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Input-Output Modeling of Economic Development in the Region

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Abstract. In the interests of strategic planning it is necessary to design and develop scientifically substantiated forecasting and analytical tools, including those used to carry out variant calculations of the consequences of management decisions and regional economic policy measures; this determines the relevance of our study, as well as its applied significance. The aim of the research is to model the trajectories of the region's economic development (in the case of the Vologda Region) for the medium term with the help of input-output tables. Tasks: to substantiate the choice of model tools for making forecasts, to develop an input-output model based on calculated regional input-output tables, to identify and substantiate forecast scenarios, as well as to forecast the trajectories of the region's economic development in the medium term as a demonstration of the capabilities of the model toolkit. The article presents the results of scenario forecasting in relation to the trajectories of the economy of the Vologda Region as a model region for the medium term under the influence of various structural policy instruments. We use our own recursive input-

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output model of the regional economy as a key forecasting tool, which makes up its scientific novelty. Within the framework of three forecast scenarios (inertial, adaptive and transformational), we determine the average annual rate of change in the main indicators of regional development (gross regional product, gross output, investments in fixed assets and net exports) in the medium term, as well as the industry (sectoral) parameters of the Vologda Region's economic structure as of the end of the forecast period. The results obtained in the course of the study are in line with macroeconomic forecasts for development of the national and regional economies in the short and medium term.

Key words: region, input-output modeling, scenario forecasting.

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Introduction

In the current geopolitical and geo-economic conditions of economic management, the economy of Russia and its regions is increasingly in need of structural transformation. This is confirmed both by the results of surveys (Shirokova, Lukin, 2024) and by the adopted strategic documents (National Security Strategy of the Russian Federation, Economic Security Strategy of the Russian Federation for the period up to 2030, Spatial Development Strategy of the Russian Federation for the period up to 2025, as well as references to the need for structural reorganization in a number of sectoral strategies).

The need to set and achieve strategic goals of the state development, as well as the current economic environment, which has a high level of uncertainty and variability of development trajectories of the Russian economy and its subjects, creates the need to provide the strategic planning system and public administration bodies with scientifically sound methodological tools, including forecasting. The implementation of economic policy (which includes structural policy) requires forecast calculations of its effectiveness in different scenarios of events.

However, the main problem in this case becomes the harmonization of initial assumptions and hypotheses in the presence of a significant number of forward and backward linkages both within the economy of the region and between the regions of the Russian Federation. In modern conditions, the implementation of economic policy is complicated by the presence of interdependencies between the processes and structural elements of the region as a system. In this case, the development of scenario forecasts of regional economic development trajectories on the basis of input-output modeling allows significantly increasing the validity of measures and tools of economic policy (Shirov et al., 2023).

The use of input-output model complexes makes it possible to assess the dynamics of socio-economic development of the region, including the impact on the production circuit and final utilization (Shirov, Yantovskii, 2011). Within the framework of structural analysis of the economy, it is the input-output balance that allows comprehensively considering the consequences of structural policy implementation, while having sufficient flexibility and taking into account a significant number of both intra-regional interactions and factors of external impact (Miller, Blair, 2009). The research notes that the input-output balance provides the

most accurate understanding of the interaction of economic entities, and the state gradually creates all the conditions for the maximum realization of the potential of input-output model complexes[1].

In this regard, the purpose of the research is to model the trajectories of economic development of the region in the medium term using input-output tools. This is conditioned (in addition to the above) by the need for variant calculations to determine the potential trajectories of socio-economic development of the region in the interests of strategic planning, as well as to assess the effectiveness of economic policy measures. The objectives of the study are: justification of the choice of modeling tools for making forecasts, development of an input-output model based on the calculated regional input-output tables, definition and justification of forecast scenarios, as well as forecasting the trajectories of economic development of the region for the medium term. Our recursive intersectoral model of regional economy was used as a key forecasting tool, which constituted its scientific novelty.

Literature review

The development of regional input-output balances and model complexes based on them is a highly specialized area of research. For instance, Russian scientists have developed balances for the Republic of Bashkortostan (Nigmatullin et al., 2006), the Ivanovo Region, Moscow, the Republic of Buryatia (Dondokov et al., 2014), the Kaliningrad Region and a number of others. The specialists of the Institute of Economic Forecasting of RAS (IEF RAS) (Moscow) and the Institute of Economics and Industrial Engineering, Siberian Branch of RAS (Novosibirsk) have advanced most deeply in this direction. Abroad, this topic is being studied more actively: regional and multiregional input-output tables and corresponding modeling tools are being developed in China (Jiang, 2011), the United States, South Korea (Flegg, Tohmo, 2019), the Netherlands and other countries.

In Russia, the problem is aggravated by the lack of the necessary array of statistical data: there is no significant array of information (up to 90%, according to the estimates of Rosstat experts) necessary for the construction of regional input-output tables (Masakova, 2019). In the conditions of incomplete statistical information, the construction of such tables is possible using various indirect methods: modeling based on available reference points, assumption of comparability of technological processes in the production of products, use of correlations and interdependencies of conjugate indicators, as well as regionalization of tables based on national tables of resources and use (Ershov, Temir-ool, 2022).

The use of input-output modeling in economic practice has a long history. The principles of input-output balances as a basis for models were developed by V.V. Leontiev in the first half of the 20th century. However, the models themselves began to be created and applied later, which is associated with a significant amount of input data and the need for many calculations, as well as the need to use sufficiently complete and high-quality statistical data.

