World Applied Sciences Journal 27 (Economics, Management and Finance): 62-66, 2013
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2013.27.emf.13

Wavelet Analysis of the Territorial Socio-Economic System Dynamics

N.G. Bagautdinova, M.V. Panasyuk and I.R. Gafurov

Kazan Federal University, Kazan, Russia

Submitted: Oct 15, 2013; **Accepted:** Dec 11, 2013; **Published:** Dec 15, 2013

Abstract: The article goes about the study of using scale transformations and shifts through building the basis of a wavelet analysis. Wavelets are capable of revealing differences in parameters on different dials by changing their scales and of analyzing their peculiar features at different points within the studied interval by way of shifting. Two main classes of wavelets were considered: the continuous and discrete ones. Wavelet transformations were applied in practice.

Key words: System · Wavelet analysis · Region · Dynamics

INTRODUCTION

The complexity and insufficient knowledge of the processes of development of territorial socio-economic systems, the majority of which are non-linear, determine the necessity to improve the existing methodological base of their analysis. The methods of wavelet analysis are a prospective trend in these terms. The theory of wavelets appeared in the middle of 1980s and aimed the solution of a small class of signal-processing tasks and, since recently, it has become a general scientific theory. Its prospective application is the analysis of system development processes, which are non-steady in terms of time and non-homogeneous in terms of space [1, 3].

MATERIALS AND METHODS

Methods of wavelet analysis are mostly used in practical researches of complex systems, including interpretation of information from observations on a single variable (e.g., analysis of electrocardiograms and DNA sequences in medicine and biology), recognition of images (analysis of shapes and classifications in biology), analysis of temporal rows (in economics, sociology and meteorology), etc. During the analysis of images, the wavelet analysis methods are usually applied for solving image decomposition, restoration and identification tasks.

Interest to the wavelet analysis of the dynamics of territorial socio-economic systems is caused by the flexibility of its methods if compared to complex non-steady spatial processes. Based on the rendered wavelet analysis, the conclusions are formed on the frequency-related peculiarities of the dynamics of studied processes, the exact time of the cycles' occurrence and duration. With the help of wavelets, we can analyze both the dynamics of aggregated indicators of the evaluation of the territorial system's status and the dynamics of individual parameters of its subsystems and elements.

The methods of wavelet analysis allow recognizing and describing the delicate points of complex processes of territory development, which cannot be approached by using the existing methods of analysis. They encourage the revealing of detailed peculiarities of the dynamics, irrelevant to the general trend. The filtration and reconstruction properties of wavelet transformations allow handling the spatiotemporal information without missing any important details [4].

From the point of view of the tasks of dynamics analysis, the main peculiarity of wavelet transformations is that they provide simultaneous expression of both the frequency parameter of the system development process and its temporal and spatial localization. The frequency and the coordinate are treated as independent variables.

The construction of the basis of wavelet analysis is based on usage of scale transformations and shifts. Wavelets are capable of revealing differences in parameters on different dials by changing their scales and of analyzing their peculiar features at different points within the studied interval by way of shifting.

Corresponding Author: Bagautdinova, Kazan Federal University, Kremlevskaya, 18, Kazan, 420008, Russia.

There are two main classes of wavelets: the continuous and discrete ones. The practical usage of wavelet transformations concerns, first of all, the discrete wavelets. They provide usually more precise transformation and notation of signals, as well as more precise reconstruction of the signal after the compression procedure.

The discrete wavelet analysis allows representing a certain variable *f (t)* as a system of functions

$$f(t) = \sum_{j,k=-\infty}^{\infty} a_{j,k} \cdot \psi_{j,k}(t)$$

where the variables *j* and *k* set the wavelet's scale and position accordingly,

$\Psi_{j,k(t)}$- the wavelet function,
$a_{j,k}$- the coefficients of discrete wavelet transformation.

