Wavelet Coherence as a Tool for Considering the Spatial Component of the Banking Activities Description

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***Abstract:** Banking activity, as a result of the functioning of the banking system, is one of the key directions in a market economy. Banking activities contribute to the attraction and redistribution of free financial resources between various participants in market relations. At the same time, the banking system is able to create conditions for the formation and accumulation of savings by the population. For the implementation of various areas of banking, both classical financial instruments and new mechanisms and approaches are used. The main (central) bank of the country provides the basis for the implementation of such directions, the possibility of using such various mechanisms and instruments for the implementation of various areas of banking activity. Control over the conduct of banking activities and, if necessary, appropriate regulation of such activities is also provided by the main (central) bank of the country. For this, various standards and indicators of the functioning of the banking system, individual banks, and areas of banking are considered. The analysis of such indicators and standards is a source of data for making appropriate decisions in the field of banking regulation. We are considering the possibility and feasibility of using the wavelet ideology for this type of analysis. We use the method of estimating wavelet coherence as a key tool for such an ideology. In this case, the object of research is a set of data for many different banks for a certain current date. This makes it possible to talk about the consideration of the spatial component of the description of banking activities. Using real data as an example, the paper presents various estimates of the wavelet coherence of the spatial component of the description of banking activities. Research results are presented in the form of graphs and diagrams. It is shown that the considered approach allows a deeper study of the relationships between the data that we are researching.*

Keywords—banking system; banking; wavelet coherence; spatial description; indicators; standards.

1. INTRODUCTION

The banking system is one of the key elements of market relationships. The banking system plays an important role in the formation of stable financial relationships between various business entities [1]-[5]. This is due to the fact that the banking system is able to accumulate and redistribute free financial resources.

At the same time, the banking system is an institutional association that is able to form and ensure the accumulation of savings for the population. The banking system is also capable of generating and servicing new financial instruments. Thus, the banking system is an element of the functioning and development of various business entities, the economy, the country [6]-[8]. This leads to practical interest on the part of researchers in solving various theoretical and practical issues of the functioning of the banking system. An important point of this analysis is also the study of the interaction and mutual influence of different elements of the banking system.

The banking system consists of a number of independent banks, among which the main bank of the country is also distinguished. The main bank of the country forms the rules for conducting banking activities regulates such activities and supervises compliance with the rules for the functioning of individual banks, the conditions for conducting their activities,

and the provision of banking services. Supervision and regulation of banking activities is carried out on the basis of a number of standards and performance indicators of banks [3], [6], [9]. These standards and indicators are the primary information that allows you to analyze banking activities, identify problem points, and form recommendations for regulating the activities of various banks [7], [10], [11]. Such standards and indicators can be viewed as time series. Moreover, such time series can reflect some dynamics of banking activities or characterize the activities of many banks at a certain current date. The presentation of the data is then critical to the choice of analysis methods.

Thus, the analysis is one of the tools for researching banking activities, the functioning of the banking system, the development of financial relationships between business entities and the economy as a whole. For such an analysis, various methods and approaches are used, which can be modified from the conditions of the research task. This makes it necessary to consider new methods and approaches for solving certain problems of analysis in the field of banking. An important point of such analysis is also data visualization. The visualization of the analysis results is also key in considering and selecting appropriate management decisions. This direction of research is the main one in this work and determines the choice of the corresponding main goal. To

achieve the main goal of the research, this work is structured accordingly.

2. MATERIALS AND METHODS

2.1 Related Work

For a clearer understanding of the problems of our research, we will briefly review the works of other authors. It should be noted that there are various areas of research and analysis of banking activities.

T. H. Ho, D. T. Nguyen, T. Ngo and T. D. Le use meta-regression analysis to analyze the efficiency of the Vietnamese banking system [12]. This analysis is based on dimensions of frontier efficiency. Thus, for their research, the authors use data coverage analysis (DEA) and stochastic frontier analysis (SFA) [12]. At the same time, meta-regression is estimated using truncated regression [12]. This approach allows the authors to explain the differences in the assessments of the efficiency of the Vietnamese banking sector, which were obtained by other researchers. In this case, the visualization of the results obtained is based on the multiple presentations of data in the form of tables.

