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Technological Inequality: Disproportion and Good

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Abstract. The aim is to analyze the possible consequences of technological inequality, which the article demonstrates graphically. The methods of spatial econometrics based on panel data of Russian regions confirm technological cooperation of the regions in the short term, convergence of the growth rates of innovation costs and granted patents in the long term. The absence of β-convergence of economic growth predicts the inefficient dissemination of technologies. The article substantiates the need for government involvement in the technological development of territorial production complexes. The main conclusions of the article can assist in the formation of scientific and technical policy in order to eliminate spatial development disproportions.

Keywords: innovation, inequality, region, convergence, spatial-econometric models.

Research area: economics, econometrics.

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Технологическое неравенство: диспропорция и благо

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Аннотация. Цель заключается в анализе возможных последствий технологического неравенства, которое графически демонстрирует статья. Методы пространственной эконометрики на панельных данных российских регионов подтверждают технологическую кооперацию регионов в краткосрочной перспективе, сходимость темпов роста затрат на инновации и выданных патентов на изобретения в долгосрочной перспективе. Отсутствие β-конвергенции экономического роста предсказывает сохранение различий в уровнях развития регионов и неэффективное распространение технологий. Статья обосновывает необходимость государственного участия в развитии технологичных территориально-производственных комплексов. Основные выводы могут помочь при формировании научно-технической политики с целью устранения диспропорций пространственного развития.

Ключевые слова: инновации, неравенство, регион, конвергенция, пространственно-эконометрические модели.

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Introduction

In recent years, there has been an increase in technological inequality, a decrease in the import of technology and the "migration" of innovations: for the most part, technologies are concentrated in the European part of the country and in its metropolitan cities, and the production of innovative goods and services is in regions with a high concentration of factors of production. The gap in the level of companies' productivity within the same industry resulting in limited competition does not create incentives for the creation of new technologies. This paper empirically presents a view on the possible consequences of such a disparity in the conditions of structural transformation of the economy.

In domestic studies of the industrialization period of the 20th century a comprehensive approach to the organization of production was proposed through creating production plants and their territorial combination (Kolosovsky, 1935). At that time, the practice of forming territorial production complexes was oriented to the development of new territories and resources, the extraction of mineral resources and their primary processing, the "pendulum" exchange of resources of remote territories. Territorial industrial complexes as an "interdependent combination of industrial enterprises and populated areas" organized by the state power (Kolosovsky, 1969) made it possible to locate industry and develop the economy. Such experience of implementing long-term goals and ensuring of various sectors of the economy interaction is applicable in modern conditions, "… first of all, for the implementation of breakthrough directions in scientific and technical policy" (Kryukov, Kolomak, 2021).

The territorial concentration of production activity from the perspective of the "region for the country" paradigm persists in our century and deserves attention from the perspective of its qualitative development through the interaction of technologically complementary companies, interregional cooperation and creation of macro-regions (Kryukov, Kolomak, 2021).

Theoretical framework

In the middle of the XX century, Simon Kuznets stressed the exceptional importance of technology: "… since the second half of the XIX century, science–based technologies have definitely become the most important source of economic growth in developed countries…" (Kuznetsov, 1966). To explain long-term economic trends, Paul Romer used an external effect of knowledge accumulation (Romer P., 1986). Later he placed special emphasis on patent-protected innovations (Romer, 1990). Empirical data in Paul Krugman (Krugman, 1999) and other scientists studies (Fritsch, Franke, 2004) recognize the primary role of technology and the crucial importance of space for the dissemination of knowledge and innovation. To measure technological knowledge, Zvi Greeliches used the number of patents granted and proposed the knowledge production function to science (KPF) (Griliches, 1979). In the space, general knowledge is represented by agglomerations and scientific and industrial centers while applied knowledge is represented as industrial centers, local as "reference" cities. The idea of developing technological territorial production complexes that generate new knowledge suggested us *the purpose of the study* that is the analysis the possible consequences of technological inequality in the context of starting possibilities of the economy structural transformation to achieve the sustainable development of regions.

