Technological Convergence in Russian Regions: Factors, Dynamics and Spatial Effects

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The concept of catch-up development, which suggests that less developed countries can gradually close the gap with economically successful states by adopting their experiences, is known in the scientific literature as the hypothesis of absolute convergence. Traditionally, it examines the dynamics of economic growth and is tested using GDP statistical data. Sharing the perspective of several scholars, we note that technological convergence plays a more significant role, as the diffusion of various technologies emerging in different regions is a key factor in economic growth (Grossman & Helpman, 1991). Moreover, it can be hypothesized that the importance of technological transfer has increased in recent years.

A study of OECD countries over the period 1970–1987 did not reveal a positive impact of technology transfer on economic convergence, nor did it allow for determining the extent to which the observed convergence was driven by technological convergence rather than by changes in the capital-labor ratio (Bernard & Jones, 1996, p. 1043). However, later studies covering 42 OECD countries from 1960 to 2000 (Battisti et al., 2018), 46 countries from 1970 to 2015 (Sofi et al., 2023), and other works (Xiao et al., 2024) confirm the presence of technological and economic convergence. The conclusion regarding the convergence of total factor productivity and output trajectories was supported by analysis of various groups of countries over the period 1970–2017. It is also noted that the key factor behind the persistent income gap between countries is the varying speed at which technologies are adopted, which contributes to further widening of this gap (Battisti et al., 2020).

In the context of structural transformations, the concept of creative destruction proposed by Schumpeter explains the mechanisms of catch-up technological development. Technological convergence is considered a key factor of economic growth, as confirmed by both theoretical studies and econometric calculations (Battisti et al., 2018; Sofi et al., 2021; Xiao et al., 2024). A crucial condition for enhancing productivity and competitiveness of countries and regions is the

absorptive capacity of technologies, which reflects the readiness of economic agents to perceive and implement innovations in their activities. This indicator is determined by the level of workforce qualification, the development of technological and information-communication infrastructure, the availability of institutional support, the volume of accessible financial resources, as well as the prevailing innovation culture.

The persistent territorial inequality in the level of innovation activity in Russia limits labor productivity growth and reduces the competitiveness of the national economy. An important task is not only to assess technological convergence but also to identify the factors that contribute to reducing regional disparities. Such factors include strengthening institutional support, developing infrastructure, fostering an innovation culture, and increasing the absorptive capacity of technologies. The significance of this research is heightened in the context of the current policy of import substitution and strengthening technological sovereignty.

Three possible scenarios of catch-up development can be identified. The first is "continuous convergence," where the lagging country or region improves technologies in all sectors at such a pace that the gap with the leaders is reduced uniformly. The second is "ascent up the ladder," which suggests a phased catch-up development: initially in low-tech sectors, and then, as the gap narrows, in more knowledge-intensive industries. The third is "discontinuous convergence," characterized by accelerated technological development in high-tech or rapidly growing sectors. This scenario is realized through high expected returns on investment and profit margins in the presence of untapped market niches.

The aim of this study is to identify the conditions and factors that contribute to technological convergence among Russian regions, followed by the development of recommendations for shaping relevant policies.

The scientific novelty of this study lies in the econometric analysis of the factors determining the conditions for catch-up technological development in Russian regions, taking into account spatial interactions. The study posits two hypotheses: (1) the nature of technological convergence and divergence varies between groups of regions depending on their absorptive capacity; (2) absorptive capacity, financial position of regions, and spatial interactions exert a differentiated impact on the processes of technological convergence.

To address the objectives of the study, the k-median method was applied, which allowed for classifying Russian regions based on their technological potential. The clustering of regions was carried out using indicators of the absorptive capacity of technologies, as defined in the methodology of the Innovation Development Rating of Russian Federation subjects, including socio-economic conditions, innovation activity, and scientific-technical potential. Within this approach, the k-median method was used to form clusters, with the centroid of each cluster

determined by calculating the median. The optimization of clustering consists of minimizing the objective function, which is the sum of Manhattan distances between the elements of the cluster and its median.

