Simulating Budget System in the Agent Model of the Russian Federation Spatial Development

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Abstract. In this paper we present methods, data and algorithms for simulating budget system in the model of the Russian Federation spatial development. We show the place of this task in methodology of our research and give a brief overview of the background results. Key objects of the budget system in the model are the federal budget, regional budgets and extra budgetary funds: pension, medical and social insurance. We determine revenues and expenditures of the budgets and funds on the basis of federal laws, Budget and Tax codes of the Russian Federation. Since the exact reproduction of excise rates and customs duties is problematic due to model aggregation, we calculate model rates of excises and duties for selected sectors on the basis of retrospective data presented on the budget system portal and in the federal input-output table. Structure of the budget expenses in the model was simplified by aggregating expenditure items into major groups correlated with sectors of the economy. Presented algorithm of the budget system simulates interaction of the federal, regional budgets and extra-budgetary funds with agents and organizations in the model. For validation of the budget system algorithms in the model we conduct retrospective modeling for the federal budget and the budget of Belgorod region in 2014.

Keywords: Computer model · Spatial development · Agent-based modeling · Budget system · Tax · Excise · Retrospective simulation

1 Introduction

Spatial development of the Russian Federation is quite disproportional: some regions are overpopulated, which causes environmental, housing and transport problems; others, conversely, suffer from outflow of population. This situation is determined by concentration of science, technology and innovations in large centers and a huge gap in quality of life in various regions. Strategy of the Russian Federation spatial

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development [26] is aimed at correcting the current situation by improving interregional infrastructure and stimulating new centers of economic activity, which would smooth socio-economic differences between regions.

The task of evaluating alternative policy options for development of territories requires special methods and tools that can integrate accumulated data on the population, economy and social sphere. Policy relevant spatial modeling is an expanding area of research, which has a lot of potential for the evaluation of the socio-economic and spatial effects of major national social policy programs [5].

In our research we construct the agent-based model of the Russian Federation spatial development, which simulates dynamics of population and production in different regions and interrelations between them. Significant part of the model is administrative institutions that implement control actions, such as tax, monetary and investment policies. Crucial element in this context is the budget system, as a key channel of financing federal and regional programs, aimed at developing infrastructure and creation of new centers of economic activity. Simulating of the budget system in the model should take into account the spatial aspect of collection and redistribution of funds at the levels of the federal and regional budgets. Thus, the structure of financing of the spatial development projects would be reflected.

2 Literature Review

Planning and prediction of the spatial development processes, which is studied within the new economic geography, summarizes a number of research tasks of the regional economy through an integrated approach and consideration of macroeconomic factors and interrelations. A number of works is devoted to the empirical studies based on statistical data and to structural modeling based on econometric estimation of the factors, included in existing theoretical models [7, 8, 22].

The main method in our research is agent-based computational economy (ACE) [13, 29], which includes heterogeneity, bounded rationality, non-equilibrium dynamics and direct interactions among economic agents [9]. ACE models are often used to study effects of policies on macroeconomic and spatial dynamics [4], and have already been implemented in different areas of macroeconomic policy such as fiscal [2], monetary [11, 21], macroprudential [1, 3, 19] and labor market policy [18, 23, 25].

One of the most complete ACE models is Eurace simulator, which is designed as an agent model of complex multiple-market economy and incorporates crucial connections between the real economy, credit and financial markets. Different markets are modeled in great detail with, for example, the labor market firms seeking credit, buying capital goods, deciding production levels, advertising and appointing staff, and selling consumption goods, and households applying for jobs, deciding on offers, commuting to work, buying goods, saving with banks, and seeking credit [12]. Dynamics of credit money in Eurace is endogenous and depends on the supply of credit from the banking system and the demand of credit from firms in order to finance their production activity. Eurace model takes into account many factors affecting parameters of economic

activity, however, studies based on it do not operate real data from EU countries, they use test environment to observe macroeconomic and social phenomena (for example, abstract 'Country 1' and 'Country 2') [12]. Similarly, in ACE models of separate markets, the study of processes through simulation is conducted on the abstract data sets [11, 18, 19].

