Technological development of smart industrial regions in Russia: A cluster analysis

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Abstract. The article is intended to assess the level of technological development of Russian industrial regions using the method of statistical cluster analysis and discusses some special features associated with the formation of smart (promising) regional clusters. The work is based on the statistical data on production capacity, investments in scientific and technological progress, the level of production automation and other indicators characterizing the technological development of industry sectors. We evaluate these indicators and identify the regions with the highest level of technological development as well as those lagging behind the average values. The authors prove the importance of enhancing the industry's technological base to increase the competitiveness of the regions and the entire country. The positive impact of advanced technologies on the development of smart (promising) regional clusters is emphasized.

Key words: Statistical cluster analysis; Technological development; industry; Industrial regions in Russia.

1 Introduction

Technological development of industry (industrial regions), including digital transformation, can be seen as a process that allows a certain sector to become competitive. This, in turn, will encourage its development, which may become the region's main specialization or micro-specialization, if development occurs within the technology park [31]. Analysis of the technology level of Russia's industrial territories is an important factor in regional development. Industrial regions have a significant impact on the country's economy, and their technological progress directly affects the socio-economic situation in the country. The study outlines an approach to assessing the level of technological development of Russia's industrial regions and reveals the potential obstacles that can hamper their expansion. The objectives of the research are to analyse statistical data and identify the factors influencing technological development. The research object is the industrial regions of the Russian

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Federation, and the research subject is a set of indicators describing the development of the country's smart industrial regions.

The study centres on identifying the special features and determining the main avenues for the technological growth of smart (promising) industrial regions of Russia. To single out the groups of regions with similar characteristics, cluster analysis was applied in the context of technological development indicators of the Russian industrial regions [6, 35]. The relevance of the study is due to the lack of research on the formation of smart region clusters from the standpoint of their technological growth.

2 Literature review

Recently, there has been significant progress in the field of digital and innovative technological development, which has led to the emergence of such concepts as smart city, smart region and digital economy. No in-depth definition of a smart region is found in legislation, but it is provided in various concepts and programs of particular regions. For example, according to the concept of introducing intelligent digital technologies in the Sverdlovsk region, a smart region is a territory where information and communication technologies and other means are used to improve the quality of life, increase performance and expand the competitiveness of the economy [36]. Today, the implementation of the concept of a smart (promising) region is becoming increasingly relevant, since it encourages region manageability, cost reduction and the overall increase in the standard of living of the population [31, 37].

Analysis of the technological development of Russia's industrial regions is among the most urgent topics in modern economics. There are works by economic experts on the introduction of advanced digital technologies in business processes, taking into account the approaches of region development theories, such as central place theory [19], growth pole theory [25], circular cumulative causation [24] and industrial clusters [6, 10, 15, 17]. Restrictions related to administrative boundaries [18, 21-23] are among the instruments of economic development strategies. The first works about the development stage of Russia's industry are studies analysing its technological level based on data on the introduction of technological innovations [13, 20]. It was found that technologically Russia's industry is poorly developed. Currently, the strategic aspects of the Russian industry's evolution are coupled with its current state and development prospects in the context of sanctions [1-5, 8, 16].

Economists address the issues of analysing industries in the context of a digital economy and identify the main challenges, such as high technological dependence, shortage of highly qualified staff, and difficulties with import substitution [11, 12, 18]. A number of studies examine the technological state of Russian industrial regions on the basis of the technological readiness index, which confirmed that their technological innovation level is insufficient [7, 9, 14].

Thus, the literature review shows that technologically the industry in Russian regions is below or at the average level. To facilitate technological development, it is necessary to actively introduce innovative technological processes into production and adopt new technologies.

As indicated in the works on foreign investment in various industrial regions of Eastern Europe, political capital affects the export and import of foreign direct investment [33]. At the same time, economists emphasize the influence of foreign direct investment on the industrial development of a region, which is contingent on the form of ownership of the company and industry [34].

3 Materials and methods

The research methodology implies selecting a sample of Russian industrial regions, which will be included in the analysis of industrial technology development (Fig. 1).

