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Abstract. This article presents a simulation-dynamic model for calculating long-term economic growth based on the neoclassical model of R. Solow. The model is developed on the basis of the system dynamics method, AnyLogic tools. In the constructed model, the calculations were carried out for two variants of the long-term Russian economy development, with and without taking into account scientific and technical progress. The model was used as a tool for researching which of the development options is more profitable. As a result of experiments with options, it was found that a variant that takes into account technical progress is preferred. The conducted study allows concluding that the developed simulation-dynamic model is universal and on its basis, it is possible to conduct various researches on various aspects of the long-term development of different levels economic systems.

1. Introduction

One of the most important long-term goals of the government's economic policy in any country is to stimulate economic growth and maintain its pace at a stable and optimal level. The need for economic growth is due, firstly, to an increase in population. This is due to the fact that a person, as an economic subject, acts, on the one hand, as a consumer of material benefits, and on the other, as the main productive force of society. Therefore, population growth is accompanied by both an increase in the demand for goods and services, and an increase in the number of workers. Consequently, if the scale of production remained unchanged, there would be a decline in the standard of living and an increase in unemployment. Secondly, the need for economic growth is caused by the constant development and growth of human needs. Needs are always ahead of production. The gap between them can be reduced, but it always exists.

Economic growth is an increase in the output of goods and services in the economic system under consideration (in the country, region and world). The measure of economic growth is the increase in real gross domestic product (GDP) as a whole or per capita. There are extensive and intensive types of economic growth. In the first case, growth is achieved by increasing the extensive (quantitative) growth factors. In the second it is due to intensive (qualitative) growth factors. With the development and development of modern achievements of science and technology, intensive growth factors become predominant. In real life, extensive and intensive types of economic growth in their pure form do not exist. There is their binding and interaction [1].

When regulating economic growth, various economic models are used, among which there are two: the neo-Keynesian model (model of E. Domar and R. Harrod) and the neoclassical model (model R. Solow) [1, 2].

Robert Solow's neoclassical model of economic growth, based on the Cobb-Douglas production function, taking into account exogenous neutral technical progress as a factor of economic growth along with such factors of production as labor and capital is presented [2].

The importance of studying the economic growth problem lies in the fact that economic growth is the basis for increasing welfare, and analyzing the factors that determine it allows explaining the differences in the level and pace of development in different countries (inter-country differences) in the same period and in the same country at different times (intertemporal differences).

The complexity of taking into account the influence of these factors predetermines the need for the use of instrumental management methods, such as economic-mathematical modeling (EMM), which increase the effectiveness of decisions to stimulate economic growth. One of such modern and widely used approaches today is simulation-dynamic modeling, the method of system dynamics [3, 4].

2. Long-term economic growth calculation model

The model for calculating long-term economic growth is presented in Figure 1.