Spatial aspect of social policies is usually taken under consideration in regional models, such as microsimulation model for Leeds City Council. The model consists of 715 thousand individuals within households along with their associated attributes and provides a spatial decision support tool for the local council officers. In particular, the system can be used to describe current conditions in neighborhoods, predict future trends in the composition and health of population and conduct analysis to measure the likely impact of policy interventions at the local level [4]. Similar system in Russia was designed for Saint-Petersburg [27].

3 Methodology of Case Study

In our research we combine ACE approach with available open data, constructing the agent-based computer model of the Russian Federation spatial development, which reflects age-sex structure and resettlement of the population, composition of households, regional economic structures, administrative and educational institutions. Research methodology includes the following steps:

1. Reconstructing current territorial and demographic structure of population, administrative and economic system of the Russian Federation in the agent-based computer model.
2. Simulating dynamics of the system through behavior of agents, organizations, regional and state administration.
3. Setting scenario parameters and alternative control actions for the system.
4. Conducting a series of experiments, statistical processing and analysis of the results.

The main task on the first stage is reconstruction of an artificial society for the base year of modeling. 2014 was chosen as the base year, since then the federal input-output table was prepared, which contains crucial information about interrelations in the real economy. Issues of search and integration of the initial modeling data are discussed in [15], reproduction of population structure and economic interrelations – in [16].

The budget system simulation considered in this article belongs to the second stage of the methodology, since it reflects the dynamic aspect of tax and duties collection, payment of transfers to the population, financing of budget organizations and key sectors of the national economy. Also at the second stage algorithms of population dynamics [14], behavior of agents in the areas of education, employment and migration [17], activities of commercial [15] and financial organizations are developed. To verify algorithms on this stage, retrospective modeling for the base 2014 is carried out. Results of retrospective simulation of population and organizations are presented in [16].

3.1 Defining Structure of the Budget System of the Russian Federation

The budget system of the Russian Federation consists of the federal budget, regional budgets and extra-budgetary funds: pension, medical and social insurance. Since the model on a geographical scale is a set of regions, without dividing into smaller components, the local level of the budget is not considered in it. Each budget has revenue and expenditure part defined by the Budget Code of the Russian Federation [6].

Sources of revenues of the federal budget are commercial organizations, the Central Bank; funds, banks and governments of the foreign countries (Fig. 1). Organizations pay income tax, value added tax, excise taxes on manufactured and imported goods, import and export customs duties, tallage for use of natural resources and negative impact on the environment. The Central bank transfers part of its profit, defined in the Federal law on the federal budget (75% of the profit in 2014, 90% in 2015–2016, 100% from 2017). Foreign sources pay interest on loans and duties under the customs agreement between Russia, Belarus and Kazakhstan.

Regional budgets receive taxes on personal income, part of the excises on manufactured goods, tallage for use of natural resources and corporate income tax. For many regions, a significant source of revenue is subsidies from the federal budget.

Extra-budgetary funds are filled by insurance fees from employers (both commercial and budget organizations) and subsidies from the federal budget.

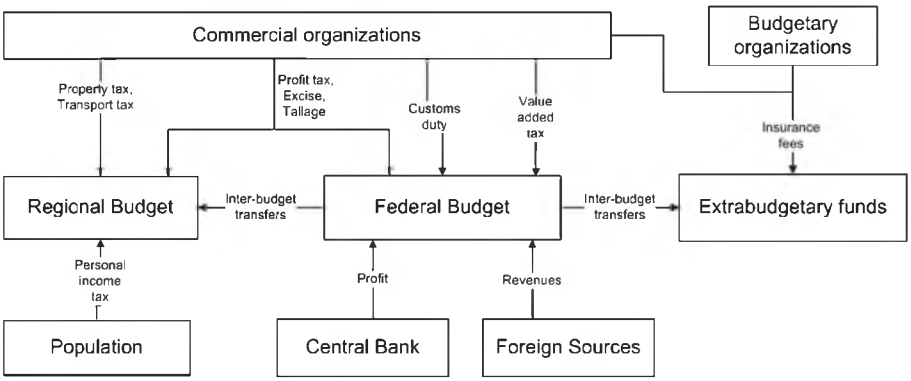

Fig. 1. Revenues of the budget system of the Russian Federation

Recipients of the federal budget in the model (Fig. 2) are ministries and departments, extra-budgetary funds, regional budgets and foreign sources. Ministries and departments provide direct financing of budget organizations and indirect financing of commercial organizations in key industries through the federal target programs. Regional budgets finance budgetary organizations and the regional programs through local departments. Recipients of extra-budgetary funds are individuals (through the system of social transfers) and medical organizations.