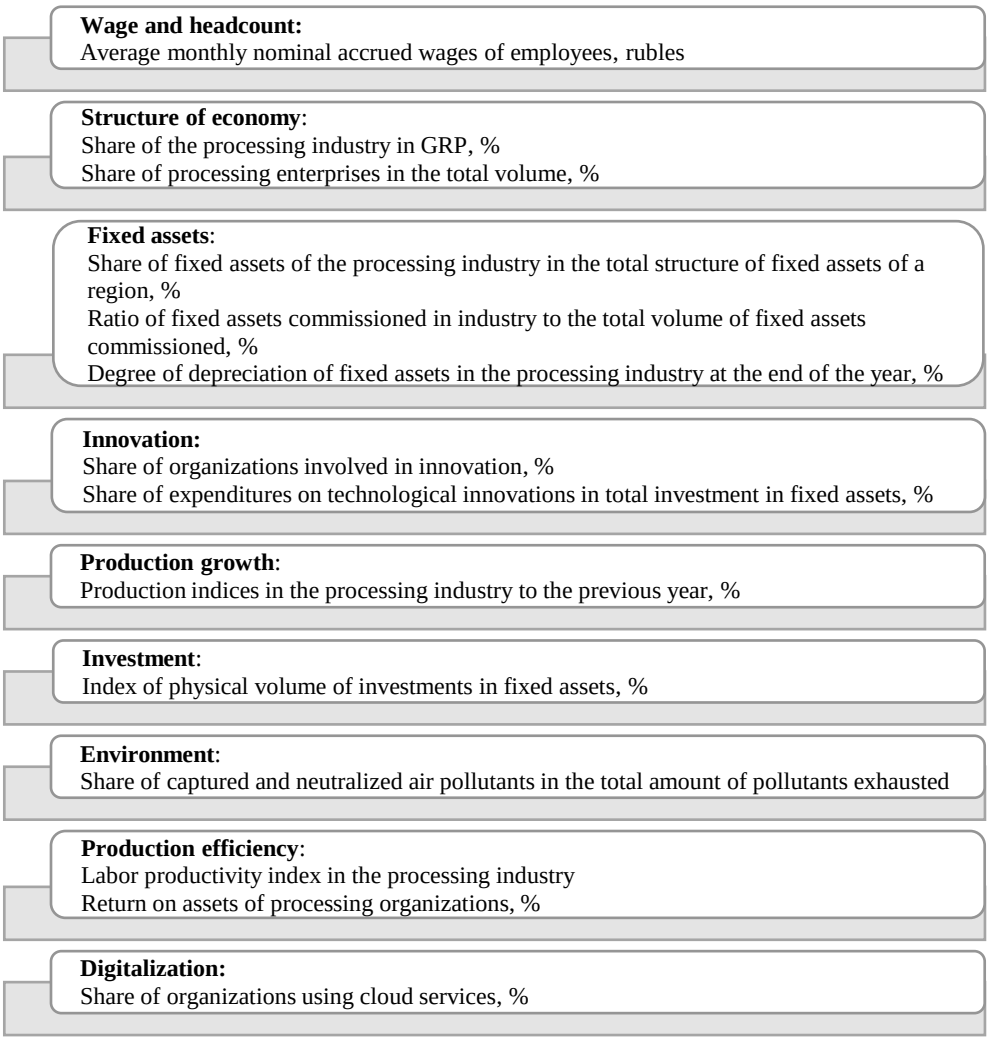

Fig. 1. Indicators of industrial regions' technological development [2, 4, 5, 26, 30].

The technological development of Russian regions will be analysed using industrial production indicators for thirteen RF constituent territories with a 27% processing industry share in GRP [27-29]. The regions under study are the Vladimir region, Ryazan region, Tula region, Yaroslavl region, Novgorod region, the Republic of Bashkortostan, the Mari El Republic, Perm region, Kirov region, Nizhny Novgorod region, Ulyanovsk region, Sverdlovsk region, and Chelyabinsk region.

To investigate the stage of technological development of the industrial subjects, we used a set of indicators, such as the number and share of high-tech enterprises, the level of production automation, the use of digital technologies and other data from the Federal State

Statistics Service (Rosstat) [2, 4, 5, 26]. The set of indicators for assessing the technological development of industrial regions is based on the existing regular statistical data of Rosstat. Data analysis is limited by the insufficiency of Rosstat indicators, and the lack of a unified terminology and methods (approaches) for evaluating the development level of digital technologies in the regional industry [29-31].

