enhancement of banking supervision generates a wide range of significant and positive long-term advantages. It promotes competition and ultimately benefits bona-fide banks by improving their financial sustainability. It is a win-win for both depositors and borrowers, especially small and medium-sized businesses.

In order to mitigate short-term negative consequences, it is necessary to bring down the negative influence produced by banks on each other. It is critical to determine the optimal speed of banking system resolution.

In light of the results obtained, during the phase of active resolution it is crucial that small and medium-sized banks signal to their customers that they are definitely 'good' and not 'bad' or mala-fide banks. Specifically, this may result in greater information disclosure by bona-fide banks, their striving for openness and transparency, primarily as far as the capital requirement observance is concerned, as well as in engagement in lending to real economy.

Since greater openness does not eliminate the problem of the disclosure of false information on banking activities by mala-fide market players, efforts shall be put in place to enhance requirements for bank rating in terms of reporting quality, including at the regulator's initiative, with subsequent public disclosure of rating results. The priority shall be given to providing the public with fair and unbiased information about credit institutions without any fear that such information disclosure might create problems for the banking system or for individual banks and trigger 'depositor flight'.

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ANNEX

Our model constitutes the simplest description of the credit and deposit markets on which banks operate. It can be viewed as a simplified version of the banking sector model outlined by Chan-Lau (2017). Non-banking sectors of the economy are not modelled and the demand for loans and deposits is determined by exogenous processes.

Banks

In the economy, there is a population consisting of j banks, each of which belongs to one of three sub-groups. The balance sheet of a bank looks as follows.

Assets	*Liabilities*
Loans	Deposits
	Net inter-bank liabilities
	Capital

Banks draw interest on their assets and pay interest on liabilities. The difference between the two flows forms banks' profit and capital gain. Banks' profit therefore comes from two sources:

1. Liabilities side operations. Banks accept household funds in deposits and place them on the interbank market (the central bank), thus earning the spread between the key rate and their deposit rate.

2. Assets side operations. Banks issue loans thus earning the spread between the key rate and their deposit rate.

The size of a bank is determined as the share of its assets in the aggregate assets of the entire banking system. The net interbank liabilities are remunerated using the key rate i. As for the rates for their own products, banks set them as follows:

   - The credit rate is determined solely by the project's default risk f_m and calculated as $i + \gamma_0 + \gamma_1 f_m$.

   - Deposit rate setting is implemented as an iterative process. Each bank chooses a deposit rate from the range $(i - \xi_1, i)$ that would earn the bank the maximum profit given the current characteristics of depositors and deposit rates of other banks.

Banks in the model are all split into three groups:

   1. Larger banks (representing major banks of federal significance)
   2. Medium-sized banks (representing smaller banks of federal and regional significance)
   3. Small banks (representing banks operating at the regional level)

The key difference between these groups lies in their credit policies. Initially, banks vary in size and maximum acceptable risk of borrower's default probability f_j^*. The size characteristic may change over time depending on the bank's success, while its appetite for risk remains the same.

Larger banks are assumed to be the least inclined to finance risky investment projects. They select only projects with a low risk level. During parameter calibration, the Top 10 banks were conventionally attributed to this Group I.

Group II banks are less critical in selecting investment projects and are more tolerant of project risks. During parameter calibration, the Top 100 banks (excluding the Top 10) were conventionally attributed to this group.

Group III banks are ready to extend loans to any investment projects irrespective of the risk level. They are specifically characterised by readiness to keep crediting firms even if latter fail to observe the capital adequacy requirements (or even have negative capital). All banks beyond the Top 100 are attributed to this group.

Apart from the division of banks into groups by their credit policy, we assume that the credit market is segmented, meaning that not every bank has the chance to finance every emerging project. In order to reflect this phenomenon, a bank may offer financing to a newly emerging borrower only with a P^L probability.

Banks stop issuing loans when their capital to credit ratio drops below the rr threshold. When a bank's capital becomes negative, there is a P^B probability (determined by the tightness of the supervisory policy) that it will lose its licence and cease to exist (its balance sheet will be merged with another, randomly chosen, bank, unless such a merger results in capital insufficiency of such other bank).

At any specific time, a new bank emerges in the system. The probability of this bank being a Group III bank depends on the regulator's policy tightness (probability of the regulator coming to the bank for supervision purposes). The tighter the policy is, the lower is the probability of new Group III banks emerging and the higher is the probability of Group II banks emerging. Thus, in each period, there is P^{S1} probability of a new Group II bank emerging, and a $P^{S2} - \delta_1 * P^B$ probability of a new Group III bank emerging. Random K deposits are added to their capital and net interbank assets appear on the asset side of their balance sheets.

Deposit market (depositors)

There are n depositors on the deposit market. At any specific time, depositors have the following options:

1. Place money in a bank, provided that at least one of the banks offers a yield above what they desire and, at the same time, the bank satisfies their minimum requirement for bank size (in terms of its balance sheet volume). In this case, the bank size is used as an observable measure of deposit risk.

2. Choose cash.

Every depositor has two characteristics.

First, the value of the minimum desired deposit interest rate i_n^D.

Second, the minimum desired size of bank s_n^*.

The fact that depositors' requirements for bank size depend on their confidence in banking system stability, is an important feature of the model. Bankruptcy of banks (or licence revocation) is therefore a negative signal influencing the behaviour of agents. The stronger is the signal (higher rate of bank bankruptcy or licences revocation), the lower is the trust in the banking system and the higher is depositors' requirements for bank size. This mechanism allows to simulate depositor migration from smaller to bigger banks (from small regional to larger regional banks and from regional to federal banks) and out of the banking system (if the minimum required rate turns out to be insufficient, given the pre-set required bank size), as it is observed in real life. This migration may be an important influence channel of bankruptcies on liquidity and profitability and, subsequently, on the compliance with capital adequacy requirements by all banks of the same size group. Banking system resolution and a decreasing rate of bankruptcy, in turn, boost trust in banks and reduce the requirements for bank size. That explains why there are increasingly more depositors who are ready to put their money in small banks with high interest rates.

