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Phase Portrait Models as a Tool for Analyzing Banking Activities

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Abstract: *Banking and the functioning of banks is one of the active areas of research. Banks play an important role in the development of the country, the functioning of individual business entities and the economy as a whole, and the satisfaction of the economic needs of certain individuals. At the same time, it is important to emphasize the complexity of carrying out an appropriate analysis. This is due to the need to consider interrelated random processes that occur simultaneously. Therefore, it is important to use adequate models that contribute to the solution of the tasks. Such models should not only adequately describe the situation, obtain the necessary results for decision-making, but also adequately interpret the processes that we are studying. Based on this, we consider the phase portrait model as a tool for analyzing banking activity. We give a general description of such a model and show its application to real data. We also consider 2D and 3D visualization of such a data analysis model. The paper summarizes some results of banking analysis modeling. The paper presents various graphs of the analysis that we carry out. This helps to understand the logic of the study and the results obtained.*

Keywords—model; uncertainty; relationship; analysis; bank; analysis tools; phase portrait; banking; time series

1. INTRODUCTION

Modeling is one of the methods for analyzing and studying complex systems. Models allow you to describe various situations and explore them without violating the integrity of the system. Among such systems, it is necessary to single out systems that describe socio-economic relations [1]-[3]. This is due to the fact that for such systems it is difficult to repeat the conditions that we study as initial ones. It is also difficult to assess the development of such systems for different subjects under the same conditions [4], [5]. Therefore, for their study, various models are used that allow us to evaluate and analyze the behavior and development of the corresponding systems.

Among the various systems that describe socio-economic relations, it is necessary to single out the functioning and development of banks, the implementation of banking activities. This type of socio-economic relations plays an important role in the development of economic relations between individual business entities, the country as a whole, and individual individuals. Banks are able to accumulate and redistribute financial resources. At the same time, for certain individuals, banks can be considered as a tool for investment activities. All this as a whole contributes to the proper implementation of financial flows in the movement, the development of various economical agents [6]-[9]. As a result, the stability of the corresponding economic relations, the integral development of economic ties is achieved.

However, determining the state of the functioning of the bank, the banking system, and even more so, determining the directions for their further development is impossible without a preliminary general analysis and comparison of various banking institutions. To do this, you can use various classical methods and approaches [10]-[14], as well as other specialized analysis tools that have found application in other areas of research [15]-[22]. The combination of these methods and approaches allows you to get more effective results.

In this case, a rather difficult task arises to determine an adequate model that can explain the interdependence between different time series of the studied indicators. The reason for this is that both the modern financial market and its individual segments are characterized by a significant complexity of the ongoing processes. At the same time, the need to take into account the existing unevenness in the development of the relevant economic processes should be indicated as an essential sign of such complexity. Consequently, there is a need to analyze the existing dynamics in the development of economic processes with the necessary consideration of interrelated random processes occurring simultaneously. As a result, this leads to the introduction of the latest approaches to the analysis of the studied characteristics, which describes the relevance of the chosen topic of this work.

Thus, the main goal of this work is to consider a model for the analysis of banking activity, where we consider the model of a phase portrait of banking activity as such an analysis tool.

2. BRIEF REVIEW OF RELEVANT LITERATURE

According to the specified topic of this work, in the scientific literature one can find a fairly wide arsenal of tools

for researching data reflecting the dynamics of banks' activities in the service market.

N. Shpak, I. Kulyniak, M. Gvozd, Y. Malynovska and W. Sroka explore the activity of banking structures [23]. First of all, it should be noted that the work of the authors is aimed at developing theoretical and practical provisions for assessing the level of marketing activity of banking structures. The article proposes a method for calculating the marketing activity of a bank, which is tested by determining the level of marketing activity of the leading Ukrainian banks [23]. Such an analysis is based on the calculation of an integral indicator by summing up the input statistical data characterizing the bank's marketing activities using two methods: the standardization method and the hierarchy analysis method (Saaty method) [23]. An important role in such an analysis is given to time series data that represent various aspects of banking.