Statement of the problem

At the beginning of the 21st century, great attention was paid to the concepts of digital society (Schwab, 2016) and sustainable development ensuring non-decreasing utility (Brundtland, 1987). Digitalization creates new opportunities for economic growth, and the availability of knowledge and innovation leads to the equalization of prices for factors of production and convergence of growth rates. We focus on the spread of technologies and formulate a *research question* if there is any convergence of knowledge production in the regions in the long term?

In the 30s of the 20th century the concept of "duplication" in state policy has become one of the successful options for a real shift of productive forces to the east (Bukin et al., 2011). At the beginning of the 21st century, Robert Barro and Javier Sala-Martin showed that the spread of technology through copying and borrowing contributes to the convergence of growth between territories (Barro, Sala-i-Martin, 1992; Barro, Sala-i-Martin, 2004). In the works of (Romer, 2010; Bloom, et al., 2013) the need is proved for technology transfer from low-cost territories to ensure macroeconomic growth. This means that technological inequality in this part sets a vector for the development of weak territories and can lead to convergence of growth rates. Therefore, *the hypothesis of the study* is to assume the cooperation of Russian regions in terms of technological innovations, i.e. new knowledge.

Methods

To visualize the technological inequality, a graphical method and the construction of cartograms were used.

To measure interactions KPF was modified (Griliches, 1979; Barro, Sala-i-Martin, 1992; Elhorst, 2014) and models of conditional β-convergence are evaluated on panel data by SAR, SDM, SEM types:

$$\frac{1}{T}\ln\frac{y_{it_{0+T}}}{y_{it_0}} = \alpha_i + \beta\ln y_{it_0} + \sum_{k=1}^{K}\gamma_k \ln X_{kit-2} + \rho W_{ij}\ln\frac{y_{it_{0+T}}}{y_{it_0}} + \varepsilon_{i,t_{0+T}}$$

$$\frac{1}{T}\ln\frac{y_{it_{0+T}}}{y_{it_0}} = \alpha_i + \beta\ln y_{it_0} + \sum_{k=1}^{K}\gamma_k \ln X_{kit-2} + \sum_{k=1}^{K}\theta_k W_{ij}\ln X_{kit-2} + \rho W_{ij}\ln\frac{y_{it_{0+T}}}{y_{it_0}} + \varepsilon_{i,t_{0+T}}$$

$$\frac{1}{T}\ln\frac{y_{it_0+T}}{y_{it_0}} = \alpha_i + \beta\ln y_{it_0} + \sum_{k=1}^{K}\gamma_k \ln X_{kit-2} + \lambda W u_{i,t_0+T} + \varepsilon_{i,t_0+T}$$

where i=1,…79 – region number, $[t_0+T]$ – convergence period from 2014 to 2019, $y_{i,\ t0}$ – the number of patents granted in 2014, β – convergence parameter, γ_k – parameters with independent variables; W_{ij} – weighting matrix, ρ, λ – spatial coefficients, $\varepsilon_{i,\ t0+T}$ – random error.

The dependent variable is the average growth rate of patents granted for inventions and utility models per 10 thousand people. Independent variables are presented in Table 1. We explain the choice of independent variables by KPF specification and the results of previously conducted researches (Bottazzi and Peri, 2003; Cuaresma et al., 2014; Qiu et. al., 2018; Castaldo et al., 2018; Xu, Li, 2019; Kramin, Klimanova, 2019; Dubrovskaya et al., 2022).

