





Technological Innovation Impact on Dynamics of Aggregate Income in Digital Transformation of the Economy

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Abstract: The study goal is to study the role of technological innovation in providing upward dynamics of the aggregate indicators of the national economy as a whole and its constituent regional entities in the context of the end-to-end digitalization of economic processes. The study objectives are defined in view of its goal and consist in identifying the role of technological innovation in increasing labor productivity as a source of total income growth, as well as in conducting an empirical test of the thesis on the dependence of labor productivity and gross regional product (GRP) on investment in innovative projects (on the example of the regions of the Volga Federal District). The methodological basis of the study is the provisions of neoclassical theories of economic growth, as well as the Cobb-Douglas-Tinbergen production function. As a result of the study, it was concluded that there is a direct relationship between investment in innovative projects and the GRP dynamics, which is confirmed by the results of statistical data analysis on the Republic of Tatarstan and the Nizhny Novgorod region. The revealed dependence is determined by the significant impact of technological innovations on labor productivity in traditional economic activity. It is concluded that it is necessary to study the role of labor productivity in providing positive dynamics of indicators of innovative spheres of economic activity, as well as in changing the employment structure and unemployment rate.


1 INTRODUCTION


The global economic crisis caused by the pandemic coronavirus infection and the restrictive measures taken by the governments of most countries to prevent its spread has brought the problem of finding endogenous sources of progressive macroeconomic dynamics, on the efficiency of which depends on the possibility of transition from recession to recovery economic growth. In contrast to the situations of deteriorating macroeconomic conditions that have taken place in the world economy in previous periods

of its development, the crisis phenomena of 2020 are characterized by a global nature and affect all spheres of human activity (Voskoboynikov, I. B., Baranov, E. F., Bobyleva, K. V., Kapeliushnikov, R. I., Piontkovski, D. I., Roskin, A. A., Tolokonnikov, A. E., 2021). The crisis is taking place under the conditions of the fourth industrial revolution (Industry 4.0), which began in the 2010s and predetermined the further development of the post-industrial technical and economic order, caused the transformation of the configuration of the economic cycle and simultaneously led to an increase in the

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level of global threats. It initiated the acceleration of processes of end-to-end implementation of information and communication technologies in innovative and traditional sectors of the economy, as well as in the system of public administration, the wide spread of remote formats of employment and service provision, the formation of value chains using information platforms and “big data” technologies, etc. Under these conditions, theoretical and methodological approaches to the interpretation of economic growth sources and to the tools composition for realizing their potential require further development. Understanding the growing role of high-tech sectors of the economy and human capital in aggregate product formation, as well as knowing the reasons and consequences of increasing the level of uncertainty of environmental factors for making effective management decisions, will allow to develop effective anti-crisis measures and justifying the tools for transition to sustainable economic growth.

The scientific hypothesis of this study is the assumption that innovation is becoming an endogenous source of economic growth and the growing role of investment in innovative projects. The study goal is to identify the elements of impact mechanism of technological innovation on the growth rate of aggregate income of the state and its constituent regional entities. In accordance with the goal, the following tasks are solved: identification of the role of technological innovation in increasing labor productivity in traditional and innovative areas of economic activity as a source of growth of aggregate income; empirical testing of the thesis about the labor productivity dependence on investment in innovative projects (on the example of the regions of the Volga Federal District).

The economic growth problems have traditionally been at the center of researchers' attention, regardless of their affiliation with economic schools and currents. In accordance with the scientific hypothesis of the study, as its theoretical basis, the concepts devoted to the analysis of innovative processes impact on the directions and rates of increase in the main macroeconomic indicators are considered.

It is advisable to distinguish four groups of theoretical models (Kaneva, M. A., Untura, G. A., 2017) that have a great epistemological potential for explaining the innovation and investment factor in ensuring total income growth. The first group of macroeconomic models includes: R. Solow's neoclassical model of exogenous growth (Solow, R., 1957), which is based on the use of the production function and proceeds from the recognition of

scientific and technological progress as an external factor ensuring continuous growth of output per employee; P.M. Romer's growth model (Romer, P. M., 1986), which recognizes the endogenous nature of technological progress and considers knowledge as a factor of non-decreasing return on capital; G.M. Grossman's and E. Helpman's three-sector model (Grossman, G. M., Helpman, E., 1991), which recognizes the key role of technological innovations that compensate for the diminishing returns to production factors, etc.