L. Drake, M. J. Hall and R. Simper consider the methodology of banking modeling for conducting an appropriate comparative analysis [24]. For these purposes, the authors use nonparametric analysis. This paper examines the efficiency of the Japanese banking system using a measure based on weak funds. The authors also note the importance of using both intermediary and production approaches for such a study, as well as a profit/revenue based approach [24]. The authors also note the difference in the estimates given by the individual methodologies. Thus, the authors conclude that the results show a very high degree of simulation dependence. Therefore, this fact must be taken into account when developing measures as a result of appropriate modeling and the results obtained.

W. D. Cook, L. M. Seiford and J. Zhu explore models for comparative analysis of the effectiveness of banking [25]. The paper considers models of mathematical programming for use in benchmarking. For these purposes, multiple performance indicators are also considered, which allow you to evaluate the change in performance. In doing so, the standard data coverage analysis method has been expanded to include benchmarks. To study the effectiveness of models, they are used in a large Canadian bank, where the services of some branches are automated to reduce costs and increase the speed of service [25]. In this study, it is also important to analyze the data, which are time series of some indicators of banking activity.

R. Raut, N. Cheikhrouhou and M. Kharat explore the sustainable development of the banking sector, provided banking services [26]. For these purposes, the work uses a strategic multi-criteria analysis. In general, the article is aimed at developing an effective and integrated MCDM model for assessing the practice of sustainable development of banking services using a multi-stage fuzzy MCDM model [26]. This model combines balanced scorecard, fuzzy AHP and fuzzy TOPSIS. To test the model, data from the six largest banks in India are used. The developed assessment model offers a valuable management tool for bank administrators, helping them in choosing a strategy to achieve their goal of sustainability and sustainable banking [26]. The paper also notes that the proposed model allows you to work with uncertainty.

N. Y. Seçme, A. Bayrakdaroğlu and C. Kahraman consider fuzzy estimates of the efficiency of the Turkish banking sector [27]. An analytical hierarchical process and TOPSIS are used to derive these scores. At the same time, the authors note that the assessment of banks' performance has important results for lenders, investors, and stakeholders, since it determines the ability of banks to compete in the sector and is crucial for the development of the sector [27]. The paper considers the activities of five commercial banks in the Turkish banking sector. The proposed model integrates the methods of fuzzy analytical hierarchical process (FAHP) and the method of fulfilling an order in the likeness of an ideal solution (TOPSIS) [27]. After determining the weights for a number of criteria based on the opinions of experts in the FAHP method, these weights are entered into the TOPSIS method for ranking banks [27]. An important point of such an analysis is the consideration of data in the form of time series.

G. A. Alrgaibat considers the classical financial and economic analysis of the activities of banks [28]. Such an analysis is carried out for banks in Jordan. The author notes that the classical assessment of performance through financial indicators gives a clear idea of the real financial situation of banks. This analysis allows a simple ranking of banks. The main results of this study show that the Islamic Bank of Jordan ranks first in terms of liquidity and also ranks first in debt ratio [28].

C. Erol, H. F. Baklaci B. Aydoğan and G. Tunç conduct a comparative analysis of Islamic banks and commercial banks in Turkey [29]. Comparative analysis of efficiency was carried out by the method of logistic regression. At the same time, the CAMELS approach is used to assess the management and financial activities of banks. The paper notes that Islamic banks operating in Turkey demonstrate the best indicators of profitability and asset management compared to traditional banks, but lag behind in terms of sensitivity to the market risk criterion [29].

A. P. Balcerzak, T. Kliestik, D. Streimikiene and L. Smrcka use a non-parametric approach in the comparative assessment of the effectiveness of banks [30]. This paper examines the methodology for a comprehensive assessment of the operational efficiency of the banking sector in the EU countries. At the same time, this problem is discussed in a non-linear form. This allows us to say that the corresponding methodological proposal should be based on the interaction of several inputs with several outputs without knowledge of the functional relationships between them [30]. The article uses Data Envelopment Analysis as a tool for this purpose.