The aggregate level of industrial regions' technological development was calculated by formula [30, 31]:

$$\mathrm{Rj} = \sum_{i=1}^{n} \mathrm{Ki}, \qquad (1)$$

where *Rj* is an aggregate indicator of the level of the industrial region's technological development; Ki is the comparable value of the *i*-th indicator of the technological development level; *n* is the number of indicators under consideration. A uniform distribution of weights is typically proposed since all the selected indicators are equally important for assessing the level of technological development of industrial regions.

The analysis used data for 2016-2021 retrieved from the Rosstat Statistical Yearbook *Russia's Regions* [26]. Based on the collected data, comparable coefficients (K) were calculated for the selected indicators. The application of the research results is limited by the problems related to the collection and presentation of data.

A cluster analysis of Russia's industrial regions was carried out, which allowed identifying groups of regions with similar industrial characteristics. The purpose of cluster analysis is to reveal the strengths and weaknesses of each region, as well as to single out promising areas of development. The squared Euclidean distance was applied as a measure of proximity between objects, the clustering method was Ward's method [32].

In this case, the economic well-being of the territory is proportional to the level of its technological development.

4 Results and discussion

Let us analyse the level of technological development of Russia's industrial regions using a ranking score to identify the heterogeneity of spatial development, which affects the technological and innovative level of the subjects.

The analysis demonstrated that the regions differ in the level of industrial development. According to Rosstat, in 2022 there was a decrease in Russia's Industrial Production Index (% to the previous year) (Fig. 2) [26].

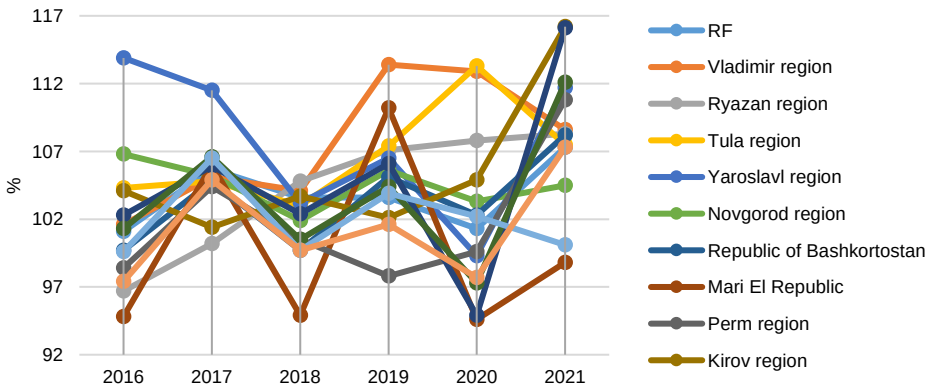

Fig. 2. Russia industrial production indices, 2016–2021 [26].

In 2021, the extractive industry experienced continuous growth; positive dynamics was observed due to the persistence of the factors typical of the analysed period at its beginning. The characteristics that determine the level of technological development of the industrial regions meet the standard requirements for quantitative and qualitative analysis. To prepare the initial data, the variables were normalized [1].

Table 1. Dynamics of Russian industrial regions' technological development in 2017–2021 [26].

Region	2017	2018	2019	2020	2021
Vladimir region	0.448	0.437	0.463	0.459	0.455
Ryazan region	0.449	0.431	0.439	0.412	0.427
Tula region	0.454	0.478	0.477	0.419	0.495
Yaroslavl region	0.437	0.427	0.428	0.417	0.453
Novgorod region	0.423	0.437	0.414	0.425	0.474
Republic of Bashkortostan	0.417	0.431	0.449	0.412	0.456
Mari El Republic	0.401	0.402	0.404	0.409	0.401
Perm region	0.432	0.433	0.485	0.421	0.470
Kirov region	0.389	0.398	0.409	0.389	0.440
Nizhny Novgorod region	0.445	0.450	0.445	0.441	0.471
Ulyanovsk region	0.405	0.381	0.383	0.366	0.448
Sverdlovsk region	0.457	0.487	0.613	0.450	0.461
Chelyabinsk region	0.467	0.496	0.499	0.436	0.469

Based on the data from Table 1, we can arrive at the following conclusions. Over the past five years, in terms of technology, Russian industrial regions have been rather unstable. Sverdlovsk and Chelyabinsk regions have shown a higher level of technological development compared to the other regions. Ulyanovsk region and the Mari El Republic have been far behind the leaders and displayed no significant advances in their technological progress. Technological development in the regions of Kirov, Ryazan, Novgorod and Perm has been characterised as fluctuating.