Discussion

Figures 1 and 2 demonstrate the decreasing dynamics of key knowledge metrics. The cartograms in Fig. 3 and 4 reflect the technological inequality of the regions, a higher level of innovation costs in the raw materials sector and the predominance of peripheral regions with low innovation costs. There are spatial clusters of the share of innovative goods, works, services in the Tyumen, Omsk, Nizhny Novgorod, Samara, Ulyanovsk, Moscow regions, the Republic of Tatarstan, the Republic of Mordovia, Perm Krai and Moscow. This can predict a technological breakthrough thanks to the leading regions. Cartograms of the Internet use also demonstrate digital inequality. The concentration of most regions in the left quadrants of the Moran diagram in Fig. 5 predicts large time lag of technological breakthroughs and economic development of the regions.

The dynamics of the Gini coefficient in Table 2 indicates an increase in inequality in the distribution of technological innovations costs in different territories, stable inequality in the distribution of patents number for inventions and uniform use of the Internet.

All types of models predict β-convergence of the growth rates of the number of patents granted, and the growth of knowledge produc-

Table 1. Descriptive statistics of variables

Variables	Mean	St. D.	Min	Median	Max
The number of granted patents for inventions and utility models per 10 thousand population	1,266	1,017	0,000	1,042	5,639
The number of research and development personnel per 10 thousand population	25,592	32,216	0,000	12,948	179,513
Internal cost of R&D per capita, thousand rubles	3,366	5,104	0,000	1,516	28,641
Use of the Internet in organizations, %	89,204	6,263	68,400	90,200	100,000
Expenditures for the introduction and use of digital technologies per capita, thousand rubles	5,953	8,589	0,296	3,291	62,467
Expenditures for technological innovation per capita, thousand rubles (as a proxy of technology development)	7,886	12,498	0,001	4,512	77,430
Fertility rate, % (as a proxy of the social environment)	2,439	0,180	2,116	2,425	3,091

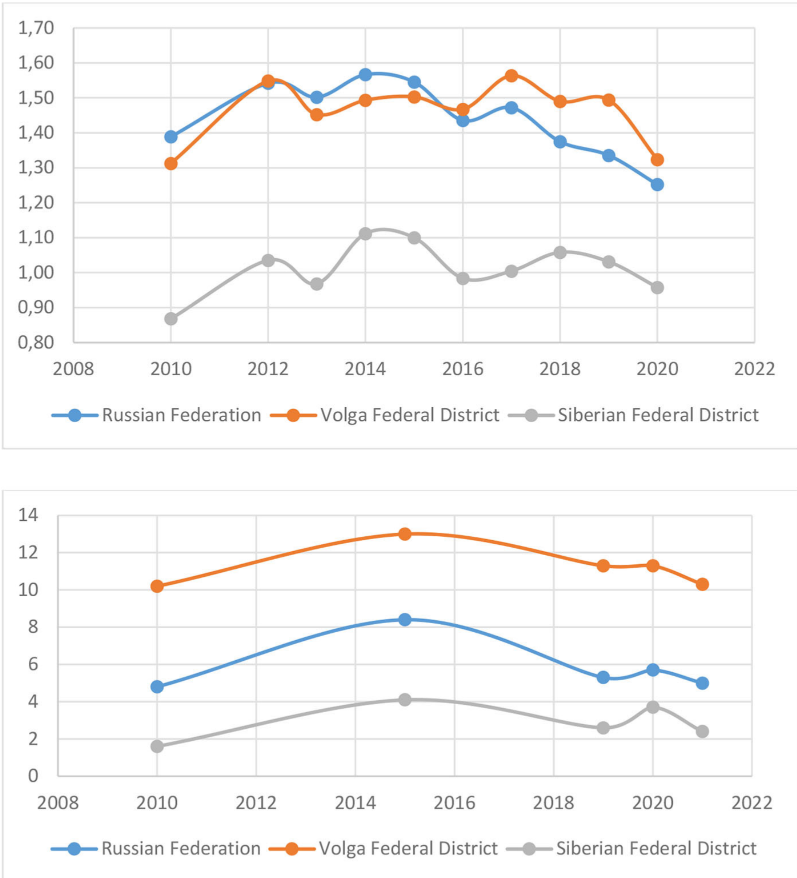


Fig. 1. Dynamics of the ratio of research and development internal costs to GRP, % (top) and the share of innovative products, works, services, % (bottom)

