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MEDIAN APPROACH TO MODELING REGIONAL INDUSTRY CYCLES: SUSTAINABLE AND BALANCED DEVELOPMENT

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Abstract

Sustainable and balanced economic development is the most important task for any country. Up until now, modeling of regional industry cycles has been mainly neglected in research of sustainable and balanced regional development. Modeling of industry development was executed "from above", i.e. based on country-wide data. In this paper, we propose a median approach to modeling, i.e. complex modeling "from below". The authors proceed from the evolutionary economics prerequisite regarding the overriding role of economic entities in the speed and nature of evolutionary changes in industry. Then, by modeling regional industry cycles, one can get an idea of the regional industry contribution to the overall industry balance or imbalance. The purpose of this paper is to develop a median approach to modeling and forecasting regional industry cycles. To do this, the authors summarized the existing approaches and identified their shortcomings, defined the particular characteristics of the median approach and the stages of its implementation. The R language and algorithmization enable processing a significant amount of statistical information relatively quickly. The authors came to conclusion that the median approach is an alternative to "from below" modeling and makes it possible to apply the median solution to any number of territories and evaluate their contribution to the overall sustainability and development balance. Moreover, the median approach has an important advantage, with its high mathematical accuracy, and can be applied not only for regions of one country, but also for countries within trade and economic unions with uniform approaches to collecting statistical data.

Keywords: Industry cycle, median approach, modelling, region cycle, sustainability

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1. Introduction

The relevance of this paper is supported by the trends of increasing cyclical nature of the world economy, by the tasks and priorities of the Russian Federation Spatial Development Strategy for the period up to 2025, focused on balanced and sustainable spatial development of regions. Integration processes are also developing in the Customs Union and Single economic area of the EAEU countries (Order of the Government of the Russian Federation of 13.02.2019 N 207-r).

The important problem of sustainable and balanced development of the country has been studied for several decades at the macro-, meso- and micro-levels of the economy, but still remains unresolved. Like many Russian and foreign scientists, the authors are supportive of the concept of the global nature of mesodynamics nonlinearity in the evolutionary economy, set out in the academic monographs by Maevsky (2018) and others. Furthermore, the research meso-level is increasingly brought to the fore (Volynskii, 2017), since it is here that the driving forces of sustainable economic development of the country are formed. The meso-level is usually associated with regional economies and industries. One of the main issues is methodological, since the existing approaches to modelling regional industry cycles do not meet the requirements of analysis accuracy (mainly in forecasting) and capacity (by the number of objects analyzed and industries).

The process of sustainable development is usually considered in a broad or narrow sense. In a broad sense, the concept of sustainable development is acknowledged as a modern socio-economic development paradigm of socio-economic system. The concept presupposes the harmonious development of Nations in the interests of present and future generations and includes environmental aspects along with economic and social aspects, with environmental risks becoming more and more urgent. The wide scope of issues determines the complexity of the socio-ecological-economic model constructed by researchers. When focusing on a narrower range of issues (social, economic), as a rule, researchers proceed from the classical interpretation of the socio-economic system stability as the ability to keep the core parameters within the specified limits, both positive and negative. The system balance issue, by which the authors understand the system ability to return to equilibrium, is also closely related to the question of stability. Thus, stability and balance of the system are, in fact, the two most important tasks determining the progressive advance of the socio-economic system and economic systems of the macro - and meso levels.

When developing methodological tool set for sustainable and balanced development, the researchers usually take the position of a systematic approach, based on which they apply various methods for assessing development sustainability and balance. Generalization of research leads to identification of three key approaches. First, there is the normative approach, which involves evaluation of the current state eligibility against certain criteria set forth by researchers as guideline values (Barabash, 2014). Applying the normative approach provides only tentative possibility for systems development prediction, since it implies comparison of the standard values predicated by the researcher's judgment with the actual values of well-known indicators of sustainable development of the region (social, economic, environmental).

Second, the balance approach, in which the sustainable and balanced development of the regional economic system is achieved through balancing the final and intermediate consumption flows (Mashunin & Mashunin, 2014). This approach has a shortcoming of a low predictive potential, since, according to the traditional input-output approach, the forecast is based on a data slice of one calendar year.

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Third, the evolutionary approach, in which the territorial economic system development is reviewed through the prism of adaptive cycle theory, the economic system stability is achieved through systematic management decisions to align the cyclical development path (Holm & Ostergaard, 2015). The evolutionary approach and the cyclical nature theory are the most promising, as they provide explanation of the system's unstable behaviour causes and develop relevant tools for imbalance parameters identification, if any. However, at present, the advantages of this approach are offset by the widespread use of simple linear models, which are ultimately invalid for significant time intervals. The country's economic development sustainability depends on the balanced development of all sectors that are essential for its economy (Semenychev et al., 2019). Another equally important aspect is understanding and comparison of industry regional cycles in certain regions of the country. Only a combination of the principles of accuracy and complexity will provide a relevant idea of the processes formed by sustainable trends in the country's economic development (Chudik et al., 2020).

