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Uncovering New Economy Potential of Russian Regions on the Basis of the Last 20 Years Dynamics' Analysis[1]

Recent global events have accelerated new technologies implementation worldwide. This process can likely lead to a future increase in regional disparities, especially in large developing countries such as Russia. Resource-based growth, which prevailed in the last 20 years in Russia, could slow down technological change in most regions. We aimed to assess regional potential for new economy formation based on its previous dynamics in 2000–2020. For that purpose, we developed a complex index that evaluates regional ability to create, use and disseminate new knowledge and technologies. There were long-term upward trends of most of the indicators in Russian regions due to intensive interregional alignment policy and a rapid spread of information and communication technologies. Economic growth, according to the Granger test results, contributed to the new economy formation. However, many research and development (R&D) indicators did not achieve higher values in comparison with 2000, when the oil prices started to grow. The growth rates in recent years have been low, and the share of R&D employees and R&D expenditures as well as entrepreneurial activity have declined especially in 2020. A significant but decreasing divide remains between leading and lagging regions. In accordance with the identified types of regions, it is necessary to pursue a diversified regional policy. Our results can be used to justify smart specialisation principles in Russia. Indirectly the study measures the resilience, or adaptability of regions to crises.

Keywords: techno-economic paradigm, knowledge economy, technological change, Russian regions, index, innovation, human capital, information and communication technologies, smart specialisation, digitalisation, entrepreneurship, resilience.

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ИССЛЕДОВАТЕЛЬСКАЯ СТАТЬЯ

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Раскрытие потенциала новой экономики в регионах России на основе анализа его динамики последних 20 лет

События последних лет ускорили внедрение новых технологий во всем мире. Этот процесс, вероятно, может привести к увеличению региональных различий, особенно в крупных развивающихся странах, таких как Россия. Рост, основанный на ресурсах, преобладавший в России в последние 20 лет, мог замедлить технологические изменения в большинстве регионов. В статье исследуется региональный потенциал для формирования новой экономики на основе анализа ее предыдущей динамики. Для этого был разработан комплексный индекс, оценивающий способность регионов создавать, использовать и распространять новые знания и технологии. В регионах России наблюдалась многолетняя тенденция к росту большинства показателей благодаря выравнивающей региональной политике и быстрому распространению информационно-коммуникационных технологий. Результаты теста Грейнджера показали, что экономический рост способствовал формированию новой экономики, хотя обратное влияние индекса знаний на региональный рост не подтвердилось. При этом многие среднерегиональные характеристики не превысили значений начала 2000-х гг., когда цены на нефть начали расти. Темпы экономического роста в последние годы были низкими, а доли занятых в НИОКР и расходов на НИОКР , а также плотность малого бизнеса снизились , особенно в период коронакризиса 2020 года. Между ведущими и отстающими регионами сохраняется значительный разрыв. В соответствии с выявленными типами регионов необходимо проводить диверсифицированную региональную политику. Результаты исследования могут быть использованы для обоснования принципов умной специализации в России. В статье измеряется устойчивость или адаптивность регионов к кризисам.

Ключевые слова: технико-экономическая парадигма, экономика знаний, технологические изменения, регионы России, индекс, инновации, человеческий капитал, информационно-коммуникационные технологии, умная специализация, цифровизация, предпринимательство, резильентность

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Introduction

The coronavirus pandemic is an undoubtedly powerful incentive to accelerate the transition to a new techno-economic paradigm worldwide (Kudrin, Radygin, Sinelnikov-Murylev, 2021; Mau et al., 2020b). The socio-economic crisis is an impetus for digital transformation of most industries: robotics, teleworking, online services etc. Recently, digitalisation and automation were typical only for the largest global cities, nowadays these trends have become present almost everywhere. Moreover, economic recovery from the crisis will directly depend on how promptly and successfully the regions adapt to the new reality (Mau et al., 2020b). The digitally transformed businesses become drivers of the regional economic growth in post-crisis period (Zemtsov, Chepurenko, Mikhailov, 2021).

After the crisis, a significant change in the economic structure may occur (Perez, 2009; Brynjolfsson, McAfee, 2014; Manyika et al., 2017; Schwab, 2017); some researchers call it new industrial revolution (Industry 4.0), characterised by digitalisation, automation and development of smart networks. In this new economy, around half of the jobs in the world, mostly routine processes, can be automated by 2035 (Brynjolfsson, McAfee, 2014; Manyika et al., 2017). The social consequences of these processes will differ significantly among regions and cities (Baburin, 2010; Berger, Frey, 2016). The most resilient regions have higher quality of human capital, higher rate of research and development (R&D) and information and communication technologies (ICT) development. At the same time, there can be some regions and cities where people are not ready for lifelong learning, competition with robots, and accordingly they are likely to be excluded from major economic activities, forming old-industrial and "old-service" regions. We call it 'nescience economy' (Zemtsov, 2020b). The ongoing processes can increase the spatial heterogeneity; therefore, it becomes increasingly important to pursue a differentiated regional policy, especially in the countries with large-scale economies.

Sanctions and restrictions on foreign trade increase the need to search for internal factors of development for Russian regions. In previous 20 years, the economy growth was largely based on the distribution of oil rent between regions (Åslund, Guriev, Kuchins, 2010). The economic crisis of 2020 and events in 2022 has once again demonstrated the vulnerability of this resource-based model. Before the crisis, this model could slow down technological change in most regions because of the 'resource curse' effect and the dependent position of a number of regions. Our main research questions: is there a connection between regional growth and new economy formation and were certain regions able to form an innovative and entrepreneurial ecosystem that can withstand new challenges.