Table 2. Assessment of technological inequality in Russian regions based on the Gini coefficient

Technology distribution indicators	2010	2012	2014	2016	2018	2019	2020	2021
Expenditures for technological innovation, ml rubles	0,629	0,576	0,637	0,596	0,752	0,765	0,783	0,652
The number of granted patents for inventions and utility models	0,725	0,716	0,726	0,734	0,690	0,691	0,753	0,612
Use of the Internet in organizations, %	0,059	0,042	0,033	0,032	0,026	0,027	0,024	0,036

tion in weak regions (Table 3). The assumption about regional cooperation and the impact of shocks from neighboring regions on the growth of knowledge production in this region was confirmed. Spatial interactions of the number of personnel employed in R&D and internal R&D costs with the number of patents granted were found. The impact of digitalization on patent activity in the regions has not been confirmed (Table 4).

In the short term, a conditional β-divergence of the growth rates of technological innovations costs and regional cooperation, characteristic for the transition economy, was revealed (Bagautdinova, Kadochnikova, 2020). For the long-term perspective, the

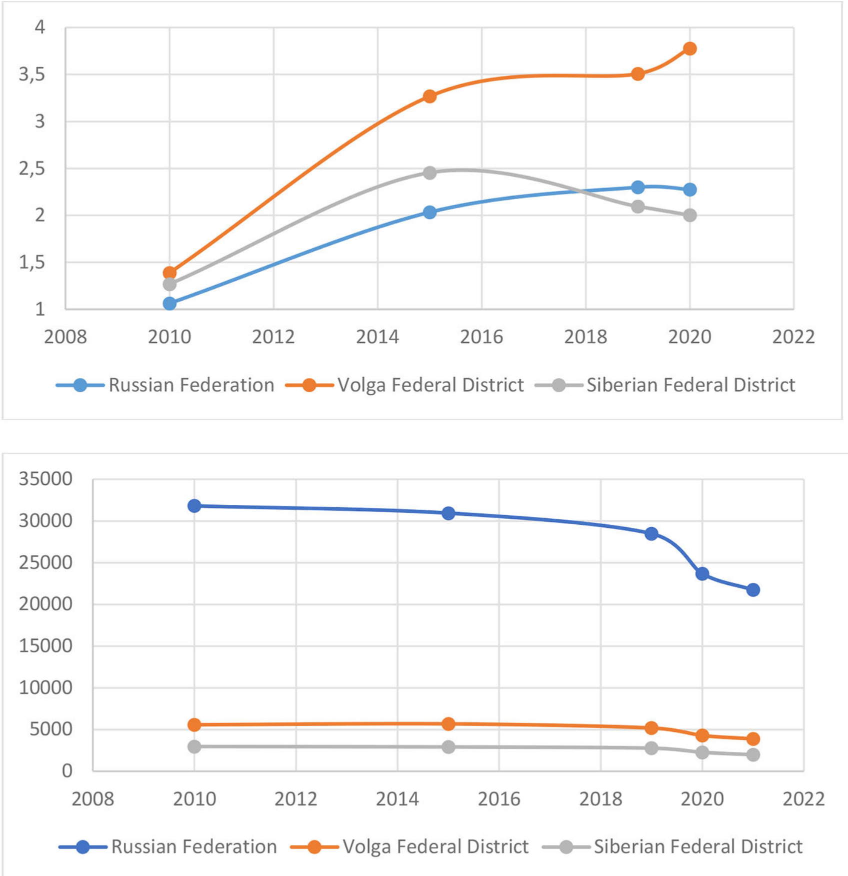


Fig. 2. Dynamics of the ratio of technological innovations costs to GRP, % (top) and issued patents for inventions and models, units (bottom).