We see that among the various tools of the corresponding analysis, fuzzy set methods, random matrix theories, boundary analysis, and many others can be used. The use of such methods allows, first of all, to obtain the main characteristics of the dynamics of the functioning of the bank, the banking

system. However, the irregularity of time series can be studied in more detail using the methods of nonlinear dynamics. The basis of such a definition is the identification of a deterministic chaotic component in the dynamics of statistical data, which helps to determine the unevenness in the development of economic processes. In particular, the methods of nonlinear dynamics have found wide application for the analysis and forecasting of data that reveal the development of the securities market, the insurance market, and the dynamics of attracting investments. At the same time, studies of the banking segment of the financial market did not find sufficient elaboration. It is these aspects that we consider next.

3. Phase Portrait as the Basis for the Analysis of Banking Activities

First of all, it should be noted that the phase portrait model allows one to study the movements of the bank's financial flows in their dynamics. The importance of such consideration is related to the need to take into account the uneven development of banking activities, which requires an appropriate analysis. Therefore, an important issue in studying the dynamics of the bank's financial flows is to consider the irregularity of the corresponding hour series.

The key concept of nonlinear dynamics is the concept of a phase portrait of a statistical series of data that characterize, for example, in the context of this work, the main indicators of banking activity, and are a reflection of the movement of the corresponding financial flows. Then, in the phase space of dimension 2, using Cartesian coordinates, the phase portrait of the statistical data series in its simplest form is defined as a set of points:

$$A(CR) = \{(g(r_i), g(r_{i+1}))\}, \; i = \overline{1, t-1}, \qquad (1)$$

where:

CR is a series of statistical data that corresponds to some financial flow, which is summarized in the form of certain indicators of the bank's performance. For example, these can be the volumes of attracting resources to bank deposit accounts, the volumes of loans issued, the share of such resources in the total volume of attracted and issued funds, and the like;

$g(r_i), g(r_{i+1})$ is a values of the studied data series in certain time intervals.

A more complex construction of the phase portrait of the time series is taking into account the first and second derivatives of the original series. So if we have a certain series of statistical values $g(r_i)$ describing the dynamics of the bank's financial flow under study at equal time intervals, then its first and second derivatives can be found using the following formulas:

$$g'(q_j) = g(r_{i+1}) - g(r_i), \qquad (2)$$

$$g''(d_c) = g'(q_{j+1}) - g'(q_j), \qquad (3)$$

where:

$g'(q_j)$ is a values of the series of the first derivative of the original series $g(r_i)$, $j = \overline{1, W(t)-1}$;

$g''(d_c)$ is a values of the series of the second derivative of the original series $g(r_i)$, $c = \overline{1, W(t)-2}$;

$W(t)$ is a parameter associated with a time interval and describing the serial numbers in the converted series according to their serial numbers in the original series.

Then the desired phase portrait is defined as a set of points:

$$\tilde{A}(CR) = \{(g'(q_j)), (q''(d_c))\}, \; j = c = \overline{1, W(t)-2}, \qquad (4)$$

or

$$\tilde{A}(CR) = \{(g'(t)), (g''(t))\}, \; t = i, \qquad (5)$$

where:

t is a time parameter that determines the change in the values of a series of statistical data.

The next section presents some examples of building phase portraits for data series describing different types of banking activities.

4. Some Examples of Building Phase Portraits of Banking Activities

As examples for constructing the corresponding phase portraits, let us consider the dynamics of the indicators of some banks that operated in the same region. Let's designate these banks: bank A, bank B and bank C. All data for analysis from the site www.finance.ua. This data reflects some of the banking activities on a monthly basis and represents data for 59 months. This is a sufficient amount of data to build the corresponding phase portraits.

Fig. 1 shows the dynamics of such an indicator of bank A as the volume of loans attracted in the interbank market.

