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MODELING REGIONAL ECONOMIC GROWTH IN THE CONTEXT OF SIMULATION MODELING OF SCIENTIFIC AND TECHNOLOGICAL PROGRESS: CASE OF THE REPUBLIC OF TATARSTAN

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ABSTRACT

The article examines the role of scientific and technological progress in stimulating the economic growth of the Republic of Tatarstan. The basic factors of economic dynamics included in the neoclassical production function are labor, fixed capital, and scientific and technological progress. When including the production functions of scientific and technological progress in models, it is often understood as the potential for the creation and diffusion of innovations in the economic environment. In this article, scientific and technological progress is regarded as a set of human, financial, infrastructural, and institutional resources that determine the overall innovative capabilities of the region and the level of its effectiveness in the field of science and technology to ensure qualitative and structural parameters of economic growth and development, increasing competitiveness at the meso, macro, and global level. The authors' approach includes a thorough examination of the scientific and technological potential of Tatarstan over the past decade, offering insights into its different aspects. The methodological framework is based on a combination of quantitative and econometric methods. Based on this approach to definition and the methodological tools for measuring scientific and technological progress proposed by the authors, the authors attempt to construct the Solow production function. The assessment results are employed to determine the specific parameters of how productive factors impact the dynamics of GRP (illustrated by Tatarstan) and to identify patterns that highlight the significance of scientific and technological progress in shaping the prospects of economic dynamics during the Fourth Industrial Revolution.

Keywords: Scientific and Technological Potential, Economic Growth, Fourth Industrial Revolution, Republic of Tatarstan, Production Function, Sustainability of Economic Development.

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INTRODUCTION

The structural organization of production factors that trigger and intensify the economic dynamics of regions is sufficiently studied by the scientific community, starting from traditional neoclassical models and ending with their modern modifications. Neoclassical methods of constructing production functions are grounded in two fundamental elements that drive economic dynamics and impact the generation of the end product: labor and capital. Over time, this approach has evolved, giving rise to enhanced methodologies for examining economic dynamics. From our perspective, one of the most noteworthy adaptations of the classical Cobb-Douglas model is the J. Tinbergen model. The distinction lies in the inclusion of a parameter within the production factors that characterizes the scientific and technological potential, which is pivotal in driving the intensive model of economic dynamics. The American economist Robert Solow shared comparable perspectives, emphasizing the strategic significance of scientific and technological progress in fostering economic growth. Solow's work underscored the vital role that innovation and technological advancements play, positioning them as key drivers in the economic system alongside the renewal of fixed assets and the development of the labor market. His analysis highlighted how the integration of new technologies and scientific advancements could lead to more efficient production processes, potentially boosting productivity and economic output.

Without going into a detailed review of derivative approaches that modify the models, it is necessary to unequivocally state that the basic factors of economic dynamics included in the neoclassical production functions are labor, fixed capital, and scientific and technological progress. More recent scientific works on this issue highlight the need to add entrepreneurial initiative to these factors. However, this modification of production functions is of a private nature and does not determine the degree of influence and significance of the three production factors. Accordingly, it seems appropriate to focus on these basic factors when forming the production function for the Republic of Tatarstan. When considering the production functions and including them into models of scientific and technological progress, the latter is often understood as the potential for the creation and diffusion of innovations in the economic environment. Within the framework of this article, scientific and technological progress is regarded as a set of human, financial, infrastructural, and institutional resources that determine the overall innovative capabilities of the region and the level of its effectiveness in the field of science and technology to ensure qualitative and structural parameters of economic growth and development, increasing competitiveness at the meso, macro, and global levels.

The main theories that laid the basis for the development of economic production models were formed by N.D. Kondratev (the theory of long waves, showing the specific role of scientific and technological progress in the process of phase shifts (Komdratev, 2002)) and J. Schumpeter (the theory of economic development (Schumpeter. 1983)), where the most important factors predetermining economic development are innovation and technological evolution. The key feature of their research is to rethink the paradigm of economic development from the perspective of technological progress.