The purpose of this article is to assess regional potential for new economy formation in Russia and identify its main long-term trends.

In the first paragraph, we argued whether the terms 'knowledge economy' or 'new economy' could be applied and why it is so important to study regional factors. The second paragraph examines different approaches to the assessment of new economy potential. The third paragraph describes the methods we use, the proposed regional index. In the last paragraph, we identify the main trends and leading Russian regions, according to the index proposed. In conclusion, there are some political recommendations.

Theory

In the literature, there are a significant number of approaches to the knowledge economy's definition (Bell, 1974; Drucker 1969; Morgan, 2007; Powell, Snellman, 2004; Acs, de Groot, Nijkamp, 2017). F. Machlup first suggested the term (Dubina, Carayannis, Campbell, 2012), referring it to education and science as economic activities. From our point of view, nowadays, the meaning of the concept has been transformed. The term is mostly associated with a new stage of the economic development, when the knowledge and creative abilities become the main factor of the economic growth (Åslund, Guriev, Kuchins, 2010; Toffler, 1981; Castells, 2000; Shahabadi, Kimiaei, Afzali, 2018). For example, the number of scientific papers, patents, etc. increases exponentially: only from 2014 to 2016, more information has been produced than ever before[1]. Winners in today's economy are those countries, regions, companies that manage to extract the valuable knowledge from this exponentially growing area and create a unique demanded product.

There are a significant number of economic theories explaining the transition to the knowledge-based economy (Freeman, 1974; Castells, 2000; Perez, 2009; Antonelli, 2003). However, one of the main characteristics, from our point of view, will be the formation of intelligent unmanned systems (Brynjolfsson, McAfee, 2014; Manyika et al., 2017; Mau et al., 2020): artificial intelligence, the Internet of things, autopilot transport, etc. It creates risks of technological unemployment. Our estimations (Zemtsov, 2020b) show that more than 44 % of the workplaces can be automated in Russia after the full implementation of existing technologies. In regions specialised in the manufacturing industry, this proportion can be even higher. These new conditions make creative people, who can produce and use new knowledge, new technologies and products, the most valuable (Barinova, Rochhia, Zemtsov, 2022). Moreover, the world is moving from competition for raw materials and investment to competition for the most creative professionals. At the same time, not only possible incomes are important for them, but also the quality of life, climatic and institutional conditions, and the presence of smart neighbours (Florida, 2002; Barinova, Rochhia, Zemtsov, 2022). The share of human capital in the national wealth already exceeds 65 % in developed countries (Dasgupta, 2014).

With acceleration of new transport and information technologies diffusion, the reduction of interaction costs leads to a subsequent increase in the economic concentration (Combes, Mayer, Thisse, 2008). Moreover, conditions for the creation and implementation of new technologies are even more spatially differentiated (Dunning, 2002). The process called glocalisation, when routine functions are distributed everywhere, and the most knowledge-intensive are concentrated in the most favourable localities (Glaeser, Ponzetto, 2007; Baburin, 2010). Tacit knowledge (Polanyi,

[1] IBM Marketing Cloud. (2017). 10 Key Marketing Trends for 2017 and Ideas for Exceeding Customer Expectations. Retrieved from: http://comsense.consulting/wp-content/uploads/2017/03/10_Key_Marketing_Trends_for_2017_and_Ideas_for_Exceeding_Customer_Expectations.pdf/ (Date of access: 01.05.2020).

1966), cannot be fully formalised, and can be only transmitted "from teacher to student" through interactive learning. It is concentrated in areas with scientific schools, universities, large research centres, etc. Knowledge spillovers are still spatially limited, despite the introduction of new distance learning and interaction technologies (Gertler, 2003). Proximity is also important in terms of access to equipment, especially for science and engineering. For example, the number of patent citations decreases quite rapidly with increasing distance between inventors (Jaffe, Trajtenberg, 2002; Bottazzi, Peri, 2003). That is why regions and cities (Dunning, 2002; Berger, Frey, 2016) have significantly different environment for new economy formation because of high inequality in human capital, R&D concentration and ICT development (Shahabadi, Kimiaei, Afzali, 2018; Dunning, 2002; Florida, 2022).

Moreover, knowledge has a cumulative nature; it takes time for innovation and technological entrepreneurship to take root in social systems (embeddedness) (Gertler, Wolfe, Garkut, 2000; Simmie, 2005; Andrés, Asongu, Amavilah, 2015; Zemtsov, Kotsemir, 2019). When economic agents know clear algorithms to create a new firm/new product as unified set of actions, "routines" (Nelson, Winter, 1982), it leads to the formation of territorial innovation systems and entrepreneurial ecosystems (Cooke, 2001; Carayannis, Campbell, 2009). They are sustainable networks of firms, scientific centres, development institutions, support infrastructure, etc. The efficiency of creating new technologies and start-ups is dramatically higher in such regions (Zemtsov, Kotsemir, 2019; Zemtsov, Chepurenko, Mikhailov, 2021).

According to the knowledge production function (Brenner, Broekel, 2011), R&D and human capital are essential factors of knowledge creation, e.g. patent output in the Russian regions (Crescenzi, Jaax, 2017; Zemtsov, Kotsemir, 2019). Regional growth through the R&D sector depends on the stock of knowledge and human capital (Romer, 1996). Nevertheless, the return from the R&D in the European Union is lower than in the United States ('European innovation paradox') (Dosi, Llerena, Labini, 2006), and it can be related to low entrepreneurial (start-up) activity in most of European regions (Audretsch, Keilbach, 2004). Startups can be considered as a transfer mechanism from the field of scientific ideas to ready-made commercial solutions (Zemtsov, Chepurenko, Mikhailov, 2021). Entrepreneurial capital is higher in specific institutional environment with higher R&D and venture funds concentration, ICT infrastructure (Kassicieh, 2010). It requires embeddedness, while in several papers it is argued that entrepreneurial culture can persist even for centuries (Polanyi, 1966; Fritsch, Wyrwich, 2014; Stuetzer et al., 2016; Zemtsov, 2020a).