Soviet science has made a notable contribution to the development of input-output modeling. In the second half of the 20th century, the USSR actively developed both individual models and entire national economic model complexes. It is worth noting the works published during this period (Kossov, 1964; Shatilov, 1974; Urinson, 1975; Yaremenko et al., 1975; Granberg, 1985; Baranov, 1989, etc.). A number of scientific teams and research institutes have been engaged in the issues of input-output modeling, and many of them continue research in this direction (*Tab. 1*).

[1] Delyagin M. Ensuring efficiency and competitiveness of the economy. Zavtra, August, 23, 2024. Available at: https://zavtra.ru/blogs/obespechivaya_effektivnost_i_konkurentnost_ekonomiki_pravitel_stvo_mishustina_sozdaet_predposilki_dlya_planirovaniya_i_upravleniya_na_osnove_mezhotraslevogo_balansa. (accessed: September 30, 2024).

Table 1. Examples of input-output models of the Russian economy

Authors	Model name	Content
Center for Macroeconomic Analysis and Short-Term Forecasting (CMASF)	Balance sheet-econometric model of forecasting of Russian economy	The model is a system of blocks that utilizes both basic economic balances and econometric interactions. The use of the model allows making forecasts for different timeframes taking into account technological changes.
E.B. Ershov and Yu.V. Yaremenko	Model of input-output interactions	The model is both a means of analyzing the economic structure and a tool for its forecasting, and the methodological basis is the assumption of qualitative heterogeneity of resources used in the economy. The central link and principal feature of the model is the modeling of the distribution flows of industries' products, which include supplies for intermediate consumption and flows forming functional elements of the final product.
Institute of World Economy and Informatisation (IWEI)	MOB modeling tools	In general, the model toolkit has many overlaps with the previous ones, the main difference being the presence of a monetary and financial block.
Institute of Economic Forecasting of RAS (IEF RAS)	Intersectoral model of the Russian economy RIM	The model complex consisting of three large blocks: the balance of production and distribution of products, the matrix of prices and incomes of economic agents, as well as the block of calculated indicators. The nomenclature of the model is represented by 25 types of economic activities, of which 15 are industries. The elements of final use are consumption of households, government and non-profit organizations, gross accumulation, including fixed capital, changes in inventories, as well as exports. Imports of products and services are also included in the composition of the economy's resources.
	Interregional forecasting and analytical model NORM	The NORM model describes economic dynamics in the medium and long term for all constituent entities of the Russian Federation, taking into account interregional and intersectoral links.
	Conto cross-industry model	The functional purpose of this model in the system of forecast-analytical calculations is to harmonize macroeconomic and sectoral indicators over the entire forecast period. It is based on the step-by-step calculation of key tables of inter-industry balance (MOB) in constant and current prices. The most important exogenous variables of the Conto model are economic policy parameters and characteristics of the world economy development.
Institute of Economics and Industrial Engineering, Siberian Branch of RAS	Optimization interregional interindustry models	A number of models have been developed: static and dynamic regional model, static interregional model, optimization regional and interregional models.
According to: (Suslov, Suspitsyn, 2005; Suspitsyn, 2009; Kuranov et al., 2021; et al.).		

Table 2. Examples of variant calculations of economic development using input-output models

Author	Direction of variant calculations
A.A. Shirov et al.	Study of economic effects for Russia, Belarus, Kazakhstan and Ukraine in the creation of the Common Economic Space
A. Baranov et al.	Assessment of the consequences of the Bank of Russia's inflation targeting policy
Yu.Yu. Ponomarev, D.Yu. Evdokimov	Analysis of the spread of COVID-19 pandemic effects by industry sector
IEF RAS, Center for Tax Policy	Analysis of the key and most effective areas of low-carbon transformation of Moscow economy
E.E. Cox, L. Carrera, O. Jonkeren, J.S. Aerts, T.G. Khusbi, M. Tissen, G. Standardi, Ya. Misiak	Analysis of the economic impacts of two flood scenarios in the Po River basin in Italy using three regional catastrophe impact models: two hybrid MOBs and a Computable General Equilibrium (CGE) model
Tadayuki Hara, Hidekazu Iwamoto	Applying MROs to assess the economic impact of tourism
R. Bardazzi	Assessment of labor productivity at the industry level using methods based on inter-industry analysis
According to: (Shirov et al., 2015; Ponomarev, Evdokimov, 2020; Shirov et al., 2023; Bardazzi, 2011; Baranov et al., 2013; Cox et al., 2016; Hara, Iwamoto, 2022).	

One of the most frequently solved tasks with the help of inter-sectoral modeling is the option calculations from the implementation of certain management decisions. Scientific research in this direction considers various scenarios – from the study of the effects from the implementation of individual investment projects to the consequences of the formation of the Common Economic Space (*Tab. 2*).

The analysis has demonstrated the relevance and significance of the experience in the development and application of input-output modeling tools in the development of scenario forecasts of the trajectory of socio-economic development of the regional economy and justification of economic policy measures on their basis.

In most cases, in the reviewed studies, the change in final demand is used as an input variable, which allows calculating the change in outputs and input-output multiplier effects (direct, indirect, and induced). When calculating the effects of economic policy measures (changes in the parameters of final consumption, investment or foreign trade), it is necessary to consider the impact of these parameters separately, which requires the development of an additional block of the model that allows obtaining the aggregate change in final utilization due to changes in its components. When this block is implemented, it can be argued that the study will make it possible to supplement the existing scientific knowledge in terms of the development of tools for regional input-output modeling and is of practical importance to justify the management decisions taken.