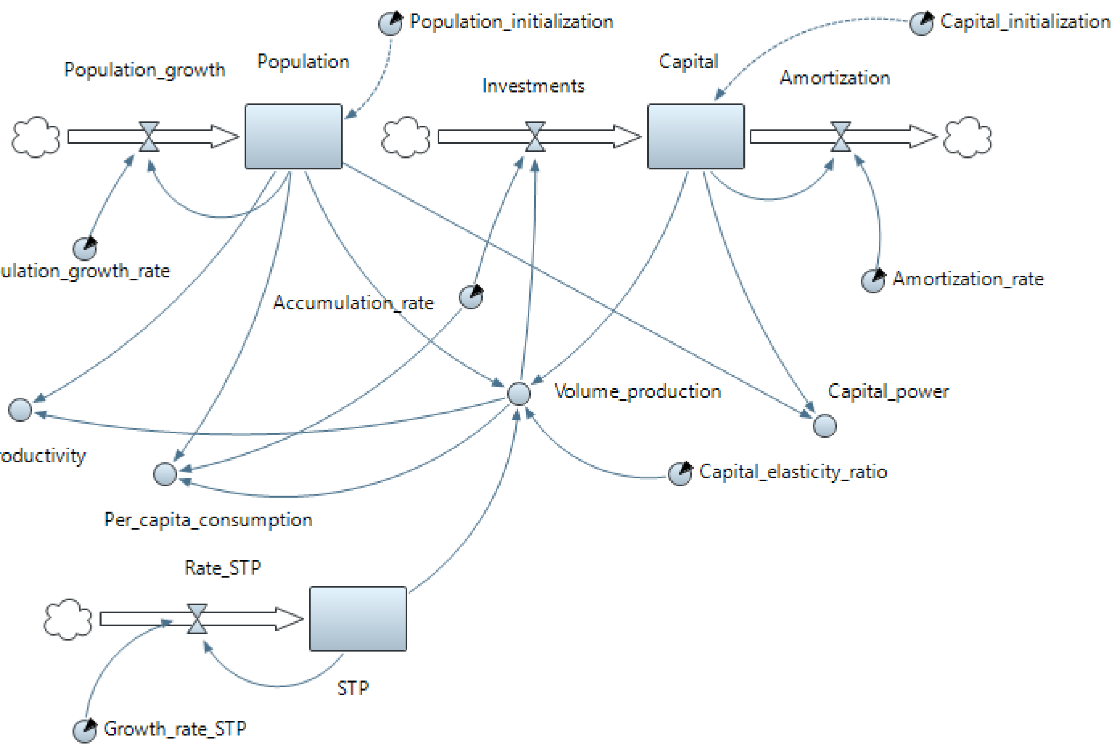

Figure 1. Flow chart and calculation levels for long-term economic growth

The model includes three levels (of storage):

- Population.
- Capital.
- STP.

Also on the chart are four streams:

- Population growth.
- Investments.
- Amortization.

- Rate_STP.

In addition to the listed flows and levels, there are auxiliary variables in the diagram. The decoding of the variables shown in the diagram is presented in Table 1.

Table 1. Used variables in the flow diagram and calculation levels of annuity and differentiated loan payments

Name	Documentation
Population	Population level
Capital	Availability of fixed assets
STP	The level of scientific and technological progress
Population growth	Population growth rate
Investments	Growth rate of investment in fixed assets
Amortization	Growth rate of depreciation
Rate_STP	The growth rate of scientific and technological progress
Volume_production	Gross domestic product
Accumulation_rate	Savings rate
Per_capita_consumption	Per capita consumption
Capital_elasticity_ratio	Coefficient of elasticity of capital
Population_growth_rate	Population growth rate
Amortization_rate	Depreciation rate
Growth_rate_STP	The growth rate of scientific and technological progress
Productivity	Labor productivity
Capital_power	Capitalization of labor
Population_initialization	Initialization of population level
Capital_initialization	Initialization of the availability of fixed assets

Consider the algorithm for calculating long-term economic growth according to the Solow model [1, 2].

Economic growth is characterized by a system of indicators which allows comparing the results of the economy functioning in time.

The model has several simplifications: there is only one product; no government spending or taxes; no change in unemployment; production is determined by the aggregated function of only three factors of production. K is capital, L is labor, A is knowledge, the efficiency of labor of one worker depends on the qualifications, education and health of the worker; savings and depreciation rates are fixed, set exogenously - and δ; growth rate of the number and technical progress is constant, set exogenously - n and g.

In the Solow model, the production function is:

$$Y = K^{\alpha} \times (A \times L)^{1-\alpha}, \quad (1)$$

where $0 < \alpha < 1$, α – the capital elasticity coefficient, $1 - \alpha$ – the labor elasticity coefficient.

Population growth rate:

$$\frac{dL}{dt} = n \times L. \quad (2)$$

Capital growth rate:

$$\frac{dK}{dt} = s \times Y - \delta \times K. \quad (3)$$

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The growth rate of scientific and technological progress:

$$\frac{dA}{dt} = g \times A. \tag{4}$$

The Solow model allows determining the optimal level of savings rate at which the maximum (specific) consumption is reached. By definition, specific consumption equals:

$$c = (1 - s) \times Y. \tag{5}$$

3. Management interface of the long-term economic growth calculation model

Figure 2 presents the interface for managing models for calculating long-term economic growth according to the Solow model.