As we showed in our brief theoretical overview, the new economy will be highly spatially differentiated. The main factors, determined new economy formation, are institutional conditions, human capital, R&D and business concentration, and ICT development.

Methods

Many approaches directly or indirectly measure the new economy dynamics. The simplest way is to separate the high-tech sector from the rest of the economy (Hatzichronoglou, 1997). However, attributing firms to certain industries introduces significant distortions. For example, the crisis of 2020 clearly showed the problems of statistical codes. Many affected firms in Russia could not receive state support, since they used codes that were not listed in the official list of the most affected industries (Kudrin, Radygin, Sinelnikov-Murylev, 2021). In addition, the phenomenon of the new economy is associated not only with the emergence of new industries, but also with a fundamental change in the entire economy. Therefore, in our opinion, it is more justified to use a complex approach that takes into account the dynamics of many factors mentioned above.

The most common comprehensive approach is to develop an index. The widely recognised regional ratings are the Regional Innovation Scoreboard (RIS) in the European Union, the Portfolio Innovation Index (PII), and the index of new economy (State New Economy Index, SNEI) in the USA. In most ratings, the regional conditions and results are divided methodically. It corresponds to the assumptions of the knowledge production function (vide supra). In Russia, the most respected are the Regional Innovation Development Rating of the Higher School of Economics (HSE) (Gokhberg, 2012) and the Rating of the Association of Innovative Regions of Russia (AIRR). Despite some differences in the methodologies, the ratings represent quite similar results. In general, the methods of both ratings are based on the RIS rating.

The Knowledge Economy Index (KEI) of the World Bank (Chen, Dahlman, 2006) measure the abilities of the countries to apply, create and disseminate knowledge. A first group of indicators is dedicated to economic incentive and institutional regime (Andrés, Asongu, Amavilah, 2015). It provides an assessment of efficient resources' allocation, wider opportunities for entrepreneurship. The second group assessed educational rate and available human resources. Educated workers can continuously upgrade and adapt their skills to create and use new knowledge, technologies and products. The third group of innovation systems' indicators show an ability to create new knowledge and technologies and adapt it to the local markets. The last group of ICT indictors shows communication, and processing of information and knowledge (Chen, Dahlman, 2006).

Data and Model

In this study, we used the complex methodology of the World Bank (Chen, Dahlman, 2006), adapted to the existing regional data in Russia. According to the theory overview, we expanded the Knowledge Economy Index with indicators of technology use and business concentration. In fact, we are measuring the resilience of the regional economy, or its adaptability to crisis according to the set of indicators (Klimanov, Kazakova, Mikhaylova, 2018).

The purpose is to identify Russian regions[1], which have developed the optimal conditions for the new economy formation and easily endure the economic crisis and technological transition. We used the official Federal State Statistics Service (Rosstat)[2] data, unless otherwise indicated. Therefore, the calculation of the Russian knowledge economy index (RKEI) consists of twelve variables characterising five blocks:

$$RKI_{i,t} = \frac{\left(\begin{array}{c} \dfrac{GRPgr_{i,t} + HDI_{i,t} + \left(10 - InvestRisk_{i,t}\right)}{3} + \\ + \dfrac{UrbHE_{i,t} + Educ_{i,t}}{3} + \\ \dfrac{R\&DEmpl_{i,t} + R\&DExp_{i,t} + ComPat_{i,t}}{3} + \\ + \dfrac{Entr_{i,t} + UsedPat_{i,t}}{2} + \dfrac{Mob_{i,t} + Web_{i,t}}{2} \end{array} \right)}{5}, \quad (1)$$

where i is a region, t is a year,

block 1: indicators of economic, social and institutional development: *GRPgr* — gross regional product (*GRP*) growth rate in constant prices; *HDI* — Human Development Index (*HDI*) for Russian regions (Grigoryev, Bobylev, 2014; Barinova, Rochhia, Zemtsov, 2022); *InvestRisk* — Investment Risk Evaluation (RAEX)[3];

block 2: indicators of human capital and education: *UrbHE* — the share of employed urban residents with higher education (Zemtsov, Kotsemir, 2019); *Educ* — the average number of years of employees' education (Zemtsov, Chepurenko, Mikhailov, 2021);

block 3: indicators of science and innovation creation: *Research* — the share of R&D employees, %; *R&D* — the R&D expenditures per GRP, % (Audretsch, Belitski, 2020); *ComPat* — the number of potentially commercialised patents per 1 million employed urban residents with higher education (Zemtsov, Kotsemir, 2019; Tripathi, Kutsenko, Boos, 2021);

block 4: indicators of potential innovation transfer and usage of new technologies: *Entr* — the number of small enterprises (including micro) to the economically active population (Zemtsov, Kotsemir, 2019; Barinova, Rochhia, Zemtsov, 2022); *UsedPat* — the number of used patents by firms per 100 billion roubles of GRP (Baburin, 2010);

block 5: indicators of the information infrastructure and conditions for digitalisation: *Mob* — number of cell phones per 100 people (Baburin, 2010); *Web* — the proportion of companies with the websites, %.

