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Dynamic Interrelation between Aggregated Revenues and Expenditures of Regional-Level Budgets of Federal States: A Time-Frequency Approach to Analysis

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ABSTRACT: *Objective:* The article analyzes the dynamic (time-frequency) relationship between aggregate budget expenditures and revenues of the federal constituent entities, considering four competing theoretical hypotheses: “expenditures-revenues”; “revenues-expenditures”; “fiscal synchronization”; and “fiscal neutrality”, over time (2013:12÷2023:03). *Method:* The study was conducted using *wavelet coherence analysis*, which made it possible to separate short-term, medium-term and long-term effects in the dynamic dependence of the analyzed variables, and identify the direction and intensity of this relationship. *Finding:* The research results indicate the existence of all four relationships between aggregated budget revenues and expenditures of the federal constituent entities for various time periods, on different time scales, throughout the entire observation time interval (2013:12÷2023:03). These findings demonstrate that, to a greater extent, the budgets of the federal constituent entities are characterized by the presence of a dynamic relationship between aggregated revenues and expenditures in the following modes: “revenues-expenditures” (when revenues are ahead of expenditures) and “expenditures-revenues” (when expenditures are ahead of revenues). In addition,the time scale and time range of the emergence of the “fiscal synchronization” and “fiscal neutrality” modes in the relationship between aggregated revenues and expenditures of the federal constituent entities are determined. *Implication:* The results obtained provide a possible explanation for the contradictory results of numerous studies based on traditional methods and empirical observations over different historical periods, since each of these methods only partially explains a particular mode of the dynamic relationship between revenues and expenditures. The *theoretical significance* of the study lies in the substantiation that continuous wavelet analysis is a powerful tool for studying the nonlinear relationship between revenues and expenditures, since understanding the causalities between revenues and expenditures on various time scales is significant for choosing measures aimed at maintaining the budget sustainability ofthe federal constituent entities. The *practical significance* of the research results is determined by the fact that they can be anessential starting point for determining the necessary fiscal policy measures aimed at increasing the budget sustainabilityof the federal constituent entities.

Keywords: regional-level budgets, sustainability of regional budget, fiscal policy, time-frequencydependence, aggregated expenses.

I. INTRODUCTION

Determining advanced instruments for assessing the sustainability of state/regional budgets is crucial for obtaining the most reliable results of such an assessment and making the necessary decisions, on this basis, to adjust the fiscal policy of the state/region [1, 2].

With the onset of the coronavirus infection (COVID-19) pandemic, the problem of fiscal sustainability has become one of the most acute and complicated for developing and developed countries. This problem is especially relevant for countries with a federal structure, such as Russia, in which it is important to study not only the fiscal sustainability at the federal level, but also that of the federal constituent entities, despite partial assistance, in particular, in the form of extrabudgetary transfers. Consequently, methods for ensuring fiscal sustainability in federal states by solely focusing on central government finances are at best incomplete and sometimes misguided. The main goal of most studies in this area is to develop methods for ensuring budgetary

sustainability, which are aimed at determining the causalities between budget expenditures and revenues of the studied federal constituent entities. Understanding the nature of the causality between expenditures and revenues provides direction for the search for effective methods for achieving long-term fiscal sustainability [3]. The scientific literature examines four main theoretical hypotheses concerning the determination of the direction and intensity of the relationship between budget revenues and expenditures: "revenues-expenditures" [4–7]; "expenditures-revenues" [8–10]; fiscal synchronization [11, 12]; and fiscal neutrality [13, 14]. Thus, proceeding from four hypotheses, the relationship between budget expenditures and revenues can be (i) unidirectional, from expenditures to revenues, or unidirectional, from revenues to expenditures; (ii) bidirectional between revenues and expenditures; and (iii) there can be no causal relationship between revenues and expenditures.

The "revenues-expenditures" hypothesis [4–7] postulates that the relationship between revenues and expenditures is unidirectional from revenues to expenditures, and that changes in expenditures are associated with changes in revenues, that is, an increase in expenditures is associated with an increase in taxes. Therefore, if revenues cause expenditures, the budget deficit can be reduced through measures aimed at stimulating fiscal revenues.

The "expenditures-revenues" hypothesis [8-10] assumes that the relationship between revenues and expenditures is unidirectional from expenditures to revenues, and that a change in revenues is associated with a change in expenditures, i.e., expenditures cause revenues. This means that government authorities first incur expenditures and then raise taxes to cover those expenditures.

The "fiscal synchronization" hypothesis [11, 12] assumes the existence of a bidirectional causality between revenues and expenditures, implying that decisions about expenditures and revenues are not made in isolation and states that expenditures and revenues are adjusted simultaneously. In this case, the government authorities can reduce the budget deficit by adjusting either expenditures or revenues, or both. The "fiscal synchronization" hypothesis [11, 12] is based on the axiom according to which authorities change expenditures and revenues simultaneously.