Materials and methods

Within the framework of the study, we have developed a recursive intersectoral model based on our own regional input-output tables to identify potential trajectories of the regional economy development and model the process of its structural reorganization. In addition to variant forecasts of the consequences of the implementation of economic policy measures, the proposed toolkit allows building scenario meso-economic forecasts.

The information base of the model is our input-output balances of production and distribution of products of the region for 2011–2020, regionalized from the national tables of resources and use[2]. As indirect information for forecasting purposes, we used country and regional statistical information on production, income of economic agents, investment and fixed assets, foreign trade[3], interregional import-export[4], etc. The model presents the regional economy in the context of 32 aggregated types of economic activities, which are described on the basis of official data of Rosstat in terms of SNA (system of national accounts), production and costs.

The first stage of modeling is the formation of the matrix of input-output balance. For this purpose, we used both direct data of the national accounting system, provided by the regional statistical office, and indirect data, providing information of production and technological character and allowing filling in the missing statistical indicators. Initially, the matrix of technological coefficients is formed on the basis of data from country input-output tables. At the same time, the model has a possibility of exogenous setting of sectoral cost coefficients, which allows estimating changes in material and energy intensity of production in different scenarios. Regionalized technological coefficients are used for the input-output distribution of fringing totals, taking into account the specifics of the regional economy. Aggregation or disaggregation to the required industry nomenclature is performed using structural proportions of the volume of goods shipped or the average number of employees in the industries of

[2] Tables of resources and utilization of the Russian Federation for 2011-2020 (Rosstat data). Available at: https://rosstat.gov.ru/statistics/accounts (accessed: September 2, 2024)

[3] Data from statistical yearbooks of the Vologda Region for 2011–2020.

[4] Data of statistical bulletins on import-export of goods and products by organizations in the Vologda Region for 2011–2020.

the region. The structure of gross accumulation is distributed according to the type structure of fixed assets in the regional economy, which allows taking into account the peculiarities of the regional investment process. The structure of exports and imports is calculated by recalculating the data of the Federal Customs Service using the average annual dollar exchange rates provided by the Bank of Russia. The balancing item in the calculated input-output balance is the balance of interregional trade (Formula 1).

Inventories at the beginning of the year + Production + Import + Interregional imports = Intermediate use + Final consumption + Gross accumulation + Export + Interregional export + Inventories at the end of the year (1)

The problem of calculating the counter flows of interregional trade arises. In official statistical sources the data on it are incomplete and have significant distortions, which forces to use calculation methods to determine the volume and direction of commodity flows between regions.

To solve this problem, we used the mathematical approach of T. Kronenberg (Kronenberg, 2009), which consists in calculating the heterogeneity of commodity flows (h) according to the data of national input-output tables using Formula 2.

$$h = \frac{q_{in}}{x_{in}+z_{in}+d_{in}}, \quad (2)$$

where h – heterogeneity factor,

q_{in} – volumes of counter flows of foreign trade in the i-th type of activity in the national economy,

x_{in} – output of i-th type of activity within the country,

z_{in} – intermediate consumption by i-type of activity within the country,

d_{in} – final utilization by i-th type of activity within the country.

Based on Formula 2,

$$q_{ir} = h\,(x_{ir} + z_{ir} + d_{ir}), \quad (3)$$

where q_{ir} – volumes of counter flows of foreign trade in the region,

x_{ir} – gross output of the region by i-type of activity,

z_{ir} – intermediate consumption of the region for the i-th type of activity,

d_{ir} – final utilization of the region by the i-th type of activity.

Further, we determine the interregional trade turnover of the region by i-th type of activity (Formula 4):

$$v_{ir} = |b_{ir}| + q_{ir}, \quad (4)$$

where v_{ir} – interregional trade turnover by i-type of activity in the region,

b_{ir} – trade balance (net exports) for i-th type of activity in the region.

Further, based on the indicator of heterogeneity and balance, and volumes of the trade balance of the region, we calculated commodity flows (volumes of import and export) by i-th type of activity according to formulas 5 (export) and 6 (import).

$$e_{ir} = (v_{ir} - b_{ir})/2 \quad (5)$$

$$m_{ir} = (v_{ir} + b_{ir})/2 \quad (6)$$

The second stage of modeling the regional economy involves forecasting the dynamics and structure of end-use elements, which, according to the SNA, are the volumes of final consumption of households, government and nonprofit organizations, gross fixed capital formation calculated through investment, changes in material stocks, as well as foreign trade flows, both global and interregional.

The model relies on the basic equation of input-output balance, which in matrix form is as follows:

$$X = AX + Y, \quad (7)$$

where X – vector of total output;

A – matrix of direct cost ratios;

Y – end-use vector.

We used the following equation in the modeling:

$$(E - A)^{-1} * Y = X, \quad (8)$$

where E – unit matrix; $(E - A)^{-1}$ – matrix of total cost ratios.

On the basis of the obtained matrix dependence, it is possible to calculate, what should be the volume of realization x in all branches of economy, if the change of final utilization y is planned, i.e. full costs are calculated.

We present the calculation algorithm.

1. Based on the data from the table of goods and services utilization, the direct cost matrix A is calculated. For this purpose, the share of direct costs F_{ij} in the volume of output X_j is determined:

$$a_{ij} = F_{ij} / X_j . \quad (9)$$

The element a_{ij} of matrix A shows the consumption of product i directly in the production of a unit of output of industry j.