Table 3. Results of evaluation of models of knowledge production conditional β-convergence

Regressors	SEM_RE	SAR_RE	SDM_RE	SEM _ FE	SAR_ FE	SDM_FE
Intercept	0.951 (0.666)	0.932 (0.670)	1.321 (1.445)			
Natural logarithm of the number of granted patents in 2014	-0.108*** (0.016)	-0.106*** (0.016)	-0.105*** (0.016)			
The number of research and development personnel per 10 thousand population	0.019 (0.032)	0.014 (0.032)	0.027 (0.032)	0.118* (0.049)	0.107* (0.050)	0.070* (0.054)
Internal costs of R&D per capita	0.028 (0.028)	0.034 (0.028)	0.019 (0.028)	0.058 (0.036)	0.066* (0.036)	0.067 (0.037)
Use of the Internet in organizations	-0.193 (0.142)	-0.188 (0.144)	-0.213 (0.143)	-0.172 (0.159)	-0.165 (0.161)	-0.171 (0.159)
Expenditures for the introduction and use of digital technologies per capita	-0.013 (0.013)	-0.013 (0.013)	-0.015 (0.014)	-0.028* (0.016)	-0.027* (0.016)	-0.027 (0.016)

Continuation of Table 3

Regressors	SEM_RE	SAR_RE	SDM_RE	SEM _ FE	SAR_ FE	SDM_FE
Expenditures for technological innovation per capita	-0.003 (0.006)	-0.003 (0.006)	-0.008 (0.007)	-0.014* (0.008)	-0.015* (0.008)	-0.022* (0.009)
Fertility rate	-0.056 (0.072)	-0.051 (0.065)	0.158 (0.101)	0.051 (0.122)	0.039 (0.096)	0.460* (0.257)
Spatial autoregression coefficient for the dependent variable		0.208** (0.064)	0.231*** (0.065)		0.286*** (0.060)	
Spatial autoregression coefficient for the shock	0.276*** (0.070)			0.292*** (0.061)		
Slag (Natural logarithm of the number of granted patents in 2014)			0.060* (0.030)			
Slag(The number of research and development personnel per 10 thousand population)			-0.086 (0.053)			-0.338** (0.054)
…						
Slag (Fertility rate)			-0.274* (0.121)			-0.335 (0.257)
Hausman test (p-value)	0.009	0.010	1.275e-05			
n	395	395	395	395	395	395

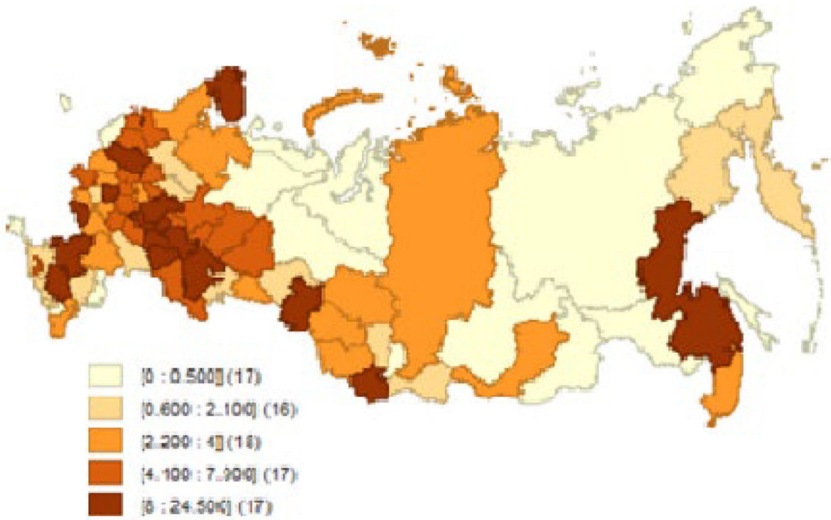
Notes: ***p<0,01, **p<0,05, *p<0,1.

