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# Concept of Multi-Level Simulation Model for Developing Regional Government's Economic Strategy

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**Abstract**

The article considers the simulation model's concept based on integration of the regional economic elements' interconnections within the united computational scheme. It has been substantiated that the development of a long-term strategy for the socio-economic development of a region requires using formalized advanced planning methods, economic and mathematical models as management tools. The model is proposed as a tool for determining the conditions and parameters of the regional strategic development in a changing macro environment.

The main attention is paid to description of the formal model and the behavior algorithm for the economic agent of the "regional government" which considered as the main functional subsystem of the imitation model. The simulation model's structure allows implementing system modeling and forecasting the parameters of the socio-economic system development at the regional level and could be used as the practical tool for substantiating integrated regional development strategies for the medium term.

**Keywords:** simulation model, economic and innovation development strategy, regional government.

## 1. Introduction

The region as the complex socio-economic system includes many of different elements interacting with each other and with the elements of the environment in time. Making decisions in the control of the systems of this scale requires a thorough and comprehensive analysis of the possible consequences of their implementation. In this regard, there is an objective need for a comprehensive science-based instruments based on the development of economic-mathematical model of the region, for analyzing alternative variants of development of the regional economy, for developing its forecast and for creating recommendations for achieving the goals.

At the moment there are sufficiently large number economic-mathematical models of socio-economic development of the region. In general, most of the constructed approaches based on the properties on the known of the classical models (input-output model, the model of general economic equilibrium system dynamics models) or focused on the synthesis of simulation techniques, agent-based modeling and decision theory, using the possibilities of modern computer technology (Makarov, 2005; Bakhtizin, 2008; Oleinik, 2005). The majority of them are the universal, multipurpose systems based on combined use of various methods and possessing significant opportunities of complex modeling. At the same time the practice of using this systems shows that despite of wide functionalities the essential lacks interfering reception of qualitative

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forecasts are inherent in them, including: weak equation of modeling results (Aitova, 2018); low forecasting accuracy (Nizamutdinov, 2017); scenarios analysis toolkit limitations (Akhmetov, 2017); information supply difficulties (Chernyakhovskaya, 2017). The main principles and requirements to the imitation model's toolkit have been formulated, namely: system approach as possibility to integrate all significant elements and relations of the real object; scientific validity as necessary to use scientifically-proved methods providing strict formalization and reliability of the simulation output; balance matrix – is complete account of formation and use sources providing preservation of basic productive proportions; alternativeness – is an opportunity of model to generate and estimate alternative development strategy realization in view of scenario conditions; practical applicability – is sufficiency of official statistical base for model construction in aim to transit from theoretical calculations to practical results.

The important stage of region model construction is system representation of social and economic system of region as sets of basic elements and their interrelations (Ulyaeva, 2015). In view of available interpretations for the purposes of modeling it was offered to consider 4 sectors of economy (industrial sector, population, public sector and an external world), 3 basic markets (commodity, financial and the market of resources) in view of their system interrelations (Nizamutdinov, 2017). According to such structure it was offered to form the basic functional blocks of complex model of region.

According to the principles formulated above the concept of the imitation model has been suggested in the following basic stages:

- Studying statistical base and allocation the main modeling parameters. The set of the parameters must be defined by structure of the real object;
- The model's system properties formalization using SAM methodology. The construction of balance equations system is the main result of the stage;
- The parameters' functional dependences should be formalized at the next stage according to logic of economic parameters relations. The econometric equations system is the result of this iteration defining functional relation between base model's parameters.
- The model's managing and scenario parameters formalization i.e. determination of inputs, outputs and variables of the model, «scenarios cards» construction defining possible limits of the parameters changing.

In this article we propose a methodical approach to developing regional economy model which combines the advantages of simulation models and behavioral models from one side and the properties of the classical balance and dynamic models on the other.

## 2. Discussion

The model of the region is hierarchically structured and logically related composition models of 3 types – complex behavioral model of economic agents, the system dynamic balance models and control model (Figure 1). The central element (core) of the proposed multi-level modeling concept is the set of models of economic subjects (agents) behavior which represent within the overall structure of the complex model of its intellectual component. As elements of this subsystem is proposed to formalize the behavior of aggregate economic subjects such as "The aggregate producer", "The household", "The state (regional level)", "The financial Sector", "The outside world."

