Vasiurenko, Oleh; Lyashenko, Viacheslav

Article

Wavelet coherence as a tool for retrospective analysis of bank activities

Economy and forecasting

Reference: Vasiurenko, Oleh/Lyashenko, Viacheslav (2020). Wavelet coherence as a tool for retrospective analysis of bank activities. In: Economy and forecasting (2), S. 32 - 44.
http://econ-forecast.org.ua/?page_id=189&lang=uk&year=2020&issueno=2&begin_page=32&mode=get_art&flang=en.
doi:10.15407/econforecast2020.02.032.

https://doi.org/10.15407/ econforecast2020.02.032
JEL: C33, C55, C65, G21

***O. Vasiurenko*[1]**
***V. Lyashenko*[2]**

WAVELET COHERENCE AS A TOOL FOR RETROSPECTIVE ANALYSIS OF BANK ACTIVITIES

The article considers the possibility and expediency of using the apparatus of the theory of wavelets to conduct analysis of banking activities. The authors determine separate stages of the complex application of various tools on the theory of wavelets to analyze the activities of banks based on retrospective data. Among these stages are: decomposition of the initial data by their approximating coefficients and coefficients of detail, and the use of wavelet coherence.

Indicated the importance of conducting a retrospective analysis to reveal hidden relationships in the data structure that determine certain aspects of banking. The advantages of using the tools of the theory of wavelets from the point of view of analyzing the activities of banks based on their statistical data are highlighted. Among these advantages, the authors highlight the possibility of studying the relationships between data over time and determining the depth of such relationships. It is noted that this can be done in one research window.

Particular attention is focused on the analysis of the reciprocity between the volume of funds in deposit accounts and the volume of loans granted, as one of the key parameters for conducting banking activities. The reciprocity between the volumes of funds in deposit accounts and the volumes of loans granted is revealed in accordance with the volumes of administrative expenses and equity of banks. It is noted that retrospective analysis allows us to identify the consequences of the onset of unwanted events and prevent them in the future.

To carry out a corresponding analysis, the content of constructing a description of spatial wavelet coherence is disclosed. Such a description makes it possible to take into account a larger number of parameters than classical approaches for calculating wavelet coherence. This expands the boundaries of the relevant analysis, allows you to explore various mutual influences between individual banks in terms of their individual indicators for banking activities. Such an analysis allows to determine not only the

[1] **Vasiurenko, Oleh Volodymyrovych** – Professor, Dr. Habil. (Economics), Vice-Rector on Economics, PVNZ "Kyiv Institute of Business and Technology" (1/5, Zorianyj Alley, Kyiv, Ukraine, 04078), ORCID: 0000-0003-3225-0744, e-mail: vasiurenkooleg66@gmail.com
[2] **Lyashenko, Viacheslav Viktorovych** – Head of the laboratory "Transfer of information technologies in quick-release systems", Kharkiv National University of Radio Electronics (14, Nauky Av., Kharkiv, Ukraine), ORCID: 0000-0001-5455-5026,
e-mail: lyashenko.vyacheslav@gmail.com

reciprocity between individual indicators of banking activity, but also the depth of influence between individual banks, taking into account such indicators of their activity. Concrete examples are given that prove the feasibility and likelihood of applying the proposed approaches to the analysis of banking activities.

Keywords: *wavelet coherence, banking, time series, deposits, loans, administrative expenses, equity*

The banking system is one of the key elements in the formation of a market economy and in the effectiveness of financial market. In addition, it defines one of the classic models of the financial market (bank based financial system), primarily focused on bank financing. Due to historical circumstances and a number of objective factors, this model is more characteristic for market relations in Ukraine [1, 2]. In particular, this explains the painful transformations that took place in the banking system of Ukraine in recent years. Thus, any aspects of the functioning and development of the banking system are important and relevant - either in terms of understanding the sustainability and efficiency of banking in particular, or in terms of the formation of foundations of Ukraine's financial market and economic development.

Interaction between all components of the banking system - the central bank, which forms the principles and requirements of legal regulation of banking activities in accordance with the needs of the economy and the functioning of various economic entities, controls compliance with such principles and requirements via an ongoing monitoring of established key indicators; and commercial banks that ensure and support economic cooperation between individual businesses, households, and the government in the financial sector (in particular, the relationship between commercial banks), - ensures the sustainability of banking, effectiveness of the banking system and national economic development. Finally, the above reasoning determines the need to consider banking activities in general terms and make their retrospective assessment, which, in our opinion, is crucial. In this case, a more detailed analysis of possible errors is possible, preventing their occurrence in the future via building an adequate forecast model. This is also important for ensuring economic security and proper management of banks, the banking system, etc., which as a result determines the so-called processes of economic dynamics.

In order to generalize and reveal certain aspects of banking, different approaches, methods, and theories are used. Among such approaches, methods and theories are: fuzzy set theory [3], probability theory [4], methods of analysis using neural networks [5], methods of statistical analysis [6], and wavelet analysis [7, 8].

However, the processes that generalize the essence of banking activities occur due to a number of factors, which are characterized by variability and volatility, which requires the use of separate approaches to their interpretation. In addition, the availability of different analytical tools allows an in-depth analysis. Therefore, the question of identifying new approaches to the analysis of banking does not lose relevance.