Fig. 2 shows the dynamics of such an indicator of bank B as the volume of loans attracted in the interbank market.

Fig. 3 shows the dynamics of such an indicator of bank C as the volume of loans attracted in the interbank market.

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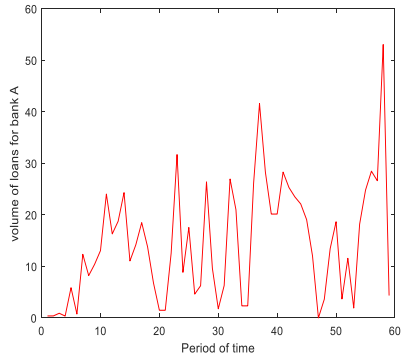

Figure 1: Dynamics of the volume of attracted loans in the interbank market for bank A

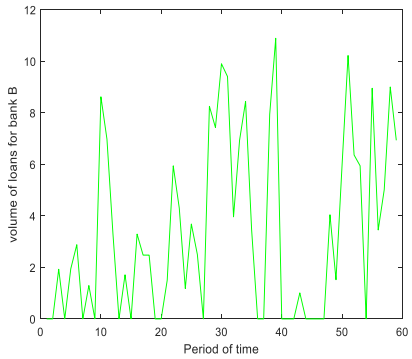

Figure 2: Dynamics of the volume of attracted loans in the interbank market for bank B

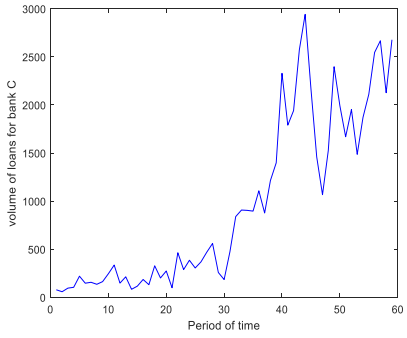

Figure 3: Dynamics of the volume of attracted loans in the interbank market for bank C

We see different dynamics of attracted loans from the interbank market for different banks. A characteristic feature of such dynamics is its volatility.

At the same time, the dynamics of such attraction of funds for Bank C is increasing.

Fig. 4 shows a phase portrait of funds raised in the interbank market by bank A.

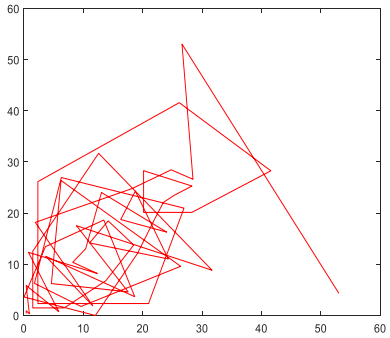

Figure 4: Phase portrait of the dynamics of attracted loans in the interbank market by bank A (two-dimensional space)

Fig. 5 shows a phase portrait of funds raised in the interbank market by bank B.

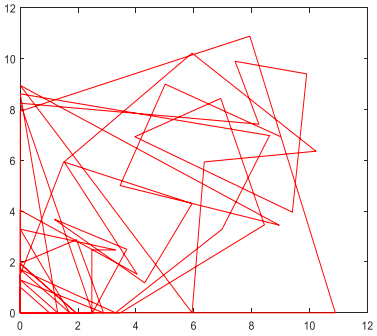

Figure 5: Phase portrait of the dynamics of attracted loans in the interbank market by bank B (two-dimensional space)

Fig. 6 shows a phase portrait of funds raised in the interbank market by bank C.

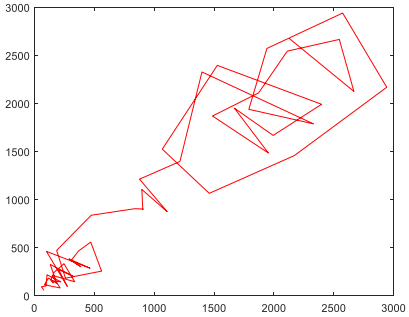

Figure 6: Phase portrait of the dynamics of attracted loans in the interbank market by bank C (two-dimensional space)

We note that the phase portrait models emphasize the difference in the dynamics of attracted funds in the interbank market from the point of view of each individual bank. Also, the volatility of such dynamics is most manifested here.

