ANALYSIS OF THE SCIENTIFIC AND TECHNICAL COMPONENT OF THE ECONOMIC GROWTH IN THE REGION

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Abstract

Regional development researchers pay special attention to the innovative component of the territories at this time as there is a direct contact between the level of the innovation and the level of socio-economic development in the region. Innovation is the key point of improving of the economic competitiveness as knowledge-based economy. Innovation policy is component of the strategy of industrial-innovative development and the primary instrument for increasing of the economic competitiveness. The goal of this research is analysis and evaluation of the innovative component in the economic development of the region. The methods considered are based on the use of econometric models as the model parameters allow to evaluate of the level of regional economic development. This paper focuses on the theoretical aspects of economic and mathematical modeling based on the use of production functions also, as well problems related to the assessment of the innovative component in the economic development of the region. When developing and constructing static models of macroeconomics, statistics were used for 15 years, where economy is an integral unstructured unit, the input of the model are resources, the output is gross regional product as the result of the functioning of the economy. Resources are arguments, gross regional product is function. Modelling was performed with the use of production functions in general for the Russian Federation, and the eighty-three regions and eight federal districts. Macroeconomic indicators such as gross regional product, costs of main production assets, population number, workforce number, economically active population number is chosen to build the models. Models were constructed in operational prices and comparable prices with consideration scientific and technological progress (innovation component) for each region. The level of scientific and technological progress estimate, first, models based on multiplicative production functions are considered, secondly, additive models, in so-called tempo records, which allow to use the cumulative productivity of the production factors to assess growth, the so-called Solow residue. The conducted research quantified the contribution of scientific and technological progress to economic growth of the region; comparative analysis of economic growth in different regions, allocate the regions with the highest and lowest share contribution of scientific and technological progress in the dynamics of growth of gross regional product. It is possible a rating of regions of innovative component of social and economic development on level.

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Keywords: economic-mathematical modeling, gross regional product, production function, scientific and technological progress, Solow residue.

1. INTRODUCTION

Successful socio-economic development of the region is impossible without effective management of the regional economy. In return, economic and mathematical modeling and forecasting of its development are great significance for effectiveness increase of regional economy management and allow making economically reasonable decision that contribute to the construction of optimal strategies for managing the economy. Developments of mathematical models and determine the most effective assessment method of the socio-economic development is the main goal in research field. First of all, search of assessment methods caused by the possibility to predefine different various for the development of the region with the highest accuracy and lowest cost. Comparative analysis of growth rates of different regions is interesting for state regulation of regional development. This analysis will allow making a decision on the support of a particular region in one form or another in a timely manner. At this time, researchers pay particular attention to the innovative component of the territories, because there is a link between the region's innovative economy and its socio-economic development. Innovations play a key role in improving competitiveness of the economy; economy, which is based on knowledge. Innovation policy is an integral part of the strategy of industrial and innovative development and is the main tool for competitiveness of the economy.

2. ANALYSIS OF SCIENTIFIC AND TECHNICAL COMPONENTS OF ECONOMIC GROWTH

2.1. The multiplicative production function

Consider the impact of technical (technological) progress using a production function (PF) of the form:

$$Y(t) = A(t) \cdot F(K(t), L(t)),$$

where $Y = Y(t)$ – GDP or GRP, $K = K(t)$– capital, $L = L(t)$– labor, $A = A(t)$ – time function t, describes the level of development of technological progress and is interpreted as an increase in the cumulative productivity of the production factors often.

Differentiate the function at variable t:

$$\frac{dY}{dt} = \frac{dA}{dt} \cdot F(K, L) + A \cdot \frac{dF(K, L)}{dt} = \frac{dA}{dt} \cdot \frac{Y}{A} + \frac{Y}{F} \cdot \left(\frac{\partial F}{\partial K} \cdot \frac{dK}{dt} + \frac{\partial F}{\partial L} \cdot \frac{dL}{dt} \right),$$

then divide both sides of the last equality by Y :

$$\frac{dY/dt}{Y} = \frac{dA/dt}{A} + \frac{\partial F/\partial K}{F} \cdot \frac{dK}{dt} + \frac{\partial F/\partial L}{F} \cdot \frac{dL}{dt} =$$
$$= \frac{dA/dt}{A} + \frac{\partial F}{\partial K} \cdot \frac{K}{F} \cdot \frac{dK/dt}{K} + \frac{\partial F}{\partial L} \cdot \frac{L}{F} \cdot \frac{dL/dt}{L}.$$

Type key:

$\frac{dY/dt}{Y} = G_Y$ – output generation rate, relative increase of output during the period t;

$\frac{dK/dt}{K} = G_K$ – capital generation rate;

$\frac{dL/dt}{L} = G_L$ – labor generation rate;

$\frac{dA/dt}{A} = G_A$ – technological progress rate (output generation rate due to technological progress);

$\frac{\partial F}{\partial K} \cdot \frac{K}{F} = E_{Y,K}$ – elasticity of output on capital inputs ;

$\frac{\partial F}{\partial L} \cdot \frac{L}{F} = E_{Y,L}$ – elasticity of output on labor inputs .