In the first block, we used two indicators (*GRP growth* and *HDI*) from the original methodology. Sustainable rates of GRP growth and quality of life help to attract high-skilled human capital (Zemtsov, Chepurenko, Mikhailov, 2021). GRP per capita growth means, ceteris paribus, productivity growth due to technological and other innovations (total factor productivity growth). In the new economy, entrepreneurial activity can become one of the possible solutions for automation problem (Zemtsov, 2020b), and startups development is highly dependent on business institutions and regional entrepreneurship ecosystems (Djankov et al., 2005; Yakovlev, Zhuravskaya, 2013; Zemtsov, 2020a). To assess the regional institutions quality, we used the RAEX rating agency estimates of the investment risks.

The second block is dedicated to the development of education and concentration of human capital in a region. We used the average number of years of employees' education (Zemtsov, Chepurenko, Mikhailov, 2021) to assess an ability of employed residents to accumulate knowledge; it indirectly measures the development of lifelong education, which has become one of the features of the new economy. Creative and highly educated professionals attract those from other regions

[1] There are no available data on new regions — the Republic of Crimea and Sevastopol.

[2] Rosstat, Federal State Statistic Service. Retrieved from: https://eng.gks.ru/ (Date of access: 01.05.2020).

[3] RAEX (2015). Rating of Investment attractiveness rating of Russian regions. Retrieved from: https://raex-a.ru/ratings_files/1925_1_regions_2015.pdf/ (Date of access: 01.05.2020).

and countries (Florida, 2002; Barinova, Rochhia, Zemtsov, 2022). It is important to mention, that not only professional researchers create new technologies (Zemtsov, Kotsemir, 2019); that is why we proposed a new indicator — number of employed urban residents with a higher education. It is important that this indicator simultaneously considers the agglomeration effects that are actively manifested in the innovation sector (Jacobs, 1969; Kutsenko, Islankina, Kindras, 2018; Mikhaylov, 2019).

A high share of scientists and a high intensity of R&D expenditures may lead to new technologies' creation (Crescenzi, Jaax, 2017) and higher startup activity (Zemtsov, Chepurenko, Mikhailov, 2021); such regions also require and attract more highly qualified professionals (Barinova, Rochhia, Zemtsov, 2022). Patent activity is an important indicator for the new knowledge itself (Griliches, 1979; Jaffe, Trajtenberg, 2002). However, the Russian regions on average have a low share of commercialised patents. Thus, we developed a new indicator (*ComPat*):

$$ComPat_{i,t} = 0.07 \times PatRus_{i,t} + 0.5 \times PatPCT_{i,t}, \quad (2)$$

where *PatRus* is the number of registered national patents; *PatPCT* is the number of PCT[1] patent applications. The coefficients reflect the commercialisation rate.

We used an indicator of R&D expenditures as a proxy for financial resources for high technology development because of the underdevelopment of the venture investments in Russia (Zemtsov, Chepurenko, Mikhailov, 2021).

We include the fourth block of new indicators to estimate the transfer of new technologies from R&D sector to production. According to the theoretical background, the ratio of the small companies per workforce (entrepreneurial activity) can be considered as a transfer mechanism (Audretsch, Keilbach, 2004). The number of used patents allows direct assessment of the intensity of technology implementation (Baburin, 2010).

ICT makes it possible to provide access to knowledge and reduce the costs of promoting collaboration. We used data on mobile phone coverage because it is widely used in Russian regions, and price of mobile internet access is one of the lowest in the world. The development of high-speed mobile Internet (5G) is especially significant for new technologies of virtual reality, additive technologies, telemedicine, especially in many remote regions, where land cables are missing. To assess the involvement of firms into digitalisation processes, we have used the share of organisations with web-sites. During the pandemic, the digitalisation rate increased in most regions (Mau et al., 2020a).

We also calculated the Russian knowledge index (*RKI*), excluding the economic performance indicators:

$$RKI_{i,t} = \frac{\left(\begin{array}{c} \dfrac{Urb_{i,t} + Educ_{i,t}}{3} + \\ + \dfrac{R\&DEmpl_{i,t}}{3} + \\ + \dfrac{R\&DExp_{i,t} + ComPat_{i,t}}{3} + \\ + \dfrac{Entr_{i,t} + UsedPat_{i,t}}{2} + \dfrac{Mob_{i,t} + Web_{i,t}}{2} \end{array}\right)}{4}. \quad (3)$$

This index describes the features of regional innovation systems only. Thus, we used it in econometric calculations to identify interrelations between economic performance and knowledge economy formation. We used the Granger causality test to determine whether one time series is useful in forecasting another.

We calculated the regional rank R_i in year *t* for each indicator (Chen, Dahlman, 2006):

$$R_{i,t} = \frac{R_{low,T}}{R_T} \times 10, \quad (4)$$

where R_{low} is the number of regions with a lower rank than the region *i* in the period *T* (1998–2020) of the subject indicator and R_T is the total number of regions in the period *T* (85 regions × × 23 years = 1955). Then we calculated the average rank index for each block. Unlike the traditional approach, we calculated indices for all years at the same time, what allows us to trace the dynamics of the process and not only compare regions with each other in one year.

Results

If we consider the comparative dynamics of the RKEI indicators, it turns out that the trends in Russia were contradictory (Fig. 1). The highest dynamics was in the ICT sector (block 5) due to worldwide digitalisation process (Fig. 2). The index of the block 2 indicators also increased about 4 times due to the growth in tertiary education in Russia and worldwide. The dynamics of the block 4 was positive due to the increase of entrepreneurial activity. However, the economic conditions (block 1) and knowledge creation factors (block 3) did not achieve higher values in 2020 in comparison with

[1] The Patent Cooperation Treaty (PCT) is an international patent law treaty, which provides a unified procedure for filing patent applications to protect inventions in each of its contracting states.