Cluster analysis of Russian industrial regions makes it possible to determine the main directions of regional development and formulate relevant strategies.

Table 2. Data for cluster analysis of Russian industrial regions' technological development in 2017-2021 [26].

Region	2017	2018	2019	2020	2021	Cluster
Vladimir region	0.4483	0.4367	0.4632	0.4590	0.4553	0
Ryazan region	0.4492	0.4310	0.4391	0.4118	0.4272	1
Tula region	0.4545	0.4778	0.4772	0.4191	0.4949	0
Yaroslavl region	0.4369	0.4272	0.4281	0.4167	0.4531	2
Novgorod region	0.4228	0.4372	0.4135	0.4245	0.4744	1
Republic of Bashkortostan	0.4167	0.4307	0.4495	0.4119	0.4565	0
Mari El Republic	0.4008	0.4021	0.4044	0.4087	0.4013	1
Perm region	0.4323	0.4330	0.4851	0.4205	0.4697	0
Kirov region	0.3888	0.3983	0.4086	0.3890	0.4400	1
Nizhny Novgorod region	0.4451	0.4497	0.4446	0.4414	0.4712	0
Ulyanovsk region	0.4046	0.3807	0.3829	0.3659	0.4476	1
Sverdlovsk region	0.4571	0.4869	0.6130	0.4503	0.4610	0
Chelyabinsk region	0.4666	0.4958	0.4988	0.4361	0.4691	1

The results of the calculations allow for delimiting three clusters (Fig. 2). *Cluster 0* includes the regions of Vladimir, Tula, Perm, Nizhny Novgorod, Sverdlovsk, and the Republic of Bashkortostan. *Cluster 1* covers the regions of Ryazan, Novgorod, Kirov, Ulyanovsk, Chelyabinsk, and the Mari El Republic. *Cluster 2* consists of only one constituent entity, namely the Yaroslavl region.

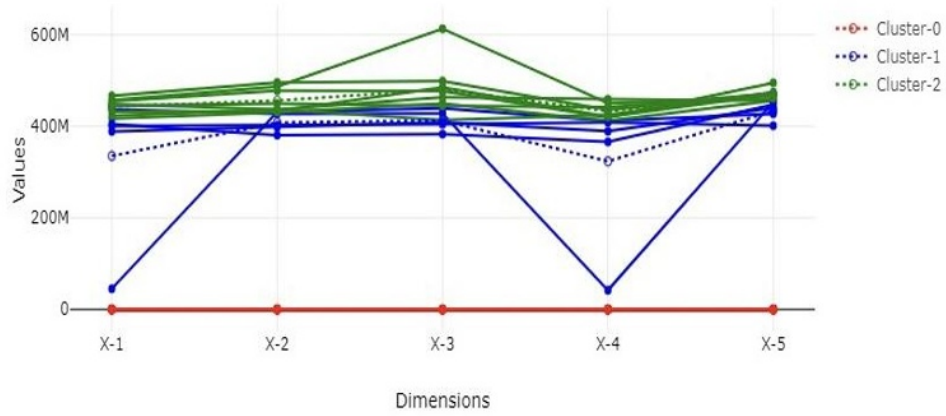

Fig. 3. Cluster analysis.

The level of production in the regions fluctuated over the years. In 2020, most regions reduced production volumes due to the COVID-19 pandemic. However, in 2021, production in many regions recovered. In 2021, the Tula and Ulyanovsk regions and the Republic of Bashkortostan were among the territories with the fastest growth of production.

The investment volume in fixed assets across these subjects is at the average level, which indicates the need to continue to work on spurring investments in them.