2. Problem Statement

The need to develop a median approach to modeling is caused by the latency of regional cyclicity impact on the production and sales dynamics in economic sectors in domestic and foreign markets, which ultimately affects the balance and sustainability of the spatial development of regions. No statement or quantitative solution of the issue using monthly monitoring of industry indicators combined with fuzzy logic tools have been found in available publications. Moreover, the testing of modern neural network modeling and forecasting in the regions is also reported. Even for a single region, standard programs were not effective (they provide significant variance assuming the normal irregular component distribution law), did not show advantages over the simplest linear models, and considered it justified to refer to additional expert estimates and fictitious variables. The object of our research is a complex system of economic relations, the consolidated influence of which forms an ambivalent landscape of industry dynamics, and it requires addressing the interdisciplinary and most modern methodology of econophysics (one of the areas of synergetics, also called the theory of self-development).The econophysics methodology provides opportunity to study characteristics of the economic system model approximation to the bifurcation point where dynamic chaos begins, and to analyze its consequences.

3. Research Questions

Research questions are aimed at developing a median approach to assessment of industry cycles that addresses the management challenges of sustainability and balanced regional development. Research questions have been identified on the basis of the existing study area. The research questions for this paper were: How is the industry cyclicity measured? What modifications and improvement need to be proposed to improve the quality of the model? What improvements can be made to the traditional approach? What are the conclusions of the cyclicity evaluation in the Russian regions' industries? What are the advantages of the median approach to modeling regional industry cycles? What is the predictive and managerial potential of the proposed median approach?

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4. Purpose of the Study

The authors of this paper develop a methodological approach to modeling and forecasting industry regional cycles (Agaeva et al., 2019). The concept of the proposed methodological approach involves possessing information about the current and projected stages of the sectoral regional cycles of promising economic specialization areas in order to increase sustainability and balance of the country's economic development.

This goal shall be achieved provided there is a quantitative, relevant and representative evaluation of regional meso-dynamic modeling and forecasting based on actual (official) data of Unified Interdepartmental Statistical Information System (UISIS, 2020). Adequacy is a qualitative evaluation of the research and/or management goal achievement, and the accuracy of modeling and forecasting is the quantitative characteristics of the achievement of the research or management goal. Accurate models may not be adequate (compare the interpolation and smoothing procedure in case of interference in the data), but adequate models are always accurate.

5. Research Methods

To improve the modeling and forecasting quality, the authors proposed a number of improvements and modifications to the traditional approach, which allowed not only to increase the models accuracy, but also to obtain new qualitative conclusions about the type and nature of the dynamics of regional economic sectors in Russia. The methodology was implemented as a program code in the R language using free open source packages provided for it. The focus is made on quantitative evaluations of analysis (the term "analysis" embraces both modeling and forecasting) generated by processing time series observations from official monthly data of the EMISS (Unified interdepartmental information and statistical system of Russia).

Modeling a dynamics series Y_t (t – moments in time) involves its decomposition (identification of unobservable components) and modeling each component separately. Traditionally, there are four main components: trend T_t, cyclical fluctuations C_t, seasonal fluctuations S_t, and stochastic component ε_t (residuals). Sometimes the model contains several components of the same type, for example, a multitrend that is a composition of two or more trends, or several stochastic components with different distributions (symmetric normal, asymmetric with heavy tails).

The interaction of components can also be different:

- additive $Y_t = T_t + C_t + S_t + \varepsilon_t$
- proportionally multiplicative $Y_t = T_t(1 + C_t)(1 + S_t)(1 + \varepsilon_t)$
- mixed additive-multiplicative, for example:

$$Y_t = (T_t + C_t)(1 + S_t) + \varepsilon_t,$$

$$Y_t = T_t(1 + C_t) + S_t + \varepsilon_t,$$

$$Y_t = T_t(1 + C_t + S_t)(1 + \varepsilon_t),$$

$$Y_t = (T_t + C_t + \varepsilon_t^{add})(1 + S_t) + \varepsilon_t^{mul}.$$

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More complex forms of components interaction are also possible. However, in research practice, mixed structures are rarely used.

Each component is modeled by a function of time, extending it into the future and thus obtaining forecasts of dynamics. A function can be either a solution to a certain differential equation describing the behavior of a system, or a phenomenological model that has no theoretical justification, but nevertheless adequately describes the available data. Naturally, actual economic dynamics are complex and inconstant, and cannot follow a simple law in the form of a function of time. Socio-economic systems, like all living systems, are gradually developing and evolving. Evolution can be either slow, with a gradual transition from one direction of dynamics to another, or fast, when there is a structural remodelling of a system. In this case the *structural changes* occur – the moments of discrete time in which the entire model or its individual components undergo significant changes and their functional appearance alters.