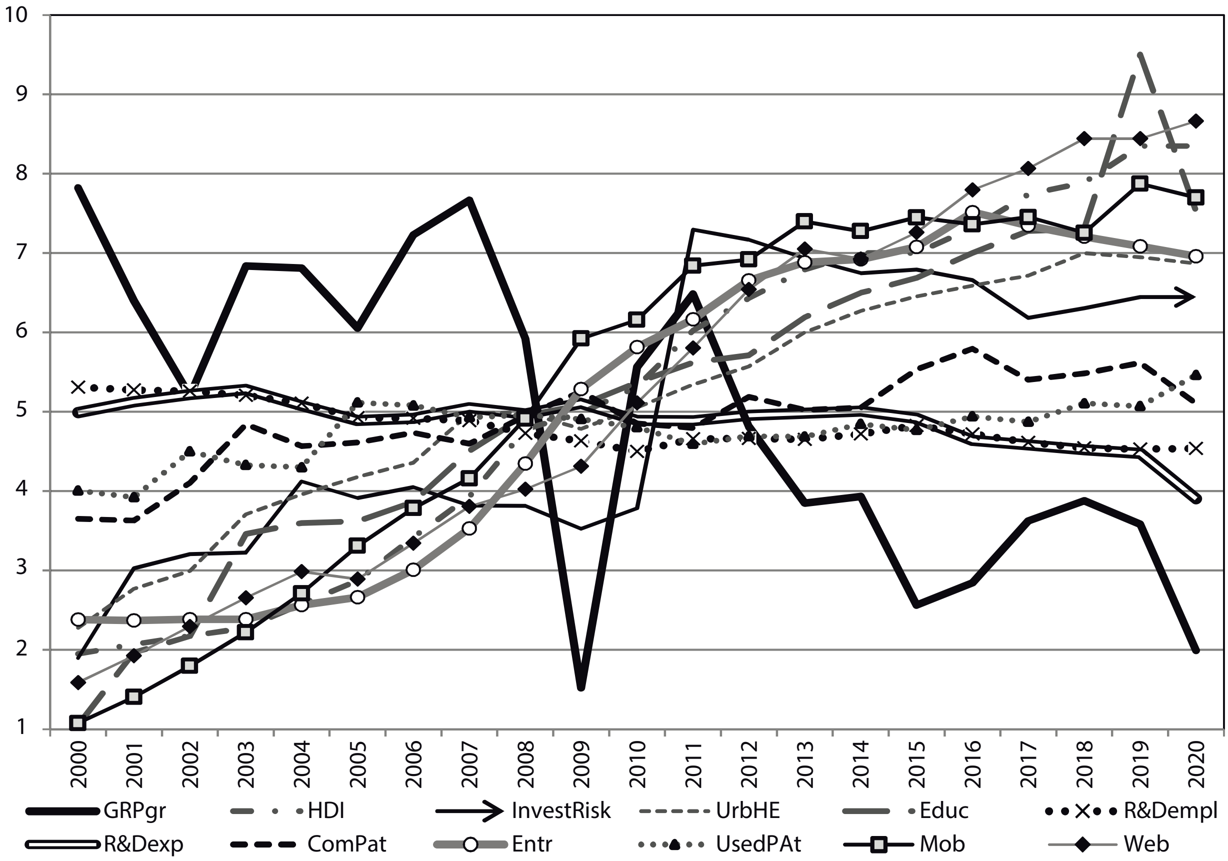


Fig. 1. *Dynamics of the indices for each indicator for the average Russian region*