Therefore, the authors choose as the purpose of this study generalization of banking activities based on retrospective data, which, in our opinion, involves the use of so-called wavelet coherence and determination, on this basis of the occurrence of adverse events and prevention of their consequences.

Description of banking activities in the form of a set of time series

Banking activities are generalized with a set of various indicators (such as individual regulatory indicators of banking, the amount of funds raised on deposit accounts, the volume of loans by individual economic sectors, interest on loans, etc.), characteristic of particular types of banking activities taking place in certain time intervals. Thus, with the help of time series, we can provide a spatio-temporal description of banking activities.

From the point of view of the time component, in general, a formalized description of banking is defined as a set of individual time series:

$$OBT = \{f_1(t), f_2(t), \ldots, f_n(t)\}, \quad (1)$$

where OBT is the generalized formalized description of banking activities in terms of generalized definition of its time component in the form of individual time series;

$f_1(t), f_2(t), \ldots, f_n(t)$ are individual time series that determine the content of banking activities during some time $t = \overline{0, s}$ with certain indicators, such as 1 - the amount of funds on the households' deposit accounts, 2 - the amount of loans granted, etc. (a total of n indicators for banking activities).

In this case, according to the formalized description of expression (1), we can consider individual descriptions of banking activities either in terms of a certain group of banks (as a separate element of the banking system) or in terms of a separate bank. This provides an opportunity to investigate different aspects of economic dynamics, as we can consider economic dynamics for a single bank, group of banks or the banking system as a whole. In particular, the formalized description of banking activity in accordance with expression (1) allows to study the current dynamics of development of banks (bank) and to determine the retrospective of the variability of relevant indicators, and their interaction or impact on some final result. This approach is traditional in researches on the current analysis of banks, in relevant activities in certain areas and in determining the conditions for further operation of banks, and development of banking activities. As an example of research where data are defined as certain time series, we can cite a number of works [2, 9, 10].

At the same time, we can also consider a spatial description of banking activities based on relevant time series. In this case, a formalized description of banking activities can be presented, for example, as follows:

$$OBP = g_n^T(P_1, P_2, \ldots, P_c), \quad (2)$$

where *OBP* is a generalized formalized description of banking activities in accordance with the definition of the spatial component of its generalization in the form of time series;

and $g_n^T(\ldots)$ is a spatial description of a separate set of banks $(P_1, P_2, \ldots, P_c)$ for a certain indicator of banks *n* for a certain date *T* from the studied period of time $t = \overline{0, s}$.

Then, having a set of spatial descriptions of banks $(P_1, P_2, \ldots, P_c)$ based on individual indicators of their activities $(1, 2, \ldots, n)$, we can generalize a formalized description of banking activities in accordance with the definition of the spatial component for a given date *T* as:

$$\{g_1^T(P_1, P_2, \ldots, P_c), g_2^T(P_1, P_2, \ldots, P_c), \ldots, g_n^T(P_1, P_2, \ldots, P_c)\}, \quad (3)$$

or for different dates $(T_0, T_1, \ldots, T_s)$ from the selected time period $t = \overline{0, s}$. for a separate indicator of banking activity n as:

$$\{g_n^{T0}(P_1, P_2, \ldots, P_c), g_n^{T1}(P_1, P_2, \ldots, P_c), \ldots, g_n^{Ts}(P_1, P_2, \ldots, P_c)\}. \quad (4)$$

Formalized description of banking activities in accordance with expressions (2–4) first of all helps determine the interactions between different banks based on the description of the relevant activities by individual indicators. This analysis allows both ranking a certain group of banks by individual indicators of banking activities, and identifying how this affects the relationship. An example of research based on a formalized description of banking activities in accordance with the spatial component of such generalization in the form of time series, we can call the method of stochastic marginal analysis [11, 12].

Thus, the display of banking activities in the form of a set of time series is a wide spread approach that allows an appropriate analysis with the use of traditional and classical approaches. However, such analysis usually reveals mostly the existing relationships between the studied parameters, which somewhat narrows the decision-making base. Moreover, in each case, for statistical analysis it is necessary to generate a separate data set. Therefore, the conclusions consist of various research windows, each of which is responsible for its own data interval. However, it is important to summarize and define such conclusions in one research window, taking into account possible changes in the mutual influences between the selected data over time. To do this, it seems advisable to use the so-called wavelet methodology, which proved successful in researching the context of different economic data [7, 8, 13].

Wavelet coherence as a component of wavelet analysis

In general, the methodology of data analysis based on the use of wavelets involves application of various specialized functions to data series, which by their characteristics should be defined as time series data. The key one among such features is a clearly defined interval (step) of sequential data selection to form a corresponding series. However, the definition of such an interval (step) may be different [14] - it can be a time step (year, month, week, day, etc.) or, for example, a certain ranking of data in accordance with a selected scale (while a data selection step can be considered the location of these data according to the ranking, where such a step indicates the number of positions by which such data differ).