The paper [13] examines the efficiency of the functioning of certain areas of banking based on machine learning methods. In particular, customer satisfaction and frustration with online banking were predicted by the authors based on machine learning techniques. For such an analysis, the authors of the study also used: logistic regression, Bayesian algorithm, support vector machine, neural network, K nearest neighbor algorithms [13]. The paper also discusses various methods for visualizing data and research results.

S. Daliri also used deep learning methods to detect problematic aspects of the functioning of the banking system [14]. In his research, S. Daliri uses an artificial neural network method and a harmony search algorithm to detect banking fraud. The proposed method searches for hidden patterns between the information of ordinary and fraudulent customers [14]. This approach expands the possibilities of analyzing banking activities, provides a basis for making appropriate management decisions.

M. Radwan and S. Drissi consider the functioning of the transmission mechanism of monetary policy to support various areas of banking [15]. For this, the authors use the tools of econometric analysis. This study is based on the use of the Vectoriel Autoregressive (VAR) model, which is not only explanatory but also predictive [15]. The authors also use a lot of statistical material, which makes this study meaningful and reliable.

S. R. Ahmad and M. N. Khan conduct an empirical comparative analysis of the efficiency of the Indian banking sector [16]. For this S. R. Ahmad and M. N. Khan consider both the Indian banking sector as a whole and the functioning of individual banks. As input data for the corresponding analysis S. R. Ahmad and M. N. Khan analyze the dynamics of deposits, assets and capital. The authors also take into account the efficiency of banking scaling to conduct an appropriate empirical comparative analysis.

R. Satutikirono and Y. Sunitiyoso use the scenario planning method to study the functioning and development of certain areas of banking [17]. The research is aimed at revealing the possibilities of the banking sector in the implementation of priority banking services. The disclosure of such a goal is achieved on the basis of an analysis of the driving forces that may affect the priority banking business [17]. As a result, the authors develop various scenarios, conditions for their use, the consequences of using such scenarios.

E. B. Susan, T. L. Okanda and S. A. Ndip conduct an empirical analysis of the impact of banking regulation on the availability of financial services [18]. The authors investigate this impact for different countries in the CEMAC region. This allows general conclusions to be drawn and reliable results obtained. The main element of the analysis is the sustainability of financial inclusion.

E. A. Durguti conducts a comparative analysis of banking activities in the eurozone countries [19]. The author analyzes various macro-financial and banking indicators. For this, various comparison approaches are used, which are based on the methods of statistical analysis. The main indicators for comparison were: assets, loans, deposits, overdue loans, interest rates. This allows for a comprehensive analysis of banking activities.

V. Druhova, O. Hirna and V. Fostyak use the factor analysis methodology to assess the impact of digital technologies on the development of the banking services sector [20]. The authors use factor analysis to determine the correlation between various variables, as well as retrospective analysis, which allow data to be analyzed taking into account the time factor [20].

There are also many works that use the ideology of wavelets for the analysis of banking activities [7], [21]-[23].

At the same time, in such works, as a rule, the classical approach of applying wavelet coherence to assess the relationship between the parameters being investigated is considered. This approach is based on the analysis of the temporal characteristics of the corresponding indicators.

However, an important point is also the assessment of banking at a certain point in time, when it is necessary to assess the relationship between individual banks.

2.2 Features of the Use of Wavelet Coherence when Considering the Spatial Component of the Banking Activities Description

The choice of wavelet ideology is due to the fact that banking can be described in the form of a certain time series $g(t)$. With the help of wavelet analysis, you can find the critical points for the time series that is being investigated [24], [25]. Thus, we get a set of new characteristics for the time series. The analysis of such points and their characteristics

allows us to conclude about the possibility of the development of processes in banking.

We can also explore the mutual dynamics of different time series that reflect different aspects in the banking industry. Such an analysis allows us to talk about the consistency or imbalance of various relevant aspects. For this analysis we use wavelet coherence [26]-[29].