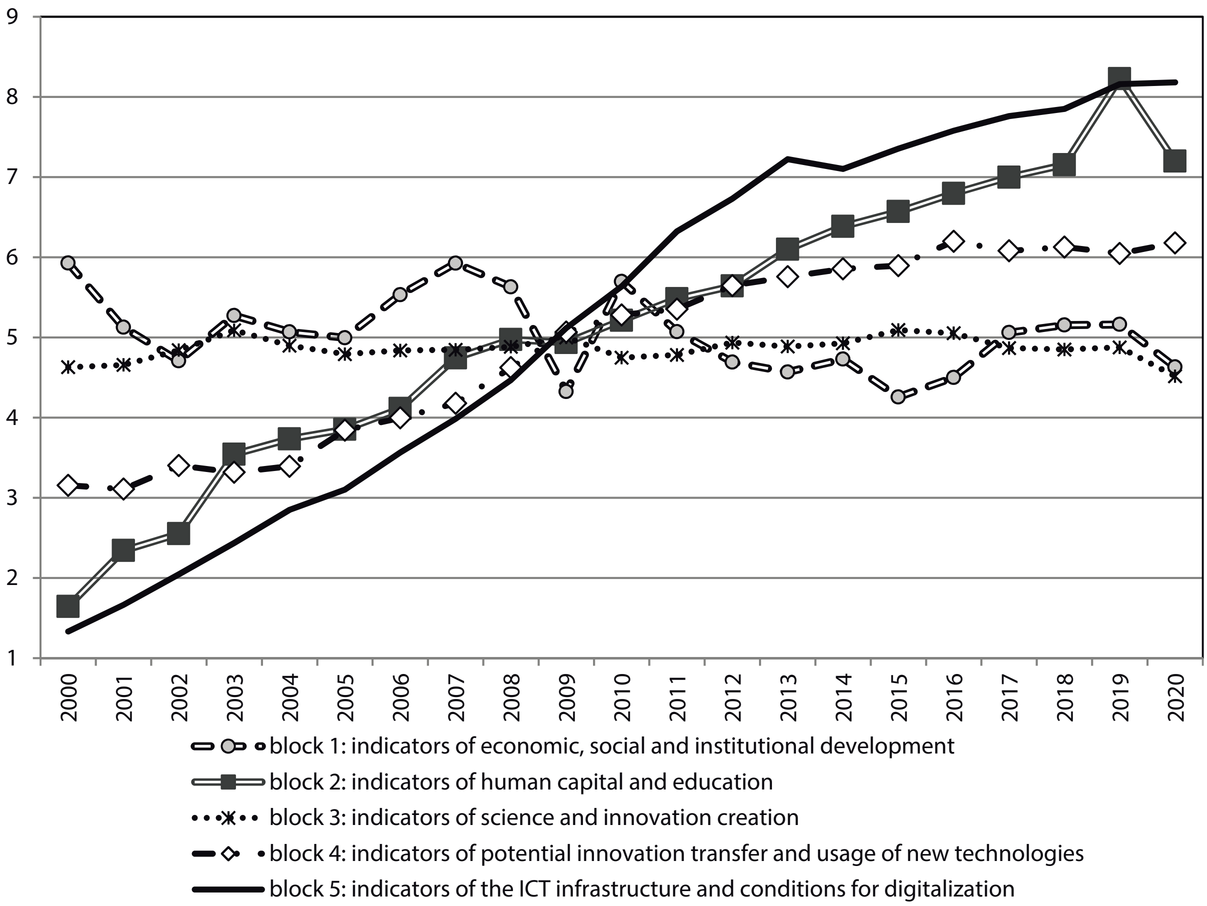


Fig. 2. *Dynamics of the indices for each block for the average Russian region*

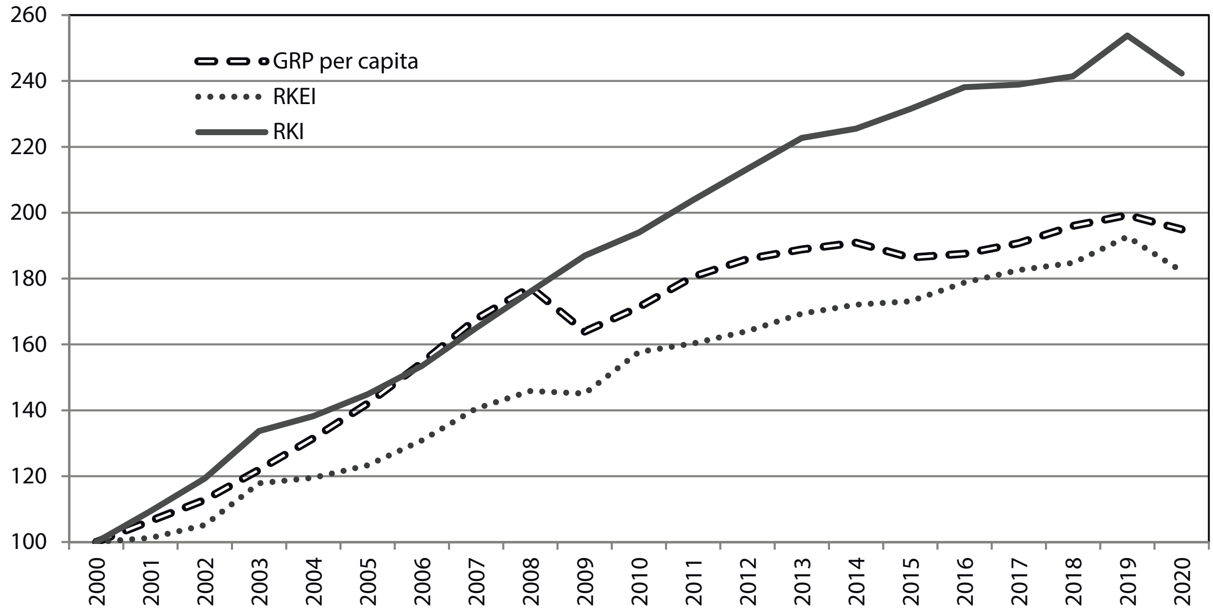


Fig. 3. *Dynamics for the average Russian region (2000 = 100 %)*

2000, when the oil prices started to grow. The economic growth rates in recent years have been low, and the share of R&D employees and R&D expenditures has declined (Fig. 1). The decline in the share of R&D employees is a contrary to the global trend.

Note that almost all indicators decreased during the 2020 crisis, with the exception of the business digitalisation and patent usage indicators. Indeed, these were the mechanisms for the survival of enterprises, especially given the doubling of the share of online commerce (Mau et al., 2020a; Zemtsov, Chepurenko, Mikhailov, 2021).