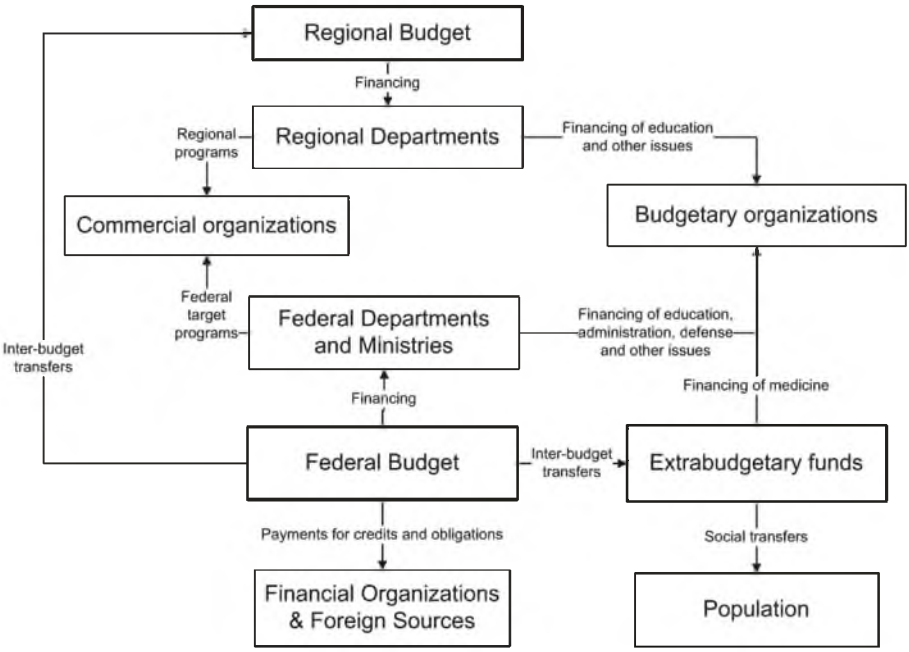

Fig. 2. Expenses of the budget system of the Russian Federation

3.2 Preparation of Initial Data

Revenues of the federal and regional budgets consist of taxes, excises, tallage and customs duties (Table 1). For a number of revenues the payment is divided between the federal and regional budgets. Main information sources on tax rates and benefits for their payment are the Tax Code of the Russian Federation [28] and the Budget Code of the Russian Federation [6], articles and expenditure in a particular year are set in the Federal Law on the federal budget [10]. Retrospective data on the execution of budgets are presented on the Portal of the budget system of the Russian Federation [20].

While the agent model of the Russian Federation spatial development simulates agents and households in detail [14], it aggregates organizations to the sector-region scale, so that one macro-organization 'Sector S in region R' presents a set of real-world organizations in this sector and region. This assumption is due to lack of information about production, employment and financial state of organizations [16, 17], while available data is presented in the regional and sector scale [25]. Due to the accepted aggregation of objects in the model, the exact reproduction of revenue items, and particularly, excise rates and customs duties on specific goods, is quite difficult. To solve this problem, we calculate model rates of excises and duties for the industry, determined on the basis of retrospective data for 2014, presented on the budget system portal [21]:

$$Rate_s = \frac{SumRevenue_s}{BaseValue_s} \quad (1)$$

where $Rate_s$ – the rate of payment (excise, tallage, duty) for sector s; $SumRevenue_s$ – sum of revenues by this type of payment from sector s; $BaseValue_s$ – value of payment base (production volume for tallage for use of natural resources and excises on products manufactured in the Russian Federation; export volume for customs duties; import volume for excises on products imported to the Russian Federation).

Using this method, for example, five types of excise taxes on various types of fuel are combined into an aggregated excise tax 'Diesel and gasoline', the rate of which is 1.33% of the output of the industry 'Production of coke and petroleum products'(Table 1).