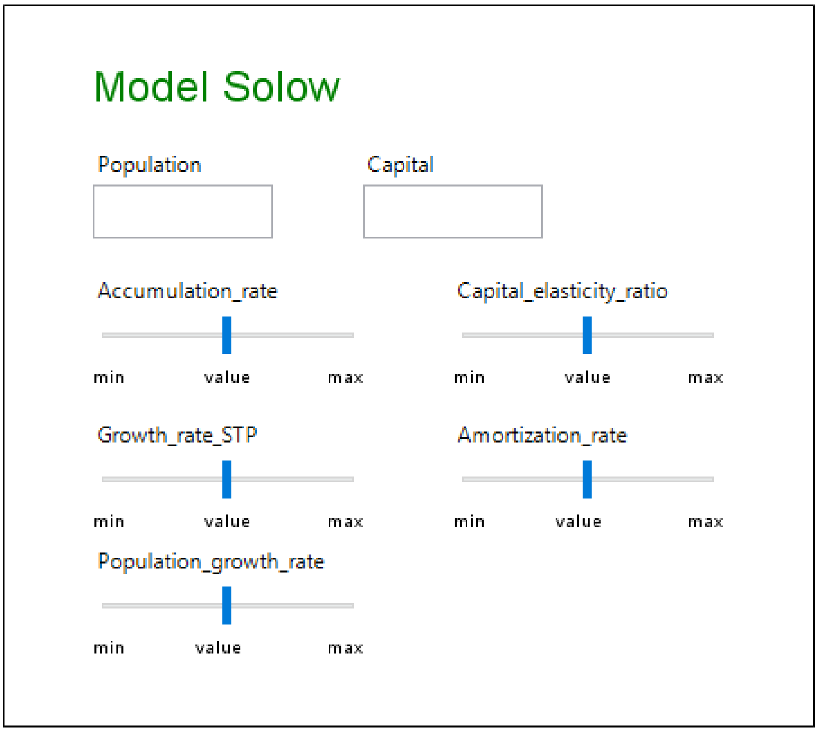

Figure 2. Long-term economic growth calculation model control panel

The interface structure consists of two parts: input of input data and monitoring of the calculation results. Before starting the calculation, the following data is entered: population size; availability of fixed assets, savings rate and growth rate of scientific and technological progress, rate of depreciation deductions and coefficient of capital elasticity. On the second part of the interface, the calculation results are displayed in graphical form: the growth rate of investments in fixed assets, the growth rate of depreciation charges, gross domestic product and the availability of fixed assets, capital-equipment and labor productivity.

4. Results

In the course of the experiment, calculations were made of Russia's long-term economic growth for 50 years using the following initial data for 2018 [5-7]: population level - 1,46880400 people; availability of fixed assets - 194649464 million rubles; savings rate - 30% per year; growth rate of scientific and technological progress - 0.01; population growth rate - 0.001 (medium version of the forecast); coefficient of elasticity of capital - 0.25; depreciation rate - 0.1.

From the graph (Figure 3, 4) it can be seen that with a neutral technological progress, Russian economic system reaches an equilibrium state by the year 30, by the 50^{th} year the GDP approaches 160 trillion rub. When taking into account technical progress, the Russian economy is growing up to 50 years, although the growth rate is slowing down, and GDP is approaching 200 trillion rub.