Table 4. Direct and indirect effects for average growth rate of patents granted for inventions and utility models per 10 thousand population

Regressors	Direct	Indirect	Total
Natural logarithm of the number of granted patents in 2014	-0.201** (0.095)	0.077 (0.084)	-0.124*** (0.014)
The number of research and development personnel per 10 thousand population	0.030 (0.064)	-0.011 (0.036)	0.019 (0.031)
Internal costs of R&D per capita	0.032 (0.061)	-0.012 (0.035)	0.020 (0.029)
Use of the Internet in organizations	-0.510 (0.353)	0.197 (0.247)	-0.313 (0.147)
Expenditures for the introduction and use of digital technologies per capita	-0.0004 (0.032)	0.0001 (0.017)	-0.0003 (0.016)
Expenditures for technological innovation per capita	-0.012 (0.015)	0.004 (0.008)	-0.008 (0.007)
Fertility rate	0.212 (0.179)	-0.082 (0.115)	0.130 (0.083)
Slag (Natural logarithm of the number of granted patents in 2014)	0.081 (0.056)	-0.031 (0.038)	0.050** (0.024)
Slag(The number of research and development personnel per 10 thousand population)	-0.112 (0.110)	0.043 (0.066)	-0.069 (0.056)

Continuation of Table 4

Regressors	Direct	Indirect	Total
…			
Slag (Fertility rate)	-0.659** (0.350)	0.254 (0.280)	-0.405*** (0.113)



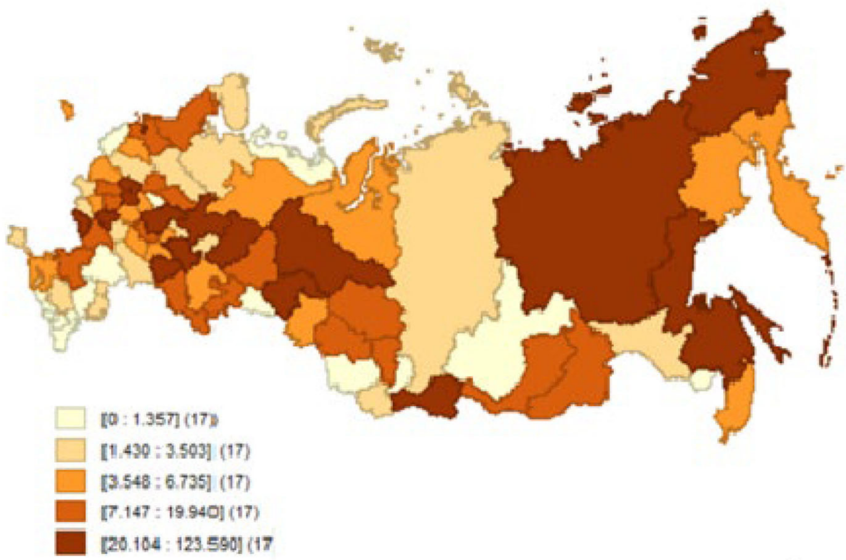
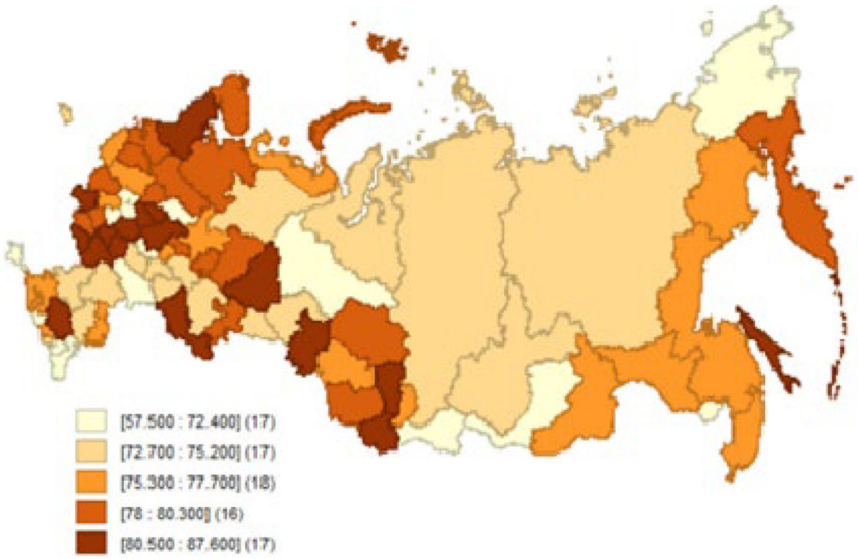


