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Empirical Analysis of the Effectiveness of the Inflation Channel of Monetary Policy in the Russian Federation

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ABSTRACT

Currently, researchers are particularly interested in studying the influence of the dynamics of various financial variables on the pace of economic development. In this regard, an important stage of the analysis is the study of the transmission of monetary impulses through the transmission channels of monetary policy to the real sector of the economy. The purpose of this article is to identify the features of the functioning of the inflation channel in the Russian Federation from 2013 to 2022 based on the construction of VAR models (vector autoregression), as well as to evaluate the function of impulse responses of variables. Through the application of this algorithm of computational and analytical actions, the mechanisms of interaction of the following variables within each of the considered chains of the inflationary channel of monetary policy were investigated: the volume of money supply, the deflator index of gross domestic product (GDP), average monthly nominal accrued wages, and gross domestic product (GDP). As a result, a consistent element of the inflation channel was highlighted, namely, the relationship between the average monthly nominal accrued wages, on the one hand, and the rates of inflation and GDP, on the other. However, the relationships between the other links of the transmission channel remain contradictory, indicating the need for further research aimed at clarifying the quantitative characteristics and direction of the relationships between the variables.

Keywords: money supply; inflation; wages; gross domestic product (GDP); monetary policy; economic growth; VAR model; impulse response

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INTRODUCTION

The current stage of development of the Russian Federation and its territorial entities is characterized by unprecedented sanction pressure from unfriendly countries, which may ultimately lead to an acceleration of inflation rates in the country. In this regard, authorities and management structures need to conduct constant monitoring of indicators reflecting the state and development of all spheres of societal activity, as well as take measures to mitigate the effects of macroeconomic instability factors and ensure sustainable economic development rates, taking into account the prevailing levels of inflation [1–3]. It is also important to note the significance of continuous monitoring of the effectiveness of the monetary policy of the Central Bank of the Russian Federation, which allows for the adaptation of managerial decisions to new conditions and minimizes the negative consequences of shocks on the socio-economic sphere of the country and its territorial entities [4–7].

The purpose of this study is to identify the mechanisms of the functioning of the inflation channel, that is, linking changes in the money supply, inflation, wages, and gross domestic product (GDP) in the Russian Federation during the period from 2013 to 2022. To achieve the set goal, the authors implemented the following algorithm of computational and analytical actions: construction of VAR models for the corresponding chains of the inflation channel (vector autoregression) and estimation of the impulse response function of the considered variables.

This algorithm will clarify the mechanisms of interaction between the considered macroeconomic variables, taking into account the inflation component, as well as identify the features and channels of transmission of inflationary impulses to the real sector of the economy [8, 9].

The theoretical basis for constructing the author's algorithm of computational and analytical actions was provided by scientific publications that describe the mechanisms of the impact of the Central Bank's decision to reduce the money supply or increase interest rates on changes in inflation rates and economic development in the country.

It should be noted that within the framework of monetary policy, the Central Bank of the Russian Federation strives to maintain a balance between combating inflation, reducing socio-economic tension, and influencing the pace of economic development. In this regard, the evaluation of the results of constructed VAR models of individual elements of the inflation channel ("Money Supply — Inflation — Wages — Gross Domestic Product (GDP)") and the analysis of the impulse response function of the considered variables will allow for the identification of coherent chains of the impact of the decisions made by the Central Bank of the Russian Federation on the real sector of the economy.

MATERIALS AND METHODS

The assessment and analysis of the viability of the transmission channel "Money Supply — Inflation — Wages — Gross Domestic Product (GDP)" can be carried out using various statistical and econometric methods, such as correlation-regression analysis; principal component analysis; hypothesis testing; time series analysis, modeling, and forecasting, etc. — both separately and in combination [10].

VAR models are a fairly reliable tool for analyzing and modeling time series. They allow for forecasting and assessing the impact of one variable in the system on others, taking into account the interaction between various economic indicators and contributing to more accurate estimates of the effects of changes in one variable on others. In VAR models, each variable is defined as a linear combination of its past values and the past values of other model variables, meaning it takes into account the dynamics of indicators over time, as well as the magnitude and direction of

their mutual influence. Moreover, VAR models allow for forecasting future values of variables, testing various scenarios and conditions of socio-economic dynamics, as well as analyzing impulse response functions that assess the magnitude and direction of the impact of one model variable on another and the effects of different management decisions.