As specialized functions for wavelet analysis, the so-called wavelet transform functions are considered, which make it possible to convert the primary data series into a set of several series in the form of approximating coefficients and detalizing coefficients. Among such functions are:

– the function of the parent wavelet $\varphi\ (t)$, which reveals the details of the studied data and the so-called detalizing coefficients;

– scaling function $\phi\ (t)$, which determines the so-called approximation coefficients and allows creating a data series, which is smaller, but close to the primary one. This helps speed up the processing time of the primary data and obtain initial approximate results.

Then a continuous wavelet transform for a certain time series $f(t) \in L^2(R)$ on the time interval t has the following formalized form [14, 15]:

$$W_f(u,s) = \int_{-\infty}^{+\infty} f(t) \frac{1}{\sqrt{s}} \varphi(\frac{t-u}{s}), \quad (5)$$

where reflects the normalization of data;

u is the parameter of the location of the time series element;

s is the scale parameter;

$$\int_{-\infty}^{\infty} \varphi(t)dt = 0. \quad (6)$$

And the primary data series $f(t)$ can be represented as a set of individual series $f^i(t)$ of its N decompositions by approximating coefficients *(apr)* and detalizing coefficients *(det)* [14, 15]:

$$f(t) = \sum_{i=1}^{N} f^i(t), \quad (7)$$

$$f^N(t) = apr^N(N)\phi(t) + det^N(N)\varphi(t), \quad (8)$$

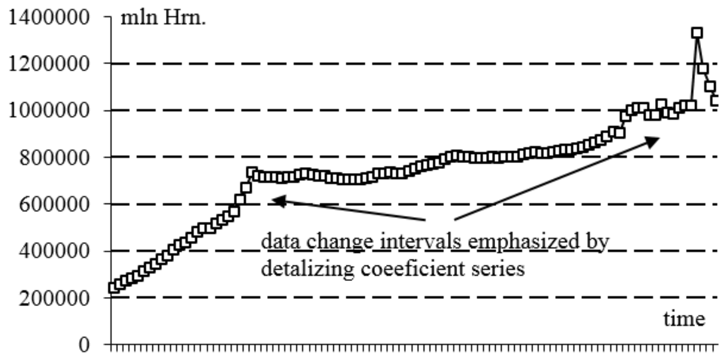
$$apr = \int_{-\infty}^{+\infty} f(t)\phi(t)dt, \quad (9)$$

$$det = \int_{-\infty}^{+\infty} f(t)\varphi(t)dt, \quad (10)$$

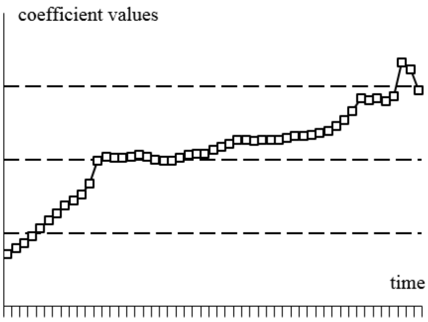
$$\int_{-\infty}^{\infty} \phi(t)dt = 1. \quad (11)$$

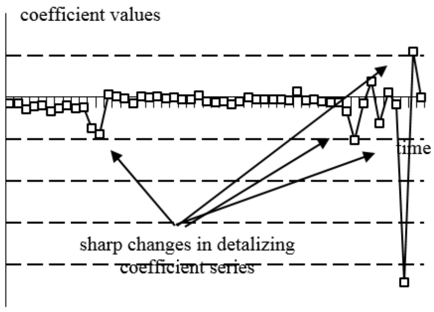
Thus, the wavelet transform allows constructing a hierarchical structure of the input investigated time series *f (t)*. As a result, you can find the most important (characteristic) points of the investigated primary time series. Therefore, it is possible to obtain a set of new characteristics for the primary data series. As a result, such a transformation facilitates a more detailed analysis of primary data, and makes it possible to reveal hidden trends. This is how the methods of wavelet theory differ from classical approaches. This is due to the fact that information flows generated by time series have fractal properties, which recognizes wavelet transforms and allows greater information [14]. In particular, the breakdown of primary data series into its individual components (approximation and detalizing coefficients) allows a more thorough and detailed study of trends in the initial data series (due to detalizing coefficients) and reduces processing time of input information (by determining the hierarchical structure of the primary series whose structural elements are much smaller, but similar to the primary data series).

As an example of a wavelet transform, Fig. 1a shows a primary data series that reflects the dynamics of loans to Ukraine's economy in 2007-2015, Fig. 1b - the dynamics of the approximating coefficients, and Fig. 1c - the dynamics of detalizing coefficients of the first level of decomposition of the primary data series in Fig. 1a (the wavelet transform was performed using the parent Deboche-1 wavelet. This wavelet is classic in the study of time series of data related to the description of economic dynamics).



a) Dynamics of the volume of loans granted to the economy of Ukraine in 2007-2015 in their monthly calculation





b) Approximating coefficients c) Detalizing coefficients

Fig. 1. Dynamics of the volumes of loans granted to Ukraine's economy in 2007–2015 in their monthly calculation and their wavelet transform in the form of approximating coefficients and detalizing coefficients

Source: constructed by the authors: 1a – based on https://bank.gov.ua/statistic, 1b and 1c – own calculations.