Table 1. Rates of revenues of federal and regional budgets in the model

Income item	Rate	Percentage paid to the federal budget	Percentage paid to the regional budget
Profit and income taxes			
Profit tax	6-20% of profit	15%	85%
Value added tax	0-18% of price of goods	100%	0%
Property & Transport tax	2.2% of property value	0%	100%
Personal income tax	13% of income	0%	100%
Excises on products manufactured in the Russian Federation			
Alcohol	6.74% of production volume	50%	50%
Tobacco products	153% of production volume	100%	0%
Diesel and gasoline	1.33% of production volume	12%	88%
Cars and motorbikes	0.95% of production volume	100%	0%
Excises on products imported to the Russian Federation			
Alcohol	6.6% of import volume	100%	0%
Cars and motorbikes	1.44% of import volume	100%	0%
Diesel and gasoline	6.47% of import volume	100%	0%
Tobacco products	52.41% of import volume	100%	0%
Tallage for use of natural resources			
Tallage for hydro-carbon extraction	35.92% of production volume	100%	0%
Tallage for other mineral extraction	7.2% of production volume	40%	60%
Customs duties			
Export of oil and gas	88.72% of export volume	100%	0%
Export of petrochemical	53.23% of export volume	100%	0%

Another complex issue is defining conditions for granting privileges on value added and profit taxes. When determining the average value added tax (VAT) rate for the industry, exceptions described in the Tax Code of the Russian Federation [28] are taken into account; so that industries where VAT is zero (such as medicine, public administration), preferential (food) or partial (where some organizations operate under the simplified tax system and are exempt from VAT) are defined. The average rate of VAT and income tax for each industry is determined by the iterative proportional fitting algorithm based on the actual VAT collected [20], total amount of taxes paid by each industry in the input-output table [24] and the list of exceptions [28].

Some non-tax revenues of the federal budget (revenues from foreign sources, payment for a negative impact on the environment) are not specified in percentage terms, but in fixed monetary terms; such parameters are set on the basis of retrospective data and change in the forecast period in accordance with the expected scenario. The part of non-tax revenues to the regional budget (fines, revenues from municipal property) is calculated as a percentage of tax revenues and is distributed among payers - organizations of the relevant industry.

Revenues of extra-budgetary funds consist of insurance fees paid by organizations for their employees, income from the fund assets and inter-budget transfers (Table 2).

Table 2. Rates and sources of revenues of extra-budgetary funds in the model

Income item	Rate	Source
Pension Fund		
Fees for compulsory pension insurance	22% of accrued salary	Budgetary and commercial organizations
Revenues from the fund assets	31.7 billion RUR	Financial organizations
Inter-budget transfers	2414.6 billion RUR	Federal and regional budget
Social Insurance Fund		
Fees for compulsory social insurance	2.9% of accrued salary	Budgetary and commercial organizations
Revenues from the fund assets	9.1 billion RUR	Financial organizations
Inter-budget transfers	52.1 billion RUR	Federal and regional budget
Compulsory Medical Insurance Fund		
Fees for compulsory medical insurance	5.1% of accrued salary	Budgetary and commercial organizations
Revenues from the fund assets	1.3 billion RUR	Financial organizations
Inter-budget transfers	30.6 billion RUR	Federal and regional budget

Structure of federal budget expenses in the model was simplified by aggregating expenditure items into major groups correlated with sectors of the economy. Expenditure of the federal budget, except from direct inter-budget transfers and repay of the federal debt, is managed by ministries and departments, which, in turn, distribute funds among the recipients. Direct beneficiaries are budget organizations of the industries

presented in Table 3. Funding for commercial organizations goes through federal targeted programs with tools of direct subsidies (in the industries 'Transport', 'Agriculture & Fishery', 'Fuel and energy complex', 'Mining', 'Forestry') and government orders ('Water management', 'Road infrastructure', 'Housing and communal services').

Expenditure of the regional budget is managed by regional departments. For each region, the budget has its own distribution structure. Expenditures of extra-budgetary funds include transfers to various groups of the population (pensioners, disabled people, persons on maternity leave, etc.). Rates of transfer payments for the base year of modeling are set on the basis of Federal state statistics service [24] data, and for subsequent years are loaded to the model as scenario parameters.