The "fiscal neutrality" hypothesis or the "institutional separation" hypothesis [13, 14] lacks a causality between revenues and expenditures and argues that due to institutional separation or fiscal independence, government spending decisions and revenue decisions are not connected with each other. with a friend, i.e., it is assumed that decisions regarding budget expenditures and tax cuts are made independently by government agencies.

Despite the large number of empirical studies devoted to the debate about the relationship between budget revenues and expenditures, no consensus has yet been found regarding the direction and sign of the correlation between these two variables.

II. LITERATURE REVIEW

Extensive literature is devoted to the results of empirical testing of four main theoretical hypotheses regarding the determination of the direction and intensity of the interrelation between budget revenues and expenditures; however, there is no consensus on the relationship between revenues and expenditures because of the inconsistency of the results obtained.

Thus, as established in Vamvoukas [15], the fiscal synchronization hypothesis was correct for 12 countries of the Economic and Monetary Union for the period from 1970 to 2006. More recently, later national-level studies [16, 17] provide evidence in favor of fiscal synchronization for Spain and India, respectively. On the other hand, the hypothesis of the relationship between tax revenues and expenditures was empirically tested for a group of six Eastern European countries, and a conclusion was drawn that the "revenues – expenditures" hypothesis was true in the selected time periods for Albania, Bulgaria, Croatia, Serbia and Slovenia, while fiscal synchronization was confirmed only for Macedonia during the same periods [18]. The empirical evidence was also provided in favor of the "revenues-expenditures" hypothesis for Gambia, Liberia, Sierra Leone and Nigeria [19, 20].

In contrast to the results of studies supporting the "revenues-expenditures" hypothesis, as found by Lusinyan and Thornton [21], applying the Granger causality test to British data for the period from 1750 to 2014, an increase in budget expenditures led to an increase in tax revenues. Therefore, for the UK during the selected period, the "expenditures-revenues" hypothesis was confirmed.

Using China's quarterly data for the period from 1980 to 2015, decomposed on the basis of wavelet transforms, and applying the Granger causality test, empirical evidence was obtained in favor of the "revenues – expenditures" hypothesis in the short term and the fiscal synchronization hypothesis in the long term [22]. Empirical results were obtained for Brazil, which indicate that fiscal synchronization was valid in the period from 2005 to 2008, while the "expenditures – revenues" hypothesis was confirmed from 2010 to 2013, and the "revenues-expenditures" hypothesis was true in the period from 2015 to 2018 [23].

Noteworthy, the results of Magazzino and Mutascu [24], which examines the direction of the causal relationship between budgetary expenditures and revenues in Italy over a fairly long period of time (1862–2013) using wavelet analysis, make it possible to study detailed information about this relationship for various sub-periods and frequencies that could not be detected using classical econometric methods. This research reveals that the relationship between these two variables varies across the frequency domain.

From the analysis of the results in the high frequency domain [24], it follows that until 1916 there was a statistically significant relationship between budget revenues and expenditures, and revenues determined expenditures with a positive sign (the variables were in phase). This means that the "revenues – expenditures" hypothesis was true. However, in 1916–1925, budget expenditures stimulated revenues with a positive sign (the variables were in phase), and the "expenditures-revenues" hypothesis was true. During the period of 1940–2000, any statistically significant co-movement between these variables occurred under the fiscal neutrality hypothesis. In 2000–2013, budget expenditures influenced revenues with a positive sign, being variable in phase. Thus, as in the previous interwar period, empirical evidence supports the "expenditures-revenues" hypothesis.

However, for the mid-frequency region [24], from 1862 to 1930, budget revenues influenced expenditures and vice versa, and the variables themselves changed in phase, with a bidirectional flow of causality, in accordance with the fiscal synchronization hypothesis. In 1930–1962, budget revenues were ahead of expenditures with a positive sign, both variables were in phase, and the "revenues-expenditures" hypothesis was confirmed. Whereas after 1962, no reciprocal movement was found, which confirms the fiscal neutrality hypothesis. Finally, spectral Granger causality tests show that over the entire time interval the "revenues-expenditures" hypothesis is true, since a unidirectional flow of causality arises, moving from revenues to expenditures.

A fairly large number of studies related to the analysis of the relationship between budget revenues and expenditures have been conducted for the United States, the results of which are also quite contradictory and ambiguous. Early studies based on the US data provide empirical evidence in favor of the "expenditures-revenues" hypothesis [25, 26]. On the contrary, as concluded by Koren and Stiassny [27] and Chang et al. [28], the "revenues-expenditures" hypothesis is true. There are also studies whose empirical results support the fiscal synchronization [29] and fiscal neutrality hypotheses [13].

Empirical results of recent studies of the interrelation between tax revenues and expenditures in the United States are also contradictory, in particular, as found by Young [30], using quarterly data from 1959 to 2007, based on the Granger causality test, tax revenues had a negative impact on budget expenditures for the chosen period, accordingly there was a fiscal illusion. Annual data from 1959 to 2005 were analyzed by Zapf and Payne [31], and the conclusion was made that budget expenditures have a positive effect on tax revenues; on the contrary, [32] revealed empirical evidence that a "revenues-expenditures" hypothesis was operating in the period from 1951 to 2008.