The second group of approaches to the interpretation of the economic growth sources is represented by models of innovation and includes: linear models of innovation (McLaurin, W. R., 1953 and others); theories of innovation systems, taking into account the composition of participants, the content of their interactions and the composition of regulatory institutions (B.-A. Lundvall. 1985, I. Yu. Shvets, 2019 etc.); theories of innovation diffusion (T. Hagerstrand, 1976, etc.); models of cyclic innovation dynamics (N.D. Kondratiev, 1993, etc.).

Within the framework of the third group of works, the validity of the above theoretical models was confirmed using empirical material (testing of the provisions of neoclassical models of economic growth in the works of R.J. Barro and K. Sala-i-Martin (Barro, R. J., Sala-i-Martin, X., 1995), the model of the production function of knowledge by D. Romer, 1990, etc.). The fourth group of works includes the results of the spatial approach to the innovation process explanation (the theory of “growth poles” and “development axes” by J. Budville 1961, etc.; the world-system concepts of I. Wallerstein 1998, etc.), the theory of regional growth P. Krugman, M. Fujita 1995 and others.

However, despite the existence of many works on economic growth in relation to innovation, a number of problem aspects remain unexplored adequately. A number of provisions and conclusions reflecting the relationship between innovation, investment and dynamics of aggregate income require further empirical verification. The regional aspect of economic growth has not been adequately analyzed. All this determines the need for further study of the sources of progressive macroeconomic dynamics in the context of changes in the role of innovation in their composition and the nature of the technical and economic structure.

2 MATERIALS AND METHODS

The statements and conclusions of the study are based on the principles of neoclassical theory of economic growth. In accordance with the scientific hypothesis of the study, general scientific and special research methods were used. In the course of empirical testing of the formulated hypothesis, the standard Cobb-Douglas-Tinbergen function was used, as well as data published by the territorial bodies of the Federal State Statistics Service, the global innovation index, calculated by the World Intellectual Property Organization in conjunction with Cornell University and the international business school INSEAD. Statistical data analysis was carried out using correlation and regression analysis and the Darbin-Watson test.

3 RESULTS AND DISCUSSION

Empirical data show that at present the rate of technological change exceeds the growth rate of the main macroeconomic indicators. In the early 2000s, the GDP growth rate in developed countries was 2-3 percent per year, in the Russian Federation - 5-8 percent, after the financial crisis of 2007-2008, this figure was 1.5-2 percent and 1.8 percent, respectively. In 2020, the GDP of all developed countries declined due to the COVID-19 coronavirus pandemic, despite the continuation of significant technological changes. As an indicator of the innovative activity of states, it is advisable to use the Global Innovation Index, which is calculated annually since 2007 (World countries ranking by innovation index). The presence of a direct relationship between the GDP value per capita and the global innovation index confirms the thesis that there is a relationship between economic growth rates, technological change and innovation. However, the presence of such a relationship does not allow to draw an unambiguous conclusion about the causal relationship between the growth rate of total society income and the innovative activity of business entities. It should be taken into account that the innovation index is calculated on the basis of 82 indicators, which reflect numerous processes in different phases of the innovation cycle, as well as the state of innovation infrastructure facilities and relevant institutions. They take into account education quality, state of the regulatory framework, level of development of information and communication technologies, state of investment, level of entrepreneurial activity, level of patent

protection of intellectual property, etc. Thus, the state of innovation potential and the level of innovation activity is determined not only by the amount of private and public investment aimed at the implementation of innovative projects, but also by the state of instruments of their regulation, as well as the innovation activity mechanism.

The innovation impact on economic growth is expressed in the fact that their production and implementation in economic processes leads to an increase in productivity, which is found in an increase in the output of traditional production factors and (or) in a decrease in the volume of their consumption. However, the analysis of statistical data reflecting the labor productivity dynamics shows that at a certain development stage of post-industrial society, the growth rate of labor productivity begins to decline. This is due to changes in the sectoral structure of the economy, in which the dominance of industry as a result of deindustrialization processes is replaced by the predominance of services, which do not provide significant increases in productivity despite the technological innovation development and implementation. For example, the self checkout introduction in supermarkets leads to a reduction in customer time and to a reduction in sales staff without changes in labor productivity. At the same time, the processes of mass production automation and robotization, which marked the beginning of the third industrial revolution, caused a significant increase in the volume of output produced by workers per unit of time.