Table 3. Expenses of the federal budget in the model

Issue	Share in budget expenses, %	Issue	Share in budget expenses, %
Financing of budget organizations in sectors:		Financing of commercial organizations in sectors:	
State administration	6.3	Transport	4.19
National defense	16.5	Agriculture & Fishery	2.65
National security	13.7	Fuel and energy complex	0.44
Environmental protection	0.7	Mining	0.8
Education	4.3	Forestry	0.48
Culture & Cinematography	0.5	Housing and communal services	0.8
Space research	0.55	Road infrastructure	8.07
Physical culture &Sports	0.4	Water management	0.47
Mass-media	0.4	Inter-budget transfers	
Science	3.85	Pension Fund	14.95
Public debt expenses		Social security fund	8.15
Internal debt	2.1	Regional budgets	5.4
External debt	0.7	Compulsory Medical Insurance Fund	3.6

3.3 Algorithms of the Model

The agent approach implies reproduction of interactions of micro-level agents. In the paper [15] interactions of a commercial organization with employees and counterparties are described. Here we consider interaction of model objects that are associated with functions of the budget system. The algorithm presented in Fig. 3 involves

interaction of federal, regional budgets and extra-budgetary funds with organizations, agents and each other.

Events of the organizations that are significant for this task are wages payment, followed by payment of fees to extra-budgetary funds; supplies (VAT and excise taxes are paid on imported goods); sales (VAT; excise taxes on goods produced in the territory of the Russian Federation; customs duties on exported goods); payment of other taxes (tallage for use of natural resources, property and transport tax) and calculation of the financial result (payment of income tax). Agents pay personal income tax on wages and profits.

The federal budget receives various tax and non-tax payments, finances departments, which in turn finance budgetary and commercial organizations. Also the federal budget distributes transfers to regional budgets and extra-budget funds, and repays the state debt.

Regional budgets receive taxes, fees and excises from the local organizations and transfers from the federal budget. Further, budgetary and commercial organizations are financed from the regional budget.

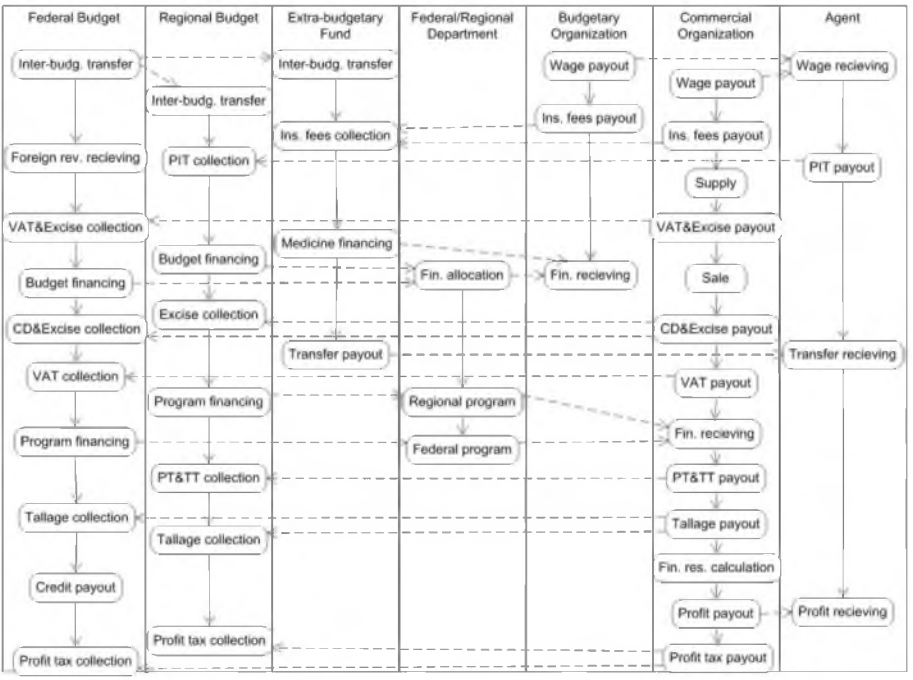

Fig. 3. Interrelation between budget system, agents and organizations in the model of the Russian Federation spatial development (CD – customs duties, VAT – value added tax, PIT – personal income tax, PT&TT – property and transport tax).