We can use various data to calculate wavelet coherence in banking analysis. At the same time, we can consider not only the time factor. We can consider the serial number of a certain bank. Then we can conduct an analysis of banking activities for a specific date. To do this, we consider a dataset for different objects on the same date. In this case, we can consider more than two data series. The first row of data serves as the basis for ranking our objects. The other two data series are used to calculate the wavelet coherence. Then the classical relation for estimating the wavelet coherence can be written as follows:

$$P^2(g,g_2) = \frac{\left|\Pi(g_2^{-1}\Omega_{xy}^u(g,g_2))\right|}{\Pi(g_2^{-1}\left|\Omega_x^u(g,g_2)\right|^2)\Pi(g_2^{-1}\left|\Omega_y^u(g,g_2)\right|^2)} ,$$

$\Omega(g,g_2)$ – is a values of cross wavelet spectra;

$P^2(g,g_2)$ – the squared wavelet coherency coefficient for data series u , g and g_2 ;

x, y – is a scale and center of time localization, that determine the scale of the wavelet transform;

Π – is a smoothing operator;

u – data series for ranking the objects under study;

g and g_2 – data series for constructing wavelet coherence;

$0 \le P^2(g,g_2) \le 1$. If these values tend to zero, then we have a weak correlation. Otherwise, we have a strong correlation [30]-[32].

2.3 Data for Analysis

For the appropriate analysis, we have selected data that characterize the development of the banking system in Ukraine. These are data on loans to business entities, deposits attracted, banks' equity and administrative costs of banks. All data are presented as of 01.01.2006, 01.01.2008, 01.01.2010 and 01.01.2012. Data from the website – https://bank.gov.ua.

The figures below show some of the data we are examining.
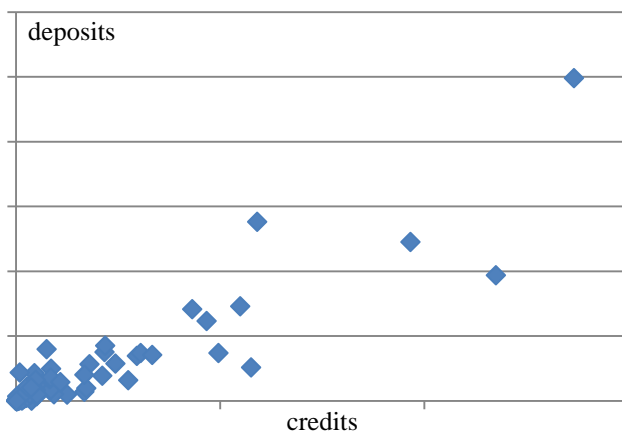
In fig. 1 shows the relationship between loans issued to business entities and deposits attracted in the banking system of Ukraine as of 01.01.2006.
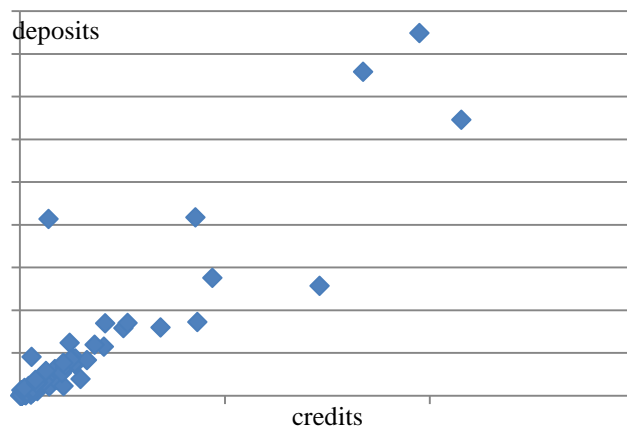
Figure 1: The relationship between loans issued to business entities and deposits attracted in the banking system of Ukraine as of 01.01.2006