Then there will be the following form:

$$G_Y = G_A + E_{Y,K} \cdot G_K + E_{Y,L} \cdot G_L,$$

which is a production function in the so-called tempo recording. The last equation describes as the increase of output is due to a change in the number of resources used $\left(E_{Y,K} \cdot G_K + E_{Y,L} \cdot G_L\right)$ and where is the technical progress $\left(G_A\right)$.

For example, productions function $Y = e^{\gamma t} F\left(K(t), L(t)\right) = \alpha_0 e^{\gamma t} K(t)^{\alpha_1} L(t)^{\alpha_2}$ for which:

$$G_Y = \gamma + \alpha_1 \cdot G_K + \alpha_2 \cdot G_L.$$

and for the function $Y(t) = \alpha_0 e^{\gamma t} K(t)^{\alpha} L(t)^{1-\alpha}$ –

$$G_Y = \gamma + \alpha \cdot G_K + (1-\alpha) \cdot G_L .$$

The multiplicative production function can be used to describe various types of technical progress. Consider $MRTS_{L,K} = \frac{\alpha_2}{\alpha_1} \cdot \frac{K}{L}$. If the ratio $\frac{\alpha_2}{\alpha_1}$ decreases over time t, then capital-intensive technical progress; if the ratio $\frac{\alpha_2}{\alpha_1}$ increases over time t, then labor-intensive technical progress; if the ratio $\frac{\alpha_2}{\alpha_1}$ invariable over time t, then labor-intensive technical progress then neutral technical progress.

Note that the constant term γ is the rate of neutral technical progress, not related to the growth in labor cost and capital cost, the value reflects the intensification of production at the micro-level, which follows from the last equation. In addition, it needs to take account that the parameter γ is constructing on the residual principle when performing practical calculations. In other words, it reflects the effect on the growth rate of output of all other factors, except labor and capital. This means that the parameter characterizes the effect on output of some other factors. However, it is the main role among "other factors" belongs to technical progress for the most of microeconomic processes. The respective software "EGRMod" was developed for work in the MS Access or under of the library AccessRuntime for the Windows OS for constructing static macroeconomic models of the Volga Federal District (PFD) regions using production functions. External database Access is used for data accumulation. Numerical calculations are realized in SQL using VBA.

The following variables were used as the main characteristics of the model:

1) gross regional product – Y ;
2) cost of main production assets – K ;
3) population – L_1 ;
4) economically active population – L_2 ;
5) labor force in the economy – L_3 ;

The models were constructed in current and comparable prices (with the consumer price index) in the form of a Cobb-Douglas production function with technical progress for each PFD region $Y = \alpha_0 K^{\alpha} L^{1-\alpha} e^{\gamma \cdot t}$ and the multiplicative production function with technical progress – $Y = \alpha_0 K^{\alpha_1} L^{\alpha_2} e^{\gamma \cdot t}$. Three kinds of labor resources L_1, L_2, L_3 were considered for each function.Для каждой функции рассматривались три вида трудовых ресурсов L_1, L_2, L_3. In this way, 180 models were built for all regions of the Volga Federal District and for the district generally.

For example, estimate γ parameter using the Cobb-Douglas production function at comparable prices for the regions of the Volga Federal District:

Table1. Assessment of the level of scientific and technological progress using the Cobb-Douglas production function at comparable prices

№	Region	L_1	L_2	L_3
1	Republic of Bashkortostan	0,0503	0,0557	0,0577
2	Kirov Region	0,0676	0,0815	0,0778
3	Republic of Mari El	0,0456	0,0498	0,0484
4	Republic of Mordovia	0,0455	0,0455	0,0461
5	Nizhny Novgorod Region	0,0473	0,0460	0,0483
6	Orenburg Region	0,1512	0,1225	0,1181
7	Penza Region	0,0965	0,0782	0,0741
8	Perm Territory	0,0153	0,0227	0,0243
9	Samara Region	0,0489	0,0526	0,0517
10	Saratov Region	0,0630	0,0611	0,0374
11	Republic of Tatarstan	0,0520	0,0485	0,0467
12	Republic of Udmurtiya	0,0274	0,0395	0,0376
13	Ulyanovsk Region	0,0618	0,0547	0,0536
14	Republic of Chuvashia	0,0041	0,0473	0,0439
15	Volga Federal District	0,0420	0,0570	0,0512

As a result of the performed researches, all regions were broke into three clusters by cluster analysis methods.