We see that the dynamics of the series in Fig. 1a and Fig. 1b coincides. At the same time, the series with data from Fig. 1b is much smaller than the primary data series in Fig. 1a (according to the general provisions of wavelet transform, the number of values of the series of approximating and detalizing coefficients compared to the primary series is halved [14]). Therefore, the time of further analysis and processing of relevant data can be significantly reduced, which is important for operational decision making. In addition, according to Fig. 1c, one can observed sharp changes in the above series of detalizing coefficients. These changes are a subject of a more detailed analysis with their implementation on the primary series in order to understand processes of the analysis of the relevant economic dynamics (volumes of granted loans) and the time of their occurrence, that is, their duration. Thus, wavelet transform is a simple and thorough tool for analyzing relevant data.

However, wavelet analysis can be performed with the use of more sophisticated tools, such as wavelet coherence, which measures the local correlation of two time series in the time-frequency area based on the analysis of cross-links between the investigated series. This allows us to analyze the mutual dynamics of different time series of data and their influence on each other. Therefore, it can be either a mutual agreement or a mutual inconsistency between the investigated data series. It should be noted that:

– we can analyze data over time and make appropriate conclusions. At the same time, we can choose a significant time interval, and all decisions before the relevant analysis will be displayed in one research window. Thus, it is possible to observe variability of certain trends and perform an appropriate analysis;

– at the same time (according to the analysis of time changes), it is also possible to define the depth of the existing relationships between the investigated data. The classical approaches in this case involve the use of various methods. In our case, the measurement of wavelet coherence makes it possible to obtain results in different areas of research and analyze them. Thus, we receive additional and very important information on how certain trends change, as well as on their duration and impact in future periods.

For a proper investigation and measurement of wavelet coherence, the following expression is used [16]:

$$R^2(f_1, f_2) = \frac{\left|\Pi\left({f_2}^{-1}\Omega_{xy}(f_1,f_2)\right)\right|}{\Pi\left({f_2}^{-1}|\Omega_x(f_1,f_2)|^2\right)\Pi\left({f_2}^{-1}|\Omega_y(f_1,f_2)|^2\right)}, \quad (12)$$

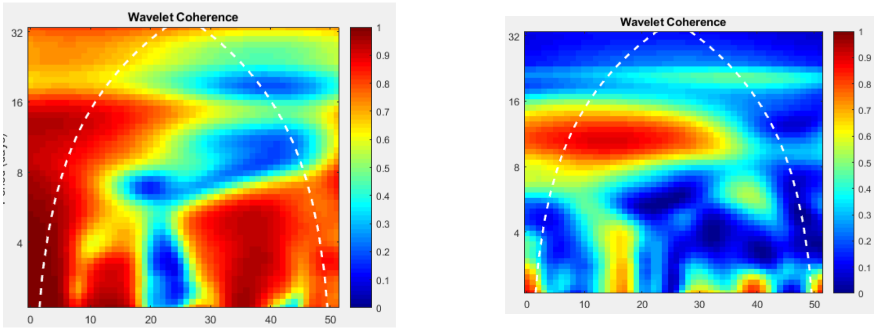
where $R^2(f_1, f_2)$ is a formalized description of the calculation of wavelet coherence in the form of a square of the absolute value of smoothed cross-wavelet spectra, normalized to multiplicative determination of the smoothed individual wavelet spectra of the power of each data series. $0 \leq R^2(f_1, f_2) \leq 1$;

$\Omega_{xy}(f_1, f_2)$ - cross-wavelet spectrum for individual time series $f_1(t)$ and $f_2(t)$ by time (x-axis) and frequency (y-axis);

and Π is the smoothing operator.

To implement the description of the calculation of wavelet coherence, the Morlet wavelet is used, which has a good frequency-time localization in the investigation of consistency between individual data series.

Fig. 2 shows, an example, two separate descriptions of wavelet coherence between time series of the data that determine the amount of funds attracted to deposit accounts and the total loans in the domestic banking system (Fig. 2a) and the spread between interest rates on loans and deposits (basis points) and the spread between the highest and lowest interbank rates (basis points) in the entire domestic banking system (Fig. 2b) in 2006-2018 by quarters. This choice of indicators for the analysis of banking activities is common in most existing studies, because they are traditional indicators of such activities. However, it should be noted that these data (as well as those that will be considered as examples) allow comparison between the results obtained using the classical approaches to banking analysis, with those obtained using the proposed approaches based on wavelet theory. This can serve as a confirmation of the soundness and reliability of the results obtained using approaches based on the methods of wavelet theory.



a) b)

Fig. 2. Example of a description of wavelet coherence between individual time series, which characterize the effectiveness of Ukrainian banking system

Source: own calculations based on https://bank.gov.ua/statistic

In the first case, the analysis of the interdependence between the amount of resources attracted to deposit accounts and the amount of loans can be considered as the efficiency of the relevant areas of banking and the use of available resources. In the second case, the spread between interest rates on loans and deposits (basis points) and the spread between the highest and lowest interbank rates (basis points) characterizes the existing conditions of banking in accordance with the consistency of interest rates with the existing market conditions.