As can be seen from the data in Fig. 4 – fig. 6 it is possible to observe the closing of cycles in the change of the indicated

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phase portraits for the time series of data that determine the activity of banks in the market of interbank loans. At the same time, it should also be noted that the cyclicity of the data series that determine the activity of banks in the interbank loan market is dynamic. The explanation for this may be that the activity of banks in the market of interbank loans is used to balance their current needs, and in particular to maintain liquidity.

Considering the phase portraits of the time series presented in accordance with Fig. 4 – fig. 6, it should also be noted that the phase portraits of the time series of data that determine the activity of banks in the interbank loan market are approximately similar. Their difference is determined mainly by the amplitude of the cyclicity of individual quasi-cycles, which most likely coincides with the frequency of the bank's entry into the interbank market. However, in general, one should speak about the effect of the same factors of influence in terms of the introduction of interbank instruments for the needs of functioning and development from the point of view of individual banks.

A more detailed analysis of the dynamics of the bank's entry into the interbank market and its activity can be considered using the phase portrait model in three-dimensional space.

Fig. 7 shows a phase portrait of funds raised in the interbank market by bank A in three-dimensional space.

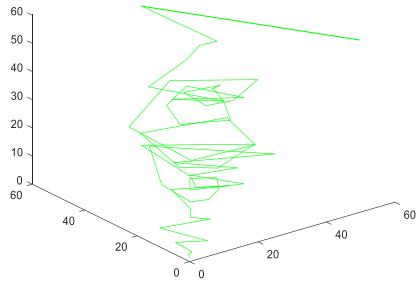

Figure 7: Phase portrait of the dynamics of attracted loans in the interbank market by bank A (three-dimensional space)

Fig. 8 shows a phase portrait of funds raised in the interbank market by bank B in three-dimensional space.

Fig. 9 shows a phase portrait of funds raised in the interbank market by bank C in three-dimensional space.

We can see a more detailed depiction of the activity of banks when entering the interbank market. This applies both to the time of entering such a market and the volume of attraction in certain periods of time.

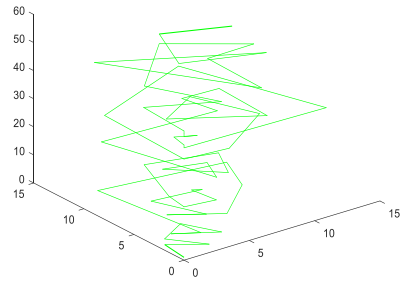

Figure 8: Phase portrait of the dynamics of attracted loans in the interbank market by bank B (three-dimensional space)

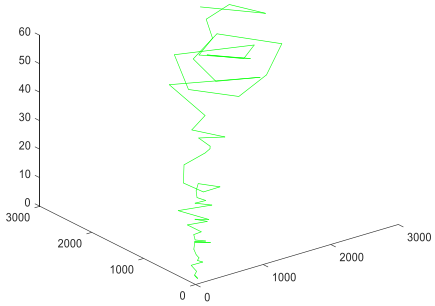

Figure 9: Phase portrait of the dynamics of attracted loans in the interbank market by bank C (three-dimensional space)

For example, Bank C is characterized by an increase in its activity in the interbank market in the last periods of time that we are considering.

Fig. 10 shows the dynamics of the volume of loans provided by bank C.

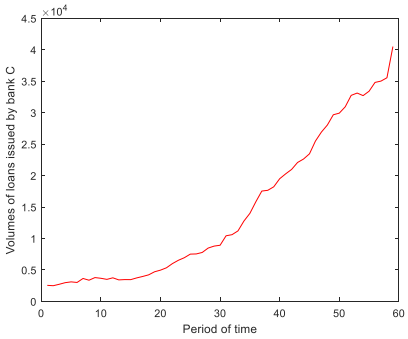

Figure 10: Dynamics of volumes of loans provided by bank C

Fig. 11 shows the dynamics of the volumes of attracted deposits by bank C.