The first cluster: Republic of Mordovia, Nizhny Novgorod Region, Penza Region, Perm Territory, Saratov Region, Samara Region, Republic of Udmurtiya, Republic of Chuvashia.

Second cluster: Kirov Region, Republic of Mari El, Orenburg Region, Ulyanovsk Region.

The third cluster with the highest level of innovation component: Republic of Bashkortostan, Republic of Tatarstan.

2.2. The Solow residue

R. Solow was asked to use the production function with constant returns to scale for assessing the contribution of production factors to economic growth in 1957, as follows:

$$Y = A \cdot F(K, L),$$

where A - level of technology development. Changes in the level of technological knowledge A lead to the same increase in marginal productivity of labor $\frac{\partial Y}{\partial L}$ and capital $\frac{\partial Y}{\partial K}$ and is often interpreted as an increase in the cumulative productivity of the production factors.

Practical realization of the change in product yield ΔY can be approximated using the full differential formula, as follows $(\Delta Y \approx dY)$:

$$\Delta Y = \frac{\partial Y}{\partial K} \cdot \Delta K + \frac{\partial Y}{\partial L} \cdot \Delta L + \frac{\partial Y}{\partial A} \cdot \Delta A = \frac{\partial Y}{\partial K} \cdot \Delta K + \frac{\partial Y}{\partial L} \cdot \Delta L + F(K, L) \cdot \Delta A =$$

$$= MPK \cdot \Delta K + MPL \cdot \Delta L + F(K, L) \cdot \Delta A,$$

where ΔK, ΔL и ΔA – changes in the values of the production factors; $MPK = \frac{\partial Y}{\partial K}$, $MPL = \frac{\partial Y}{\partial L}$ – marginal productivity of capital and labor, appropriately.

Dividing both sides of this equation $Y = A \cdot F(K, L)$:

$$\frac{\Delta Y}{Y} = \frac{MPK}{Y} \cdot \Delta K + \frac{MPL}{Y} \cdot \Delta L + \frac{\Delta A}{A}.$$

The equation can be transformed to the form:

$$\frac{\Delta Y}{Y} = \left(K \cdot \frac{MPK}{Y}\right) \cdot \frac{\Delta K}{K} + \left(L \cdot \frac{MPL}{Y}\right) \cdot \frac{\Delta L}{L} + \frac{\Delta A}{A},$$

where expressions in parentheses are elasticity of the output with respect to capital and labor.

From the last ratio follows, that increases in product rate $\frac{\Delta Y}{Y}$ is equal to the sum of three terms:

1) Capital generation rate $\frac{\Delta K}{K}$, multiplied by the share of capital in total income.
2) Labor generation rate $\frac{\Delta L}{L}$, multiplied by the share of labor in total income.
3) Rate of growth in the cumulative productivity of the factors $\frac{\Delta A}{A}$.

Ratios $MPK \cdot \frac{K}{Y}$ and $MPL \cdot \frac{L}{Y}$ as share of income for capital and labor assuming that, in conditions of perfect competition, labor and capital are paid for by their marginal productivity. The contribution of labor and capital to economic growth can be calculated using statistical data. Assessment of the contribution of scientific and technological progress to economic growth cannot be carried out directly. Usually, the estimate is calculated as the remainder term of the final equation, called the Solow residue:

$$\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - \frac{\partial Y}{\partial K} \cdot \frac{K}{Y} \cdot \frac{\Delta K}{K} - \frac{\partial Y}{\partial L} \cdot \frac{L}{Y} \cdot \frac{\partial L}{L}. \quad (1)$$

Therefore, strictly speaking, the Solow residue $\frac{\Delta A}{A}$ determines not only the contribution of scientific-technological progress to economic growth, but also the part of economic growth that cannot be measured directly (due to any reasons except the changes in the quantity of labor and capital used). When Cobb-Douglas PF $Y = AK^{\alpha} L^{1-\alpha}$, the ratio (1) takes the form:

$$\frac{\Delta Y}{Y} = \alpha \frac{\Delta K}{K} + (1 - \alpha) \frac{\Delta L}{L} + \frac{\Delta A}{A}, \quad (2)$$

and the Solow residue will be calculated by the formula:

$$\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - \alpha \frac{\Delta K}{K} - (1 - \alpha) \frac{\Delta L}{L}. \quad (3)$$