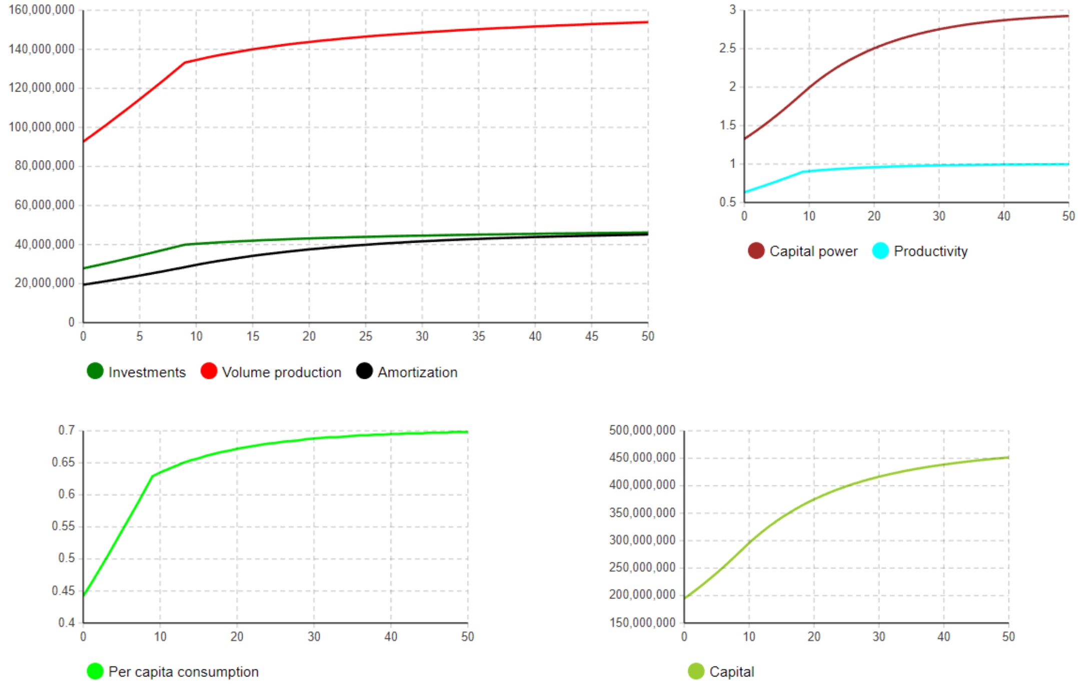

Figure 3. Results of the long-term economic growth calculation without scientific and technological progress

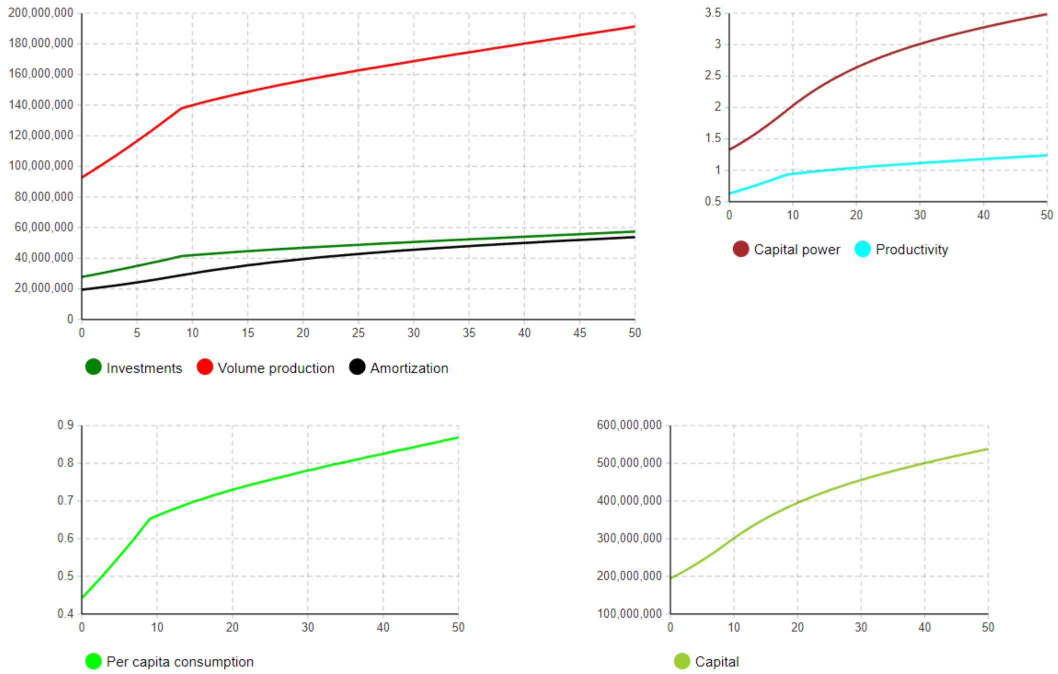

Figure 4. Results of the long-term economic growth calculation in Russia, taking into account scientific and technological progress

5. Conclusion

As a result, based on the calculations, it can be concluded that scientific and technological progress plays a key role in ensuring the long-term economic development of economic systems.

It should also be noted that the constructed simulation model of long-term economic growth can be used to determine the optimal level of savings rate at which maximum (specific) consumption is achieved and to study other aspects of economic growth, therefore it can be considered universal.

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