It should be taken into account that traditional approaches to the labor productivity measurement cannot be used to assess the innovation impact on the effectiveness of the use of labor resources in service sector. To reflect in the official statistics the qualitative benefits that consumers of services receive, they should be monetized. The latter is associated with difficulties in making calculations. So, for example, the answer to the question about the monetary measurement of benefit in monetary terms, which is received by buyers of goods in supermarket using the services of self checkouts, seems to be ambiguous.

At the level of an individual enterprise, interdependence of innovations and progressive dynamics of indicators of financial and economic activity takes place (Akhmetova, I., Tyfetylov, A., Tamakchi, A., Khadiyllina, G. and Derevianko, O., Syed Z., 2018). Technological innovation lead to the creation of added value by increasing the efficiency of available resources and expanding markets, which initiates companies to make additional investments in

innovative projects. At the macroeconomic level, the benefit of increasing the diversity of choice of economic agents, the absence of intermediaries, the availability of information on characteristics of the goods offered and their complements, provided by the innovation introduction, is reflected in the growing surplus of a consumer. However, in order to apply the indicators included in the traditional system of national accounts, the growing level of customer satisfaction should acquire a monetary value. Constant monitoring of information available on various platforms increases transparency and encourages competition, which helps prevent shortages and surpluses in industry markets. Thus, the supply of innovation is growing exponentially due to the development of information platforms that connect producers and consumers of services, the availability of information, and the lower costs of developing and implementing information and communication technologies. At the same time, it is necessary to take into account the structural changes in the labor market, which are associated with the disappearance of professions connected with the mechanical repetition of the same type of operations with an increase in demand for carriers of unique competencies. The latter determines the need to review the content of educational programs and technologies used in the process of training personnel for the modern economy.

The regionalization of innovative development programs is updated in the development of socio-economic development strategies aimed at accelerating innovation processes in the constituent entities of the Russian Federation. The analysis of the innovative development of the regions of the Volga Federal District (Nikonov, S. M., Solovyova, S. V., Sitkina, K. S., 2020) showed a relatively higher level of innovation activity in the Republic of Tatarstan and Nizhny Novgorod region. In this regard, it is of interest to study the impact of innovation and investment potential of these regions on the socio-economic development of the subjects of the Russian Federation. This study is implemented with the help of production functions reflecting the correlation between relative indicators of labor productivity and investment in fixed capital, as well as research and development expenditures. For the purpose of this study, the standard Cobb-Douglas-Tinbergen function is used (1):

$$ALP = A \cdot SI_{FA}^{\alpha} \cdot UC_{R\&D}^{\beta} \quad (1)$$

where α , β , and A – statistically estimated model parameters based on a regional sample;

ALP – average labor productivity, calculated as the ratio of the gross regional product to the number of employed people in the region;

UCR&D – the volume of regional research and development expenditures in relation to the number of employed people in the region;

SIFA – the volume of investments in fixed assets in relation to the number of employed people in the region.

The result of model experiments on the basis of the Federal State Statistics Service data for the regions of the Russian Federation for 2020 (Regions of Russia. Socio-economic indicators-2020) allowed to form the following econometric dependences of labor productivity on the proposed indicators (Table 1):

Table 1: Econometric dependences of average labor productivity on innovation and investment factors of the Republic of Tatarstan and Nizhny Novgorod region, 2020

| Region | Production function | Statistics | |
|------------------------|---|----------------|-------|
| | | R ² | DW |
| DW | $ALP = 9,983 \cdot SI_{FA}^{0,761} \cdot UC_{R\&D}^{0,203}$ | 0.937 | 2.164 |
| Nizhny Novgorod Region | $ALP = 9,462 \cdot SI_{FA}^{0,682} \cdot UC_{R\&D}^{0,281}$ | 0.922 | 1.794 |

Determination coefficient and Durbin-Watson coefficient calculated in the analysis of statistical characteristics of the Republic of Tatarstan and Nizhny Novgorod region meet the basic criteria, which characterizes the built models as corresponding to the basic statistical tests and determines their practical applicability.

The result of the revealed econometric dependence is proof of the high impact of innovation and investment factors on labor productivity, causing a significant increase in labor-saving technologies. At the same time, the analysis of the models demonstrates the prevailing value of the coefficient of elasticity of labor productivity in the Republic of Tatarstan ($\alpha=0.761$) compared to Nizhny Novgorod region ($\alpha=0.682$), which reflects the increase direction of investment in innovative developments to save labor. The significant impact of technological innovation and the resulting increase in labor productivity in providing the growth of total product of the regions is due to the dominance of traditional areas of economic activity in the sectoral economy structure.