One of the avid followers of Schumpeter, British researcher and scientist C. Perez dwells on technological progress in an even more radical form, which is reflected in the formulations used. For example, her scientific work “Technological Revolutions and Financial Capital. The Dynamics of Bubbles and Periods of Prosperity” contains the concept of technological revolution. According to the author, the latter acts as a key factor in strengthening the productive potential of the economic system and creates the potential for creating new technologies, which leads to rapid economic development by increasing the efficiency of using production resources (Perez, 2011). The need for scientific and technological development is caused by constant changes in the enterprise environment and growing competitiveness.

Today, Schumpeter’s ideas are supported by many renowned economists, including S.Yu. Glazyev, C. Perez, R. Solow, P. Drucker, etc.

MATERIALS AND METHODS

This study relies on a comprehensive dataset gathered from various sources to quantify the scientific and technological potential of Tatarstan. Data sources include government reports, academic literature, and specialized databases. These sources provide information on human resources, financial investments, infrastructure development, and institutional resources, all contributing to the scientific and technological potential of the region.

The quantitative measurement of the scientific and technological potential of Tatarstan over the past 10 years is presented in Table 1 and Figure 2. The methodological basis for calculating the integral values of the scientific and technological potential index is implemented in accordance with the algorithm presented in Figure 1. A total of 74 effectiveness indicators were used in the assessment.

It is also necessary to explain the methodological aspects of this research stage.

In a general conceptual form, the problem is solved by constructing the so-called production functions using econometric analysis methods.

The approach used not only determines patterns that reveal general trends and trends in the economic growth of the region within the three-factor model under consideration but also identifies the contribution of individual production factors to the formation of economic dynamics in the conditions of a new development paradigm that corresponds to the key parameters of the sixth technological order.

The values involved in the modeled production functions of factors are determined based on algorithmic solutions presented in this article in relation to the assessment of the scientific and technological potential index of the region. For the other two factors, the values are calculated based on a statistical assessment regarding the parameters of the formation of fixed assets in the region under study, as well as parameters characterizing the labor market.

In a concentrated form, the model of economic growth of the region can be presented as follows:

$$Y = A * K^{\alpha} * L^{\beta} * STP^{\gamma} \quad (1)$$

where

Y is an aggregate indicator assessing economic growth;

K is a factor assessing the state of the regional capital;

L is a factor assessing the region’s labor resources;

STP (scientific and technological potential) is a factor that assesses the level of scientific and technological potential in the region;

α, β, γ are elasticity coefficients characterizing the degree of change in Y when production factors are adjusted by 1%.

Considering that the indicators used in the calculations have different dimensions, measurement scales, and evaluation systems, they were subject to a normalization (standardization) procedure to unify the values in a single coordinate system. The procedure was carried out in accordance with the rules below.

Integrated assessment of indicators characterizing the effective use of the scientific and technological potential (the Active):

$$A = \sum_{i=1}^{n} Ai$$

where

A is an integral assessment of the effective use of the scientific and technological potential;

A_i is subindices assessing the effectiveness of scientific and technological progress (human capital, personnel, quality of R&D, index of research opportunism, global rating of research organizations/reputation capital of the regional scientific and technological progress, innovative activity of enterprises);

n is the number of subindices used to evaluate A.

↓

Integrated assessment of indicators that determine the financial, institutional, and infrastructural components of the formation of the scientific and technological potential of the region (the Passive):

$$P = \sum_{i=1}^{n} Pi$$

where

P is an integral assessment of the resource intensity of the region's scientific and technological potential;

Pi is subindices that assess the financial, institutional and infrastructural components of the scientific and technological potential of the region (R&D expenses, institutional support for scientific and technological progress, infrastructure support for scientific and technological progress);

n is the number of subindices used to evaluate P.

↓

Integrated assessment of the effective use of the scientific and technological potential of the region:

$$Iestp = \frac{A}{P}$$

Figure 1. Algorithm for the empirical assessment of the effective use of the scientific and technological potential of the region (Calculated by authors)

The analyzed factors are stimulants, i.e., their higher values correspond to the positive development of the region. To normalize these indicators, the following formula can be applied:

$$Z_i = \frac{X_i - \overline{X_i}}{\sigma_i}, \qquad (2)$$

where

X_i is an actual value of the i indicator;

$\overline{X_i}$ is an average value of the i indicator;

σ_i is a root mean square (standard) deviation.