Let's compare the data in Fig. 10 and Fig. 11 among themselves.

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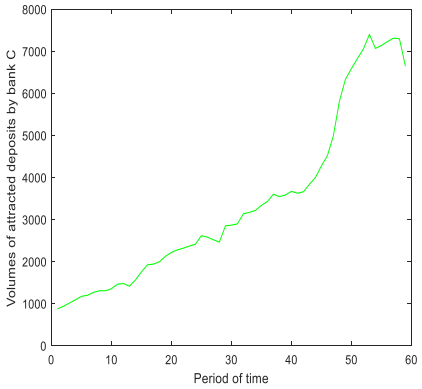

Figure 11: Dynamics of volumes of attracted deposits by bank C

We can observe approximately the same dynamics in terms of issued loans and attracted volumes of deposits in Bank C. Therefore, the phase portraits of such dependencies will be approximately the same (in accordance with formula 1). Therefore, we consider the corresponding phase portfolios, which are built using formula 5.

Fig. 12 shows a phase portrait of the dynamics of loans issued by bank C in accordance with formula 5.

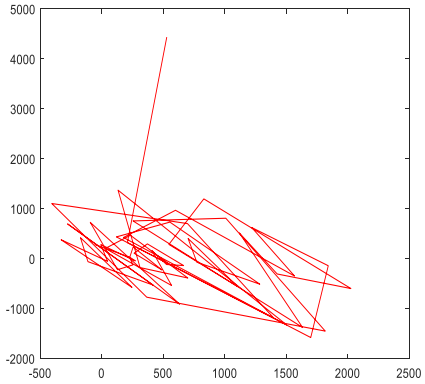

Figure 12: Phase portrait of the dynamics of loans issued by bank C in accordance with formula 5

Fig. 13 shows the phase portrait of the dynamics of attracted deposits in bank C in accordance with formula 5.

Note that these phase portraits are constructed in two-dimensional space.

We can observe a different display of phase portraits for the dynamics of the volumes of loans issued the volume of dynamics of attracted funds for Bank C. These phase portraits have a different direction and a different range of changes in the corresponding parameters.

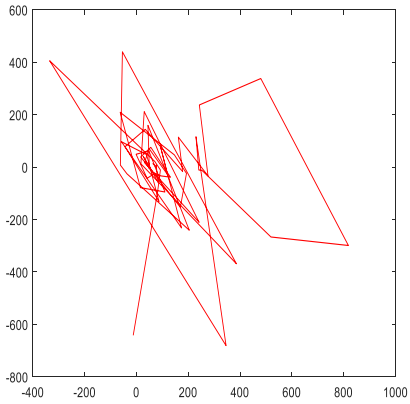

Figure 13: Phase portrait of the dynamics of attracted deposits in bank C in accordance with formula 5

It should be noted that phase portraits in three-dimensional space provide new information about the dynamics of banking activity, which we are considering. We can observe fluctuations in the speed and acceleration of changes in the volume of funds raised and loans issued.

5. Conclusion

The conducted study confirmed the feasibility and possibility of using the methods of nonlinear dynamics for the analysis of time series of data characterizing various aspects of banking activity. The basis for this definition is that unevenness, cyclicity is characteristic of dynamic economic systems, which include banks. Based on the method of nonlinear dynamics, defined by the concept of a phase portrait, the presence of cyclical changes in the time series of data from the point of view of various indicators of banks' performance is shown.

The paper shows the difference in time series of data that determine the dynamics of the volume of attracted loans in the interbank market. For this, phase portrait models in two-dimensional and three-dimensional spaces were used. In general, it should be noted that the analysis of phase portraits of various time data reveals the dynamics and specifics of the functioning of banks.

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