Thus, VAR models can be adapted to various scenarios and used to analyze a range of transmission mechanisms, as well as to assess the effects of macroeconomic shocks, making them a flexible tool for analyzing economic processes. For example, the results of VAR model estimation are used to analyze the potential recovery timelines of the economy after a crisis or to identify variables that may be most sensitive to changes in global markets [11–19].

A special role and significance in the study of the viability of the transmission channel "Money Supply — Inflation — Wages — GDP" is assigned to the methodology of estimating Impulse Response Function in the VAR model, particularly the construction of impulse response graphs of variables to a unit shock of another variable [20].

However, it should be noted that VAR models have a number of limitations; in particular, they cannot account for all the factors that influence the economic processes under consideration: some variables may be implicitly related through other indicators that were not included in the model. Therefore, when interpreting the results of impulse response analysis, it is necessary to consider the specific socio-economic situation and context within which the analysis is conducted, as well as the model's limitations.

The authors conducted a study on the viability of the inflation channel within the framework of the following algorithm of computational and analytical actions:

1. Selection of variables for modeling: growth rates of the money supply (M2) and average monthly nominal accrued wages of employees in organizations (in % to the previous period), indices of the physical volume and deflator of gross domestic product (GDP) (in % to the previous period).

To assess the inflation component of the transmission channel, the authors used the GDP deflator instead of the consumer price index, as its calculation covers the prices of all goods and services produced within the country, whereas the CPI is based on measuring the price level of goods and services purchased by households. Moreover, the calculation of the GDP deflator takes into account any changes in the structure of nominal GDP, meaning that this indicator can essentially be called a more comprehensive index of inflation. Considering that the final element of the inflation channel is the gross domestic product, and its deflator represents a "broader" indicator of economic development with regard to the inflation component, its use in this analysis can provide additional information for characterizing the studied transmission mechanism.

2. Application of the augmented Dickey-Fuller test to check the stationarity of the time series of the studied variables.

Determination of the optimal lag order of a VAR model based on the Schwarz Information Criterion (SIC), which allows for the selection of a model with the best balance between accuracy and complexity, making it preferable for determining the optimal lag order for a VAR model.

3. Estimation of the VAR model parameters using the least squares method, allowing to determine the degree of influence between each variable and their lagged values and the values of other variables.

4. Calculation of the impulse response function, which is a graph that shows the change in each variable in the system due to a unit shock in another variable.

5. Testing the statistical significance of impulse responses using the bootstrap test and constructing confidence intervals for each variable.

6. Substantive interpretation and analysis of the transmission channel mechanism.

The authors used quarterly data (from 2013 to 2022) on the dynamics of the money supply (M2), GDP deflator index (DEF_GDP), average monthly nominal accrued wages (WAGE), and gross domestic product (GDP) from the official databases of the Federal State Statistics Service (Rosstat)[1] and the Central Bank of the Russian Federation[2] [21, 22].

These indicators most accurately reflect the dynamics of the variables under consideration in the study of the viability of the inflation channel; moreover, they are publicly available and published at regular intervals, ensuring the completeness and reliability of the research being conducted.

RESULTS AND DISCUSSION

As part of the extended Dickey-Fuller test (with a constant and trend), non-stationarity of the time series of the studied variables was identified. In this regard, the authors transitioned to their first differences, and the test results indicated the need to reject the hypothesis of a unit root at the 0.01 significance level; consequently, the time series of the first differences of the variables turned out to be stationary.

The next step in the study of the viability of the inflation channel is to determine the optimal lag order for VAR models based on the Schwarz Information Criterion (SIC). As a result, we have the following lag values: for the channel element "Growth rates of the money supply (M2) — GDP deflator (DEF_GDP)" — 1, for the channel elements "GDP deflator (DEF_GDP) — Growth rates of average monthly nominal accrued wages (WAGE)" and "Growth rates of average monthly nominal accrued wages (WAGE) — Physical volume index of GDP (GDP)" — 4 lag order.

Next, we will proceed to construct VAR models based on the optimal lag orders found using the Schwarz Information Criterion (SIC).