We see that there are different groups of banks that have different volumes of loans issued and attracted funds. Therefore, it is important to analyze the overall dynamics of indicators of banking activities on a specific date. Such an analysis can characterize the general trends in the functioning and development of banking and the banking system.
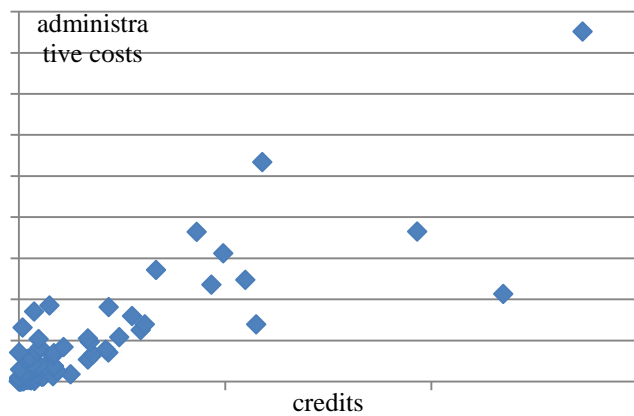
In fig. 2 shows the relationship between loans issued to business entities and deposits attracted in the banking system of Ukraine as of 01.01.2010.

Figure 2: The relationship between loans issued to business entities and deposits attracted in the banking system of Ukraine as of 01.01.2010

We see that over time, the overall dynamics of the volume of loans issued and attracted funds is transforming. However, the presented data do not answer the question of how the corresponding transformation takes place.

In fig. 3 shows the relationship between loans issued to business entities and the administrative costs of individual banks in the banking system of Ukraine as of 01.01.2010.
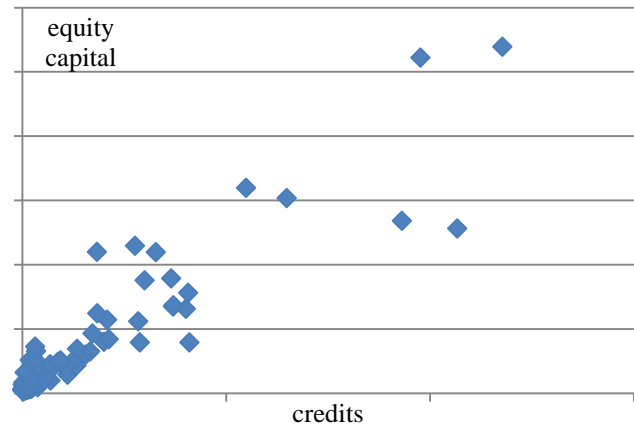

Figure 3: The relationship between loans issued to business entities and the administrative costs of individual banks in the banking system of Ukraine as of 01.01.2010

We see that administrative costs affect the volume of loans issued. A similar conclusion can be drawn based on the data in fig. 4, which shows the relationship between loans issued to business entities and the administrative costs of individual banks in the banking system of Ukraine as of 01.01.2006 (see in comparison with fig. 1).
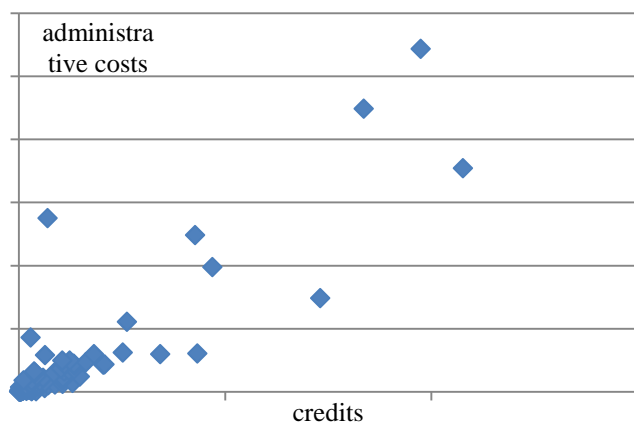
Figure 4: The relationship between loans issued to business entities and the administrative costs of individual banks in the banking system of Ukraine as of 01.01.2006
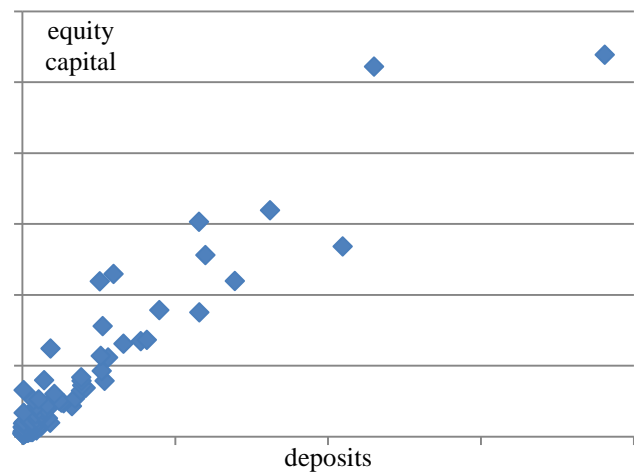
We also consider the impact of a bank's equity capital on the ability to carry out banking activities.