The time-frequency relationship between budget expenditures and tax revenues was examined using the wavelet coherence approach based on the US data for the period from the second quarter of 1960 to the third quarter of 2019. As follows from the results, budget expenditures lead to an increase in tax revenues in the short and long term at certain periods of time, confirming the "expenditures-revenues" hypothesis [33].

Another study by Surugiu et al. [34] analyzes the type of interrelation between budget revenues and expenditures using a wavelet approach and monthly data for Romania for 2000–2021. According to the results obtained, two hypotheses ("revenues-expenditures" and "expenditures-revenues") are valid in the case of Romania, but for different periods of time.

The interrelationship between revenues and expenditures of the Canadian federal budget was examined using continuous wavelet analysis for the period 1867–2017 [35]. The research results support all four hypotheses, each of which explains part of the dynamic relationship between revenues and expenditures of the Canadian federal

budget, but the "expenditures – revenues" hypothesis is the most pronounced and dominates in this regard in the long term. This study showed that continuous wavelet analysis is a significant tool for studying the dynamic relationship between revenues and expenditures as applicable to fiscal sustainability.

With regard to research on the sustainability of regional budgets, Febriani and Rambe [36] tested hypotheses explaining the relationship between tax revenues and budget expenditures in six regions of Indonesia using Granger's causality approach from 2006 to 2017. The results showed five bidirectional causal relationships between tax revenues and expenditures of local budgets from six regions. Furthermore, the fiscal synchronization hypothesis was identified in five regions, while the "revenues – expenditures" hypothesis was typical in the Papua and Maluku regions.

In Gurvich and Krasnopeeva [37], the relationship between revenues and expenditures of Russian regional budgets was analyzed. The research results show a significant causal relationship, directed from revenues to expenditures. Based on panel data for 18 years (2000–2017) for 80 regions of Russia, response factors were constructed that reflect the elasticity of changes in regional budget expenditures by revenues. The resulting estimates range (depending on the econometric model) from 0.72 to 0.78, which exceeds the doubled individual response factor for the federal budget. This indicates that the policy of budget expenditures at the regional level (as opposed to the federal level) is of a pronounced pro-cyclical nature.

It should be noted that in Gurvich and Krasnopeeva [37] only the short-term relationship between revenues and expenditures of regional budgets was studied on the basis of an assessment of budget shocks. Whereas the nature of long-term causal relationships between revenues and expenditures of the Russian regional budgets, which differs from the nature of the short-term relationship between them, was studied by Krasnopeeva [38, 39]. The results obtained by Krasnopeeva [38] show that 25% of regions are characterized by dominance of revenues, expenditures prevail in 7% of regions, fiscal synchronization is common in 34% of regions, and the absence of a causal relationship is also observed in 34% of regions. Poor regions with a high share of transfers from the federal budget in revenues or regions with oil production prevail in the revenue dominance group. The richest regions (for example, the cities of Moscow, St. Petersburg and the Krasnodar Territory) prevail in the fiscal synchronization group.

China's fiscal sustainability was assessed on the basis of studying national and regional interrelations between budget revenues and expenditures using time-frequency analysis [40]. The time-frequency relationship between budget revenues and expenditures was analyzed using annual data from 1952 to 2020. The findings showed that national and regional fiscal revenue-expenditure interrelations were frequency-dependent and time-varying, providing a possible explanation for the mixed and sometimes contradictory results of traditional time-only models. In addition, as follows from the results obtained, the medium- and long-term national and regional relationships between budget revenues and expenditures in recent years predominantly have confirmed the fiscal neutrality hypothesis. Thus, the results of this study indicate an increase in fiscal risks for China recently, which requires fundamental reforms to prevent these risks, and to improve fiscal sustainability. It should be emphasized that the contradictory empirical results assessing the direction and intensity of the dynamic relationship between budget revenues and expenditures in different countries may be associated with the fact that this relationship is dynamic and, therefore, the four hypotheses found in the literature may alternate over time and frequency. Most studies used either time- or frequency-domain methods, and therefore, were unable to observe these effects. In this regard, this study applied an approach based on wavelet coherence analysis, which allows us to overcome these problems.

The purpose of this research is to study the dynamic (time-frequency) relationship between aggregate budget expenditures and revenues of the federal constituent entities, regarding four competing hypotheses: "expenditures-revenues", "revenues-expenditures", "fiscal synchronization", and "fiscal neutrality", over time (2013:12÷2023:03).

To achieve this goal, a scientific assumption was formulated in this study: (A1) The use of wavelet coherence analysis tools will make it possible to separate short-, medium- and long-term effects in the dynamic relationship between aggregated budgets revenues and expenditures of the federal constituent entities, considering four competing hypotheses: "expenditures-revenues", "revenues- expenditures", "fiscal synchronization", and "fiscal neutrality", over time (2013:12÷2023:03).