The results of estimating the first-order VAR model between the differences of the variables "Growth Rates of Money Supply" and "GDP Deflator Index" allowed us to draw the following conclusions:

- equation (1) describes the dependence of changes in the first differences of the money supply on the first differences of its past values and changes in the first differences of the GDP deflator index. The coefficients of equation (1) indicate that an increase in the previous values of the first differences of the money supply (d_M2_1) by 1% leads to a decrease in the current values of the first differences of the money supply by 0.46%. At the same time, changes in the values of the first differences of the GDP deflator index do not have a statistically significant impact on changes in the first differences of the money supply values;
- equation (2) describes the dependence of changes in the first differences of the GDP deflator index on the first differences of its past values and changes in the first differences of the money supply volume. The coefficients of equation (2) indicate that an increase in the previous values of the first differences of the money supply (d_M2_1) by 1% leads to a decrease in the current value of the first differences of the GDP deflator by 0.10%, but this coefficient is not statistically significant. At the same time, changes in the first differences of the GDP deflator index in the past (d_DEF_GDP_1) and current periods do not have a statistically significant impact on changes in the first differences of the GDP deflator index.

The results of estimating the VAR(4) model between the first differences of the variables "GDP Deflator Index" and "Growth Rates of Average Monthly Nominal Accrued Wages of Employees in Organizations" showed the following results:

- the first equation of the model relates the change in the first differences of the GDP deflator index values to the first differences

[1] Website of the Federal State Statistics Service (Rosstat). URL: https://rosstat.gov.ru/ (accessed on 01.07.2023).

[2] Website of the Central Bank of the Russian Federation. URL: https://cbr.ru/ (accessed on 01.07.2023).

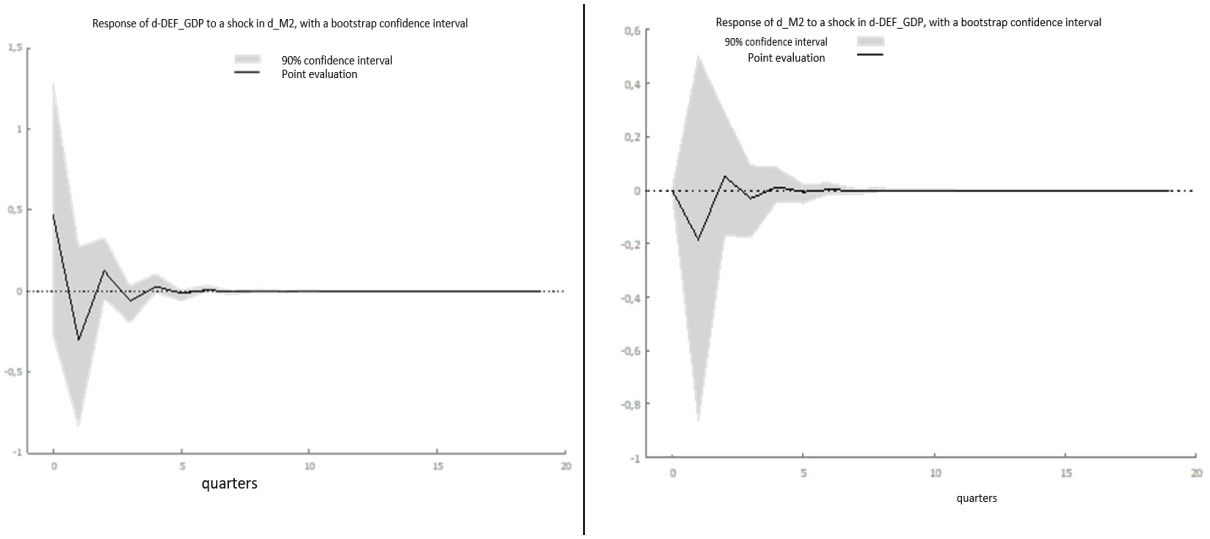

Fig. 1. **Graphs of the Impulse Response Function for the First Differences of the Variables "Monney Supply Growth Rate" (d_M2) and "GDP Deflator Index" (d_DEF_GDP)**

Source: Author's calculations.

of this variable over the previous four quarters, as well as to the changes in the first differences of the average monthly nominal accrued wages of employees in organizations for the same periods. The estimate of the GDP deflator coefficient at lag 4 is statistically significant at the level of $p < 0.001$. However, all coefficient estimates for the changes in the first differences of the average monthly nominal accrued wages are not statistically significant, except for the coefficient for the variable d_WAGE_3.