Also, note that Fig. 2 generally displays [17]:

– along the abscissa axis - time parameters of the analyzed data series, which define the numbers of individual time measurements from the investigated sequence in the period from 2006 to 2018 by individual quarters. In total, we have 52 such measurements. According to the above, the abscissa axis allows analyzing the relationship between data over time,

– along the ordinate axis - a weighted characteristic of the wavelet coefficients of the analyzed series in time-frequency space, where each unit of measurement indicates the depth of the relationship between the investigated data series. That is, the data from the y-axis makes it possible to analyze the depth of their relationship to the corresponding data on the abscissa axis in certain time intervals,

– the figure field shows numerical values of the description of wavelet coherence between individual time series presented as colored values. These color values are presented according to the significance scale located to the right of each figure. The values of wavelet coherence are within the range from 0 to 1. Some areas represent the localization of consistency (the value of wavelet coherence goes to 1) or inconsistency (the value of wavelet coherence goes to 0) of the investigated series,

– the dashed white line limits the range of reliable values of wavelet coherence (with confidence level no less than 0.95. Thus, we have statistical parameters indicating the reliability of the results). These wavelet coherence values are inside the dashed line.

Therefore, from the data of Fig. 2a it follows that it is impossible to speak of a full consistency between the amount of funds attracted to deposit accounts and the amount of granted loans in the context of the Ukrainian banking system as a whole. That is, the data of Fig. 2a show that there are both periods when such data series were consistent (this is typical for 2006–2010 and 2013–2018) and periods when such data series were inconsistent (2011–

2012). At the same time, we can note that such consistency was mainly observed for those cross-links between the investigated series, which have a smaller depth of interconnection (see Fig. 2a on the ordinate axis. This is clearly seen for the data of 2013-2018.). Therefore, one can state that in the long run the volume of resources sufficient to maintain consistency between the amounts of borrowed funds on deposit accounts and the amounts of loans granted in the entire Ukraine's banking system is declining. Therefore, it becomes a factor that restricts the expanded lending to the economy.

At the same time, the data of Fig. 2b show a lack of general consistency in the relationship of the spread between interest rates on loans and deposits and the spread between the highest and lowest interbank rates in the entire Ukraine's banking system. Moreover, it should be emphasized that such consistency is fragmentary. Therefore, we can speak about a violation of the key principles of banking as to the consistency of fixed interest rates as one of the conditions for their formation under the influence of market factors.

As noted above, we can also consider time series of data in the form of their spatial features in accordance with the formalized description in expressions (2-4). Accordingly, it is possible to transform the methodology of implementing wavelet coherence. So let us look into this issue in more detail.

Wavelet coherence when considering the spatial component of the description of banking activities in the form of time series

First of all, let us note that the main condition for applying the wavelet methodology is to implement the procedure of sequential data selection for the formation of corresponding data series, where the key issue is to consider the constant step between the individual elements of such a series. If we speak about the introduction of a spatial description of the time series, then it is worth noting first of all expressions (2) and (3). Then to form the corresponding data series, one can use the number of a particular bank from the total bank list. That is, we will use the number of a particular bank when compiling the description of wavelet coherence on the abscissa. Thus, such number is generated owing to ranking of set of banks according to the set task of research. The ordinate axis in this case shows the depth of the relationships between the banks, which are investigated in their spatial description in the form of time series.

The corresponding description of wavelet coherence in terms of spatial description of banking activities in the form of time series is wavelet coherence, which determines the relationship of objects investigated at a given point in time. This approach allows us to analyze the interaction, during banking activities, between individual banks, which is extremely important for development dynamics of both individual banks and the banking system as a whole. It should be noted that this approach expands the scope of the relevant analysis and provides it with new tools (because we can consider any combination of indicators of banking activities in the context of the economic task of such analysis).

Therefore, let us consider a certain set of spatial time series $(g_1(\ldots), g_2(\ldots), g_3(\ldots))$ for certain date T for a set of banks $(P_1, P_2, \ldots, P_c)$. To construct a description of spatial wavelet coherence, it suffices to consider three time series $g_n(\ldots)$. That is, one of these series will be the basis for the banks' ranking, and the other two are used to construct a description of the spatial wavelet coherence. In this context, expression (12) takes the following form:

$$P_{g_3}^2(g_1, g_2) = \frac{\left|\Pi(g_2^{-1}\Omega_{xy}^{g_3}(g_1,g_2))\right|}{\Pi(g_2^{-1}\left|\Omega_x^{g_3}(g_1,g_2)\right|^2)\Pi(g_2^{-1}\left|\Omega_y^{g_3}(g_1,g_2)\right|^2)}, \quad (13)$$

where: $P_{g_3}^2(g_1, g_2)$ is a formalized description of the calculation of spatial wavelet coherence in the form of a square of the absolute value of the smoothed cross-wavelet-spectra, normalized to the multiplicative determination of the smoothed individual wavelet power spectra for each data series. $0 \leq R^2(f_1, f_2) \leq 1$;

$\Omega_{xy}^{g_3}(g_1, g_2)$– cross-wavelet spectrum for individual time series $g_1(\dots)$ та $g_2(\dots)$ by time (along axis X) and by frequency (depth of the relationship between individual banks) - (along axis y);

$g_3(\dots)$ is a time series for ranking the investigated banks in the spatial description of banking activities;

and Π is the smoothing operator.