III. MATERIAL AND METHOD

This research uses a wavelet transform-based method to study the individual volatility of the variables of the empirical model (budget revenues and expenditures), and to determine their possible joint movements. This approach allows for estimation of the local volatility of the analyzed time series in both the time and frequency domains, using the technique of constructing a wavelet power spectrum to identify a possible relationship between two time series – wavelet coherence and to determine the lead-lag relationships between the time series of analyzed variables – wavelet phase difference.

The basic advantage of using the wavelet approach, compared to traditional econometric methods, is associated with the fact that this method:

(a) does not require the assumption of stationarity of time series, as in econometric methods;
(b) does not require the assumption of normal distribution of the time series;
(c) allows time series to be analyzed in terms of time and frequency;
(d) makes it possible to effectively assess the strength and direction of dynamic relationships between time series and distinguish short-, medium- and long-term relationships over time;
(e) makes it possible to study nonlinear dependencies typical of financial and economic time series;
(f) provides the ability to efficiently track evolution and co-movements between time series;
(g) makes it possible to identify bidirectional relationships (lead-lag) between time series in various combinations of time and frequency [41-45].

In this research, we used seasonally adjusted monthly time series data reflecting the expenditures and revenues of the consolidated budgets of the constituent entities of the Russian Federation for the period from December 2013 (2013:12) to March 2023 (2023:03)1 to study the time-frequency dependence between budget expenditures and revenues using the wavelet coherence method. The time period of analysis (2013:12÷2023:03) covers various events that significantly influenced the dynamics of aggregated budget revenues and expenditures the federal constituent entities: the introduction of a floating exchange rate regime in November 2014; introduction of a new version of the budget rule at the end of 2017; the COVID-19 coronavirus pandemic at the beginning of 2020, etc.

A set of time series of aggregated budget revenues and expenditures of Russian regions, in current prices, was selected from the statistical database of the Ministry of Finance of the Russian Federation [46]. Following the logic of the approach discussed by Wang and Wei [35] and Jones and Joulfaian [47], the variables of the empirical model (revenues and expenditures) are expressed in current prices in this study, since authorities use this information when making decisions.

For seasonal adjustment of time series, in this study we used the Season package developed in [48], which allows us to decompose the time series, xt, $t \in \{1, \dots, T\}$, into a trend component, yt, $t \in \{1, \dots, T\}$, seasonal component, zt, $t \in \{1, \dots, T\}$, and irregular component, ut, $t \in \{1, \dots, T\}$: $xt = yt + zt + ut$ for all t, using the nonparametric spline method, HP filter and orthogonal parameterization-based filter. The seasonally adjusted time series is obtained by subtracting the estimated seasonal component, zt, from the original time series: $xt - zt = yt + ut$.

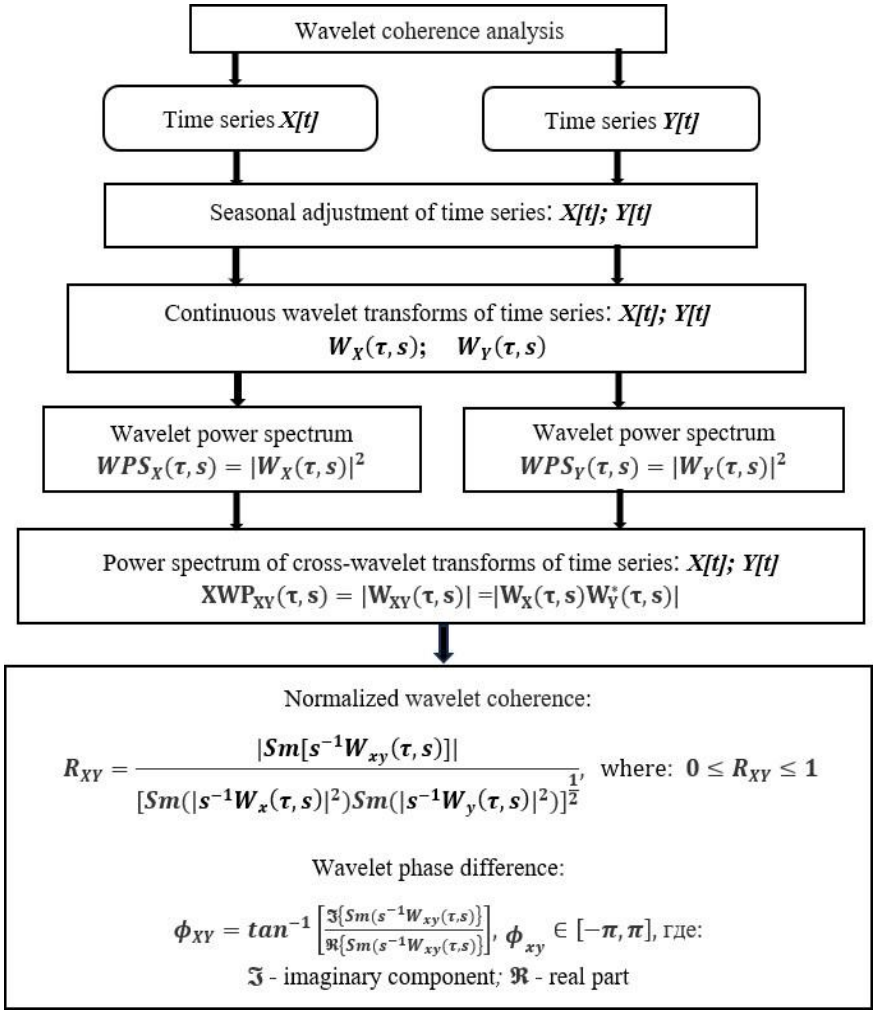

FIGURE 1. Flowchart framework computational thinking activity

The dynamics of aggregated monthly budget revenues and expenditures of the constituent entities of the Russian Federation are calculated based on their growth rates (percentage change for the current month relative to the previous month).

