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APPLYING EVOLUTIONARY-SIMULATION METHODOLOGY ISSUES IN MODELING OF LONG-TERM ECONOMIC DEVELOPMENT

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Abstract. The global economic crisis of 2008 has had a paralyzing effect on the world economic growth. It has reinforced research on the geopolitical and socio-economic forecasting. The new methodologies of long-term socio-economic simulating and forecasting have been proposed over the last ten years. However, the complexity of estimated model parameters has always been against them being used for analytical modelling. Simple and at the same time so efficient tool for analytical modelling is the use of The Evolutionary-Simulation Methodology (ESM), developed by Russian scientists – G.V.Ross and V.E.Lichtenstein. The approach suggested by the authors of the article makes it possible to apply world dynamics modelling with ESM.

Keywords: The Evolutionary-Simulation Methodology, Model-ling and Forecasting World Dynamics, Long-term Economic Development, The global economic crisis.

Over the past twenty years, we can see new pickup of activity in the field of mathematic modeling and forecasting of global and regional dynamics. This intensification relates to both global crisis (Asian financial crisis in 1997, the dot com bubble in 2000, The Global Financial Crisis of 2007) and to ecological, energy and demographic challenges. The objectives of the forecasting are ecology, demography, economics, scientific-and-technological advance and quality of life. The key parameters of the forecasting are the population size, the available resources, the level of technology. Typical forecast indicators are the Gross Domestic Product (GDP), population and labor force, capital investment, labor productivity and others. The forecast horizon can reach 30 – 50 years.

In the research [7] was identified the following leading direction of long-term forecasting. *The extrapolation method*. The method examines trends of the last period trends, and then extrapolates it to the future. Its field of application is short- and medium-term forecasting. *The expert evaluation method.* It is based on evaluations of experts in specific subject. Its field of application is short-, medium- and long-term forecasting. The Delphi and Foresight methods are applied to reach fully agreement of the expert community. *The integral macro forecasting* methodology is based on synthesis of Nikolai Kondratieff's theory and Wassily Leontief's Input-Output Analysis. The methodology was designed by Yuri Yakovets [3]. *The scenario method.* It is applied in long-term forecasting with a lack of appropriate data. Three scenarios are considered: optimistic, pessimistic and most likely. *Mathematical modelling.* In addition to produce the forecast it allows to decide the planning problem – development management according to the scenario obtained in the forecasting. The complex models are being developed by R&D teams or consulting centers (see, for example, the PwC report "The World in 2050. The Acceleration Shift of Global Power: Challenges and Opportunities", [8] and the Goldman Sachs report "Dreaming with BRICs: The Path to 2050", [9]). Economy of the U.S. has often been chosen as reference economy for comparison. The method relies on Solow's neoclassical model of long-term economic growth, which is based on a Cobb-Douglas production function:

$$Y(t) = A(t)K^{\alpha}(t)L^{1-\alpha}(t)$$

where $Y(t)$ – the current volume of the GDP; $K(t)$ – the current volume of the physical capital; $L(t)$ – the total employed in entire economy (the labor capital); $A(t)$ – the technological advances (the level of technological development).

According to the research [7] the new dynamic macro models are designed to address the combined effects of the equilibrium long-term growth and cyclical fluctuations round it, specified by supply-demand balance.

When making the forecasting calculations of economic growth and development it is generally considered as *the total factor productivity* (*TFP*) (TFP is named as "technological progress" by Solow). The growth of TFP leads to better standards of living and quality of life of the population. So-called R&D model is the most effective and promising model among existing models for TFP calculating. The improved R&D model was presented by Akaev et al. [1, 2, 5]. This model is taking into account the allowance per one R&D worker and skills of the labour force in addition to number of R&D workers, and number of workers in the economy as a whole.

In the situation of the lack of information there is a need to use special techniques of evaluation of expected GDP value and, first of all, analytical modelling method.

The advantage of this approach is the provision of brief research results and it is sufficiently flexible at a minimum of expenses. It is possible to change the factor composition, contents of the model, and the use of any evaluation techniques.

The main problem of applying analytical modelling method is that the forecast GDP values (the plan) estimated based on the model (as numerical characteristic in modelling model of economic growth) can have unacceptably high error, sometimes exceeding the evaluation itself. That is because the value of model's factors can be evaluated only approximately (using expert opinions), the factor error of estimation has been an exponential increase during the required plan calculation in accordance with formulas of the optimization model.