The general procedure for the formation of a spatial description of wavelet coherence for the analysis of banking activities is as follows.

The first step: the research task is formulated and separate data time series are selected $(g_1(\dots), g_2(\dots), g_3(\dots))$.

The second step: determined a time series for ranking the investigated banks.

The third step: according to the ranking with the selected time series, the other two spatial time series of data are streamlined. Also, the records with negative or zero values for any indicators of banking performance are deleted: we remove those records that introduce a clear imbalance in the banking process. Therefore, we are of the opinion that it is necessary to analyze more stable banking institutions and identify hidden factors of inconsistency in the movement of the bank's financial flows, which are determined by the relevant data of time series for individual indicators

The fourth step: individual time intervals T are selected and spatial description of wavelet coherence for such time intervals is calculated.

The fifth step: a comparative analysis of the calculated descriptions of spatial wavelet coherence is performed and conclusions are formulated.

In general, this approach allows:

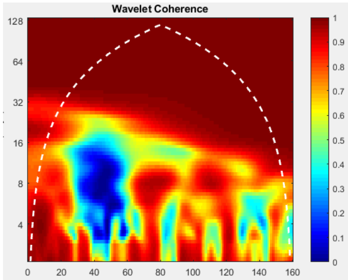
– analyzing mutual influence between individual banks, taking into account various indicators of their activities,

– and comparing and finding changes in mutual influences over time.

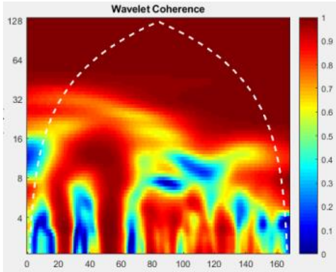
Let us consider a few examples of such an analysis. According to the first step of the proposed procedure, let us formulate the problem of analysis and select specific data time series $(g_1(\dots), g_2(\dots), g_3(\dots))$.

Given the fact that the volume of attracted deposits and the volume of granted loans in the traditional sense determine the content of banking, let us consider a spatial description of wavelet coherence exactly between the volumes of loans and deposits. Let us choose a group of Ukrainian commercial banks for certain periods of time, namely: as of: 01.01.2006, 01.01.2008, 01.01.2010 and 01.01.2012. This choice in particular allows understanding in more detail what is reflected in Fig. 2a. All data for calculations are retrieved from https://bank.gov.ua/statistic.

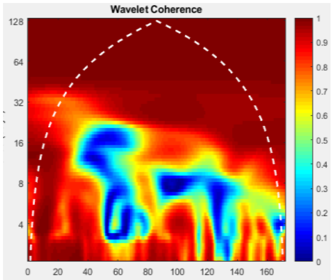
However, it should be understood that the consistency between the volume of loans and deposits is also determined by a number of different factors. As one of such factors, it is necessary to mention the bank's general development level. To some extent, this can be reflected in the amount of administrative costs. Therefore, regarding the banks' ranking, we choose the data that determines the amount of administrative costs in different banks. So we will analyze the consistency between the amount of granted loans and the amount of attracted deposits relative to the amount of administrative costs. More specifically, this ranking is carried out in relation to the growth of administrative costs (although there is no fundamental difference in the ranking in the opposite direction).



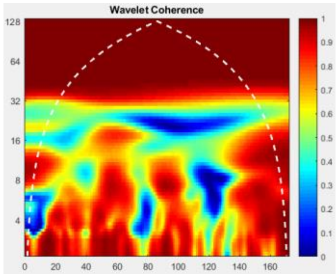
a) 01.01.2006



b) 01.01.2008



c) 01.01.2010



d) 01.01.2012

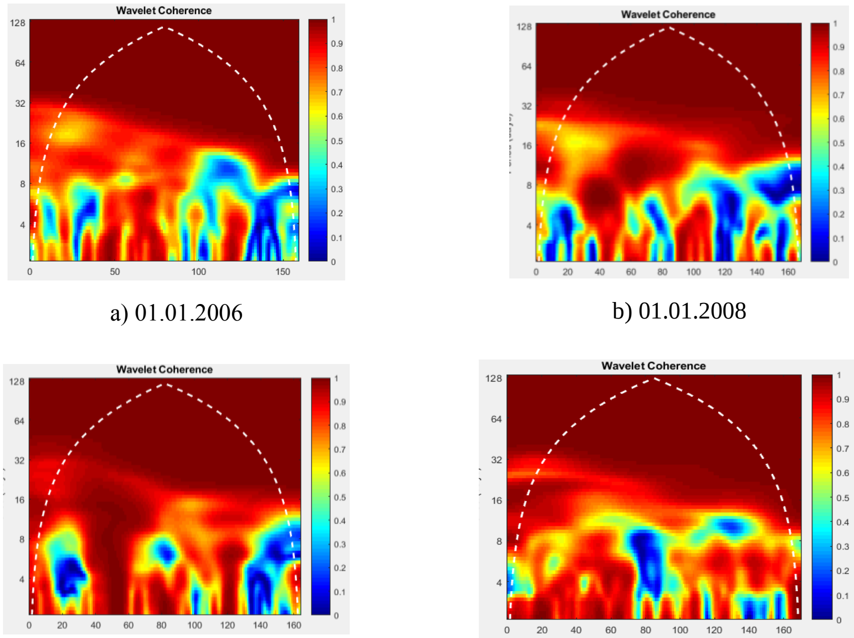
Fig. 3. Description of the spatial wavelet coherence between the volumes of granted loans and the volumes of deposits relative to the volume of administrative costs in terms of individual time periods

Source: the authors' own calculations.