The results of numerous studies indicate that using monthly data instead of quarterly data for the same observation period leads to the opposite results [49, 50]. The ambiguity and inconsistency of these results may well be caused by the fact multiple time scales are involved in the nonlinear dynamic relationships of the variables (revenues and expenditures of regional budgets), and that traditional analysis may be inadequate to single out the structured time scales of the relationships between these variables. Therefore, wavelet analysis was used for empirically study of the relationship between these variables, which allowed for identification of different time scales of change in the analyzed variables. Time scale decomposition is crucial for analyzing the relationship and mutual influence of economic variables to empirically explore the relationship between these variables.

Figure 1 provides a schematic representation of the main stages of the research methodology. The calculations in this research were performed in the computer system Wolfram Mathematica [51]. Wavelet coherence analysis was conducted using continuous wavelet transforms of the Gabor family: cwt = ContinuousWaveletTransform[data, GaborWavelet [8]. As a smoothing operator, both in time and in frequency (scale), Sm, the research uses Gaussian Filter[data, r] - a convolution-based filter that uses the Gaussian matrix as the main kernel, radius r (in a given the value r = 8 was used in this work). As follows from Figure 1:

With $RXY \approx 0$, a fiscal neutrality mode is observed, when there is no correlation between expenditures and revenues; with $RXY \approx 1$ and $\phi XY \approx 0$, a fiscal synchronization mode is observed, when changes in expenditures

and revenues occur in a coordinated manner (coherently). Figures 2 and 3 were constructed using the ListDensityPlot function, with regard to the linearity of the frequency scale, based on the LinearScalogramFunction.

IV. RESULTS AND DISCUSSION

Let us consider the results obtained in more detail and analyze the dynamics of the interrelations and mutual influence of aggregated expenses and revenues of the federal constituent entities' budgets. Figures 2 and 3 display the most significant measurement results (heat maps) of wavelet coherence and lead- lag ratios based on the values of the wavelet phase difference between the variables of the empirical model: aggregated revenues and expenditures of the federal constituent entities' budgets (the Russian Federation) (2013:12 – 2023:03).

Figures 2 and 3 show time, measured in months, on the horizontal axis, and frequency or time scale on the vertical axis. Analysis period, in months, varies from high frequency (0÷20 months), medium frequency (20 ÷ 60), to low frequency (60 ÷120 months) periods (frequency bands). At the same time, time is counted starting from the beginning of 2013. The white line marks the area that is not influenced by end effects – the Cone of Influence. The color range on the right side of Figure 2 shows how strongly the variables are correlated: cool blue indicates minor dependence between variables, while red indicates a significant correlation between expenditures and revenues. Recall that when $RXY \approx 0$, a "fiscal neutrality" mode is observed.

The direction of causality and correlation between variables is shown in Figure 3, which demonstrates a heat map of the wavelet phase difference. When the correlation between variables is significant ($RXY > 0.7$) and there is a zero-phase difference, $\phi XY \approx 0$, the variables move harmoniously and consistently, on a certain scale, and this is the "fiscal synchronization" mode.

When two variables, X and Y, are in phase, this means that they move in one direction: with $0 < \phi_{XY} < \frac{\pi}{2}$, X is ahead of Y (if X - revenues; Y - expenditures, "revenues-expenditures" fiscal mode is observed); with $\frac{\pi}{2} < \phi_{XY} < 0$ Y is ahead of X ("expenditures-revenues" fiscal mode).

When these variables are out of phase, they move in opposite directions: with $\frac{\pi}{2} < \phi XY < \pi$, Y is ahead of X ("expenditures-revenues" fiscal mode); with $\pi < \phi XY < -2$, X is ahead of Y ("revenues-expenditures" fiscal mode).