2. Next, the full cost matrix $B = (E - A)^{-1}$ is calculated. For this purpose, matrix A is subtracted from unit matrix E. The obtained matrix is raised to degree -1, i.e. inverse matrix $(E - A)^{-1}$ is found. Element b_{ij} of matrix B characterizes the need for gross output of industry i, which is necessary to obtain a unit of the final product of industry j in the process of material production.

3. Full cost matrix B multiplied by the vector of planned end uses Y equals the gross output of all industries X:

$$x_i = f(y_1, y_2, y_3 \ldots, y_n) = \sum_{j=1}^{n} b_{ij} y_j. \quad (10)$$

Execution of this algorithm allows obtaining vector X (gross output) for each industry. However, to forecast the dynamics of end-use elements, it will be necessary to calculate the values of vector Y, which includes such components as household consumption, investment, exports, etc.

The formula is used to calculate the rate of change of individual elements y_j of end-use vector Y:

$$y_j = fc_j * w_j^{fc} + ga_j * w_j^{ga} + ge_j * w_j^{ge}, \quad (11)$$

where fc_j – dynamics of final consumption;

ga_j – dynamics of gross savings;

ge_j – dynamics of net exports;

$w^{fc}_j, w^{ga}_j, w^{ge}_j$ – shares of respective elements in the end-use structure.

This decomposition is used because some elements of final use can be predicted more accurately using indirect statistics: for example, changes in population and income for final use, dynamics of investment in fixed capital for gross capital formation, demand for key commodities and price changes for net exports.

Within the framework of the current study, the shares in the structure of final use were averaged on the basis of retrospective dynamics (forecasting of structural proportions is considered as the development of the model complex and the direction of the study as a whole), while the dynamics of indicators by industry is an exogenous variable of the model and is calculated taking into account hindsight and expert estimates.

The result of modeling is the final estimates of gross output, gross regional product in constant prices, investment in fixed capital, calculated through gross fixed capital formation and net exports, taking into account interregional imports and exports. In the model, they are represented by the estimated quadrants of input-output balances over the entire forecasting horizon.

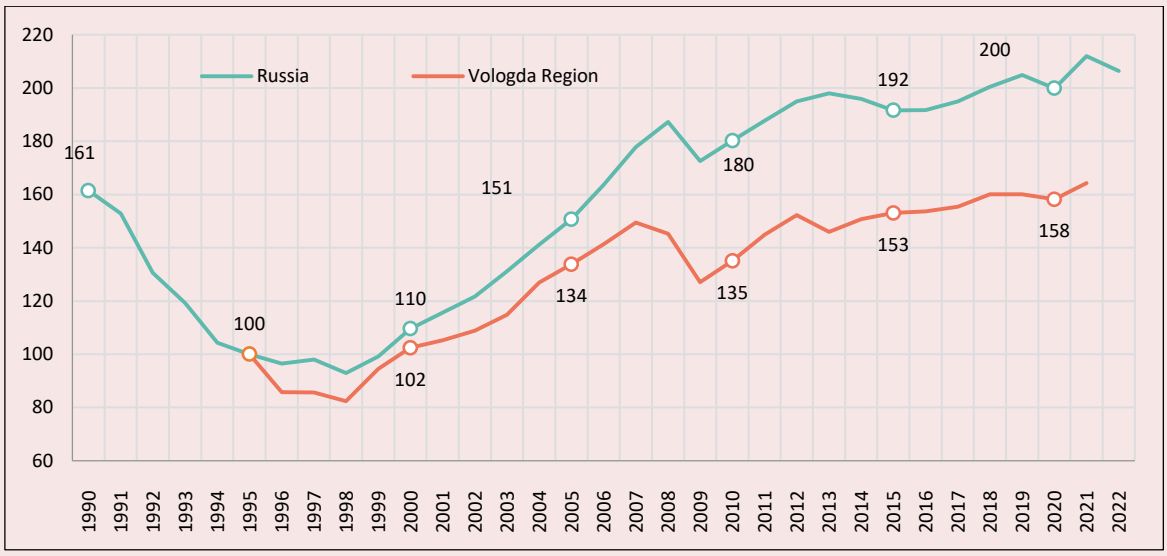
Characterization of the model region

The study uses the Vologda Region as a model region. Due to the accumulated limitations of structural development at all stages of the reproduction process, the need to transform its economy has been repeatedly justified in earlier studies (see, for example, Rumyantsev, Leonidova, 2020).

The key problems constraining regional development and causing low rates of economic growth (*Fig. 1*) are the simplification of the economic structure and deterioration of its ability to generate added value.