Extra-budgetary funds receive insurance fees from organizations, transfers from the federal budget, as well as revenues from the fund assets management. Then, from the

fund's expenditures, money is allocated to finance budgetary organizations in the medical sector to pay for health care expenses. Funds also pay benefits, pensions and other social transfers.

4 Empirical Analysis of the Case

The model of the Russian Federation spatial development is being programmed on C# in Microsoft Visual Studio 2015. Figure 4 shows interface of the model and sequence of data processing in it. Initial modeling data sets are loaded in the form of Excel tables, checked for completeness and consistency [16]. In the generation module, initial modeling data is transformed to information objects of the model (agents, households, organizations, administrative institutions). Results of the generation procedure are stored in the model database [15], which is being changed during retrospective or scenario modeling.

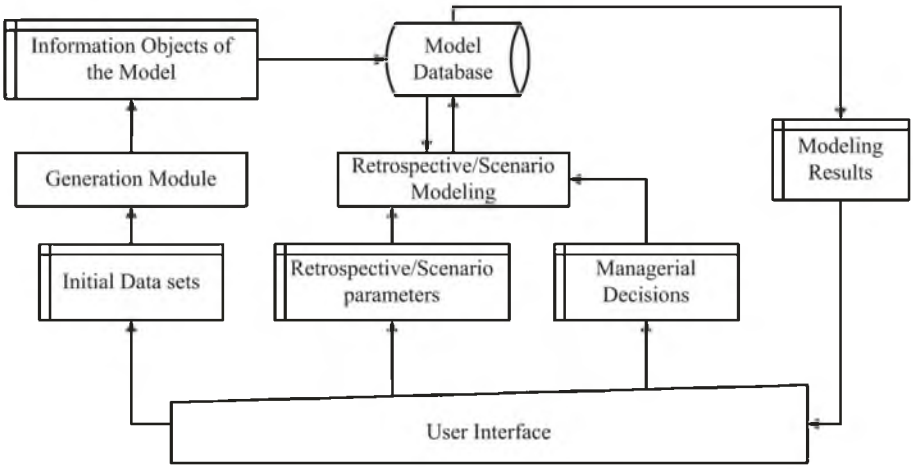

Fig. 4. Software implementation of the model

When generating initial structure of the model, all objects of the budget system form the account for accumulating income and distributing expenses during the simulation. The user loads retrospective parameters for revenues and expenses of the budgets. The simulation starts from the base year, when the budget system works on the retrospective parameters. For further years the user sets scenario parameters (such as export volume and exchange rate) and managerial decisions for revenues and expenses of the budgets (tax and fees rates, structure of the expenditures).

For validation of the budget system algorithms in the model we conduct retrospective modeling for 2014 year. In Table 4 there are presented revenues of the federal budget and budget of Belgorod region in the model, compared with the real data from Portal of the budget system of the Russian Federation [20].

Table 4. Results of the retrospective simulation

Income item	Revenues of the federal budget in 2014 (simulation results)	Revenues of the federal budget in 2014 (real data)	Revenues of the budget of Belgorod region in 2014 (simulation results)	Revenues of the budget of Belgorod region in 2014 (real data)
Profit and income taxes				
Profit tax	420650	420510	12960	12740
Property & Transport tax	–	–	7880	7840
PIT	–	–	13092	12970
Taxes and excises on products manufactured in the Russian Federation				
Value added tax	2184225	2181420	–	–
Alcohol	85930	85930	1100	1100
Tobacco products	314000	314000	–	–
Diesel and gasoline	102500	102500	2580	2580
Cars & motorbikes	16850	16850	–	–
Taxes and excises on products imported to the Russian Federation				
Value added tax	1750350	1750240	–	–
Alcohol	35400	35400	–	–
Cars & motorbikes	18820	18820	–	–
Diesel & gasoline	12680	12680	–	–
Tobacco products	4760	4760	–	–
Tallage for use of natural resources				
Tallage for hydro-carbon extraction	2836800	2836800	–	–
Tallage for other mineral extraction	47820	47820	712	710
Customs duties				
Export of oil and gas	3107610	3107610	–	–
Export of petrochemical	1489390	1489390	–	–
Revenues from the Customs Union	762400	762400	–	–