To find points of structural changes, the breakpoints function implemented in the 'strucchange' package for R can be applied (Bai, & Perron, 2003). This function makes possible finding an arbitrary number of structural changes for a given type of model.

Another important issue is the applied criterion for the model identification, with respect to which the parameters estimates are found. In modern statistics and econometrics the most commonly used are least-squares estimates of model parameters.

$$\sum_{t=1}^{n}\left(Y_t - Y_t^0\right)^2 \to \min$$

The least squares technique (OLS) provides BLUE (best linear unbiased estimator) when the conditions of the Gauss-Markov theorem are satisfied for linear parameters models. The minimization of the sum of model residuals squares is, as the name implies, the criterion by which parameters are identified. However, only the asymptotic consistency of the estimates is proved for nonlinear models. Gauss-Markov hypotheses are often not checked, and the normal law of distribution is taken for granted.

The wide scope of OLS application is caused rather by its intuitive apprehensibility and implementation in all standard computing packages. Another well-known method is the method of least absolute deviation (LAD), but it is also not lacking a disadvantage of distorting the multiplicative forecast model.

In the actual context of the study, researchers cannot know exactly whether the stochastic component in the data point series structure is additive or multiplicative. Neither they know exactly the stochastic component distribution law. Thus, it is advisable (or justified) to combine possibility of absolute and relative residuals through the choice of the following criterion type:

$$\frac{1}{\overline{Y}}\sum_{t=1}^{n}\left|Y_t - Y_t^0\right| + \sum_{t=1}^{n}\left|\frac{Y_t - Y_t^0}{Y_t}\right| \to \min$$

Based on the outlined principles, a method for identifying dynamics models is formed, which involves performing the following sequence of steps:

1. Preprocessing of the dynamics initial series, removing random outliers and replacing them with median smoothed values.

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2. Determining the structure (additive or multiplicative) and detecting seasonal fluctuations using the STL function, which returns the smoothed trend, seasonal fluctuations, and random residuals based on LOESS smoothing.
3. Deseasonalization (removing seasonal fluctuations from the initial series).
4. Determining the structure of cyclic fluctuations.
5. Plotting a linear trend without structural shifts on the rectified data.
6. Detrending (removing a trend from a series).
7. Identification of cyclic fluctuations on the rectified data as the sum of several harmonic curves with non-proportional frequencies. The number of harmonic curves is selected individually for each series.
8. Removal of cyclical fluctuations from the rectified data.
9. Plotting of the median trend without structural shifts. To do this, all available types of trends are identified (currently there are 11) and the median value from all trend estimates is taken at each point in the dynamics series.
10. Repeat steps 6-8 for the new estimates of the trend.
11. Plotting median trend with structural changes is performed similarly to step 9, but each trend is built both from the full data set and splitting the dynamics series into subsamples at structural shifts points.
12. Repeat steps 6-8 for the new estimates of the trend.

The resulting estimates of dynamics and its components are used for modeling and forecasting.

When studying the Russian regions dynamics, regional models are built independently of each other, and general trends are sought in the results of modelling.

Let's take a closer look at procedures of the component identification.

In our methodology, the following methods and algorithms are applied to get estimates for the specified criterion:

- probabilistic simulated annealing algorithm (Xiang et al., 2012) for finding the global minimum area and initial estimates of model parameters;

- RPROP algorithm (Igel & Huesken, 2003), which is used to minimize errors in training neural networks and uses only signs of the minimized function derivatives, not their values;

- the minimization algorithm implemented in the standard nlm (non-linear minimization) function (Dennis & Schnabel, 1983) allows obtaining the most accurate estimates in situations where RPROP "does not sum up".

The complex of trend models currently includes linear, exponential, power trends, four cumulative logistic (S-shaped) and four impulse logistic (bell-shaped) trends with different skewness settings. For each series of dynamics, all 11 trend models are identified, both over the entire sample length and divided into parts by points of structural changes (for each model, the points may be different). Thus, for each point in the time series, we get up to 22 estimates for different trends. For 82 regions of Russia (with exception of Crimea, Sevastopol, and the Republic of Chechnya due to a lack of statistical data) and for Russia as a whole identification was carried out by 14 indicators (consumer price index and industries according to the OKVED2 classifier):

- basic consumer price index;
- building;

- extraction of minerals;
- crude oil and natural gas extraction;
- mining of metal ores;
- manufacturing;
- food production;
- production of petroleum products;
- production of chemicals and chemical products;
- production of pharmaceuticals and materials used for medical purposes;
- production of rubber and plastic products;
- metallurgical production;
- production of computers, electronic and optical products;
- production of motor vehicles, trailers and semi-trailers.