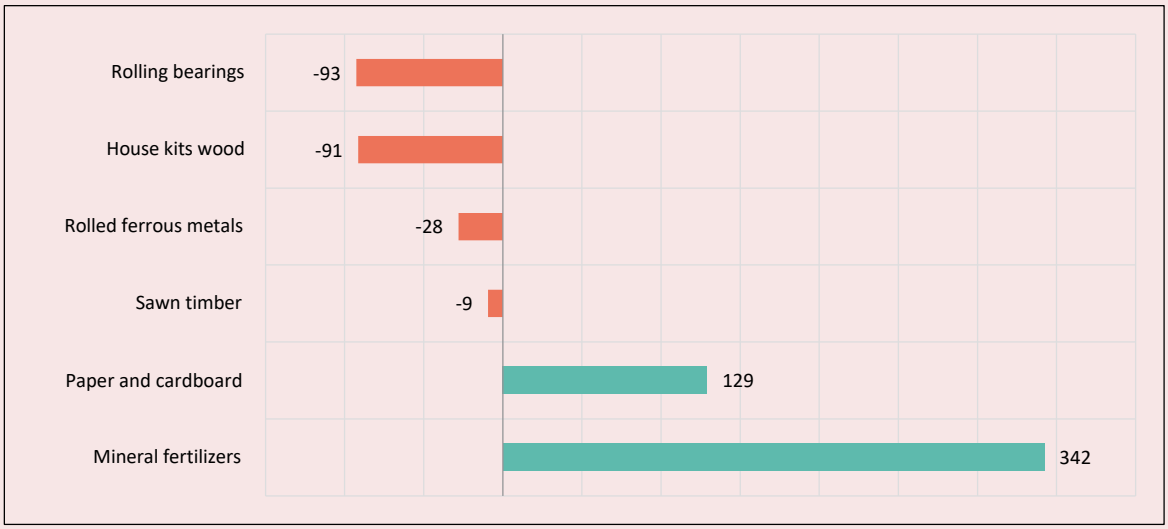
In the post-Soviet period, the region occupied a narrow market specialization in the international and national division of labor in the production of primary products (rolled metal products, mineral fertilizers, timber), while at the same time inter-sectoral ties weakened to a large extent, positions in machine building (including machine tools), light industry, woodworking were lost (*Fig. 2*).

Figure 1. Growth rates of average per capita GDP of Russia and GRP of the Vologda Region in 1990–2022, to the level of 1995



Source: calculated on the basis of Rosstat data using GRP physical volume indices.

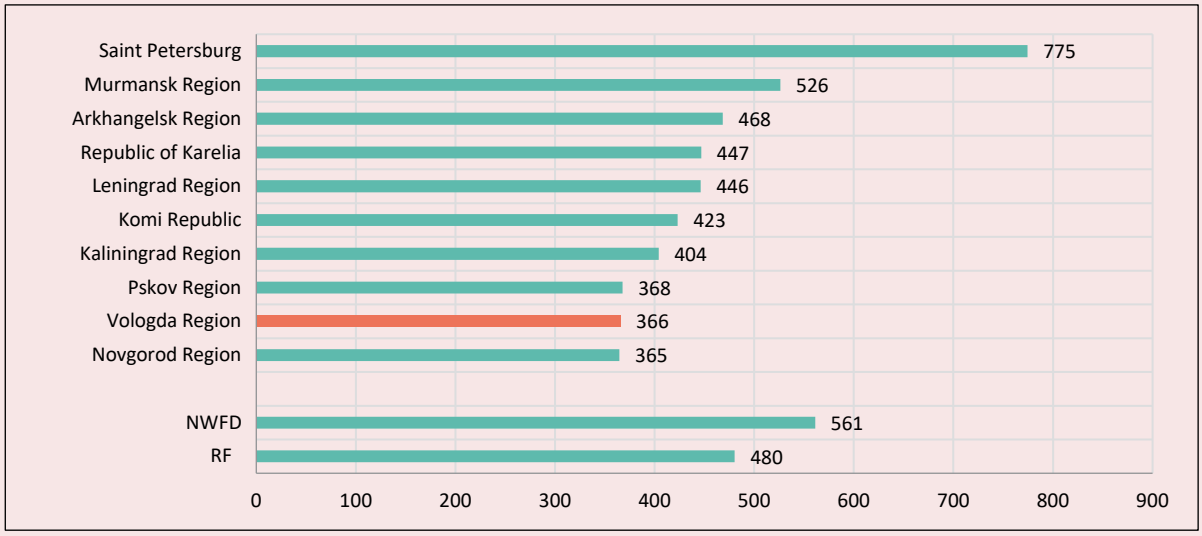
Figure 2. Increase (decrease) in the physical volume of production of certain types of products in the Vologda Region in 1985–2022, % to 1985



Source: calculated on the basis of Rosstat.

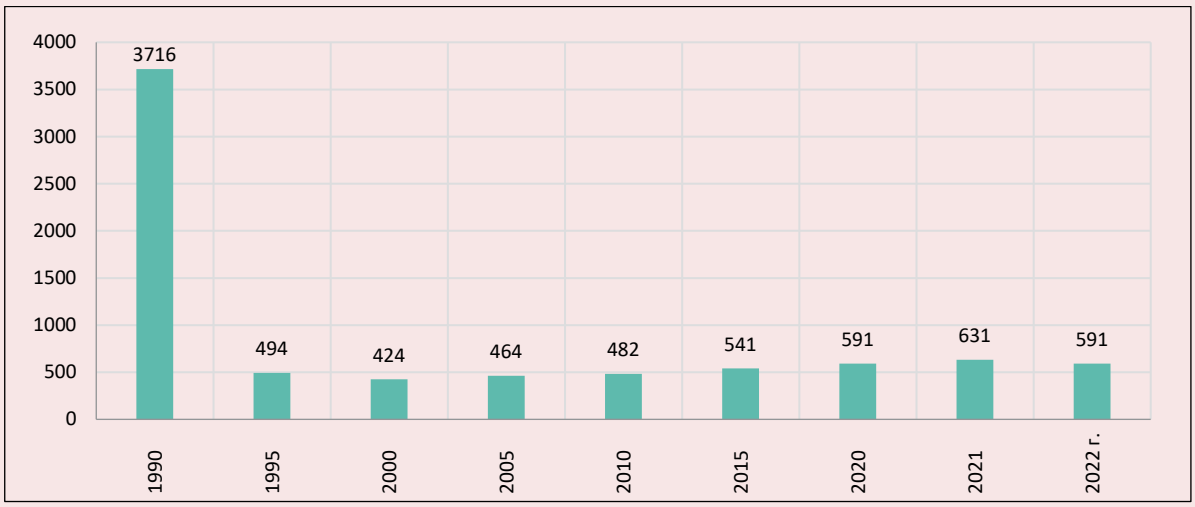
As a consequence of this situation, problems in the reproduction circuit of the economy have been growing: disproportions at the stage of production (reduction of the role of material production, knowledge-intensive sector of the economy, deterioration of the geographical, sectoral and professional structure of employment), formation and distribution of added value (concentration of the economy's income in a limited number of industries, stagnation of employees' remuneration level of), use of income (lagging behind the savings rate, slowing dynamics and low volume of intra-regional consumer demand (*Fig. 3*), etc.).