The Evolutionary-Simulation Methodology (ESM) allows to reduce uncertainty by one or two degrees at the expense of optimization.

It changes the whole situation and makes a theoretical economics an effective tool of business practice.

Let's consider an example of estimating of the general model for exponential growth (the Anchishkin model [5])

$$Y = Y_0 e^{q_0 t},$$

where Y_0 – the start value of GDP, q – growth indicator, t – time.

The evolutionary-simulation model of output of GDP on the base of the general model for exponential growth contains:

$$\bar{f} = q;$$

$$\bar{p} = Y_0, t;$$

$$Fa = IM_0(\bar{f}, \bar{p}) = Y_0 e^{qt};$$

$$R_1 = IM_1(PL, Fa, \bar{f}, \bar{p}) = PL - Fa;$$

$$R_2 = IM_2(PL, Fa, \bar{f}, \bar{p}) = Fa - PL;$$

where q – factor – a random values which are defined by interval values.

Y_0, t - indicators – conditionally constant values;

IM_0 – the simulation model that calculating of GDP output value.

IM_1 и IM_2 – the simulation models for costs calculations (the overstate plan costs and the understate plan costs are equivalent in proposed model).

Let's calculate equilibrium output value of the production by using the "Equilibrium" software in the R environment [4]. Load a package and define the evolutionary-simulation model. The model includes: q-factor; Y, t indicators; the overstating/understating calculation functions UZav и UZan; the overstating/understating cost calculation functions IZav и IZan:

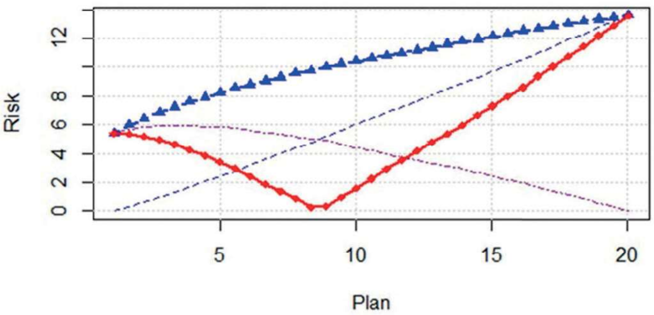
The result of calculation of equilibrium value of production output and a risk chart (see figure 1) presents the planning production value ($8.3595 billion) which is attained minimum difference between overstating and understating risks.

The evolutionary-simulation model has reduced uncertainty to the range from $6 billion up to $13 billion (the interval in which difference of risks is less of both values).

The further use of the ESM could include scenario analysis of the impact to GDP of the value changes of the various factors and indicators (and their combinations).

The combination of ESM with dynamic macro model allows not only to get the forecast but also to consider the various risks of scenarios of socio-economic development for solving the development management problem.

```
library(esm)
model.Anchishkin <- setClass("Anchishkin",prototype = prototype(
    factors = list (# Random variable
      q=esm.factor(min=0.1, max=3, name=" Growth indicator ", dimension = " units.")),
    indicators = list(# Conditionally constant values
      Y=esm.indicator(value=1, name=" The initial issue volume of the national production    dimension = " billion.$"),
      t=esm.indicator(value=1, name=" time ", dimension = " year ")),
    UZav = function (df){ df["Y"]*exp(df["q"]*df["t"])},
    UZan = function (df){ df["Y"]*exp(df["q"]*df["t"])},
    IZav = function (df){ (df["PL"]-df["Fa1"])},
    IZan = function (df){ (df["Fa2"]-df["PL"])},
    name = "Anchishkin"),contains ="Model")
```




```
Model: Anchishkin(Anchishkin)
RESULTS OF OPTIMIZATION CALCULATION
 --- PLAN
                                   value
Optimum                           8.3595
Reliability for overstating       0.3014
Reliability for underestimation   0.3014
Overstating/Underreporting        2.3462

--- Co-distribution of factors and indicators
                                                                  value
Fa1                                                               8.356
Fa2                                                               8.356
Growth indicator, units.                                          2.123
The initial issue volume of the national production, billion. $   1
Time, year                                                        1
```

Fig. 1 Graph and equilibrium values of risks

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