Fig. 3. Cartograms of innovative products and works share (top) and organizations innovative activities costs per capita in the regions of Russia in 2021 (bottom)



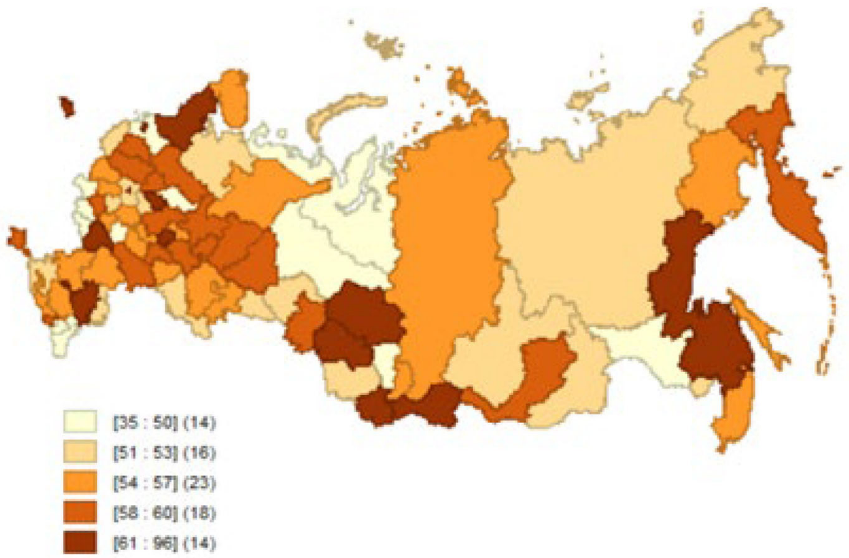


Fig. 4. Cartograms of Internet use by organizations (top) and households (bottom) in the regions of Russia in 2021

process of β -convergence of the average growth rate of technological innovations costs (Bagautdinova, 2021) and the competition of regions in terms of technological innovations are revealed: the strong "pull" innovations from the weak.

The absence of the β-convergence process of the average growth rate of the real gross regional product per capita of the able-bodied population (Kadochnikova et al., 2022) indirectly indicates the inefficient technologies diffusion and is consistent with the work (Kolomak, 2022). The impact of the number of patents granted for inventions and the Internet use in organizations on the growth rate of the gross regional product has not been confirmed. The obtained result did not confirm the theoretical conclusions (Barro, Sala-i-Martin, 2004) about the impact of the technologies spread on the β-convergence of economic growth shown