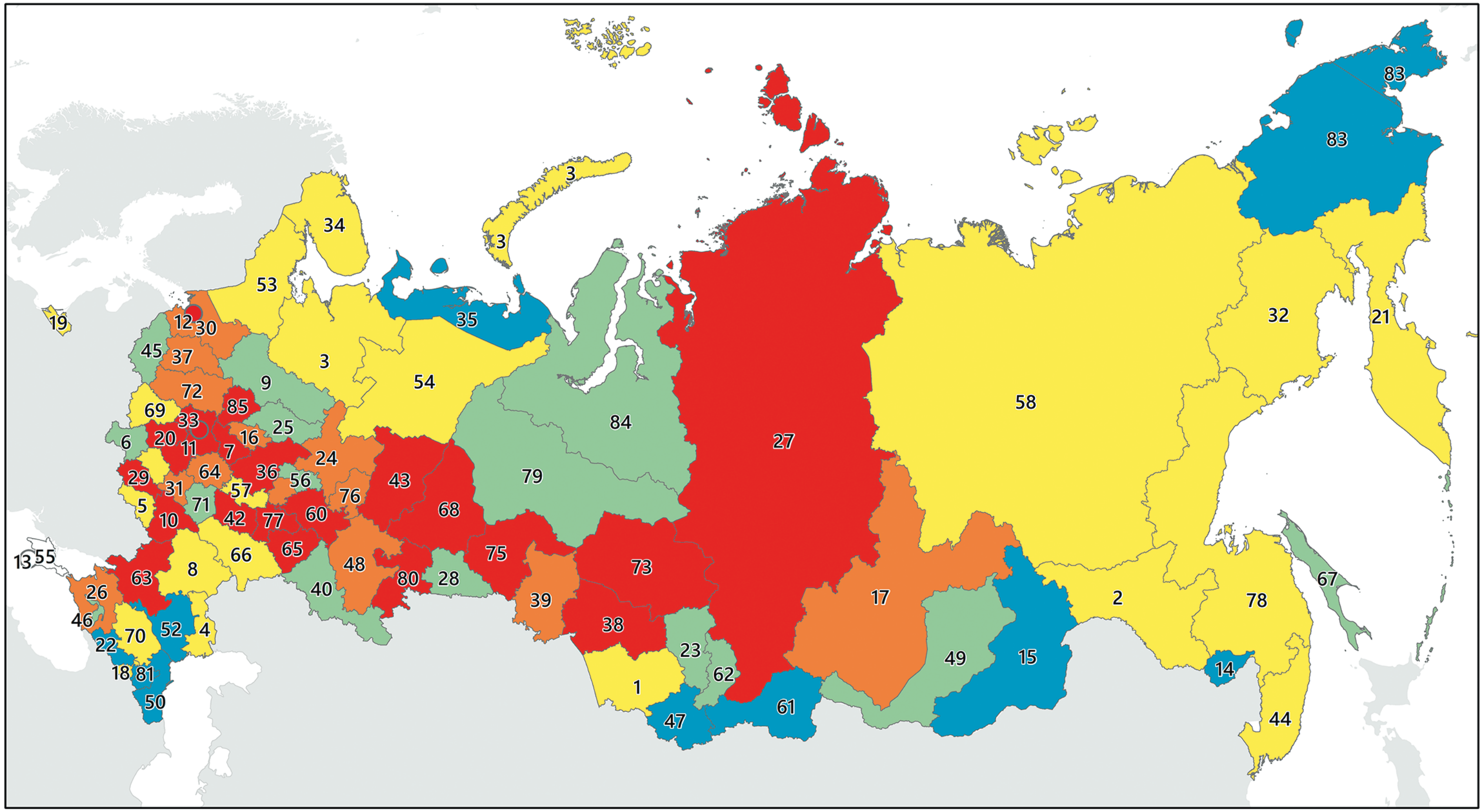
The RKEI, the RKI and GRP per capita have quite similar trajectories (Fig. 3). It is important that despite the slowdown in economic growth in 2010th, the RKI have grown continuously. However, the pace has slowed in recent years under the influence of a economic slowdown. And in 2020, the values of most indicators fell more than GRP per capita; RKI returned to the level of 2018. In other words, the crisis of 2020 reduced, on average, the ability of regions to adapt through the development of new technologies and start-ups.

We were also interested in whether there is a connection at the regional level between regional development and new economy formation. We carried out the Granger causality test for panel data, and the results show significant relation between GRP per capita and the RKI. In other words, higher regional performance affects knowledge economy indicators. However, the quality of the models for testing the RKI influence on GRP is quite low, and we cannot speak of the mutual effect of the two indicators. It is clearly visible on the graph that the slowdown in economic growth has led to a gradual slowdown in the development of the innovation system, and not vice versa. Although the spread of digital technologies provides economic growth on average (Ponomareva, 2021), it slows down in the leading regions, and subsequent automation can generate mentioned negative effects. The digital divide between regions remains high, although it has been declining, especially during the pandemic.

The first stage in new regional policy, based on the principles of smart specialisation, is the typology. According to the cluster analysis, we identified five types of the Russian regions (Table 1, Figure 4).

The group of the knowledge core regions is represented by multifunctional innovation centres: Novosibirsk, Tomsk, Samara, Moscow, Nizhny Novgorod regions, Tatarstan. They have a wide scientific and technological specialisation. Two regions — Moscow and St. Petersburg have the maximum potential; they concentrate all stages of the innovation cycle: creation, implementation and dissemination of new technologies. These are the global cities, participating in creation and diffusion of new knowledge, technologies and products worldwide. They will have less socio-economic consequences during the shift of techno-economic paradigm because they already have quite diversified economy with qualified and creative employees and high level of the ICT development.

The regions of the second group (Leningrad, Irkutsk, Krasnodar, Omsk regions, etc.) have average innovation potential, but high production potential. In the regions, there are large enterprises, including the ones of the military-industrial com-