To put the indicators onto a single scale (from 0 to 1), as well as to calculate the index, the data were converted into a standard cumulative distribution function at the fourth stage:

$$Z_i^{norm} = \frac{1}{\sqrt{2\pi}} e^{\frac{-z_i^2}{2}}, \qquad (3)$$

where

Z_i is a normalized value of the indicator.

The statistical database involved in the process of constructing production functions is presented in Appendix 4.

The most important prerequisite that determines the order and reliability of the implemented estimates is that the production functions modeled for the regions imply the need to use the principle of non-negativity of argument values.

RESULTS

Based on the proposed methodology for the empirical assessment of the region's scientific and technological progress, Table 1 presents the final calculations for Tatarstan between 2010 and 2021.

Table 1. Empirical Assessment of the Aggregated Value of the Scientific and Technological Potential Index of Tatarstan between 2010 and 2021 (Calculated by authors)

Year	The active	The passive	STP index
2010	0.458	0.483	0.948
2011	0.461	0.488	0.944
2012	0.472	0.472	1.000
2013	0.482	0.468	1.030
2014	0.491	0.486	1.010
2015	0.505	0.489	1.034
2016	0.490	0.481	1.019
2017	0.511	0.486	1.051
2018	0.519	0.497	1.044
2019	0.512	0.489	1.048
2020	0.520	0.496	1.048
2021	0.514	0.502	1.024

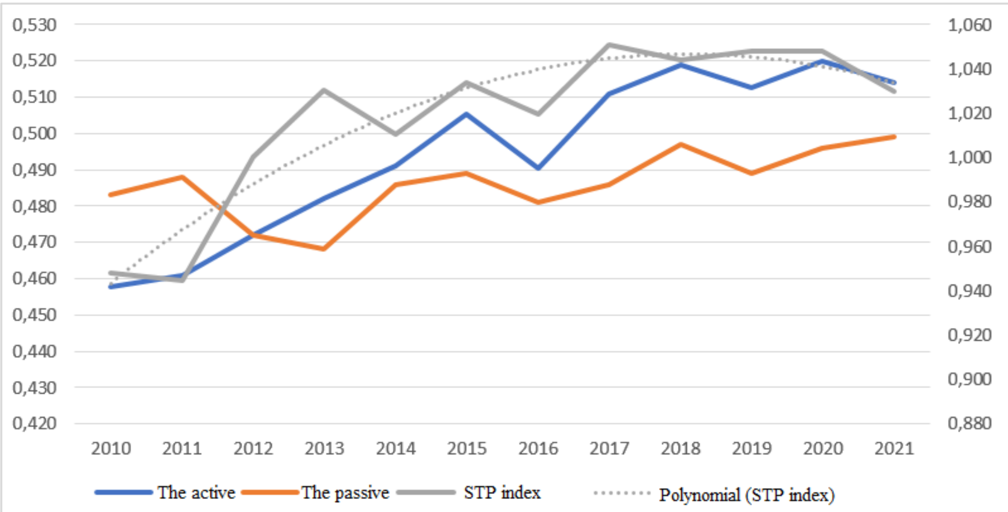

Figure. 2. Dynamics of the aggregated value of the STP index of Tatarstan between 2010 and 2021 (calculated by the authors)

Following these methodological approaches, the corresponding quantitative parameters and simulation estimates of the studied data are presented below.

The standardized estimates of the production function factors under study allowed us to construct the corresponding functional dependencies.

At the first stage of constructing the production function, the standardized data were logarithmized. We will demonstrate the results of reproducible iterations as exemplified by Tatarstan (Table 2).