Management model

$$U = F(Y_p, Y, Sc, T, G; t)$$

Dynamic balance model

$$X = F(In, Exp, Fl, St, t)$$

Agent's behavior model

$$B = F(U; X; S; R; Y_a; t)$$

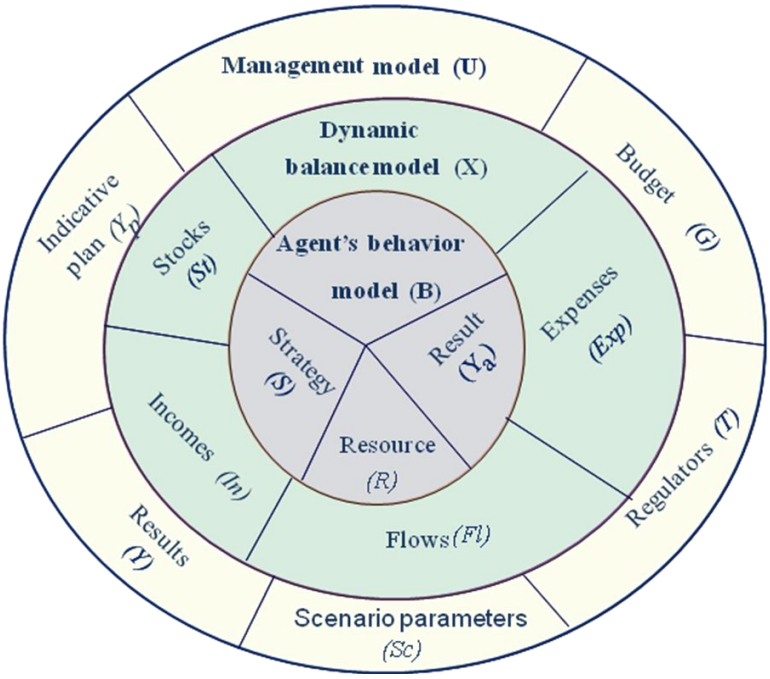


**Fig. 1.** General modeling concept scheme

The common logic of simulation of the economic agents' behavior represents some formalized mechanism for the transformation of existing economic agent (primarily financial) resources *R* in final result of its activities *Y* through the implementation economic strategy *S*. In this case, the logic of the behavioral models suggests that each economic agent through their own strategy implementation considers other economic agents strategies over a horizontal interrelation system and also through a vertical interrelation system considers the conditions and limitations, installed him to model a higher level of the hierarchy. Economic agents are adapting to the current strategies of each other within each model time point, ensuring the achievement of own local goals, and at the same time through controls system achieving a higher level of global development of the entire system – the sustainable economic growth dynamics.

The intermediate element in the hierarchical structure of models is dynamic balancing system, which is implemented on the principles of national accounting and extended modification based on an integrated matrix of financial flows SAM. The identities balance presence provides preservation basic proportions of the production and distribution of the end product at the coordination of financial flows between the models of micro-macro levels and also a. A dynamic balance models subset represents certain system of mathematical equations that reflect the static context of the balance of income *In* and expenses *Exp* the economic agents for each simulation step within the framework iterative algorithm in the dynamic section - balance the rate of input and output flows of *Fl* financial and economic agents accumulated amount of inventories *St*.

The top level of the models hierarchy submitted the control model which represents the economy macro level and within the framework implementing the integrated model of the functions of planning and regulation of the entire macroeconomic system. In fact, this level of the hierarchy implements a subset of the functions of the entity "The state" which will be considered below.

A distinctive feature of the proposed concept is to link their own strategy of each economic agent with the strategies of other economic agents. This procedure is carried out through system of horizontal interrelations and the conditions and restrictions which set him by the models of a higher level of the hierarchy through the vertical interrelations. This approach allows us to form medium and long-term development strategy of the region including the mutual influence of the objectives and results of activities of different levels.