Production efficiency varies greatly by year and region. A number of territories, such as the Vladimir region and Novgorod region, exhibit stable growth over the years, while in others, such as the Ryazan region and Ulyanovsk region, fluctuations and even sharp drops in certain years were observed.

The highest production efficiency was recorded in the Novgorod region in 2021 (0.668), and the lowest – in Ryazan region (0.119).

The overall conclusion is that regional production in Russia is unevenly developed and faces different challenges in different years.

The level of digitalization in Russian industrial regions is not heterogeneous. The highest indicators for the period under analysis are obtained in the Novgorod region (0.381), and the lowest – in the Ulyanovsk region (0.236) [26]. In general, in 2017–2021, most territories experienced rapid digitalization with the exception of Kirov and Tula regions, where a decline was recorded [26]. Interestingly, remote subjects (e.g., Novgorod region) have a higher level of digitalization than the central ones (e.g., Ulyanovsk region). Thus, we can conclude that the level of technological development in Russian industrial regions in 2021 was moderately high, and the Sverdlovsk and Chelyabinsk regions were ahead of the others. However, many subjects, including the Kirov region, the Mari El Republic and Ulyanovsk region, are still lagging behind. Hence, there is a potential for further technological development of the territories.

5 Conclusion

Our study demonstrates that six subjects (Vladimir, Tula, Perm, Nizhny Novgorod and Sverdlovsk regions, and the Republic of Bashkortostan) are most predisposed to technological transformation. This indicates that in these regions there are favourable conditions for the introduction of technologies and a comfortable life for the population. The regions have a high scientific, technological and innovative potential, are rich in infrastructure and create opportunities for further digital transformation. The results obtained expand the methodological tools for assessing the technological progress in industry and can be applied to develop particular subjects.

The future avenues of research are likely to be concentrated on the design of econometric models to examine the processes of technological development of industrial regions. The findings of the current study can be of use when developing and elaborating the directions for the technological progress in industry at regional and industry-specific levels.

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References

1. V.V. Akberdina, Journal of New Economy (2020) https://doi.org/10.29141/2658-5081-2020-21-3-3
2. V.V. Akberdina, Journal of the Ural State University of Economics (2018) https://doi.org/10.29141/2073-1019-2018-19-3-8
3. I.O. Aleksandrov, M.N. Braslavskaya, A.P. Shurshilova, *The impact of digitalization on sustainable competitive advantages of the Russian industry*, in Proceedings of the 6th Int. sci.-pract. conf. Science, Business, Government: The Triad of Regional Development, 20 April 2021, Velikiy Novgorod, Russia (2022) https://doi.org/10.34680/978-5-89896-779-6/2022.triad.03
4. A.G. Ataeva, D.M. Ataev, Ars Administrandi (2023) https://doi.org/10.17072/2218-9173-2023-1-153-173
5. A.D. Bobryshev, O.V. Krasnyanskaya, N.L. Pirogov, Microeconomics (2021) https://doi.org/10.33917/mic-1.96.2021.11-21
6. A.A. Buchenkova, O.E. Kichigin, *Prospects for sustainable development of the industrial cluster: Digital maturity*, in Proceedings of the 5th Int. sci.-pract. conf. Digital Region: Experience, Competencies, Projects, 25 November 2022, Bryansk, Russia (2023)
7. N.S. Zalutskaya, Scientific Discussions **3**, 60 (2023)
8. O.V. Krasnyanskaya, Innovations (2021) https://doi.org/10.26310/2071-3010.2021.269.3.009
9. K.V. Lebedev, L.V. Vasilyeva, E.S. Semenova, ETAP: Economic Theory, Analysis, and Practice 4 (2019)
10. G.D. Mamontov, Economics and Management: Problems, Solutions (2023) https://doi.org/10.36871/ek.up.p.r.2023.04.01.002
11. M.S. Oborin, Bulletin NGIEI **2**, 113 (2021) https://doi.org/10.24411/2227-9407-2021-10020