In fig. 5 shows the relationship between loans issued to business entities and the amount of equity capital of individual banks in the banking system of Ukraine as of 01.01.2008.

Figure 5: The relationship between loans issued to business entities and the amount of equity capital of individual banks in the banking system of Ukraine as of 01.01.2008
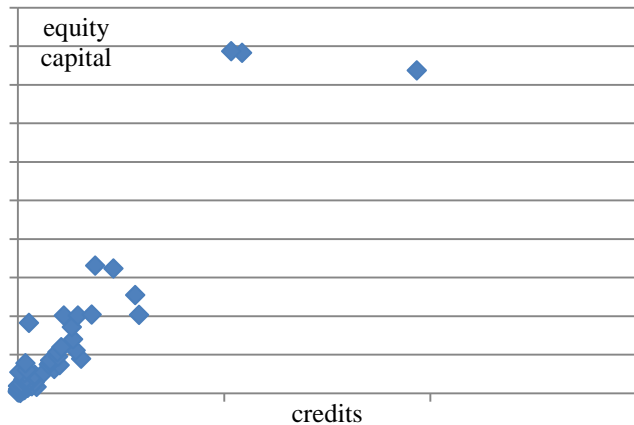
In fig. 6 shows the relationship between the volume of attracted deposits and the volume of equity capital of individual banks in the banking system of Ukraine as of 01.01.2008.

Figure 6: Relationship between the volume of attracted deposits and the volume of equity capital of individual banks in the banking system of Ukraine as of 01.01.2008

We can observe some differences between Fig. 5 and fig. 6. This is evidence that the volume of the bank's equity capital has a different effect on the volume of attracted deposits and the volume of loans issued.

In fig. 7 shows the relationship between loans issued to business entities and the amount of equity capital of individual banks in the banking system of Ukraine as of 01.01.2012.

Figure 7: The relationship between loans issued to business entities and the amount of equity capital of individual banks in the banking system of Ukraine as of 01.01.2012

In fig. 8 shows the relationship between the volume of attracted deposits and the volume of equity capital of individual banks in the banking system of Ukraine as of 01.01.2012.
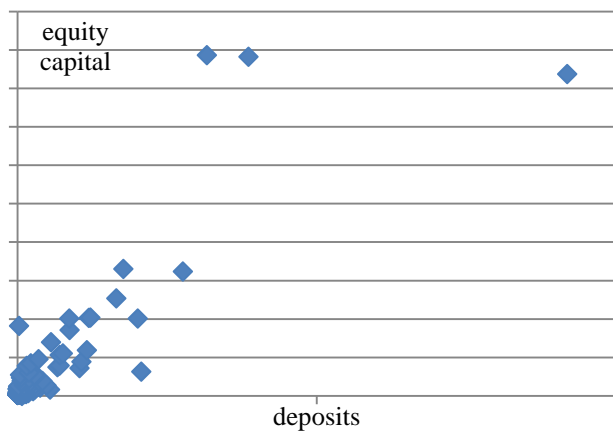

Figure 8: Relationship between the volume of attracted deposits and the volume of equity capital of individual banks in the banking system of Ukraine as of 01.01.2012

Fig. 7 and fig. 8 differ from the data in fig. 5 and fig. 6. Thus, the issue of analyzing the spatial component of banking remains relevant.