The continuous wavelet analysis *f (t)* is set using the function:

$$C(a,b) = \int_{-\infty}^{\infty} f(t) \cdot a^{-1/2} \cdot \psi\left(\frac{t-b}{a}\right) dt$$

where the parameters *a* and *b* set the scaling and position of the wavelet,

$\Psi(t)$-the wavelet function.

RESULTS

In this research, application of the wavelet analysis methods for analytical and forecasting models of the dynamics of territorial socio-economic system is primarily based on the transition from the assignment of the signal analysis task to the assignment of the static task. The existing analytic variables are interpreted as statistic observations.

It is assumed that the dynamic row was set and it was the selection of the observed period $V(V_1,V_2,...,V_N)$. It is analyzed with the help of the methods of discrete wavelet analysis. The analysis is based on decomposition of the studied process and identification of the detailing level and further level-by-level analysis and revealing of specific features and latent peculiarities of the process development at various detailing scales. Within the wavelet analysis, the total of components of various types is considered: the average values on large intervals of averaging, the cyclic components with certain intervals, the local peculiarities of various classes and the fluctuation of higher values around all of the components listed above.

The tool of identification of the geosystems dynamics components is the large-scale analysis, which would allow carrying out quick numerical calculations of local parameters at different scales. The important principle of the wavelet analysis of a dynamic row is the braking up the approximation functions into two groups: the approximating functions with quite slow temporal dynamics and the detailing functions with local fast (if compared to the previous one) dynamics of changes at their further fractioning and detailing on the other levels of the selection decomposition.

If the variable *j* sets the extent of detailing, at the n^{th} level the j_n reconstruction of the selection in general cases is determined with the following expression:

$$V(t) = \sum_{k=-\infty}^{\infty} s_{j_n,k} \cdot \varphi_{j_n,k}(t) + \sum_{j=j_n}^{\infty} \sum_{k=-\infty}^{\infty} d_{j,k} \cdot \psi_k(t)$$

where *k*- is the index of the averaging interval of the analyzed row,

$\varphi_{j_n,k(t)}$ - is the scaling function, which determines the approximation of the analyzed row,
$\Psi_k(t)$- is the wavelet function, which determines the details of the analyzed row,
$s_{j_n,k}, d_{j,k}$ - are the coefficients of approximation and detailing, accordingly.

The development forecast based on the analysis of dynamic rows is the special sphere of application of the wavelet analysis, which is currently being developed. Two main directions of development of the theory of wavelets in the sphere of forecasting complex systems can be identified:

- The first direction does not provide for creation of special forecast models; it comes only from the capability of the wavelet analysis to extract hidden detail peculiarities of the studied system dynamics, which evidence the happening of certain events in the future. In this case, the wavelet decomposition allows obtaining previously unknown information on the nature of the process progress at different levels of detailing, which manifests itself in a set of wavelet coefficients.

- The second direction of the wavelets application in forecasting is related to usage of coefficients of wavelet decomposition in an autoregressive model and at implementation of neural network forecasting. This direction, as opposed to the first one, is based on the development of special methods of forecasting and forecast models.

There are two approaches to the usage of coefficients of wavelet decomposition in forecast models: decomposition and scaling. The decomposition approach assumes using a set of wavelet coefficients. The scaling approach lies in fulfillment of modeling and forecasting independently of each other at every level of detailing and further uniting of the received results.

The specificity of building the territorial socio-economic system dynamics model based on the methods of the wavelet theory is determined by the capability to account for the details of every level of the temporal row detailing dynamics, which assumes better quality of forecasting research.

The wavelet analysis methods served the basis of the dynamics model of the system of development of municipal districts in the Republic of Tatarstan (RT). The analysis of dynamics of basic macroeconomic indicators was provided, namely the scope of manufacture of industrial products, the average headcount of employed people in the economy, the investments in the capital stock, etc [2].

As a result of the wavelet decomposition based on the Daubechies function of order 4, the approximating and detailing components of dynamic rows of indicators for 32 quarters were identified, which characterized the general trend and short-term fluctuations, accordingly.