In every period of time, the minimum desired bank size parameter is adjusted for the unfavourable news index D_t, which depends on the number of bank licences revoked over the period L_t. Thus, the current minimum desired bank size $s_{n,t}$ is determined as follows:

$$s_{n,t} = s_n^* + \alpha_1 \, D_t$$
$$D_t = L_t + \alpha_2 \, D_{t-1}$$

Bank deposits change their owners all the time. This is done to reflect in the model transactions that are conducted in real life. Since lending automatically creates deposits, the issue of loans to firms increases household deposits in the model. This also reflects the fact that, in real life, firms use loans to pay for goods and services, so they end up on the accounts of individuals in the form of deposits. So, in order to map the process of deposit owner change in every period, the i_n^D and s_n^* parameters are chosen randomly from a respective distribution.

During every period, there is P^D probability of depositors reconsidering their choice of bank where they hold deposits. If they do, they select a bank with a maximum deposit rate from among the banks that are larger than $s_{n,t}$. If the rate does not exceed i_n^D, the depositor decides to keep money in cash.

A bank, that has increased (decreased) its deposits as a result of depositor migration, decreases (increases) proportionally the value of its net inter-bank liabilities.

The initial equilibrium (under a soft supervisory policy) of depositor distribution by bank group was structured so that the respective distribution of deposits by bank group would match the distribution from the actual Russian banking system data prior to the supervision enhancement (the 2011–2013 average). As a result of calibration exercise, we received the 55-35-10 distribution which reflects the share of deposits of individuals and legal entities 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.

Credit market (investment projects)

Every period, there appear m investment projects for which borrowers want to get loans. Of those, m_1 have low risks and m_2 are highly risky.

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 will be this very probability of the borrower's default, which would result in a respective reduction in the bank's credit portfolio and capital. A high default probability does not necessarily and automatically lead to default. In the event of default, no return on investments is received and the loan is not repaid. The cost of pledge is assumed to be equal to zero and the entire loss is charged to the capital of the bank that financed the project[16].

The second characteristic is the project rate of return i_m^L. If there is no default, the firm repays the loan and pays to the bank the interest rate set at the time the loan was issued.

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

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[16] This assumption highlights once again that lending process is not risk-free and the cost of pledge cannot compensate for credit loss. There will be loss anyway, even if compensation for some percentage of credits is possible.

A borrower chooses a prospective bank to get credit randomly (with a probability proportionate to the bank size) from among the banks ready to finance a given project (this is determined by the market segmentation and bank risk appetite). If the rate offered by the bank is above i_m^L, no loan is issued and the project ceases to exist.

When a loan is issued, the size of a randomly picked deposit is increased by a respective amount (for more detail on money supply creation through crediting, see McLeay et al. (2014)). The bank that has issued the loan increases its net inter-bank liabilities, while the bank that gets a newly-created deposit reduces them.

Regulator

There is a certain probability of the central bank inspecting a bank, which is assumed to have two values in the model: 0.2 prior to the supervision policy enhancement and 0.8 thereafter. If negative capital is revealed, the bank's licence is revoked and the bank itself is taken over by another bank (see above). Note that Group I and II banks voluntarily stop issuing loans if capital adequacy requirement is not met.

Initial conditions

As the initial conditions of the population of *NB* banks (for the calculation of Herfindahl indices, it is assumed that each bank constitutes an aggregate of 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 inter-bank liabilities offset the balance sheet.

Additionally, there are *NC* depositors which hold *C* worth of financial assets in foreign exchange cash.

Sequence of events at any specific time

1. Borrowers declare default.
2. Banks with negative capital have their licences revoked and are taken over by other banks.
3. Banks examine deposit rate options and select the optimal ones.
4. Depositors update their characteristics and make decisions on deposit placement.
5. Interest is paid on loans and deposits and loans are repaid.
6. New projects are generated. Banks offer financing and add new loans to their portfolio.
7. Interest is paid on interbank liabilities.
8. New banks are created.

Initial conditions

Parameter	Value
NB (Bank Groups I; II; III)	3; 25; 25
nb (bank group I; II; III)	1; $\in (10,15)$; $\in (90,110)$
ND (bank group I; II; III)	30; 10; 5
D (bank group I; II; III)	200; 100; 100
NL (bank group I; II; III)	50; 10; 5
L (bank group I; II; III)	300; 100; 100
NC	50
C	100
rr0	0.3

Model parameters

Parameter	Value
α_1	0.0075
α_2	0.85
i_n^D	max $[0, \sim N(0,3)]$
s_n^*	max $[0, \sim N(0.015,0.05)]$
β_1	0.005
f_m (project group I; II)	max $[0, \sim N(0,0.025)]$; max $[0, \sim N(0,0.15)]$
i_m^L (project group I; II)	$\sim N(12,1.5)$; $\sim N(12,3)$
m_1; m_2 (project group I; II)	300; 50
n	515
γ_0	1
γ_1	40
ξ_1	4
f_j^* (bank group I; II; III)	0.03; $\in (0.03,0.06)$; 1
i	10
rr	0.2
P^D	0.05
P^L (bank group I; II; III)	1; 0.6; 0.3
P^B (before; after supervision enhancement)	0.2; 0.8
P^{S1}	0.33
P^{S2}	0.75
δ_1	0.75
K (bank group II; III)	5; 2