• The second equation of the model relates the change in the first differences of the average monthly nominal accrued wages to the values of the first differences of this variable over the previous four quarters, as well as to the change in the first differences of the GDP deflator index over the same periods. The estimates of the coefficients for the variable d_DEF_GDP for all considered lags are not statistically significant at the $p < 0.05$ level. However, all coefficient estimates for the variable d_WAGE are significant at the $p < 0.001$ level, except for the coefficient for the variable with a lag of 4.

Analyzing the results of the VAR (4) model estimation between the first differences of the variables "Growth rates of the average monthly nominal accrued wages of employees of organizations" and "Index of physical volume of GDP", the following conclusions are:

• in the first equation, the significance of the coefficients for all lags of the variable d_WAGE is confirmed, except for the last one. Speaking of the significance of the parameter estimates for the coefficients of the variable d_GDP, it can be noted that the coefficient is significant only for the variable with a lag of 3. The R-squared value of 0.97 indicates the high quality of the constructed model;

• a significant contribution to explaining the changes in the variable d_GDP is made by all lags of the variable d_WAGE and the last lag d_GDP_4, which is the only significant one.

Next, we will proceed to analyze the impulse response function for the first differences of the variables "Growth Rates of Money Supply" (d_M2) and "GDP Deflator Index" (d_DEF_GDP) (see *Fig. 1*).

Based on the data from *Fig. 1*, it is evident that the dynamics of the variable d_DEF_GDP in response to a one standard error shock of the variable d_M2 in the first period is positive and amounts to 0.47 (an increase in the money supply will lead to higher inflation,

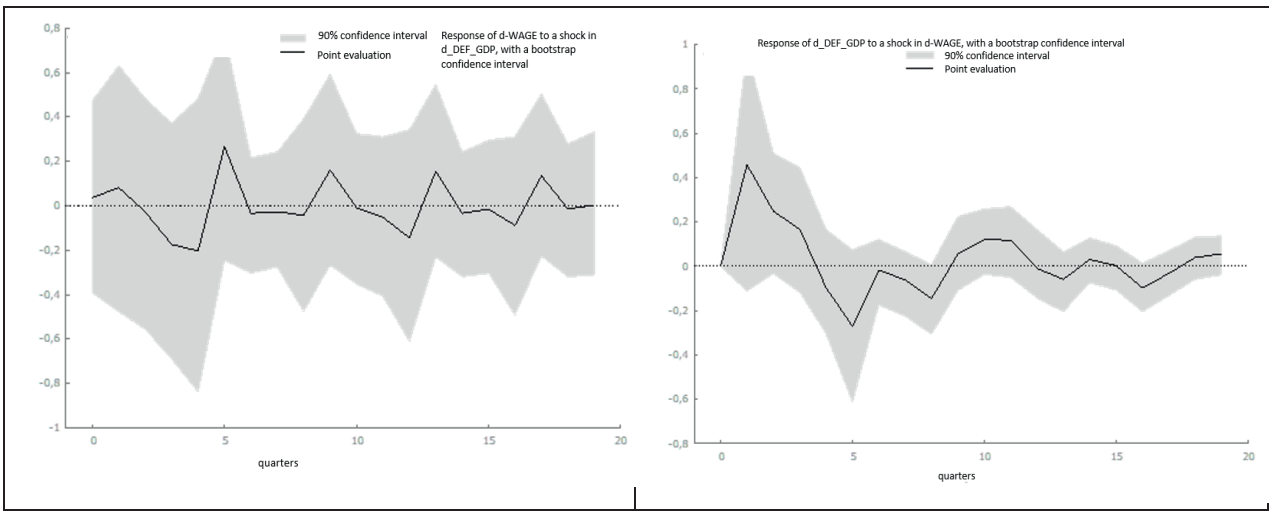

Fig. 2. **Graphs of the Impulse Response Function for the First Differences of the Variables "GDP Deflator Index" (d_DEF_GDP) and "Growth Rates of Average Monthly Nominal Accrued Wages" (d_WAGE)**

Source: Author's calculations.

as a greater amount of money available for consumption increases the level of demand for goods and services, which, in turn, can lead to a rise in price levels). In subsequent periods, a stepwise nature of the impulse response function changes is observed, which may indirectly indicate the presence of nonlinear effects in the dynamics of the inflation level, which slows down in periods 7–8, meaning that the inflation level stops reacting sharply to changes in the money supply and "dampen" starting from period 12.