The research of the industrial products manufacture dynamics by approximating components on the detailed level of decomposition allowed revealing generally stable trends of change of the indicator for the given territorial system. During the analyzed period, the trends in dynamics of production scopes were equal for the majority of municipal districts.

The only exclusions are some relatively weakly developed districts in Tatarstan, in which a stable tendency to the decrease of the products manufacture was documented, including the foreseeable future. Along with it, approximately 10% of the total number of districts shows unstable dynamics with unstable fluctuations of the indicator, which evidences the transitional stage of their economy development.

At the stage of calculation of the detailing coefficients at the maximum level of detailing, the conclusions were made that approximately 20% of the total number of districts of the regional system of Tatarstan have a high level of development stability with regular cyclic fluctuations of the indicator value. The lower level of stability along with expected stabilization of the situation is typical of approximately 25% of the total number of districts, including Zainsk, Buinsk, Tukaevsky, Bugulma and other municipal districts, as well as the City of Kazan.

In the result of the wavelet analysis of the values of average employment in economy of municipal districts in Tatarstan, it was revealed that the dynamics of this indicator is notably less stable than the dynamics of the production. The generally unstable trend is typical of approximately 50% of the total number of districts in Tatarstan and, at that, the majority of them show irregular fluctuations. There are two groups of districts by the peculiarities of the average headcount dynamics. The dynamics of the first group of districts is distinguished for a certain increase of the employed people in the beginning of the analyzed period. It includes approximately 50% of the total number of municipal districts of Tatarstan and the cities of Naberezhnye Chelny and Kazan. The second group shows gentle decrease of the average headcount during the analyzed period.

The study of detailing components of the wavelet functions allows revealing the prospects of improving the stability of the employment indicator dynamics by means of decreasing the amplitude of fluctuations around the main trend in the Nizhnekamsk and Almetyevsk districts and in Kazan. The increase of instability degree will be typical of not more than 2 or 3 regions of the analyzed territorial socio-economic system. And approximately 10% of the system regions will show stable dynamics.

CONCLUSIONS

The results of the wavelet analysis of investments in the capital stock show quite high stability of the dynamics of this indicator. The unstable nature of the development is typical of just 8% of total number of districts of the analyzed system. The general trend is the weak growth of the investment scopes. At that, the analysis of the detailing coefficients shows that, in the long term, the increase of unstable trends of the dynamics is to be

expected, as, for the majority of districts, the trend of the increase of the amplitude of fluctuations around the main trend has been observed. The increase of the stability level will be typical of approximately 15% of municipal districts with relatively stable dynamics. And an opposite trend will be observed in approximately the same number of districts. The high level of stability at stable fluctuations describes the dynamics of more than one third of municipal districts and two cities - Kazan and Nabereznye Chelny.

In the result of approaching the objectives of the wavelet analysis, the main types of the dynamics of the municipal districts system development in the Republic of Tatarstan were identified. Depending on the peculiarities of the combination of the general trend and short-term fluctuations, it is reasonable to consider the four types of the dynamics:

- With *the stable main trend of the indicators' dynamics at superposition of regular fluctuations.*
- With *the stable main trend of the indicators' dynamics at superposition of irregular fluctuations.*
- With *the unstable main trend of the indicators' dynamics at superposition of regular fluctuations.*
- With *the unstable main trend of the indicators' dynamics at superposition of irregular fluctuations.*

For the objects of the analyzed territorial socio-economic system, those types of dynamics prevail, which are distinguished for their irregular fluctuations mostly observed at the stable main trend of development and more rarely - at the unstable one. This phenomenon is explained by the general unsteadiness of the dynamics of the processes of the socio-economic system development in the Republic of Tatarstan.

The received results showed that the methods of wavelet analysis have good prospects at studying the development of complex territorial socio-economic systems with unsteady dynamics, which is marked by the union of fluctuations of various levels. The wavelet analysis allows carrying out a detailed study of the processes of development of the territorial system based on the detailed determination of the fluctuation structure of the observed dynamic rows, providing the identification of those peculiarities of the dynamics, which cannot be revealed against the background of the general trend.