In this research, we describe the detail modeling of the economic agents' behavior «The state (state government) » which is represented by a set of federal, regional governments, as well as

extra-budgetary funds. The basic functionality of the agent "The state (state government)" is all kinds of tax collection of and the formation of budget revenues due to tax and other financial income and accumulated redistribution of financial resources among the other agents. Moreover, the agent has the power, which is reflected in the decision to regulate financial flows of between the agents. The economic agent "The state" appears within the framework of model one of the consumers of the end product and carries out the main macro-economic control. The strategy of agent behavior is to regulate the level of public demand for the end product and determine of the economic regulators to provide the desired indicative plan for growth in supply (economic growth).

The model agent behavior «The state (regional government)» is described in the framework of the proposed strategy for the behavior of economic agents on a «Income» – «Expenses» – «Result» – «Strategy».

Incomes agent $In_3(t)$ in the current year formed at the expense incomes of the region $In_3^{br}(t)$, the federal budget $In_3^{bf}(t)$ and extra-budgetary funds $In_3^{obf}(t)$ in accordance with formula (1)

$$In_3(t) = In_3^{br}(t) + In_3^{bf}(t) + In_3^{obf}(t). \quad (1)$$

Regional budget $In_3^{br}(t)$ in the current year consists of the tax $In_t(t)$, non-tax $In_{nt}(t)$ revenues, intergovernmental transfers $In_{tr}(t)$, income from investments $Dep_3(t)$ and budgetary borrowings $Cr_3(t)$ by the formula (2):

$$In_3^{br}(t) = In_t(t) + In_{nt}(t) + In_{tr}(t) + Dep_3(t) + Cr_3(t) \quad (2)$$

The components $Dep_3(t)$, $Cr_3(t)$ are the input model parameters. Their values are formed in the modeling of the behavior agent «The financial sector». Demand for the state credit $Cr_3^{AD}(t)$ specified in the same formation process which controlled and carried out on the basis of information on the regional budget savings $S_3^{br}(t)$ under rule (3):

$$Cr_3^{AD}(t) = \begin{cases} c(t)In_t(t), S_3^{br} < 0, \\ 0, S_3^{br}(t) > 0 \end{cases} \quad (3)$$

This flow $In_{tr}(t)$ is formed in the simulation of the federal budget. Coefficient calculation $c(t)$ is based on an iterative algorithm, as follows: in the case of formation deficit parameter $c(t)$ is corrected by a certain positive value to λ until the condition $S_3^{br}(t) \geq 0$ is reached. The initial value is $c(t) = 0$, value λ = 0,001 (0,1 %), the maximum number of iterations is 1000 steps.

The calculation of tax revenue $In_t(t)$ is from the formula (4):

$$In_t(t) = Tp_1^{br}(t) + Tp_4^{br}(t) + A(t) + T_2(t) + Tk(t) + T_3(t) \quad (4)$$

where $Tp_1^{br}(t)$, $Tp_4^{br}(t)$ – part of the income tax, "a collection of producers" and "financial sector", respectively, coming into the regional budget to the aspect ratio $k_{br}$ defined as constants of the model; $A(t)$ – excises, $T_2(t)$ – required payments and contributions households; $Tk(t)$ – the property tax; $T_3(t)$ – other tax incomes. The components $Tp_1^{br}(t)$, $Tp_4^{br}(t)$, $T_2(t)$ are formed in modeling the agents' behavior «The aggregate producer», «Financials» and «Households» and are the input model parameters.

The excise volume $A(t)$ in the current year calculated as a certain percentage of the amount of indirect taxes $TI(t)$ to the aspect ratio $c_a(t)$, which in turn acts as a regulator agent «The state (state government)».

The calculation of property tax $Tk(t)$ in the current year $t$ is commensurate with the rate of property tax $c_K(t)$ on the value of fixed assets $K(t)$. This parameter $c_K(t)$ acts as the regulator agent.

The volume of other tax income is determined by the equation (5):

$$T_3(t) = c_t(t)(Tp_1^{br}(t) + Tp_4^{br}(t) + A(t) + T_2(t) + Tk(t)), \quad (5)$$

where the coefficient $c_t(t)$ describes share of other tax income in the budget tax incomes and a scenic setting agent «The state (state government)».

The volume of non-tax income $In_{nt}(t)$ calculated in proportion to the volume of tax incomes $In_t(t)$ to the aspect ratio $k_{nt}$ which determined the proportion of non-tax revenue in the tax revenues of the budget of the region, and serves as a model constant.