Figure 3. Actual final consumption of households per capita in NWFD regions in 2021, thousand rubles



Source: based on Rosstat data.

Figure 4. Number of personnel engaged in research and development in the Vologda Region in 1990–2022, persons



Source: based on Rosstat data.

The region's specialization in export-oriented production of primary products has led to gradual deindustrialization, "washing out" of the economic structure of machine-building and industry producing final consumption products, compression of domestic demand for research and development: in 1990–2022 the number of personnel engaged in R&D decreased by more than 6 times (*Fig. 4*). The consequences of this were the growth of technological import dependence, increasing economic inequality and the compression of the populated area of the region with the concentration of population in the largest agglomerations (Vologda and Cherepovets).

It seems that in such conditions the structural policy of the Vologda Region should be aimed at multidimensional complication of the regional economy, its repositioning in interregional value-added chains, echeloned development of promising market niches on the basis of reasonable variant calculations of possible development trajectories and attraction of federal funding for these purposes.

The implementation of such a policy within the framework of the strategy of socio-economic development of the Vologda Region will contribute to the stimulation of manufacturing of products for investment purposes and final consumption, will create demand for R&D and import-substituting technologies. As the effects of its implementation, it is also predicted to increase the income of enterprises included in the value-added chain and, as a consequence, of other economic agents, to accelerate the dynamics of the region's development, to create new jobs and to reduce the differentiation between municipalities.

Based on the analysis of structural imbalances in the Vologda Region, as well as studies of available statistical information, we came to the conclusion that the Vologda Region can become a "testing ground" for approbation of our model toolkit and demonstration of its capabilities.

Scenario assumptions

We carried out three scenarios – inertial, adaptation and transformation – when carrying out variant forecasting of regional economic development on the basis of our input-output model. As mentioned earlier, the scenarios set the dynamics of end-use indicators in the sectoral context, taking into account the retrospective dynamics, which were then adjusted taking into account the scenario assumptions, macroeconomic forecasts of analytical centers (the Ministry of Economic Development of the Russian Federation, the Bank of Russia, the Institute of Economic Forecasting of RAS, the Center for Macrostructural Analysis and Short-Term Forecasting, etc.), expert assessments and relevant sectoral studies.

1. Inertial scenario.

The inertial scenario was used as a baseline scenario (as a control scenario). Its main premise was the retrospective dynamics of the region's economy, which is not affected by geopolitical and geo-economic instability. The scenario assumes the preservation of the previous development rates, but in fact it can no longer be realized.

The inertial scenario envisages the following structural changes:

– increase in the share of construction in the industry structure due to the active growth of preferential mortgage lending;

– slowdown in the growth rates of metallurgical production due to saturation of export markets and weak focus on domestic demand;

– fluctuations in the shares within manufacturing industries associated with the inertial development trajectory and the transition of a number of investment projects to the operational stage (food industry, sawing and planning of wood, production of rolled products and other industries of primary resource processing).

2. Adaptation scenario.

The second scenario assesses the impact of foreign trade restrictions and restrained economic

policy to stimulate domestic demand and support import substitution.

The main assumptions of this scenario are:

– export-oriented sectors of the Vologda Region economy (timber industry, ferrous metallurgy; production and supply of fertilizers were not affected by the sanctions) significantly reduced production volumes due to bans from key consumers – EU countries (in the first years after the shock up to 30%, later the dynamics becomes more positive – from 5–10% decrease to 3–4% increase per year depending on the sector);

– reduction in imports of investment goods and, as a consequence, slowdown in investment activity (-10–15% from 2022, including due to the termination of access to foreign capital markets);

– decrease in physical volumes of imports of end-use goods with simultaneous increase in their price due to the complexity of supplies (up to 20% of the 2022 volumes);

– fragmented growth of industries producing import-substituting products (machine building, final consumption goods, high-tech intermediate consumption products), change in the direction of logistics flows and their volumes;

– slowdown in the investment activity of enterprises against the background of tight monetary policy of the Central Bank of the Russian Federation, deterioration of financial results, increase in the general level of uncertainty in the economy and restricted access to imports of means of production.

The most active direction of economic policy implementation in unstable macroeconomic conditions was to maintain the level of domestic demand. The main measures to support consumption were:

– tourist cashback (tourism is the most multiplicative end-use industry);

– stimulation of preferential mortgages (one of the most important drivers for construction), support for which has been reduced, and there is currently a slowdown in housing commissioning;

– social transfers in cash and in kind and a number of others.

A significant contribution to the increase in final consumption was also made by payments to participants in the special military operation, whose incomes are much higher than the level of average annual wages.