(*continued*)

Table 4. (*continued*)

Income item	Revenues of the federal budget in 2014 (simulation results)	Revenues of the federal budget in 2014 (real data)	Revenues of the budget of Belgorod region in 2014 (simulation results)	Revenues of the budget of Belgorod region in 2014 (real data)
Other custom duties	104020	104020	–	–
Other revenues				
Income from the state property	417673	445580	610	610
Administrative fees and charges	286920	286920	840	840
Inter-budget transfers	–	–	22700	22700
Other budget revenues	247324	471710	–	160
Total	14246122	14496800	62384	62160

Tax, excise and duties rates were taken from Tables 1 and 2. A number of items of income were set as a set of retrospective parameters, in particular: property income (for the federal budget it consists of income from stocks, income from managing budget assets and profit of the Central Bank; for regional - rental payments); administrative fees (distributed among organizations in proportion to their income); other custom duties (paid by exporting organizations in proportion to the export volume). Other revenues to the federal budget in the model are income of budget organizations, in the real budget these are a number of different items, the total amount of which is less than 3% of the total budget revenues.

Presented in Table 4 results of retrospective simulation show a fairly high accuracy of the revenue part formation of federal and regional budgets in the model. Deviation of total amount of income of the federal budget from the real values was 1.7%; for comparison, the deviation of the forecast values of the federal budget during its formation from its execution was 1.8% according to the portal of the budget system of the Russian Federation [20].

The resulting deviation is due, firstly, to the presence of a certain set of revenues, which cannot be taken into account by the specification of the model and the data presented (for example, when the government sells intangible assets, it is unclear to which industry these assets belonged and who was the buyer); and, secondly, approximation in the formation of the list of tax benefits for various industries. Due to the method described in Sect. 3.2, the excises and duties are reproduced with high accuracy on the base year of the simulation, although some errors may occur in subsequent periods.

For the budget of the Belgorod region, deviation of income for the base year of the simulation is 0.4%.

5 Discussion of Results

The scientific value of the proposed approach is creation of methods for integrating large arrays of real data into social simulation models, which makes it possible to reflect in detail the social institutions existing in the country, in this case the tax and budget system. In practice, this would allow to carry out multivariate scenario calculations in the recreated socio-economic environment to support managerial decisions in the field of spatial development.

Particularly, the budget system, simulated in detail, would allow to reflect directions of financing of the infrastructure projects, aimed at more even spatial development of the country. Since the volumes of financing required for such projects are quite significant, it is necessary to determine the sources and the cost of attracting them through issuing bonds or changing tax rates, and the model is capable of making such estimates.

Calculations on the model are aimed at assessing positive effects of project implementation in relation to production growth, employment and living standards in various regions, as well as sustainability of the budget system in the long-term period during project implementation and the risks of their incompleteness.

6 Conclusions

In this article we presented methods and algorithms of simulating budget system in the agent-based model of the Russian Federation spatial development. Basis for research at this stage were previously modeled population and organizations [14, 16] and algorithms for their interaction [15, 17]. As information sources for the budget system reconstruction we used Tax and Budget codes, federal laws and the official portal. Study of these sources allowed to define components of the budget system and relationship between them; types, rates and sources of revenues to budgets of various levels; volumes and recipients of government transfers and subsidies.

To reproduce mechanisms of the budget system in the model, a number of generalizing assumptions were made, due to the lack of information on some items of income and expenditure budgets of various levels, a large list of tax benefits for various industries, as well as level of aggregation of model objects. Taking these assumptions into account, the model rates of taxes, excise taxes and fees were determined. The budget expenditure items were also aggregated according to the characteristics of the beneficiaries of funding - organizations and residents.

For verification of the developed module, retrospective modeling was performed on the values of the base 2014 year. Comparison of simulation results with the real data for the Russian Federation and Belgorod region showed high accuracy (deviation does not exceed 2%).

For prognostic modeling characteristics of the budget system are loaded to the model as scenario parameters and managerial decisions. Changes in the tax rates and benefits influence on the amount of financing attracted, while distribution of funds among various sectors affect implementation of economic and territorial development programs.

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