Incomes of the federal budget $In_3^{bf}(t)$ at the current time $t$ are formed by the profit tax and indirect taxes by the formula (6):

$$In_3^{bf}(t) = Tp_1^{bf}(t) + Tp_4^{bf}(t) + TI^{bf}(t), \quad (6)$$

where $Tp_1^{bf}(t)$, $Tp_4^{bf}(t)$ – part of profit tax «The aggregate producer» and «The financial sector», respectively, receive to the federal budget with a coefficient of proportionality $k_{bf}$; $TI^{bf}(t)$ – the value of indirect taxes receives to the federal budget. Herewith parameter $k_{bf}$ is set as a model constant, and the component $TI^{bf}(t)$ is calculated according to the formula (7):

$$TI^{bf}(t) = TI(t) - A(t) \quad (7)$$

Extra budgetary funds $In_3^{obf}(t)$ formed by the flow of tax payments in the form of a consolidated social tax $TS(t)$. Their volume formed in the agent's behavior modeling «The aggregate producer».

In the current year $t$ agent expenses $Out_3(t)$ are formed by the regional budget expenditures $Out_3^{br}(t)$, the federal budget $Out_3^{bf}(t)$ and extra budgetary funds $Out_3^{obf}(t)$. The calculation of the regional budget $Out_3^{br}(t)$ expenditures in the current year carries on by the formula (8):

$$Out_3^{br}(t) = a(t)In_3^{br}(t) + RCr_3(t), \quad (8)$$

where $a(t)$ – the proportion of the regional budget expenditures from its income, $RCr_3(t)$ repayment of government loans. The calculation of the value $a(t)$ made on the basis an iterative algorithm with the following scheme: parameter $a(t)$ is corrected by some positive value λ as long as the current supply volume of the end product $Y^{fac}(t)$ (factual GRP) will not match the size of the final product $Y^{plan}(t)$ (planned GRP), given the indicative plan. The initial value is $a(t) = 0$, value is λ = 0,001 (0,1 %), the maximum number of iterations of steps is 1000.

The expenditure $RCr_3(t)$ which directed to repayment of the loan in the *t* year is calculated by the formula (9):

$$RCr_3(t) = (1 + r_{cr}(t-1))Cr_3(t-1), \quad (9)$$

where $RCr_3(t-1)$ – the volume of attracted loans (budgetary of borrowing) in the previous period; $r_{cr}(t-1)$ – the bank rate on last year loans, which is an external controller agent «The financial market». At the initial time value of the parameter $RCr_3(t_0)$ set. The costs of loans repayment $RCr_3(t)$ are output the model coordinate and sent to the agent's behavior model «The financial sector».

The regional budget expenditures $Out_3^{br}(t)$ decomposed in the following directions: the expenditure on state consumption $C_3^{br}(t)$, budgetary investment $I_3(t)$, social transfers $Tr_3(t)$ and subsidies.

The expenditure on government consumption $C_3^{br}(t)$ is calculated according to (10):

$$C_3^{br}(t) = u_C(t)Out_3^{br}(t), \quad (10)$$

where $u_C(t)$ – the proportion of the state (regional) consumption in the regional budget expenditures. The coefficient $u_C(t)$ used as an endogenous model parameter whose value depends on the strategy of the agent.

The volume budget investment $I_3(t)$ in the current year $t$ is determined according to (11):

$$I_3(t) = u_1(t) Out_3^{br}(t), \quad (11)$$

where $u_1(t)$ characterizes the share of budget investments in expenses of the regional budget and used as an endogenous parameter of the model, the value of which depends on the strategy of the agent.

Flows $C_3^{br}(t)$ and $I_3(t)$ are outputs and forwarded as input to the agent behavior model coordinate «The aggregate producer».

The volume of social transfers from the regional budget $Tr_3(t)$ in the $t$ year calculated based on the share $k_{tr}$ of social transfers in the regional budget expenditures. The flow $Tr_3(t)$ is the output and sent as input the coordinates into theagent behavior model «The households».

The federal expenditures $Out_3^{bf}(t)$ on the current time $t$ consist of the costs of inter budget transfers $In_{tr}(t)$, and government (federal) consumption $C_3^{bf}(t)$.