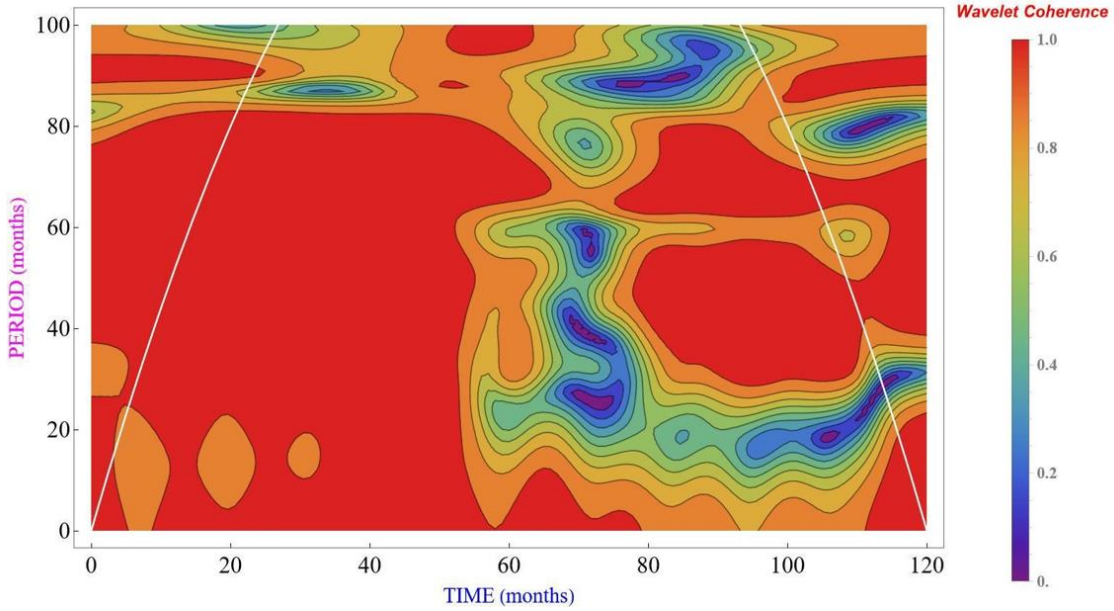

FIGURE 2. Heat map of wavelet coherence of growth rates of aggregated revenues and expenditures of the federal constituent entities' budgets (2013:12÷2023:03). Source: developed by the authors.

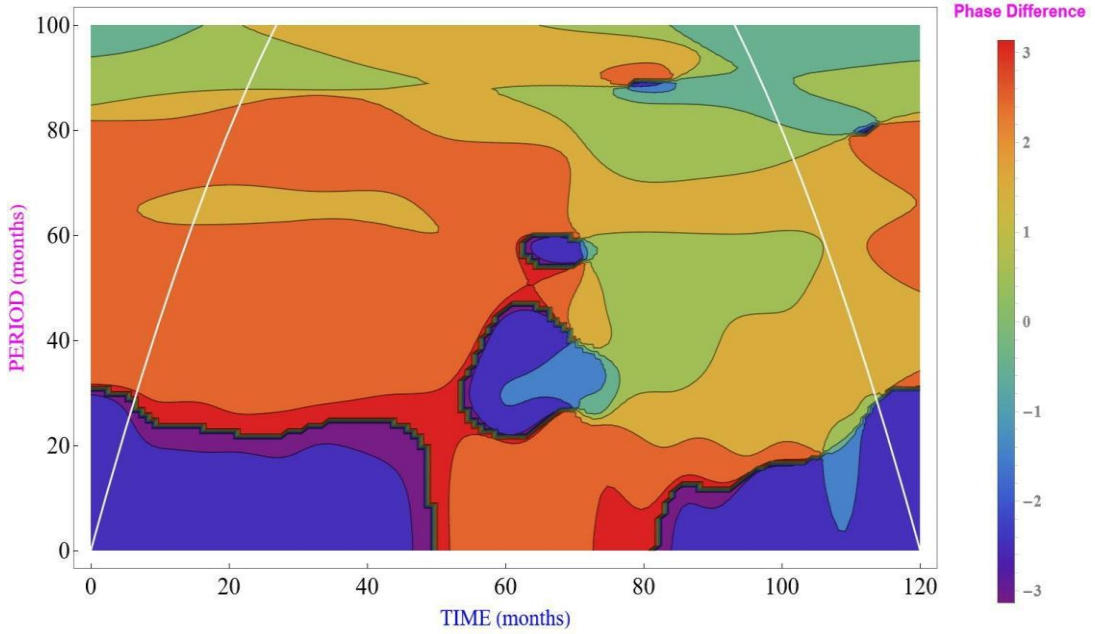

FIGURE 3. Heat map of phase difference of growth rates of aggregated revenues and expenditures of the federal constituent entities' budgets (2013:12÷2023:03). Source: developed by the authors.

1. *VERIFICATION OF THE ASSUMPTION (A1)*

As follows from the analysis of Figures 2 and 3, in the short term, in the frequency band (0÷20) months, during the time period (0÷50) months (2013:01÷2017:02), aggregated revenues and expenditures move in antiphase, but in a mode where expenditures outstrip revenues. Then, during the time period of (50÷80) months (2017:02÷2019:08), a change in dominance occurs when revenues outpace expenditures, while the variables also move in antiphase. Subsequently, during a time interval of (80÷120) months (2019:09÷2022:12), a sharp change in leadership occurs again, when, in antiphase mode, aggregate expenditures outstrip revenues. In addition, in the frequency band, (0÷20) months, during the time interval (106÷110) months (2021:09 ÷2022:01), there is an area with zero wavelet coherence, which indicates the absence of correlation between aggregated revenues and expenditures, and this is typical for the fiscal neutrality mode.