For the analysis of spatial interactions, Moran's I and Geary's C indices were used. The assessment of catch-up technological development in the clusters of Russian regions was conducted using an econometric model of conditional β-convergence (Barro & Sala-i-Martin, 1992), which accounts for the time lag of independent variables and spatial lags in the form of SAR and SEM models on panel data.

Additionally, an analysis of the relationship between innovation activity and economic development of regions was carried out. It was found that the leading regions are predominantly concentrated in the European part of Russia (Moscow, Saint Petersburg, Tatarstan), while regions with low absorptive capacity are located in the Asian part of the country and are characterized by resource-extracting economies.

In the pool of independent variables, we include the profitability of sales and the share of equity in total capital as variables of interest to test the hypothesis of the study. As an economic condition for the absorptive capacity of regions to technologies, financial resources contribute to the growth of R&D and influence their qualitative aspects. We hypothesize that potentially high R&D growth may increase the likelihood of technological convergence through the transfer of technologies to neighboring regions and the coverage of heterogeneous scientific and technical fields. This perspective defines the positive impact of the scale of funding on the onset of technological convergence. Profitability of sales, as a measure of the region's profit margin, and the share of equity, as an indicator of the autonomy of the region's resources, indirectly measure the accumulation of its financial resources, which may enhance the region's ability to attract researchers and create opportunities for the merging of diverse technologies. The study by Alkathiri (2021) demonstrates that capital accumulation is a key factor in the observed unconditional convergence of productivity in the manufacturing industry.

As control variables, we select the number of employees engaged in scientific research and development, the share of the adult population with higher education, R&D expenditure per 1,000 researchers, the share of researchers with academic degrees, the share of organizations using fixed high-speed internet, investments in fixed capital per capita, the share of expenditure on innovation activities in the total volume of shipped goods, works, and services, and the level of innovation activity of organizations.

A comparative analysis of centroid values for technological potential indicators revealed initial disparities in socio-economic conditions, levels of innovation activity, and scientific-technical potential, most pronounced in the European part of the country. A positive spatial

correlation between labor productivity, as an indicator of technological development in regions, was established, indicating the stimulating effect of "breakthrough" regions on the economic growth of neighboring territories.

The absence of σ-convergence in labor productivity and financial indicators of regions during the period 2010–2022 suggests persistent technological inequality. Furthermore, the identified β-divergence in labor productivity, considering spatial interactions, indicates the inefficiency of technology diffusion, which leads to accelerated growth in regions with an initially high level of technological innovations and the preservation of interregional disparities. This result aligns with previous studies (Kadochnikova et al., 2022).

The analysis of the factors of technological convergence revealed a positive relationship between labor productivity growth and investments in fixed capital, R&D expenditures, and the share of the adult population with higher education. At the same time, a negative correlation with the level of innovation activity was established, which corresponds to the theory of creative destruction. It was also shown that regions with high absorptive capacity rely more on their own financial resources.

The results of the study may contribute to the improvement of regional scientific, technical, and innovation policies, as well as to the formation of an informational base for implementing measures aimed at structural transformations and removing barriers to technological development. This is especially relevant in the context of territorial heterogeneity in technology adoption in Russia, where innovation expenditures are primarily concentrated in the raw materials sector of Asian regions, while in the European part, there is a diversification of product innovations.

Based on the obtained data, recommendations were developed for different types of regions. For territories with a mature technological level, it is advisable to enhance the utilization of scientific and technical potential and strengthen financial support for researchers. Regions with an above-average level are recommended to increase investments in fixed capital, develop human capital, and mobilize internal financial resources. In regions with below-average levels, priority areas remain the activation of innovation activity and an increase in expenditure on technology adoption. For regions at an early stage of technological development, improving socio-economic conditions becomes a key focus.

Thus, the aim of the study is to develop analytical tools for assessing the conditions for catch-up technological development, which constitutes an important contribution both to the scientific field and to the practical implementation of measures aimed at reducing the technological gap between regions. It also contributes to strengthening the advantages of territorial concentration

of production activities, focusing on its qualitative development through interregional cooperation and the creation of macroregions.

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