According to the above, Fig. 3 provides a description of the spatial wavelet coherence between the volumes of loans and deposits relative to the volume of administrative costs in terms of individual time periods.

Analysis of data in Fig. 3 shows the variability in the consistency between the volumes of granted loans and volumes of attracted deposits relative to the volume of administrative costs by individual time periods. In this case, the greatest discrepancy between the investigated series can be observed on 01.01.2012. This is quite consistent with the data of Fig. 2a and provides some explanations. That is, the data in Fig. 3 indicate that the available administrative costs - as a generalized manifestation of the effectiveness of the bank's management system - are insufficient to provide full consistency between the volumes of loans and deposits. Certainly, among the factors of such influence one should also take into account external factors (market environment, activity of the bank's customers, actions of competitors, etc.), but the bank's management system should also be quickly adapted to such variability of factors. In this regard, it is also necessary to consider the consistency between the volumes of granted loans and the volume of deposits relative to the amount of equity.

The amount of equity is one of the key banking indicators, which determines the bank's ability to withstand potential risks (in particular - to adequately respond to the variability of environmental factors). Therefore, let us consider the description of the spatial wavelet coherence between the volume of granted loans and the volume of attracted deposits relative to the volume of equity (Fig. 4).



a) 01.01.2006 b) 01.01.2008

c) 01.01.2010 d) 01.01.2012

Fig. 4. Description of the spatial wavelet coherence between the volume of loans and the volume of attracted deposits relative to the volume of equity in terms of individual time intervals

Source: own calculations.

Based on Fig. 4, we also note the lack of full consistency between the volume of loans and the volume of attracted deposits, on the one hand, and the amount of equity on the other. However, this consistency is higher compared to Fig. 3. Therefore, as to the effects of equity volume, it can be noted that banks pay sufficient attention to the consistency between the volume of loans and deposits. Thus, equity performs its protective functions, and its amounts are acceptable and sufficient, which smoothes out the existing discrepancy between the volume of loans and deposits and the volume of administrative costs. As a result, this demonstrates the appropriateness of applying the wavelet methodology to the retrospective analysis of banking activities.

References

1. Vartsaba, V.I. (2018). Problems of securing financial stability of Ukrainian banking systems. *Naukovyj visnyk Uzhhorods'koho universytetu. Seriia Ekonomika – Science News of Uzhgorod University. Seriya Ekonomika*, 1: 51, 311-316. https://doi.org/10.24144/2409-6857.2018.1(51).311-316 [in Ukrainian].
2. Rushchishin, N.M., Kostak, Z.R. (2018). Banking system of Ukraine: current standard and future development. *Ekonomika i suspil'stvo – Economy and society*, 6, 783-789. Retrieved from http://economyandsociety. in. ua/journal/16_ukr/119. pdf [in Ukrainian].
3. Liang, D., Zhang, Y., Xu, Z., Jamaldeen, A. (2019). Pythagorean fuzzy VIKOR approaches based on TODIM for evaluating internet banking website quality of Ghanaian banking industry. *Applied Soft Computing*, 78, 583-594. https://doi.org/10.1016/j.asoc.2019.03.006