All indicators are provided in the EMISS in the form of monthly operational data, as a percentage over the previous month (quantity index number). To be able to identify the dynamics components, they were recalculated into base indices with respect to the beginning of the period (by December 2004). The analysis period is from January 2005 to August 2020. This time interval is interesting since it covers important periods and milestones in the Russian economy evolution. It embraces the economy growth in the noughties of the XXI century, the crisis phenomena of 2008-2009, the subsequent recession and recovery, the growth of political turbulence, the adoption of economic sanctions against Russia, the beginning and development of the COVID-19 pandemic.

6. Findings

The analysis made it possible to assess the proposed models adequacy, and on the other hand, to compare the scale and time points of fluctuations in regional economic sectors, to compare them with all-Russian ones, and to suggest measures for their regulation (correction). It is important that the resulting slice of industry cycles for all regions of Russia helps to get an operational and adequate idea of the sectors of economy with the greatest growth potential, and vice versa, to clearly see the regions and regional industries at the stage of stagnation and decreasing economic growth, requiring immediate management decisions.

The modeling and forecasting methodology has been developed in the following areas:

- wide application of a variety of mixed multi-component time series structures;
- accounting for the dynamics evolution, including identification of structural shifts;
- application of a mixed non-quadratic criterion for model identification, which is especially important for distributions with heavy tails
- using the median value of a multitude of trends, instead of choosing a single "best" trend, thus increasing the obtained estimates and forecasts stability;
- modeling of non-periodic cyclic fluctuations by the sum of harmonic curves with aliquant frequencies.

The high level of the Russian economic space heterogeneity has determined solutions that overpassed the Russian and world levels and are applicable in all subjects of analysis. The proposed

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methodological approach makes it possible to significantly mitigate the modeling and forecasting process for the promising economic specializations development (Order of the Government of the Russian Federation of 13.02.2019 N 207-r).

7. Conclusion

The key findings of the evaluation:

- estimates of the forecasts accuracy obtained on control samples with a depth of 3-12 months do not exceed 30%, whilst the accuracy of models for R2 > 0.65 for all of the studied industries, and in most cases is more than 0.8, which corresponds to high accuracy;

- the global crisis of 2008 had a negative impact on all regions and industries, which affected the depth of the plunge, but not all regions are experiencing a regional industry cycle recovery;

- hardly had industry region-leaders recovered from the impact of the global crisis, than the sanctions of 2014 hit the economy again. Some regions have not recovered from this shock thus far, but in general, cyclical fluctuations in industries have been more smoothed-out than during the global crisis;

- a moderately upward trend across all regions was observed only in relation to the consumer price index, the cycles are similar in length and scope of fluctuations, which is a consequence of the strong common monetary policy impact in Russia;

- cyclicity is observed in all regions and industries, which once again supports the cyclical theory validity;

- the length and depth of the economic cycle decline and growth in the same industry, but in different regions is different and is not directly related to the industry scale in the region;

- identified are the regions that, regardless of the industry scale in the region, made a positive contribution to the overall sustainable growth; Different industries have different leaders. For example, in manufacturing, such regions were: Chelyabinsk Oblast, Tyumen Oblast, Stavropol Krai;

- identified are the regions that, along with relatively high sustainability of economic growth, have shown high upward growth in recent months.

The created models and drawn conclusions can serve as an important informational support in making managerial decisions of economic policy.

Our study was conducted on the example of Russian regions and does not include a quantitative estimate of each region impact on the overall sustainability and balance of economic development. However, the built models of regional cycles by industry allow us to conclude that there is such an influence. Furthermore, the obtained models allow identification of regions with a high degree of economic growth sustainability in certain industries and those at an upward stage of growth, where special attention should be paid to these effective specializations in the short and medium term.

Future research will focus on the cyclical nature and share of the relevant sector in the economic structure. In addition, the question of quantitative and qualitative assessment of the individual regions impact in the overall industry growth, imbalance, or, vice versa, the balance of industry development is of interest. The high accuracy of the median approach models leads to the good predictive potential that the authors intend to implement in future research.

The results of this study increase the ability to adequately assess the economic growth sustainability (UN, 2015) in countries with a developed regional network, as well as groups of countries integrated in economic unions. An imbalance in the economy is an excess pressure of negative forces over positive ones. Sustainable growth in the industry or in the economy as a whole is possible if the growing trend is observed in most regions or its impact in some regions is higher than in others. It is impossible to achieve sustainable and balanced growth in a country without understanding each region's contribution to this growth.

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