In the short term, in the frequency band of (0÷20) months, in the time interval of (0÷50) months (2013:01÷2017:02), the dynamics of variables is as follows: aggregated revenues and expenditures of regional budgets are in the anti-phase, when expenditures are ahead of revenues. But then, over a time period of (50÷80) months (2017:02÷2019:08), a change in dominance occurs, when revenues are ahead of expenditures, while the variables are also in the anti-phase. At the next time interval of (80÷120) months (2019:09÷2022:12), a sharp change in leadership occurs again, when, in the anti-phase mode, aggregated expenditures are ahead of revenues. In addition, in this frequency band, (0÷20) months, over the time interval of (106÷110) months (2021:09 ÷2022:01) there is an area with zero wavelet coherence, which indicates the absence of correlation between aggregated revenues and expenditures, and this is typical for the fiscal neutrality mode.

In the medium term, in the frequency band of (20÷70) months, in the time interval of (0÷60) months or (2013:01÷2017:11), there is an area with high wavelet coherence, in which aggregated revenues are ahead of expenditures, i.e., the relationship is directed from revenues to expenditures. In the time interval of (70÷78) months (2018:09÷2019:05), on time scales of about 20, 40 and 60 months, areas with zero wavelet coherence are observed, characteristic of the fiscal neutrality mode, in which changes in revenues and expenditures are independent from each other. Subsequently, in the time interval of (80÷110) months (2019:08÷2022:02), an area with high wavelet coherence is again observed, in which a large share is occupied by a subregion where revenues and expenditures change synchronously. That is, the wavelet phase difference is near zero (fiscal synchronization mode), and in the remaining subregion a mode is formed in which revenues are ahead of expenditures, i.e., the relationship is directed from revenues to expenditures.

In the long term, in the frequency band of (60÷100) months, both areas with high wavelet coherence and areas with zero wavelet coherence of variables are observed. In the frequency band of (60÷80) months, in time intervals of (0÷70) months (2013:01÷2018:09) and (80÷110) months (2019:08÷2022:02), areas were formed with high wavelet coherence, in which in the time interval of (0÷70) months (2013:01÷2018:09) revenues are ahead of expenditures, and in the time interval (80÷110) months (2019:08÷2022:02) revenues and expenditures change synchronously in the fiscal synchronization mode. On the time scale in the frequency band of (80÷100) months, different modes of interconnection and mutual influence of regional aggregated budget revenues and expenditures are also observed. In the time interval of (70÷90) months (2018:09÷2020:05) in the frequency band of (80÷90) months, an area was formed with zero correlation of aggregated revenues and expenditures, characteristic of the fiscal neutrality mode. An area with high wavelet coherence is observed in the frequency band of (90÷100) months, in the time range of (50÷70) months (2017:01÷2018:09), in which revenues are ahead of expenditures.

Thus, the research results confirm assumption (A1), namely, the use of wavelet coherence analysis tools made it possible to separate short-, medium- and long-term effects in the dynamic relationship between aggregated budget revenues and expenditures of the federal constituent entities, regarding four competing hypotheses: “expenditures-revenues”, “revenues-expenditures”, “fiscal synchronization”, and “fiscal neutrality”, over time (2013:12÷2023:03).

The research results demonstrate all four relationships between aggregated the budget revenues and expenditures of the constituent entities of the Russian Federation available in different time periods, on different time scales, over the observation time interval (2013:01÷2023:03): “revenues-expenditures”, “expenditures-revenues”, “fiscal synchronization” and “fiscal neutrality”.

The research results indicate that, to a greater extent, the budgets of the federal constituent entities (2013:01÷2023:03) are characterized by the available dynamic interrelation between aggregated revenues and expenditures in the following modes: “revenues-expenditures” (revenues ahead of expenditures) and “expenditures-revenues” (expenses ahead of revenues). Assessing the relationship between budget revenues and expenditures at the appropriate time interval is an essential factor in the development of fiscal policy measures aimed at increasing the budget sustainability of the federal constituent entities, based on the nature of this dynamic relationship.

In the case where the “revenues ahead of expenditures” hypothesis is confirmed, the fiscal policy of regional authorities should be aimed at early repayment of debt obligations, considering the current structure of the regional public debt portfolio and the cost of servicing the corresponding types of debt obligations – primarily at debt repayment for regional government securities and loans from credit organizations, and secondly at debt repayment for budget loans. The task of forming budget reserves, in particular regional reserve funds, is becoming urgent, which will make it possible to further use accumulated funds in the event of unfavorable macroeconomic and geopolitical challenges. Measures can be taken to increase the level of socio-economic development of the regions aimed at increasing social, investment-related and other priority budget expenditures for the region. In the future, while maintaining a stable “revenues – expenditures” trend, it is possible to take measures to optimize taxation, including by regulating tax rates within the permitted limits and providing tax benefits at the regional level [36, 52].