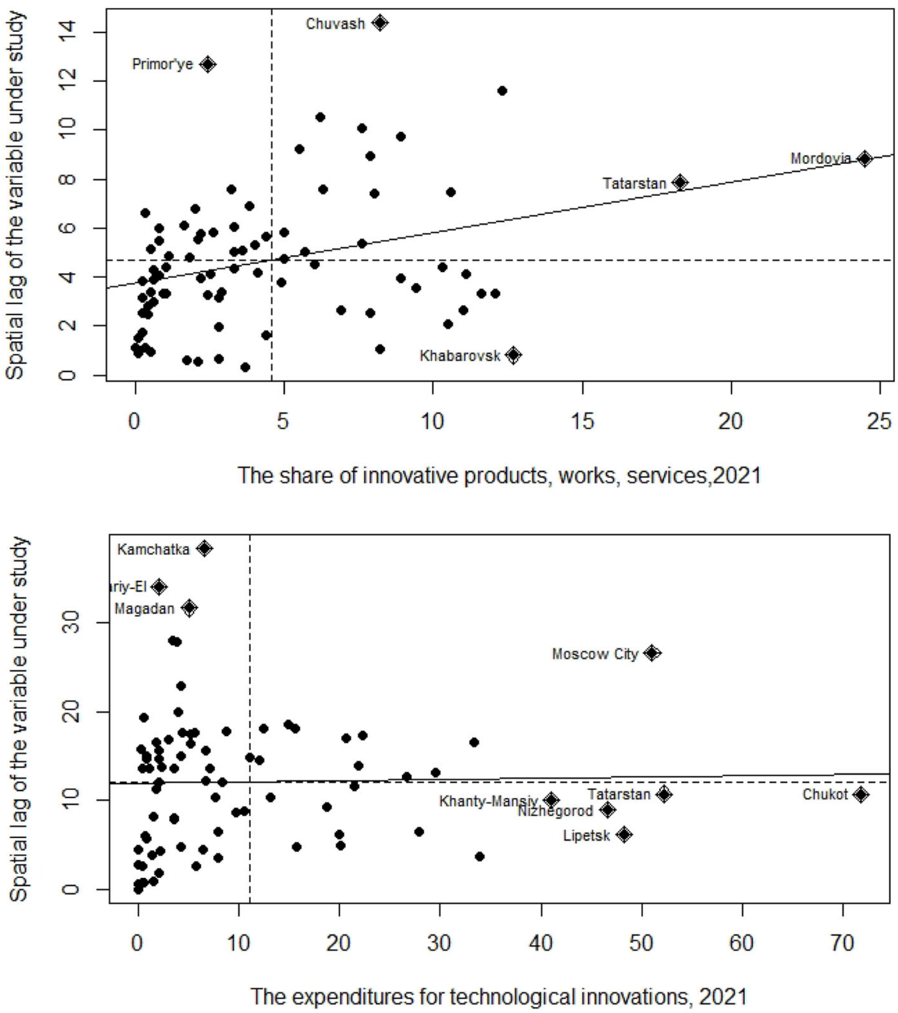


Fig. 5. Moran spatial diagrams innovative products, works, services share (top) and expenditures for technological innovations (bottom) in the regions of the Russian Federation in 2021

for the Russian economy in earlier periods (Balash, 2012; Kholodilin et al., 2012).

Conclusion

The study allowed us to formulate the following conclusions:

– concentration of technologies in metropolitan cities and a small number of regions indicates the strengthening of their role in distribution of production factors and results;

– decrease in the innovative component of the economy demonstrates the need for government involvement in these processes control;

– β-convergence of the average growth rates of issued patents in conditions when there is little patenting in many regions can indirectly confirm the spread of technologies by copying them from the leading regions;

– technological cooperation of regions and divergence predict higher short-term growth in regions with a higher initial level of technological innovation and increased disparities, assuming that clusters of technologically growing regions “tug along” their neighbors, but cannot or do not want ‘to ”draw out”;

– technological competition of regions and convergence in the long term as a market good predicts faster growth in regions with a low level of innovations, accompanied by the "pulling" of innovations by strong regions from the "got stronger" weak ones, which does not contradict theoretical judgments about a decrease in the growth rate of a more mature economy due to the diminishing return of production factors.

The results of this study confirmed the hypothesis formulated, pointing, however, to the insufficiency of market mechanisms for the development of the technological component of the regions. They can be used for state policy of the technological territorial production complexes development through the mechanism of short-term cooperation and long-term competition in order to prevent imparities in sustainable spatial development.

In further research, it seems appropriate to use a differentiated approach (Demidova, 2021) to determinants of economic development measuring.

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