12. K.V. Samonova, I.K. Shevchenko, Engineering Journal of Don 2-2 (2015)
13. L.V. Strelkova, S.S. Kabanov, Vestnik of Lobachevsky University of Nizhni Novgorod 2-2 (2012)
14. O.S. Sukharev, E. Onishchenko, Investments in Russia **11**, 33 (2003)
15. L.V. Tashenova, E.Yu. Onishchenko, *Features of a modern industrial cluster*, in Proccedings of the 8th Int. sci.-pract. conf. INPROM, 27-30 April 2023, Saint Petersburg, Russia (2023) https://doi.org/10.18720/IEP/2023.1/124
16. M.A. Shabykova, Financial Markets & Banks **1**, 115 (2023)
17. A.Yu. Shamkov, *Industrial cluster as a promising form of intra-regional technological cooperation*, Proccedings of the 12th Int. sci.-pract. conf. Problems and Prospects for the Development of Russian Industry, 30 November 2022, Moscow, Russia (2023)
18. Y.L. Cai, G.L. Wu, D.S. Zhang, Annals of Economics and Finance **21**, 483 (2020) http://aeconf.com/Articles/Nov2020/aef210208.pdf
19. W. Christaller, Central places in southern Germany (Prentice Hall, 1933)
20. I. Dezhina, A. Ponomarev, A. Frolov, Foresight and STI Governance (2015) https://doi.org/10.17323/1995-459x.2015.1.20.31
21. Y.A. Doroshenko, I.V. Somina, Y.S. Krasnokutskaia, Journal of Applied Engineering Science (2016) https://doi.org/10.5937/jaes14-10720
22. Yu.A. Doroshenko, M.S. Starikova, I.V. Somina, I.O. Malykhina, Economy of Region (2019) https://doi.org/10.17059/2019-4-24
23. O.S. Firmansyah, S. Handayani, Economy of Regions (2023) https://doi.org/10.17059/ekon.reg.2023-1-17
24. G. Myrdal, Economic theory and underdeveloped regions (G. Duckworth, London, 1957)
25. F. Perroux, The Quarterly Journal of Economics (1950) https://doi.org/10.2307/1881960
26. Russia's Regions. Statist. Yearbook (Rosstat, Moscow, 2022)
27. O.A. Romanova, A.O. Ponomareva, *Labor productivity in the regional economy: Factors of growth*, in Proceedings of the 9th All-Russia sci.-pract. conf. with int. part. Topical Problems of Economics and Management, Yekaterinburg, Russia (2021)
28. O.A. Romanova, A.O. Ponomareva, R-Economy (2021) https://doi.org/10.15826/recon.2021.7.3.014
29. O.P. Smirnova, L.K. Chesnyukova, *Assessment of the impact of human capital on labour productivity in industrialized regions of Russia*, in Proceedings of the 10th All-Russia sci.-pract. conf. with int. part. Topical Problems of Economics and Management, Yekaterinburg, Russia (2022)
30. O.P. Smirnova, A.O. Ponomareva, Economic Analysis: Theory and Practice (2020) https://doi.org/10.24891/ea.19.8.1431
31. O. Smirnova, L. Averina, A. Ponomareva, Advances in Systems Science and Applications (2020) https://doi.org/10.25728/assa.2020.20.3.851
32. E.S. Kovanova, Vestnik NSUEM **4**, 166 (2013)
33. R.J. Sawant, L. Nachum, A. Panibratov, Which Types of Political Capital Matter for Internationalizing Firm and Where Do They Matter? Evidence from Russia FDI and Exports (January 1, 2017) http://dx.doi.org/10.2139/ssrn.3001554
34. R. Creţan, L. Guran-Nica, D. Platon, D. Turnock, *Foreign Direct Investment and Social Risk in Romania: Progress in Less-favoured Areas*, in Foreign Direct

Investment in Eastern Europe, London, Ashgate (2005)
http://dx.doi.org/10.13140/2.1.4921.9525

35. V.V. Kalinina, Russian Journal of Industrial Economics (2016)
https://doi.org/10.17073/2072-1633-2016-3-259-269
36. The concept of introducing intelligent digital technologies in Sverdlovsk region «Smart Region» for 2017-2030.
https://digital.midural.ru/uploads/document/1530/umnyjregion--smart-region-kontseptsiya-postroeniya-na-territorii-sverdlovskoj-oblasti.pdf
37. Yu.V. Lyshchikova, Economics: Yesterday, Today and Tomorrow (2020)
http://dx.doi.org/10.34670/AR.2020.10.63.051