In turn, the dynamics of the variable d_M2 in response to a shock of one standard error of the variable d_DEF_GDP in the first period is equal to 0 (the dynamics of the inflation rate do not affect the change in the money supply), then it becomes negative (an increase in the inflation rate leads to a decrease in the money supply). At the same time, it can be noted that the amplitude of changes in this function is lower compared to the one considered earlier. Next, the response begins to oscillate around 0 after the 6th period.

Let's consider the impulse response function graphs between the first differences of the variables "GDP Deflator Index" (d_DEF_GDP) and "Growth Rates of Average Monthly Nominal Accrued Wages" (d_WAGE). (d_WAGE) (see *Fig. 2*).

Based on the data from *Fig. 2*, it is evident that the dynamics of the variable d_WAGE in response to a shock of one standard deviation of the variable d_DEF_GDP in the first period is positive and amounts to 0.038 (an increase in the inflation rate causes a rise in wage levels, which may be related to an increase in the prices of goods and services, leading to higher income levels for enterprises and organizations, as well as an increase in the demand for labor). In subsequent periods, an intermittent of the impulse response function changes is observed, which may be explained by the presence of a seasonal component in this time series.

In turn, the dynamics of the variable d_DEF_GDP in response to a shock of one standard error in the variable d_WAGE in the first period is equal to 0 (a change in the wage level does not affect the dynamics of the inflation rate), then becomes positive up to the 4th period (an increase in the wage level leads to a rise in the prices of goods and services). At the same time, it can be noted that the amplitude of the fluctuations in the values of

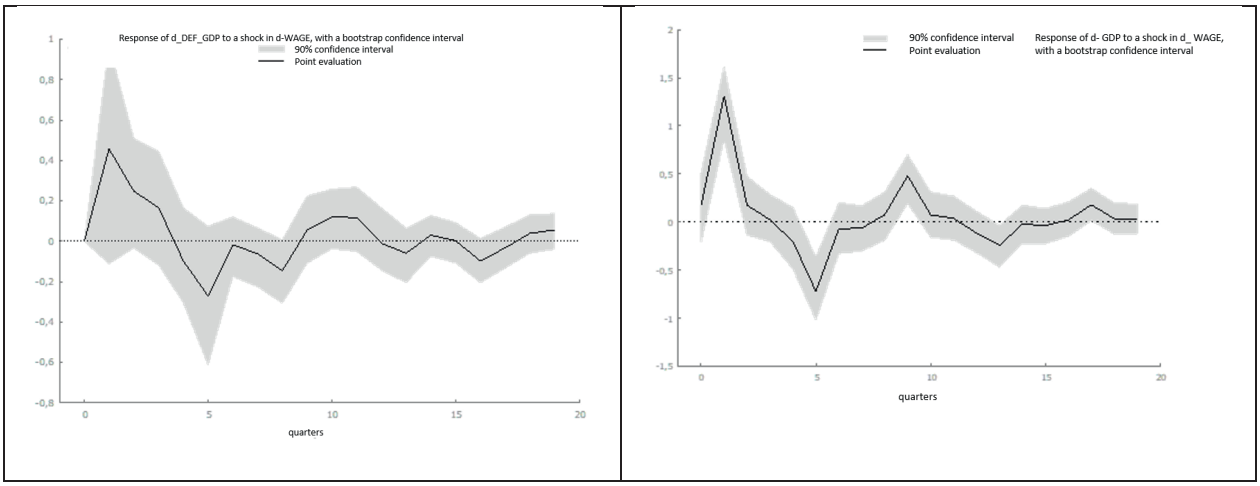

Fig 3. **Graphs of the Impulse Response Function for The First Differences of the Variables "Growth Rates of Average Monthly Nominal Accrued Wages" (d_WAGE) and "GDP Volume Index" (d_GDP)**

Source: Author's calculations.

Table

The Results of the Analysis of the Mechanisms of Functioning and Effectiveness of the Inflation Channel

Inflation Channel Component	Outcome of Vector Autoregression (VAR) Model Estimation	Outcome of the Period 1 Impulse Response Function Assessment
Money supply — Inflation	insignificant	Positive feedback
Inflation — Money supply	insignificant	0, then negative feedback
Inflation — Wages	insignificant	Positive feedback
Wages — Inflation	significant (lag 3)	0, then negative feedback
Wages — GDP	significant	Positive feedback
GDP — Wages	significant (lag 3)	Positive feedback

Source: Compiled by the authors.

the impulse response function subsequently varies between –0.2 and 0.26.