These support measures had a temporary effect on stimulating final demand – at the beginning of the forecast period the growth rates of the stimulated industries ranged from 3 to 12%, later they stagnated to zero growth rates.

The adaptation scenario assumes a shift in structural proportions toward domestic demand: an increase in the share of market services, in particular wholesale and retail trade, a decrease in the influence of export-oriented sectors of the economy on its dynamics (with the exception of fertilizer production due to the growing food crisis in the world), as well as an increase in the share of construction.

3. The “active transformation” scenario.

The main prerequisite for the third scenario is the state’s active structural policy, which should ensure the rates of economic growth necessary to address key socio-economic tasks in the new economic environment. Such tasks include improving the quality of economic growth and the quality of life, increasing the complexity of the economy and expanded reproduction of capital, as well as observing the interests of national security.

Under this scenario, it is assumed that the process of structural adjustment of the economy will be based on joint actions of the state, business and population, with the role of the state at the first stage should be strengthened (in terms of investment incentives), which in the future should be balanced by the growth of business activity and consumer demand. An important aspect is technological development; in the absence of an inflow of technologies, their borrowing and reverse engineering are required, as well as the activation of

technological import substitution. In the future, this strategy can be transformed into an expansive one due to the realization of competitive advantages.

The main direction of structural policy under this scenario will be the development of promising economic specializations of the territory in the interests of lengthening value chains and increasing the complexity of the economic structure. A necessary condition dictated by both the current geopolitical situation and the logic of business processes is the reorientation of foreign trade activities to domestic markets and partners from friendly countries.

In addition, an active structural policy includes tools to stimulate consumer demand and investment support for industries with promising specialization of the region's economy. The role of the state is to create conditions for their development by both direct methods (state participation in investment projects, infrastructure investments, budget loans and subsidies) and non-economic methods (various benefits, preferential tax regimes, etc.).

We believe that the consequences of the structural policy implementation in the region will be the following trends of the Vologda Region economy development:

– slowdown in the growth rates of export-oriented industries due to the transition to the domestic market under foreign trade restrictions (up to 1.5% per year);

– acceleration of investment activity in industries with promising specialization (deep wood processing, machine building, high value-added chemistry) up to two or threefold growth depending on the volume of state support and increase in their investment attractiveness;

– support for end-use industries will allow accelerating their growth rates to 3–4% annually.

The list of assumptions for forecasting in this scenario is not final, there are some hidden consequences of structural policy. The transformation scenario assumes an increase in the share of machine building, timber industry in terms of deepening wood processing, and a reduction in the share of metallurgy with simultaneous reorientation of its commodity flows from external to domestic markets.

Calculation results

Table 3 presents the results of forecast calculations within the proposed scenarios. It is worth noting that in the inertial scenario the growth of investment activity remains due to the high results

Table 3. Average annual growth rates of key economic indicators of the Vologda Region in 2023–2031, % to the previous year

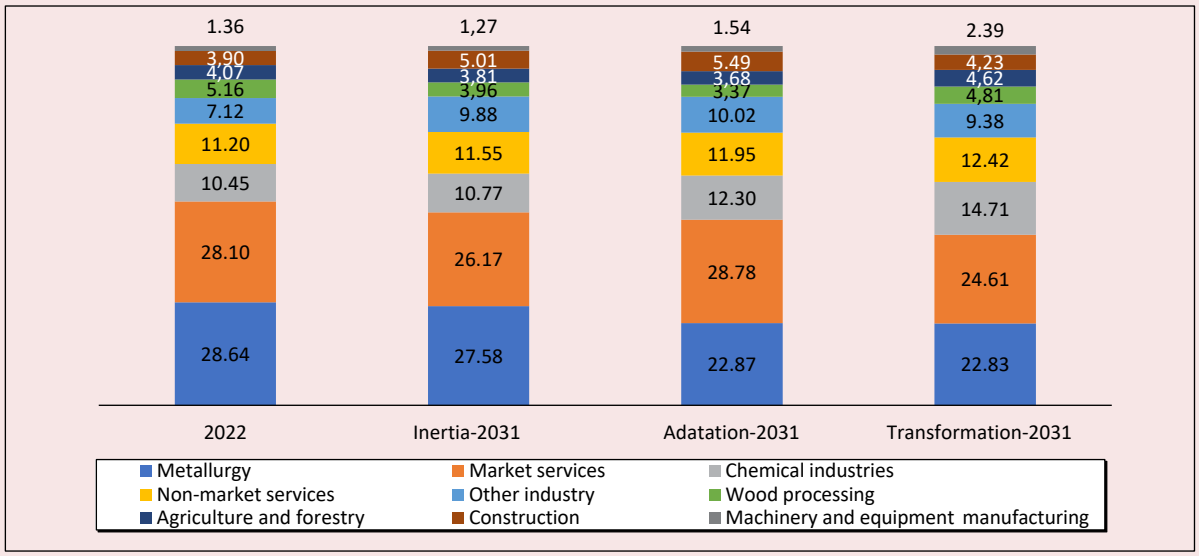
Indicator	Scenario	2023–2025	2026–2028	2029–2031
Release	Inertia	101.8	102.2	102.4
	Adaptation	102.3	102.8	103.1
	Transformation	103.1	104.2	104.6
GRP	Inertia	99.6	101.0	102.1
	Adaptation	98.0	102.2	102.2
	Transformation	100.3	103.5	103.6
Investments in fixed assets	Inertia	103.0	103.1	104.0
	Adaptation	103.8	105.2	105.4
	Transformation	105.0	108.0	107.4
Exports	Inertia	99.0	104.5	109.2
	Adaptation	93.0	107.7	112.3
	Transformation	97.6	99.7	102.6
Import	Inertia	119.9	110.3	106.5
	Adaptation	97.7	102.9	103.7
	Transformation	100.0	99.1	96.3