4. Affes, Z., Hentati-Kaffel, R. (2019). Predicting US banks bankruptcy: logit versus Canonical Discriminant analysis. *Computational Economics*, 2019, 54: 1, 199-244. https://doi.org/10.1007/s10614-017-9698-0
5. Sharma, S. K. (2019). Integrating cognitive antecedents into TAM to explain mobile banking behavioral intention: A SEM-neural network modeling. *Information Systems Frontiers*, 21: 4, 815-827. https://doi.org/10.1007/s10796-017-9775-x
6. Li, Y., Allan, N., Evans, J.R. (2017). A Nonlinear Analysis of Operational Risk Events in Australian Banks. *Journal of Operational Risk, Forthcoming.* Retrieved from https://ssrn.com/abstract=2906327. https://doi.org/10.21314/JOP.2017.185
7. Saiti, B, Bacha, O.I., Masih, M. (2016). Testing the conventional and Islamic financial market contagion: evidence from wavelet analysis. *Emerging Markets Finance and Trade*, 52: 8, 1832-1849. https://doi.org/ 10.1080/1540496X.2015.1087784
8. Edurkar, A., Shaikh, A. A. (2018). Application of Morlet Wavelet Transform for analysis of Business Practices of Foreign Banks in India. *Wealth: International Journal of Money, Banking & Finance*, 7: 1, 12-17.
9. Okeke, C., Nwude, E.C. (2018). A Statistical Simulation for the Profitability of Banks: A Study. *International Journal of Economics and Financial Issues*, 8: 2, 243-254.
10. Affes, Z., Hentati-Kaffel, R. (2019). Predicting US banks bankruptcy: logit versus Canonical Discriminant analysis. *Computational Economics*, 54: 1, 199-244. https://doi.org/10.1007/s10614-017-9698-0
11. Vasyurenko, O., Lyashenko, V., Podchesova, V. (2014). Efficiency of lending to natural persons and legal entities by banks of Ukraine: methodology of stochastic frontier analysis. *Visnyk Natsional'noho banku Ukrainy – Herald of the National Bank of Ukraine*, 1, 5-11 [in Ukrainian].
12. Anwar, M. (2019). Cost efficiency performance of Indonesian banks over the recovery period: A stochastic frontier analysis. *The Social Science Journal*, 56: 3, 377-389. https://doi.org/10.1016/j.soscij.2018.08.002
13. He, F., He, X. (2019). A Continuous Differentiable Wavelet Shrinkage Function for Economic Data Denoising. *Computational Economics*, 54: 2, 729-761. https://doi.org/10.1007/s10614-018-9849-y
14. Lyashenko, V., Deineko, Z., Ahmad, A. (2015). Properties of wavelet coefficients of self-similar time series. *International Journal of Scientific and Engineering Research*, 6: 1, 1492-1499. https://doi.org/10.14299/ijser.2015.01.025
15. Heil, C.E., Walnut, D.F. (1989). Continuous and discrete wavelet transforms. *SIAM review*, 31: 4, 628-666. https://doi.org/10.1137/1031129
16. Grinsted, A., Moore, J.C., Jevrejeva, S. (2004). Application of the cross wavelet transform and wavelet coherence to geophysical time series. *Nonlinear Processes in Geophysics*, 11: 5/6, 561-566. https://doi.org/10.5194/npg-11-561-2004
17. Lyashenko, V., Zeleniy, O., Mustafa, S. K., Ahmad, M. A. (2019). An Advanced Methodology for Visualization of Changes in the Properties of a Dye. *International Journal of Engineering and Advanced Technology*, 9: 1, 7111-7114. https://doi.org/10.35940/ijeat.A1496.109119

Received 25.02.20
Reviewed 13.05.20
Signed for print 12.10.20

***Васюренко О.В.*[3]**
***Ляшенко В.В.*[4]**

ВЕЙВЛЕТ-КОГЕРЕНТНІСТЬ ЯК ІНСТРУМЕНТ РЕТРОСПЕКТИВНОГО АНАЛІЗУ ДІЯЛЬНОСТІ БАНКІВ

Розглянуто можливість та доцільність застосування апарату теорії вейвлетів щодо проведення аналізу банківської діяльності. Визначено окремі етапи комплексного застосування різних інструментів з теорії вейвлетів щодо проведення аналізу діяльності банків на основі ретроспективних даних. Серед таких етапів відзначено розкладання початкових даних за їх апроксимуючими коефіцієнтами та коефіцієнтами деталізації, застосування вейвлет-когерентності.

Зауважено про важливість проведення ретроспективного аналізу щодо розкриття прихованих взаємозв'язків у структурі даних, які визначають окремі аспекти банківської діяльності. Підкреслено переваги застосування інструментів теорії вейвлетів для аналізу діяльності банків на основі статистичних даних про їхню діяльність. Серед таких переваг виділено можливість як дослідження зв'язків між даними у часі та визначення їх глибини, так і виконання цього в одному дослідницькому вікні.

Особливу увагу зосереджено на аналізі взаємозв'язку між обсягами коштів на депозитних рахунках та обсягами наданих кредитів – як одних із ключових параметрів щодо ведення банківської діяльності. Зауважено, що такий взаємозв'язок залежить від обсягів адміністративних витрат та власного капіталу банків.

Відзначено, що ретроспективний аналіз дає можливість виявити наслідки настання небажаних подій та попередити їх у майбутньому.

Для проведення відповідного аналізу розкрито зміст побудови опису просторової вейвлет-когерентності, що дає можливість врахувати кількість параметрів більшу, аніж за класичних підходів до її обчислення. Це розширює межі відповідного аналізу, допомагає дослідити різноманітні взаємні впливи між окремими банками з погляду їх окремих показників щодо ведення банківської діяльності. Такий аналіз дає змогу визначати не лише взаємозв'язок між окремими показниками банківської діяльності, а й глибину впливу між окремими банками з урахуванням таких показників їх діяльності. Наведено конкретні приклади, що доводять доцільність та вірогідність застосування пропонованих підходів до аналізу банківської діяльності.

Ключові слова: *вейвлет-когерентність, банківська діяльність, часові ряди, депозити, кредити, адміністративні витрати, власний капітал*

[3] **Васюренко, Олег Володимирович** – д-р екон. наук, професор, проректор з економіки, ПВНЗ "Київський інститут бізнесу та технологій" (пров. Зоряний 1/5, Київ, Україна, 04078), ORCID: 0000-0003-3225-0744, e-mail: vasiurenkooleg66@gmail.com

[4] **Ляшенко, Вячеслав Вікторович** – завідувач лабораторії "Трансферт інформаційних технологій в системах скорочення ризиків", Харківський національний університет радіоелектроніки (пр. Науки, 14, Харків, Україна), ORCID: 0000-0001-5455-5026, e-mail: lyashenko.vyacheslav@gmail.com