However, it should be noted that the interdependence between the level of inflation and the wages is quite complex and is determined by specific conditions in the labor market and the economic situation in the country.

Let's consider the graphs of the impulse response function between the first differences of the variables "Growth rates of average monthly nominal accrued wages" (d_WAGE) and "Index of physical volume of GDP" (d_GDP) (see *Fig. 3*).

Based on the provided data, the dynamics of the variable d_GDP in response to a shock of one standard error in the variable d_WAGE

is positive up to the 4th period (an increase in wage levels stimulates an increase in the consumption of goods and services, as well as the amount of investments in various types of capital, which in turn leads to an increase in production volume and, ultimately, GDP, due to the fact that a higher level of income for workers in enterprises and organizations increases their ability to consume goods and services, thereby supporting sustainable economic growth rates). The response value becomes negative from periods 5 to 8 inclusive, and then its fluctuations begin to gradually "dampen" after period 13.

The dynamics of the variable d_WAGE in response to a one standard error shock of the variable d_GDP clearly contain a seasonal component, leading to a high amplitude of its fluctuations throughout the entire period under consideration.

Thus, the analysis of impulse response function graphs allows for the identification of coherent chains in the inflation channel: a large amplitude of curve changes indicates a sufficiently strong impact of one variable on another.

However, it should be noted that to obtain more accurate results, it is necessary to use several different methods to assess the impact of monetary policy on real economic dynamics and to conduct an analysis based on the aggregate of the obtained results.

CONCLUSION

The results of the conducted research showed that VAR models allow for a sufficiently deep study of the functioning of various transmission mechanisms and the assessment of the effects of macroeconomic shocks, identifying variables that are most sensitive to changes in specific factor markets, as well as determining the key factors of economic growth and the direction of their response to changes in external conditions [23–24].[3]

Overall, VAR models provide a tool for a deeper understanding of economic processes, their interconnections, and responses to various events and shocks. They allow for analysis and forecasting, which helps authorities and management make more informed decisions and develop effective policies for stable economic development.

According to the conducted analysis of the viability of the inflation channel based on the construction of VAR models and the analysis of impulse response functions, the following conclusions can be drawn (see *Table*).

Thus, the significance of the following elements of the inflation channel has been confirmed:

- "Wages — Inflation" (the increase in the average monthly nominal accrued wages in the first quarter does not affect the inflation growth rates, but in subsequent periods, there is a positive response);
- "Wages — GDP" (an increase in the average monthly nominal accrued wages leads to an increase in the physical volume of GDP in the first quarter);
- "GDP — Wages" (the growth of the physical volume of GDP leads to an increase in the average monthly nominal accrued wages in the first quarter).

The growth of the average monthly nominal accrued wages contributes to an increase in the inflation rate. At the same time, the increase in the average monthly nominal accrued wages stimulates the growth of economic activity and production volume, which is reflected in the positive dynamics of GDP. However, if the rate of economic growth outpaces the growth rate of the money supply or wages, a decrease in inflationary pressures may be possible. It is also worth noting that the increase in economic activity and production volume, expressed in GDP growth, contributes to the rise in wages.

At the same time, based on the conducted computational and analytical actions, it was found that the dynamics of the money supply does not have a statistically significant impact on the change in the inflation rate.

[3] Main Directions of the Unified State Monetary Policy for 2023 and the Period of 2024 and 2025. Moscow: Bank of Russia; 2022. 159 p. URL: https://cbr.ru/Content/Document/File/139691/on_2023(2024–2025).pdf (accessed on 01.07.2023).

Thus, when analyzing the mechanisms of the inflation channel of monetary policy in the Russian Federation, it is necessary to consider the interconnections between macroeconomic indicators and their impact on the socio-economic situation in the country and its regions, which will allow determining the feasibility and effectiveness of various managerial decisions for stabilizing the economic situation in the Russian Federation and ensuring sustainable rates of non-inflationary economic growth.

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I.S. Ivanchenko — formulating the research's purpose and objectives, developing the article's concept, reviewing, systematizing, and analyzing existing research and developments related to the article's topic.
G.A. Bondarenko — carrying out calculations, interpreting and describing the obtained results.
G.V. Pavlenko — collection and primary processing of data arrays, as well as graphically visualizing the calculation results.

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