Table 2. Logarithmic Values of Production Function Factors (Calculated by the Authors)

No.	LnY	LnL	LnK	Ln STP
2011	-3.320767643	-5.233758171	-1.780274012	-1.07434136
2012	-1.917116813	-1.573237804	-1.237204222	-1.11657828
2013	-1.454109637	-0.471930642	-1.426288263	-0.98442085
2014	-1.114859889	-0.611953107	-1.299286704	-0.96791051
2015	-0.842917609	-0.266181525	-1.252813487	-0.94803348
2016	-0.462596709	-0.19993869	-1.015293797	-0.97705529
2017	-0.237977224	-0.191805078	-0.872033765	-0.94445493
2018	-0.203674276	-0.424049531	-0.718556959	-0.99555251
2019	-0.169282685	-0.54865975	-0.593400101	-0.9249663
2020	-0.133135852	-0.517424002	-0.029970921	-0.92848543
2021	-0.129798348	-1.134136353	-0.025334035	-0.98073253

The obtained values helped to proceed with the second research stage associated with the construction of an economic-mathematical function characterizing the relationship between time series. Regression analysis was selected as a methodological tool for solving this problem. The results and statistical significance of the regression model are presented in Tables 3 and 4.

Table 3. Key Parameters Characterizing the Statistical Significance of the Resulting Equation (Calculated by the Authors)

Multiple R	0.97645
R-square	0.953455
Standardized R-square	0.933507
Standard error	0.258893
Observations	11

Table 4. Regression Model Coefficients (Calculated by the Authors)

	Coefficients	Standard error	t-statistics	P-value
Y intersection	3.468624	1.815437	1.910628	0.097667
L variable	0.344485	0.075844	4.542004	0.002661
K variable	0.854225	0.174638	4.891402	0.00177
STP variable	3.277459	1.932171	1.696258	0.133654

The presented parameters characterizing the statistical significance of the realized estimates indicate a high level of reliability of the calculation results, which forms the prerequisites for asserting the adequacy of using the regression equation to identify the desired patterns and develop other analytical estimates.

The resulting equation is as follows:

$$LnY = 3.468+0.344LnL+0.8541LnK+3.277LnSTP \quad (4)$$

After converting the equation from a logarithmic form to a power function, the following equation was formulated:

$$Y = 3.18*L^{0.344}*K^{0.854}*STP^{3.277} \quad (5)$$

DISCUSSION

Resulting model allows us to formulate a conclusion. At the current stage of development, the significance of scientific and technological potential as a production factor in the regional economy surpasses that of traditional factors such as labor and capital.

The observed outcome can be comprehensively attributed to the integration of the Fourth Industrial Revolution into the framework of economic interactions on a global, national, and regional scale. Given that each industrial revolution typically reshapes the labor market, often reducing the demand for labor, the Fourth Industrial Revolution that commenced in the 21st century has triggered additional shifts and redistributions among production factors. The role of capital suppliers (both physical and intangible or cognitive) acquires an almost comprehensive character due to the declining role of labor (Bourguignon, 2003; Ekins, 2000; Balatskii, 2019; Teixeira & Fortuna, 2010; Vyas & Vyas, 2019). Furthermore, within the framework of the Fourth Industrial Revolution, scientific and technological progress is emerging as the paramount catalyst for economic growth. This assertion aligns logically with the findings, underscoring the pivotal role of the Scientific and Technological Potential (STP) factor, which characterizes the region's scientific and technological development. In other words, the scientific and technological progress of the ecosystem determines the parameters and prospects of economic dynamics while reducing the importance of the employment factor. This conclusion is consistent with the research by other scholars dealing with similar issues Vyas & Vyas, 2019; Safiullin & Elshin, 2023).

Based on the obtained results, a 1% increase in the scientific and technological potential index corresponds to a 3.28% increase in the region's Gross Regional Product (GRP). This indicates its high sensitivity to scientific and technological advancements.

CONCLUSIONS

It can be argued that the developed regional production function opens up new opportunities not only for identifying key patterns of economic development at the meso level, with due regard to the scientific and technological progress factor, but also contributes to the formation of predictive theories of regional economic growth.

Our conclusions are objectively and generally predictable based on the theory of economic dynamics. To a greater extent, our position on the strategic importance of scientific and technological advancements at the present stage of economic development is the basis for new organizational solutions in this area, considering regional characteristics and fundamental approaches.

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