Source: own compilation.

of the previous years, however, such growth rates of production and capital investment are characteristic of the traditional industries of the Vologda Region (ferrous metallurgy, fertilizer production, timber industry complex). The key structural problem is the degradation of machine-building industries, which leads to increased import dependence in terms of means of production, which in the long term will slow down investment activity, reduce the profitability of production and, consequently, its competitiveness. Export growth rates will accelerate over time, but the creation of trade balance imbalances is inevitable.

The main trend in the adaptation scenario is the sanctions pressure: foreign trade restrictions will significantly slow down the dynamics of export-oriented industries of the region and its economy as a whole. Countermeasures in this case will be the activation of domestic demand for both intermediate and final products, reorientation of exports to friendly markets, as well as the development of interregional markets. This will accelerate economic growth and increase investment activity, but in the long run, which is not covered by this study, we assume that the dynamics will slow down again, up to negative values.

Figure 5. Forecast variants of the Vologda Region economic structure in 2031, % of the total



Note: The sectors presented in the figure include the following types of economic activities:
1. Metallurgy – metallurgical production and production of finished metal products;
2. Market Services – wholesale and retail trade, hotels and restaurants, transportation and communications, finance and insurance activities, real estate operations, rentals and services;
3. Chemical industries – chemical production, production of rubber and plastic products;
4. Non-market services – public administration, education, health and social services, provision of other services;
5. Other industry – mining, food production (including beverage production), textile and clothing production, leather, leather goods and footwear production; production of other non-metallic mineral products; other production; production, transmission and distribution of electricity, gas, steam and hot water; water collection, treatment and distribution;
6. Timber manufacturing – wood processing and manufacture of wood products, pulp and paper production, publishing and printing activities;
7. Agriculture and Forestry – agriculture, forestry, hunting, fishing and fish farming;
8. Building;
9. Mechanical engineering: manufacture of machinery and equipment, manufacture of electrical, electronic and optical equipment, manufacture of vehicles and equipment.
Source: own compilation on the basis of GVA calculations using modeling tools.

Under the transformation scenario, it is expected that the economic growth driver will be high-tech sectors of the economy (machine building, medium- and low-tonnage chemistry, production using additive technologies, industries of human capital formation), which will contribute to the acceleration of growth rates and recovery from the crisis in the medium term and, in our opinion, the most important thing – the "complication" of the economic structure. At the same time, traditional sectors of the economy will not lose their importance, but will become reference points – basic sectors – for the development of promising economic activities. This will result in a reorientation from export activities to domestic markets and deeper processing of products produced in the region, as well as strengthening technological sovereignty and increasing the level of economic security of both the region and the country as a whole.

Figure 5 shows the forecasted structure of the Vologda Region economy according to the calculations. We should say that the structural changes are rather slow and we should not expect a radical change in the structure in the forecast period. The main changes in the inertial scenario are the growth of the share of construction stimulated by preferential mortgages and local production of construction materials, the reduction of the share of metallurgy due to the saturation of export markets and insignificant changes in the structure of manufacturing industries that do not lead to the complexity of the economy and deepening of product processing.

The adaptation scenario assumes a shift in structural proportions toward domestic demand: an increase in the share of market services, in particular wholesale and retail trade, a decrease in the influence of export-oriented sectors of the economy on its dynamics (with the exception of fertilizer production due to the growing food crisis in the world), as well as an increase in the share of construction. The transformation scenario assumes an increase in the share of machine-building, timber industry in terms of deepening wood processing, and a reduction in the share of metallurgy with simultaneous reorientation of its commodity flows from external to domestic markets.

The structural policy inherent in the transformation scenario will make it possible to overcome the existing limitations of the region's economic development and create prerequisites for sustainable growth in the long term. In general, to realize the transformation scenario as a target scenario, it is necessary to conduct active structural policy in at least three key areas: stimulation of domestic demand, strengthening of structural investment policy, repositioning of the region in existing and prospective value chains.

Conclusion

The research has developed and tested the model toolkit based on our regionalized input-output balances on the materials of the Vologda Region. The use of the proposed model complex allows carrying out variant calculations of the trajectories of economic development of regions depending on the implemented measures of economic policy, stimulation of various types of economic activity, and is also a flexible basis for the construction of additional blocks of the model that allow to estimate budgetary effects, the need for labor resources and a number of other economic parameters.

As a result of approbation on the materials of the Vologda Region, we determined that the improvement of the quality of the economy with its stable growth is possible during the implementation of structural policy aimed at maintaining domestic final demand, increasing investment activity and development of industries of promising economic specialization within the existing value added chains. The results obtained in the course of the

study are consistent with macroeconomic forecasts of national and regional economic development in the short and medium term.

Further research will be carried out in such directions as expansion of the model's industry nomenclature, formation of additional blocks to increase the number of estimated effects, development of tools for endogenous calculation of end-use industry components for more automated and objective forecasting, as well as expansion of the list of regions through regionalization of input-output tables.

The research results can be used by public authorities in the development of strategic planning documents, by a wide range of researchers in the field of regional and sectoral economics, as well as by teachers and students in the framework of training in economic specialties.

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