## 3. SOME ESTIMATES OF THE SPATIAL COMPONENT OF THE BANKING ACTIVITIES DESCRIPTION

In fig. 9 - fig. 12 presents a spatial assessment of the wavelet coherence between the volume of issued loans and attracted deposits in relation to the volume of administrative costs, taking into account different periods of time.
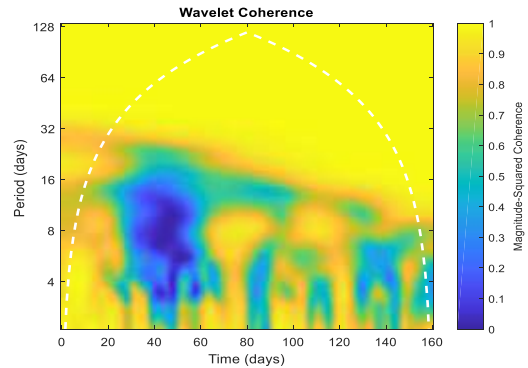
Figure 9: Spatial assessment of the wavelet coherence between the volumes of issued loans and attracted deposits relative to the volume of administrative costs as of 01.01.2006
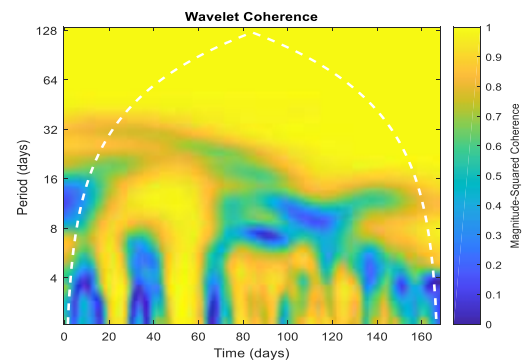
Figure 10: Spatial assessment of the wavelet coherence between the volumes of issued loans and attracted deposits relative to the volume of administrative costs as of 01.01.2008
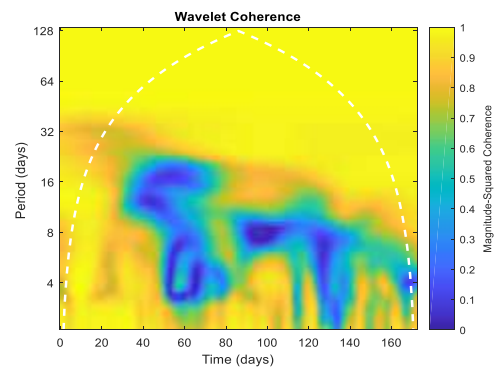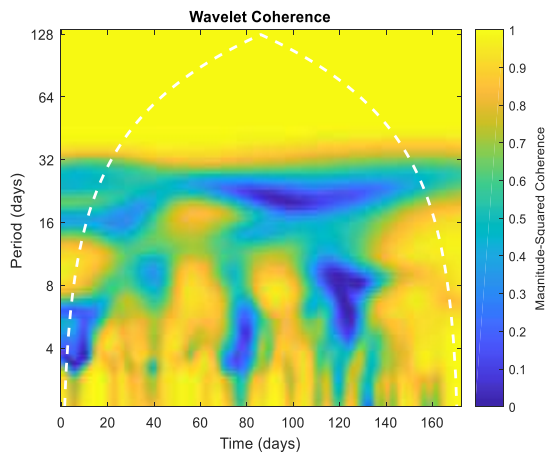

Figure 11: Spatial assessment of the wavelet coherence between the volumes of issued loans and attracted deposits relative to the volume of administrative costs as of 01.01.2010

We note the fragmentation of the corresponding assessment. At the same time, we can talk about the stability of such an assessment. This indicates the presence of a close relationship between individual banks in the banking system of Ukraine, the effectiveness of banking regulation. It should

also be noted that the value of such an estimate increases over the investigated time interval.
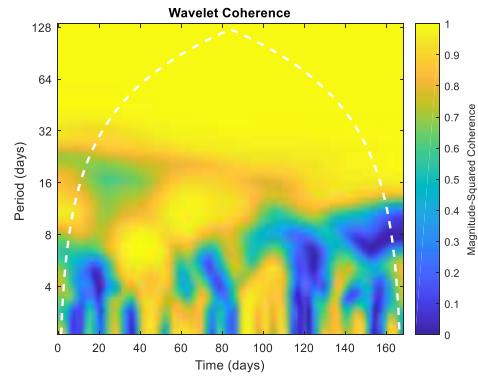

