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Russian Interbank Network Reconstruction via Metaheuristic Algorithm

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Abstract

We propose an application of the metaheuristic algorithm to interbank market reconstruction. This is a simulated annealing algorithm that is considered, and it is Russian interbank market that this is applied to. We consider a network with the 504 largest Russian banks to be compared with corresponding empirical results obtained by Leonidov & Rumyantsev. The topological properties of a graph to be fitted was average in- and out- degree, density and average clustering coefficient. The proposed algorithm of network reconstruction is compared with maximum entropy, minimum density, low density methods. Results shown the efficiency of the approach.

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Keywords: interbank market, network reconstruction, simulated annealing

1 Introduction

The problem of banking system systemic risk estimation often considers the spreading of contagion throw interbank networks with further evaluation of the value of loss. This class of studies usually takes empirical data on interbank transactions obtained from daily and/or monthly reports. These reports are presented for central banks usage only and consequently they are not public. Therefore, studying the systemic risk is restricted by incompleteness of information on the interbank market.

The information that we have about interbank transactions can be considered as a subgraph, in terms of graph theory. Nevertheless, more often we only have information about row and column sums of a graph adjacency matrix. These reasons give rise for the problem of complex networks reconstruction in the case of incomplete information.

Usually used approaches for interbank networks reconstruction are focused on the estimation of single types of systemic risk (fire sales, for example), therefore they can restrict the

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consideration by several types of configuration models or modifications of maximum entropy approaches. Other studies show the maximum entropy approach underestimates systemic risk in some cases. In addition, maximum entropy method basely generates random graphs therefore the networks reconstructed in such way usually demonstrate degree distribution with Poisson properties. In this way, other algorithms of networks reconstruction, providing raw material for more accurate and comprehensive exploration of systemic risk in complex interbank markets, are important to develop.

To diminish above mentioned imperfect we apply the simulated annealing algorithm to the issue of Russian interbank network reconstruction, which allows us to approximate graph properties more accurate. As empirical data for reconstruction we take the values of total interbank assets and liabilities of the largest 504 Russian banks. Data are considered for the period from January to December 2013. The results obtained are compared with maximum entropy method, since its popularity, and with low and minimum density methods, since they replicate density more plausibly.

The rest of the paper is organized as follows. Literature review (sec. 2) considers some existing methods of interbank network reconstruction, heuristic algorithms for complex networks reconstructions reproducing topological properties as well as functional network properties, and related empirical studies on the topological properties of Russian interbank market. Section 3 presents a brief description of methods we used. Dataset is described in Section 4. Section 5 demonstrates the comparison of algorithms applied for Russian interbank network reconstruction, and finally, discussion, future work and conclusion are observed.

2 Related Work

2.1 Naive Approaches to Networks Reconstruction

The often used maximum entropy method for interbank market reconstruction was shown to underestimate systemic risk [18], since this reconstructs a complete graph. Links weights are assigned uniformly in accordance with initial restrictions. After that the distance between resulting matrix and restriction matrix (with the values of bank assets and liabilities) is minimized via Kullback-Leibler divergence [6, 12]. This was an algorithm of sparse network reconstruction that was presented by [16] to decrease the density of resulting graph. Musmeci [19] offered the bootstrapping method for reconstruction, which is based on known topological properties of a sub-graph and use them to generate the ensemble of networks. The authors were focused on topological features which mostly affect shock contagion (namely, density and k-core).

Methods described in [3] are based on the knowledge about sub-graph structure or global non-topological features and are aimed to reconstruct "macroscopic or statistical properties". In [15] authors emphasize the difficulty of weighted networks reconstruction and present the enhanced analytical and unbiased maximum entropy method that is computationally efficient and does not require network samples as input. Anand et al. [2] diminish the flaw of graph completeness in the maximum entropy approach by presenting the minimum and low density methods, which reconstruct random networks with density being tuned by some λ parameter.

Despite the maximum entropy method was being repeatedly criticized, this continues to be used and modified. The authors of [7] apply maximum entropy approach to the ensemble of networks and combine that with capital asset pricing model. They show the model is appropriate for the estimation of systemic risk due to fire sales spillover. The approach presented in [20] is based on statistical mechanics techniques applied to bipartite market networks and this is referred to as fitness-induced bipartite configuration model (FiBiCM). The approach was vali-