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Default contagion risks in Russian interbank market

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HIGHLIGHTS

- Systemic risks of default contagion in the Russian interbank market are investigated.
- The study uses the actual data on interbank obligations.
- Probabilistic model of interbank contagion taking into account realistic topology of the interbank market is developed.

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ABSTRACT

Systemic risks of default contagion in the Russian interbank market are investigated. The analysis is based on considering the bow-tie structure of the weighted oriented graph describing the structure of the interbank loans. A probabilistic model of interbank contagion explicitly taking into account the empirical bow-tie structure reflecting functionality of the corresponding nodes (borrowers, lenders, borrowers and lenders simultaneously), degree distributions and disassortativity of the interbank network under consideration based on empirical data is developed. The characteristics of contagion-related systemic risk calculated with this model are shown to be in agreement with those of explicit stress tests.

The recent financial crisis has brought into the focus of attention systemic risks related to economic interactions between banks. Such interactions are most naturally described in terms of a network of their mutual obligations [1–4]. The notion of systemic risks refers to various crisis phenomena involving many economic agents having their origin in their interaction, e.g. in the outstanding interbank loans [5–9]. Game-theoretical foundations for building a quantitative description of financial contagion were discussed in Refs. [10–12].

One of the most important types of crisis phenomena taking place on complex networks are epidemic type cascading processes, see Ref. [13]. In the particular case of interbank network considered in the present paper this is a contagion process triggered by the default of some bank possibly followed by defaulting of some of its neighbors and, finally, to a formation of a default cluster. The phenomenon of contagion in interbank markets has drawn a lot of attention in the literature, see e.g. the recent reviews [8,9]. Foundations of quantitative analysis of contagion spreading in interbank networks were laid

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2 The material presented does not necessarily reflect the position of the Bank of Russia on the issues under discussion.

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in the paper [14],[3] in which the underlying interbank network was considered as a weighted directed Poissonian random graph with neither clustering nor degree–degree correlations taken into account. The focus of Ref. [14] was on systemic risk associated with the percolation phase transition and formation of giant cluster and the related robust-yet-fragile property of default contagion where a small probability of a catastrophic event goes together with its huge volume.

The research following Ref. [14] was to a large extent aimed at checking the assumptions on the properties of interbank network made in Ref. [14] against existing data and, if necessary, incorporating the corresponding modifications into the theoretical formalism describing default propagation. In terms of network properties the question is thus on degree distributions, degree–degree correlations and clustering in realistic interbank networks, while theoretically a central issue is that of an interplay between topological properties of a network and those of epidemic cascades on it.

Analysis of empirical properties of the Russian interbank network was made in Refs. [16,17] for the period of 01.08.2011-03.11.2011 and in Refs. [18,19] for the period of 10.2004–08.2008. It was found that this network is characterized by a heavy-tailed degree distribution [16–19], heavy-tailed distribution of exposures [18,19], pronounced disassortative degree–degree correlations and significant anomalous clustering [16,17].[4] In Ref. [21] effects of taking into account heavy-tailed nature of degree distributions, degree–degree correlations and clustering on default contagion propagation in the framework of Ref. [14] were studied, on a feature-by-feature basis, in a Monte-Carlo simulation. The first Monte-Carlo simulation on interbank network with realistic topology was performed in Refs. [16,17].

On theory side it is necessary to incorporate the above-mentioned characteristic features of real interbank networks (heavy-tailed degree distributions, disassortativity and anomalous clustering) into an analytical formalism. The generating function formalism used in Ref. [14] is directly applicable for arbitrary degree distributions, so the remaining problem is to take into account degree–degree correlations and clustering. There exists a considerable literature on the effects of the influence of these features on percolation transition and epidemic diffusion. Effects of degree–degree correlations on the percolation transition was studied in Ref. [22] for undirected and Ref. [23,24] for directed graphs, while that of clustering was analyzed in Refs. [25,26].

The present paper continues investigation of systemic risks at the Russian interbank market begun in Refs. [16,17] and focuses on developing a mathematical model of contagion process taking into account all aspects of geometry of interbank network, important features of the balance sheet structure of participating banks and institutional regulation relevant for providing a quantitatively correct description of default cascades. We argue that to build such a description one should take into account empirical default propagation probability, bow-tie structure, degree distribution and disassortative correlation structure of interbank networks. An interesting feature we observe is that although the original interbank network is characterized by high clustering, default clusters are predominantly tree-like. This latter property agrees with the findings of Refs. [26] and [27].[5]

The main objectives of this paper are the development of the above-described analytical model based on an enlarged set of empirical data on the Russian interbank market.

The plan of the paper is as follows.

In Section 1 we discuss the structure and main characteristics of the Russian money market and the data used in the analysis. In Section 2 we analyze empirical characteristics of the deposit market from the network perspective including its bow-tie structure, degree distributions and correlations, clustering and default propagation probabilities. In Section 3 we explore the structure of the default cluster caused by the default of a randomly chosen bank and after that introduce mathematical formalism for systemic risk representation in chapter 4. Conclusions are presented in Section 5.

1. Russian money market: empirics and data description

Russian money market consists of three main segments, the markets of deposits, REPO and SWAP.

Operations at the deposits market are uncollateralized: banks bound their risk in lending money to counterparties by setting limits calculated with the help of in-house models and taking into account expert opinions. Lending risks are also regulated by the special requirement of the Bank of Russia constraining the value of exposure to a counterparty. The uncollateralized nature of the deposit market makes it the most vulnerable with respect to trust evaporation during crises when deposit markets can freeze requiring significant efforts from regulators for their relaunching.

Less risky is the REPO market at which collateral, usually government and corporate bonds and equities, is required. In operations with money borrowing the value of different types of collateral includes discounts thus reducing the corresponding market risk. Credit risk is more often accounted for in the credit rate. Let us note that while at the beginning of the Russian crisis in 2008 the REPO market in Russia did collapse, it started functioning faster than the deposit one.[6]

The least risky is the SWAP market. Often swap operations are used as a source of short-term ruble liquidity when in exchange of rubles a lender gets foreign collateral (most often USD and EUR). SWAP operations were attractive for Russian

[3] See also an interesting comment [15].

[4] Similar results for degree distribution, degree–degree correlations and clustering were found for the Brasilian interbank market in Ref. [20].

[5] We are grateful to C. Borgs for pointing out this reference.

[6] The collapse of deposit and REPO market took place after the Lehman Brothers default. Due to efforts of Bank of Russia and Ministry of Finance the Repo market was partly retrieved in two weeks whereas the credit risks still remained too high.