Figure 12: Spatial assessment of the wavelet coherence between the volumes of issued loans and attracted deposits relative to the volume of administrative costs as of 01.01.2012

In fig. 13 - fig. 16 presents a spatial assessment of the wavelet coherence between the volume of issued loans and attracted deposits relative to the volume of banks' equity capital, taking into account different periods of time.
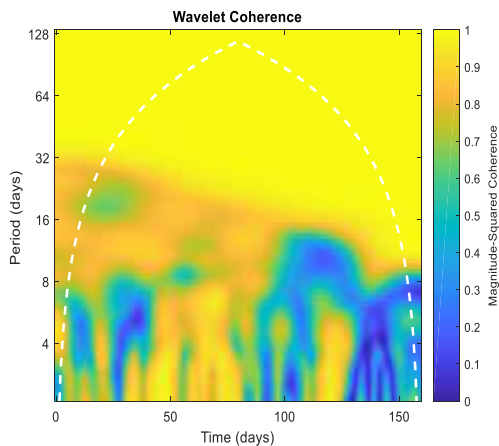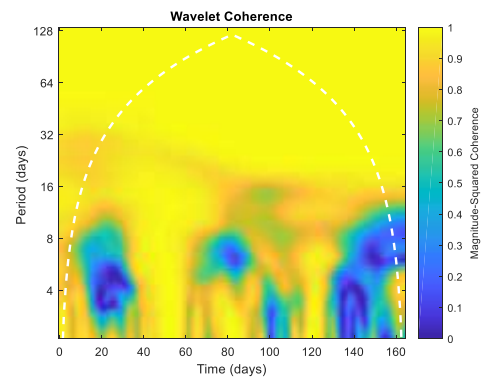

Figure 13: Spatial assessment of the wavelet coherence between the volumes of issued loans and attracted deposits relative to the volume of banks' equity capital as of 01.01.2006

It should be noted that this estimate differs from the previous estimate. Thus, we can observe a different degree of influence of administrative costs and volumes of equity capital on the dynamics of loans issued and attracted deposits.

Figure 14: Spatial assessment of the wavelet coherence between the volumes of issued loans and attracted deposits relative to the volume of banks' equity capital as of 01.01.2008

Figure 15: Spatial assessment of the wavelet coherence between the volumes of issued loans and attracted deposits relative to the volume of banks' equity capital as of 01.01.2010
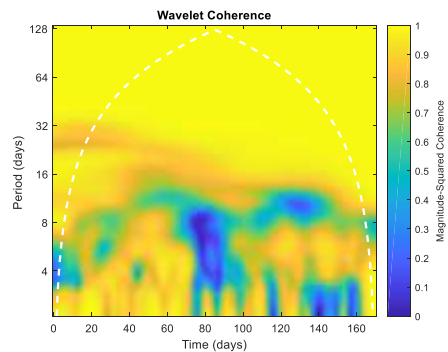
Figure 16: Spatial assessment of the wavelet coherence between the volumes of issued loans and attracted deposits relative to the volume of banks' equity capital as of 01.01.2012

Thus, we have shown the feasibility of using the assessment of wavelet coherence for the analysis of the spatial component of the banking activities description.

4. CONCLUSION

The paper deals with the assessment and analysis of the spatial component of the banking activities description. It is proposed to make such an assessment based on the wavelet analysis. The main tool for such analysis is the assessment of wavelet coherence.

This work is a continuation of our early work on assessing the spatial component of the banking activities description. At the same time, in this work, the initial data for the corresponding analysis are presented more fully. We have also provided a brief overview of related work on the research topic. This served as a rationale for the possibility and feasibility of using wavelet coherence for the analysis of the spatial component of the banking activities description.

All data and results are presented in the form of clear visual information. This makes the results easier to understand.

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