Types of regions

1 2 3 4 5 No data

1 – Altai; 2 – Amur; 3 – Arkhangelsk; 4 – Astrakhan; 5 – Belgorod; 6 – Bryansk; 7 – Vladimir; 8 – Volgograd; 9 – Vologda; 10 – Voronezh; 11 – city of Moscow; 12 – city of St. Petersburg; 13 – Jewish Autonomous; 14 – Transbaikal; 15 – Ivanovo; 16 – Irkutsk; 17 – Kaliningrad; 18 – Kaluga; 19 – Kamchatka; 20 – Kemerovo; 21 – Kirov; 22 – Kostroma; 23 – Krasnodar; 24 – Krasnoyarsk; 25 – Kurgan; 26 – Kursk; 27 – Leningrad; 28 – Lipetsk; 29 – Magadan; 30 – Moscow; 31 – Murmansk; 32 – Nenets; 33 – Nizhny Novgorod; 34 – Novgorod; 35 – Novosibirsk; 36 – Omsk; 37 – Orenburg; 38 – Oryol; 39 – Penza; 40 – Perm; 41 – Primorsky; 42 – Pskov; 43 – Adygea; 44 – Altai; 45 – Bashkortostan; 46 – Buryatia; 47 – Dagestan; 48 – Ingushetia; 49 – Kabardino-Balkarian; 50 – Kalmykia; 51 – Karachay-Cherkess; 52 – Karelia; 53 – Komi; 54 – Mari El; 55 – Mordovia; 56 – Yakutia; 57 – North Ossetia; 58 – Tatarstan; 59 – Tyva; 60 – Udmurtia; 61 – Khakassia; 62 – Chechen; 63 – Chuvash; 64 – Rostov; 65 – Ryazan; 66 – Samara; 67 – Saratov; 68 – Sakhalin; 69 – Sverdlovsk; 70 – Smolensk; 71 – Stavropol; 72 – Tambov; 73 – Tver; 74 – Tomsk; 75 – Tula; 76 – Tyumen; 77 – Ulyanovsk; 78 – Khabarovsk; 79 – Khanty-Mansiysk; 80 – Chelyabinsk; 81 – Chukotka; 82 – Yamal-Nenets; 83 – Yaroslavl; 84 – Crimea; 85 – city of Sebastopol

Fig. 4. *The types of the Russian regions*

Table 1

The average block values (indices) for the identified types of the Russian regions

Types / blocks	1	2	3	4	5
1. Knowledge core (the highest values in all blocks of indicators)	7.98	9.82	9.2	8.82	9.9
2. Intensive knowledge users (high values for knowledge use, knowledge transfer and ICT diffusion; concentration of the developed manufacturing sector)	5.07	5.77	6.89	8.22	8.31
3. Potential knowledge creators and consumers — «middle Russia» (the most varying characteristics with the second highest human capital concentration)	3.64	9.47	5.12	4.45	8.77
4. Weak knowledge consumers (regions with high share of low-tech industries, the weakest R&D sector, having an average human capital concentration)	3.61	6.98	0.38	2.37	6.96
5. The least developed regions with the weakest human capital and knowledge usage	3.41	0.81	2.65	1.63	5.49

plex. Middle Russia regions are very diverse (Altai, Kaliningrad, Arkhangelsk, Belgorod regions, etc.), but their potential is moderate. They borrow and introduce more new technologies and products than create. There is also a group of raw and agrarian regions.

Semi-peripheral regions (Kemerovo, Tambov, Pskov regions, etc.) have low and medium innovation capacity. They specialise mostly on low technological industries.

Underdeveloped regions (Altai, Tyva, Chukotka, Chechnya, Nenets Autonomous district, Jewish Autonomous area, etc.) have weak potential: they weakly use and diffuse new knowledge and are the most vulnerable concerning the techno-economic paradigm change. Digitalisation and automation may increase the unemployment rate in these regions. Institutional barriers are the highest in this group, which will not allow potentially unemployed people to start their own businesses. Their development is poorly based on new technologies, and federal subsidies have a significant share in their budgets.

All Russian regions have the similar positive trend of the RKEI, which was broken in 2009 as a result of the economic crisis. The coefficient of the RKEI variation between regions decreased from 0.46 to 0.21 due to regional alignment policy and general digitalisation.

Conclusion

The present research has demonstrated high and increasing importance of regional environment in new economy, especially for large developing countries. Using proposed methodology (the Russian knowledge index) we assess the regional potential for the new economy formation. Russian regions are very diverse; however, the differences were levelled out due to the persistent alignment policy — the redistributive budget system. There were long-term upward trends in all Russian regions before the 2020 economic crisis.

Moreover, according to the Granger causality test for panel data, there was a significant relation between GRP per capita and the Russian knowledge index. In other words, higher regional performance positively affects new economy formation, thus, resource-based growth contributed to economic transformation. However, we cannot speak of the reverse effect at that period, that is, positive changes in the innovation sector may or may not influenced regional growth. Most likely, this influence can be traced in certain periods and for more developed regions.

Average regional growth and knowledge creation factors did not achieve higher values in 2020 in comparison with 2000, when the oil prices started to grow. The economic growth rates in recent years have been low, and the share of R&D employees and R&D expenditures has declined. In the crisis of 2015–2016, many indicators of socio-economic development returned to their values of the mid-2000s. In 2020, the values of most indicators fell more than GRP per capita; RKI returned to the level of 2017. Moreover, there remains a significant digital divide between leading and lagging regions.

Our research can be used to justify smart specialisation principles in Russia (Kutsenko, Islankina, Kindras, 2018). The regional policy after the crisis should become more differentiated (Tödtling, Trippl, 2005; Asheim et al., 2007; Foray, 2016) according to specialisation and efficiency for creating and diffusion of new knowledge and technologies. Therefore, in our opinion, the efforts of regional authorities should concentrate primarily at preserving human capital and attracting high professionals (Barinova, Rochhia, Zemtsov, 2022).

In accordance with the identified types of regions, it is necessary to pursue a diversified regional policy. The largest agglomerations require intensification of international and university-business cooperation, the leading universities' support. The high- and middle tech industrial centres require support and formation of high-tech clusters. They may suffer from automation more than others (Zemtsov, 2020b), and therefore, need the specialised measures to develop STEM education, introduce retraining programs, etc. Improving the business climate will contribute to the attractiveness of the lagging regions (Barinova, Rochhia, Zemtsov, 2022) and help to stimulate entrepreneurial activity.

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