In turn, when the “expenditures ahead of revenues” hypothesis is confirmed, regional fiscal policy should be aimed at restraining growth and optimizing the structure of expenditures [52-54], and at stimulating the strengthening of the revenue base. In these conditions, measures are important to adjust the division of state powers, especially in areas of joint jurisdiction of the federation and its constituent entities, and create an effective mechanism for financial support of state powers delegated to the regions. Measures for creating a favorable investment climate and financial stimulation of the regions’ investment potential, including the provision of tax preferences (considering the assessment of the growth of tax expenditures in regional budgets), and the attraction of additional financial resources for infrastructure provision of territories are of particular importance. It is relevant to use special instruments for strategic and operational response, including attracting budget reserves, using inter-budgetary redistribution instruments, restructuring the region’s debt portfolio in favor of “cheap” debt obligations (enabling to reduce expenditures on servicing public debt). Within the framework of administrative regulation, measures are significant to improve the quality of tax administration and combating

tax evasion, monitoring and control the regions' compliance with regulatory restrictions and obligations under concluded agreements regarding the improvement of regional finances [55-57].

V. CONCLUSION

This research analyzes the dynamic (time-frequency) relationship between aggregate budget expenditures and revenues of the federal constituent entities, considering four competing hypotheses: "expenditures-revenues", "revenues-expenditures", "fiscal synchronization", and "fiscal neutrality", over time (2013:12÷2023:03). The study was conducted using wavelet coherence analysis, which made it possible to separate short-, medium- and long-term effects in the dynamic dependence of the analyzed variables, and identify the direction and intensity of this relationship.

Significant results of the analysis were obtained – heat maps of wavelet coherence and lead-lag relationships based on the values of the wavelet phase difference between the variables of the empirical model: aggregated budget revenues and expenditures of the federal constituent entities.

The research results indicate the existence of all four relationships between aggregated budget revenues and expenditures of Russian regions during different time periods, on different time scales, over the observation time interval (2013:01÷2023:03).

The results obtained reveal that continuous wavelet coherence analysis is a tool for studying the dynamic relationships between budget revenues and expenditures of the federal constituent entities over different time periods and scales, on the basis of which strategic and operational decisions are made by authorities within the framework of fiscal policy aimed at increasing sustainability of regional budgets.

The novelty of this research lies in demonstrating the effectiveness of using wavelet coherence analysis to study the individual volatility of empirical model variables (budget revenues and expenditures of regions of a federal state), and determine their possible joint movements, using the technique of constructing a wavelet power spectrum to identify the direction of the dynamic dependence between two time series – the wavelet coherence and to determine the lead-lag relationships between the time series of the analyzed variables – the wavelet phase difference.

The theoretical significance of the research is determined by the fact that the dynamic interrelations between the aggregated monthly revenues and expenditures of the Russian federal constituent entities' budgets (2013:01÷2023:03) were analyzed using the wavelet coherence approach. Assessing these interrelations is a crucial factor in developing fiscal policy aimed at increasing the sustainability of budgets at the regional level in federal states.

The practical significance of the results obtained is of undoubted interest and makes it possible to more effectively apply fiscal policy measures aimed at increasing the sustainability of budgets at the regional level in federal states, depending on the nature of the dynamic interrelations between budget revenues and expenditures. Creating optimized recommendations for evaluating wavelet coherence analysis data increases the accessibility of this powerful technology to policymakers.

VI. LIMITATIONS AND FUTURE RESEARCH

Despite the significant results obtained, it is necessary to note some limitations of the research: in this study, the sustainability of the budgets of the constituent entities of the Russian Federation is considered at the aggregate level. The subsequent studies will examine the sustainability of the budgets of specific regions of the federal state. In addition, the use of this methodology in different federal states will increase the generalizability of the findings and facilitate comparison of results in other economic and political environments.

The seasonal adjustment procedure is an important stage in the pre-processing of initial time series characterizing the dynamics of budget revenues and expenditures of the federal constituent entities. This research applies the procedure of seasonal adjustment of time series, which uses the assumption of the additivity of the components of the original time series: trend, seasonal and irregular. With this approach, a seasonally adjusted time series is obtained after subtracting the seasonal component from the original time series. Future studies will use the seasonal adjustment procedure for time series under the assumption of the multiplicativity of the original time series components. With this approach, a seasonally adjusted time series is obtained by dividing the original

time series by the seasonal component. The results of both approaches to the seasonal adjustment procedure will be compared.

In this study, wavelet coherence analysis was conducted using continuous wavelet transforms of the GaborWavelet family. In further research it is planned to expand the range of wavelet families used (DGaussianWavelet[]; MorletWavelet[]; PaulWavelet[]; MexicanHatWavelet[]).

Including political and economic externalities in the study will provide a deeper understanding of the dynamics affecting regional budgets. Since the dynamic relationship between expenditures and revenues depends on economic events and conditions associated with economic growth, the subsequent studies will examine the impact of GDP, inflation, interest rates and real sector indicators on the dynamic relationship between budget expenditures and revenues of the federal constituent entities.

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