4 CONCLUSIONS

The study confirms the thesis that technological innovations act as an endogenous factor of economic growth in the context of systemic digital transformation of the modern economy. Analysis of statistical data reflecting the dynamics of the global innovation index and GDP growth in various countries confirms the existence of a positive relationship between the innovation activity indicators and the aggregate supply dynamics. However, the insufficient amount of empirical information due to the short period of observation over the processes of digital transformation of the modern economy, as well as the lack of adaptation of traditional measurement tools to assess the benefits of innovations do not allow to uniquely determine the impact of the latter on the GDP dynamics and the structural transformation of the modern economy. Statistical analysis shows a material effect of the investment and innovation potentials of regional entities on the direction and rate of change in the total product of Russian regions, which confirms the scientific hypothesis of the study. However, the nature of the impact of technological innovations on labor productivity and the total income of states (regions), in the sectoral structure of which innovative areas of economic activity dominate, requires further study. Recognition of the thesis about the technological innovation role in increasing the efficiency of labor resources use can become a starting point for the study of structural transformations in the labor market and the impact of labor productivity growth on employment level in the economy.

REFERENCES

- Voskoboynikov, I. B., Baranov, E. F., Bobyleva, K. V., Kapeliushnikov, R. I., Piontkovski, D. I., Roskin, A. A., Tolokonnikov, A. E., 2021. Recovery experiences of the Russian economy: The patterns of the post-shock growth after 1998 and 2008 and future prospects. *In Economic Issues*. 4. pp. 5-31.
- Kaneva, M. A., Untura, G. A., 2017. Evolution of Theories and Empirical Models of a Relationship between Economic Growth, Science and Innovations (Part 1). *In World of Economics and Management*. 17(4). pp. 5–21.
- Solow, R., 1957. Contribution to the theory of economic growth. *In Quarterly Journal of Economics*. 70(1). pp. 65–94.
- Romer, P. M., 1986. Increasing returns and long-run growth. *In Journal of Political Economy*. 94(5). pp. 1002–1037.
- Grossman, G. M., Helpman, E., 1991. Innovation and Growth in the Global Economy. CAMBRIDGE: MIT PRESS. pp. 384.
- McLaurin, W. R., 1953. The sequence from invention to innovation and its relation to economic growth. *In Quarterly Journal of Economics*. 67. pp. 97–111.
- Lündvall, B.-Å., 1985. Product innovation and user-producer interaction. *In Industrial development. Research Series 31*. AALBORG: AALBORG UNIVERSITY PRESS. pp. 39.
- Shvets, I. Yu., 2019. Institutional aspects of the national innovation system. *In Drucker's Bulletin*. 5. pp. 5-18.
- Hägerstrand, T., 1976. Innovation Diffusion as a Spatial Process. UNIVERSITY OF CHICAGO PRESS. pp. 334.
- Kondratev, N. D., 1993. Selected works. MOSCOW: ECONOMY. pp. 543.
- Barro, R. J., Sala-i-Martin, X., 1995. Economic Growth. New York: McGraw-Hill. pp. 539.
- Romer, D., 1990. Endogenous technological change. *In Journal of Political Economy*. 98(5). pp. S71–S102.
- Boudeville, J., 1961. Les espace économiques. PARIS. pp. 16-37.
- Wallerstein, I., 1998. Miro-system analysis. *In Time of the world*. 1. pp. 105-123.
- Fujita, M., Krugman, P., 1995. When is the economy monocentric: von Thunen and Chamberlin unified. *In Regional Science and Urban Economics*.
- World countries ranking by innovation index. *In Humanitarian portal*. <https://gtmarket.ru>.
- Akhmetova, I., Tyfetylov, A., Tamakchi, A., Khadiyllina, G. and Derevianko, O., Syed Z., 2018. Improving the competitiveness of automobile engineering enterprises by advancement the internal control over its indicators. *In International Journal of Civil Engineering & Technology (IJCIET)*. 09(13). pp. 1865-1876. <http://www.iaeme.com>.
- Nikonorov, S. M., Solovyova, S. V., Sitkina. K. S., 2020. Sustainable development of regions and cities of Volga region. pp. 255.
- Regions of Russia. Socio-economic indicators-2020. Statistical collection. <https://gks.ru>.