REFERENCES

1. Aussem, A., J. Campbell and F. Murtagh, 1998. Wavelet-based Feature Extraction and Decomposition Strategies for Financial Forecasting. Journal of Computational Intelligence in Finance, 6: 5-12.
2. Bagautdinova, N.G., I.R. Gafurov, N.V. Kalenskaya and A.Z. Novenkova, 2012. The Regional Development Strategy Based on Territorial Marketing (the Case of Russia). World Applied Sciences Journal, 18: 179-184.
3. Aussem, A. and F. Murtagh, 1998. A Neuro-Wavelet Strategy for Web Traffic Demand Forecasting. Journal of Official Statistics, 1: 65-87.
4. Safiullin, L.N., N.G. Bagautdinova, N.Z. Safiullin and I.R. Gafurov, 2012. Influence of Quality of the Goods on Satisfactions of Consumers. International GSTF Business Review (GBR), 2(2): 225-232.
5. Larionova, N.I. and Y.A. Varlamova, 2013. The Trends of Household Economic Behavior in International Comparison. Procedia Economics and Finance, 5: 737-746.
6. Safiullin, L.N., G.N. Ismagilova, D.Kh. Gallyamova, N.Z. Safiullin 2013. Consumer Benefit in the Competitive Market. Procedia Economics and Finance, 5: 667-676.
7. Novenkova, A.Z., N.V. Kalenskaya and I.R. Gafurov, 2013. Marketing of Educational Services: Research on Service Providers Satisfaction. Procedia Economics and Finance, 5: 667-676.
8. Bagautdinova, N.G, I.V. Goncharova, E.Y. Shurkina, A.V. Sarkin, B.A. Averyanov and A.A. Svirina, 2013. Entreprenuerial Development in a Corrupted Environment. Procedia Economics and Finance, 5: 73-82.
9. Kamasheva, A., J. Kolesnikova, E. Karasik and E. Salyakhov, 2013. Discrimination and Inequality in the Labor. Procedia Economics and Finance, 5: 386-392.
10. Aussem, A. and F. Murtagh, 2001. Web Traffic Demand Forecasting Using Wavelet-Based Multiscale Decomposition. International Journal of Intelligent systems, 16: 215-236.
11. Fischer, P., G. Baudoux and J. Wouters, 2003. Wavpred: A Wavelet-Based Algorithm for the Prediction of Transmembrane Proteins. Comm. Math. Sci., 1(1): 44-56.

12. Glebova, I., D. Rodnyansky, R. Sadyrtdinov, R. Khabibrakhmanova and Y. Yasnitskaya, 2013. Evaluation of Corporate Social Responsibility of Russian Companies Based on Nonfinancial Reporting. Middle-East Journal of Scientific Research, 13: 143-148.
13. Ioup, J.W., M.L. Gendron and M.C. Lohrenz, 1999. Vector Map Data Compression with Wavelets. In the Proceedings of the Symposium on Advanced Moving-Map Displays. US Naval Research Laboratory Detachment at the NASA Stennis Space Centre, Mississippi.
14. Safiullin, M.R., L.A. Elstin and A.I. Shakirova, 2012. Evaluation of Business and Economic Activity as a Short-term Forecasting Tool. Herald of the Russian Academy of Sciences, 4: 290-294.
15. Mao, G., 2005. A Timescale Decomposition Approach to Network Traffic Prediction. IEICE Trans. Commun, V. E88-B., 10: 3974-3981.
16. Ramsey, J.B. and C. Lampart, 1998. Decomposition of Economic Relationships by Timescale Using Wavelets. Macroeconomic Dynamics, 2: 49-71.
17. Renaud, O., J.L. Starck and F. Murtagh, 2003. Prediction Based on a Multiscale Decomposition. International Journal of Wavelets, Multiresolution and Information Processing, 1(2): 1-16.