When the multiplicative production function of the form $Y = AK^{\alpha_1} L^{\alpha_2}$, the ratio (1) takes the form:

$$\frac{\Delta Y}{Y} = \alpha_1 \frac{\Delta K}{K} + \alpha_2 \frac{\Delta L}{L} + \frac{\Delta A}{A},$$

and the Solow residue will be calculated by the formula:

$$\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - \alpha_1 \frac{\Delta K}{K} - \alpha_2 \frac{\Delta L}{L}.$$

The share of capital in income as θ, the share of labor in income as $(1-\theta)$, then from (1) follow:

$$\frac{\Delta Y}{Y} = \theta \frac{\Delta K}{K} + (1-\theta)\frac{\Delta L}{L} + \frac{\Delta A}{A}.$$

The choice of the particular formula of the production function makes it possible to estimate the values of the parameters θ and $\gamma = \frac{\Delta A}{A}$. For example, significant Cobb-Douglas production function is statistically estimated for a market economy, it is considered that $\theta = \alpha$ (see formula (2)) then can be used α and $1-\alpha$ as estimates of capital and labor shares in total income. Backward, if the parts θ and $1-\theta$ are known then the parts can be used as approximate values of the parameters α and $1-\alpha$ in the Cobb-Douglas function. If the parts α and $1-\alpha$ are known then the single parameter unknown as the rate of technical progress is estimated using the linear regression model γ. The use of the Cobb-Douglas PF is one of the possible ways to estimate and analyze these parts. However, these estimates are not stable for the Cobb-Douglas PF and statistically significant estimates are not found for some periods at all. Also the Cobb-Douglas function can be estimated for an economy that is planned centrally, but the elasticities α and $1-\alpha$ may differ from the share of capital (θ) and labor $(1-\theta)$ in output. Such variation can point to inefficiency in the resource allocation and can point to need for their reallocation.

If the share of capital and labor in income is stable, and the annual growth of output and costs of production factors are known in competitive economy then the annual technological progress rate $\gamma = \frac{\Delta A}{A}$ is calculated by the formula (3).

Ratios $MPK \cdot \frac{K}{Y}$ и $MPL \cdot \frac{L}{Y}$ can be regarded as parts of income for capital and labor, assuming that labor and capital are paid for by their marginal productivity in conditions of perfect competition. For developed countries, the shares of capital and labor in income are very stable and make up about 25-30% of gross income. For the least developed countries, usually, the share of capital is higher. For example, its estimates are 0.40-0.55 for Latin American countries. For example, the Solow residue resulted to the following results for the regions of the Volga Federal District:

Table 2.The calculation of the Solow residue by the formula $\frac{\Delta A}{A} = \frac{\Delta Y}{Y} - \alpha \frac{\Delta K}{K} - (1-\alpha)\frac{\Delta L}{L}$ in comparable prices

№	Region	L_1	L_2	L_3
1	Republic of Bashkortostan	0,0571	0,0555	0.0523
2	Kirov Region	0,0472	0,0491	0,0473
3	Republic of Mari El	0,0636	0,0612	0,0609
4	Republic of Mordovia	0,1686	0,1684	0,0500
5	Nizhny Novgorod Region	0,0518	0,0458	0,0449
6	Orenburg Region	0,1013	0,0871	0,0864
7	Penza Region	0,0409	0,0382	0,0383
8	Perm Territory	0,0373	0,0383	0,0392
9	Samara Region	0,0465	0,0452	0,0424
10	Saratov Region	0,0638	0,0566	0,0539

11	Republic of Tatarstan	0,0415	0,0388	0,0380
12	Republic of Udmurtiya	0,0278	0,0282	0,0341
13	Ulyanovsk Region	0,0479	0,0433	0,0442
14	Republic of Chuvashia	0,0663	0,1722	0,0606
15	Volga Federal District	0,0458	0,0454	0,0429

The values γ and estimates of the Solow residue $\frac{\Delta A}{A}$ are similar which suggests the advisability of using multiplicative production functions to estimate the impact of scientific and technical progress on the dynamics of the GRP in the Volga Federal District

If the values of the level of technical progress have similar values, which calculated through the Cobb-Douglas production function and through the Solow residue, then the constructed functions can be used for further modeling of GNP.

Undoubtedly, technological progress has a major impact on the economic growth and structure of the economy of individual countries and the world economy as a whole, because it affects all elements of the productive forces. Technological progress is an important mover of economic growth and growth of output, which is used to solve both internal and international socio-economic problems.

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