The calculation of the inter-budget transfers $In_{tr}(t)$ and the government consumption $C_3^{bf}(t)$ is carried out in proportion to their shares in the federal budget revenues.

The expenditure budget funds $Out_3^{br}(t)$ in the current year are calculated based on the share $k_{obf}$ of expenditure budget funds in their incomes.

Flows $C_3^{bf}(t)$, $Out_3^{br}(t)$ are output and routed to the agent behavior model «The aggregate producer».

The financial result of the agent "The state" at the current time $t$ is the amount of savings $S_3(t)$.The balance of the state savings is described by equations (12):

$$\frac{dS_3(t)}{dt} = In_3(t) - Out_3(t). \quad (12)$$

Balance of the regional budget savings $S_3^{br}(t)$ is described by equations (13):

$$\frac{dS_3^{rb}(t)}{dt} = In_3^{rb}(t) - Out_3^{rb}(t). \quad (13)$$

The regional budget savings flow $S_3^{br}(t)$ is an output parameter of the model and sent as a stream of deposits in the model of agent behavior «The financial sector».

Similar scheme implemented to the complex of the other economic agents' behavior simulation model, which are then integrated into a single logical computing scheme in the simulation environment Matlab/Simulink.

The proposed model construction allows implementing the computational experiments on modeling and quantifying the effects of the implementation of various strategies for region social and economic development in the long term. As a model control parameter is given some regional development desired trend which specifies the indicative plan for one or more key parameters (Putilov, 2004). Under experimental conditions the indicative plan represented targets the dynamics of GRP given the long term.

On the basis of a given indicative plan model calculates for the main region macroeconomic indicators, providing specified rate of the economic growth. The long-term dynamics of the order of 15 basic parameters of socio-economic development of the region, in detailed form – about 40 indicators modeled in an aggregated form. The fragment of the simulation results by aggregate indicators of socio-economic development of the region (Republic of Bashkortostan) for the period up to 2020 for a given rate of economic growth is presented in Table 1.

**Table 1.** Estimate macro parameters long-term development of the Republic of Bashkortostan for the given parameters of economic growth, billion rubles.

| Indicators | 2005 year | 2010 year | 2015 year | 2020 year |
|---|---|---|---|---|
| Gross Regional Product | 409,3 | 520,3 | 671,3 | 859,8 |
| Wages | 131,0 | 174,7 | 225,4 | 288,7 |
| Gross profit | 164,6 | 198,9 | 256,6 | 328,7 |
| Investments in fixed capital | 64,5 | 82,0 | 105,8 | 135,6 |
| Incomes of the population | 338,4 | 523,3 | 633,7 | 800,2 |
| Expenses of the population | 293,9 | 438,7 | 524,2 | 668,4 |
| Savings of the population | 44,5 | 84,6 | 109,5 | 131,7 |
| Budget revenues of the region | 62,4 | 93,6 | 107,6 | 136,9 |
| Federal budget revenues in the region | 35,6 | 44,9 | 58,0 | 74,2 |
| Revenues extra-budgetary funds | 34,3 | 45,8 | 59,1 | 75,6 |
| The volume of lending | 40,3 | 39,6 | 76,9 | 98,2 |
| Exports | 135,1 | 93,6 | 161,1 | 206,3 |
| Imports | 81,9 | 93,6 | 120,8 | 154,8 |

In general, the results the proposed dynamic simulation model testing indicate a sufficient adequacy degree and forward-looking estimates accuracy that allows to use it as a practical tool for forecasting and decision analysis tasks in the planning of regional development in the medium and long term (Tsybatov, 2006).

## 3. Conclusion

The main results of the research:

–concept of the integrated region's simulation model is suggested which produces long-term development strategy taking into account the mutual influence of the objectives and results of the economic agents at the micro level and priorities of socio-economic development at the meso-level;

–model of the economic agent "government" is developed formalizing the logic of its behavior through the mechanism of public demand regulation for the gross product and the quest for supply given by indicative plan growth of the overall supply of the gross product;

–prognostic evaluation the basic macroeconomic indicators dynamics in the long term has been implemented for the Republic Bashkortostan.

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