

The Risks of Digitalization and the Adaptation of Regional Labor Markets in Russia

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Abstract

The implementation of new automation technologies together with the development of artificial intelligence can free up a significant amount of labor. This sharply increases the risks of digital transformation. At the same time, certain regions and cities differ greatly in their ability to adapt to future changes. In this article, we seek to determine the capabilities of Russian regions to reduce risks and adapt to digital transformation. The literature stipulates that there are several factors able to reduce these risks. First of all, they are associated with retraining, ICT and STEAM-technologies' development, the promotion of economic activities that are less subject to automation. As

a result of econometric calculations, we identified several factors that contribute to the new industries' development (in our case, ICT development), and, accordingly, increase regional adaptivity. These factors include diversification, the concentration of human capital, favorable entrepreneurship conditions, the creative potential of residents, and the development of ICT infrastructure. We identified several regions with high social risks and low adaptivity, which are mainly the poorly developed regions of southern Russia, where entrepreneurial risks are high, STEAM specialists are not trained, shadow economy is large. This work contributes policy tools for adaptation to digital transformation.

Keywords: digital economy; robots; STEAM; automation risks; technological exclusion; nescience economy; human capital; entrepreneurship; ICT

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With the development of new technologies, many routine operations, primarily simple manual work, gradually become automated [Brynjolfsson, McAfee, 2014]. At the same time artificial intelligence (AI) systems are beginning to threaten medium-skilled professional jobs such as drivers, sales assistants, and technologists. The main risk associated with accelerated digital transformation and the automation of production is that people will find it difficult to adapt to the changed situation in time. Although until recently the development of digital technologies in Russia was slower than in the world's leading countries [OECD, 2017; Abdrakhmanova et al., 2018], even with the relatively smooth transition to automation and no large-scale “technological” unemployment (which can be achieved at the cost of major monetary injections)¹, it will still be necessary to adapt to the digital economy. This implies that people will have to learn new approaches to doing business, running their households, using public services, and so on. Meanwhile, Russian regions are quite diverse in terms of both their digitalization potential and their ability to adapt to changing conditions [Zemtsov, 2017, 2018].

In recent years, the number of able-bodied Russian population has been steadily declining, so the retirement age was raised to accomplish economic and social objectives. In the foreseeable future, this trend is likely to transform the labor market. The development of a digital economy may provide an answer to the declining workforce problem and serve as an additional economic growth factor; however, at the same time it might lead to significantly decreased employment, and increased unemployment among less skilled workers. For example, in the US, the use of industrial robots resulted in considerably reduced employment and wages [Acemoglu, Restrepo, 2017]. The use of digital technologies is a strategic development goal in Russia for the period until 2024.² The implementation of national projects to promote the digital economy and labor productivity can lead to the liquidation of a large number of jobs, about 12.5 million [CMASF, 2018]. These risks affect workers employed in primary industries and manufacturing, where the shares of manual work and routine operations are higher [Berger, Frey, 2017].

This paper considers Russian regions' potential to adapt to the digital economy and analyzes conditions for new job creation in the information and communication technology (ICT) sector. Regions more vulnerable to the above risks are identified. The data and the methods used to identify factors affecting ICT development are described. Regional adaptation prospects are dis-

cussed, taking into account the identified factors and a typology of regions is suggested. Recommendations on reducing digitalization-related risks are provided.

Literature Review

Smart technologies are rapidly penetrating practically all key sectors including municipal services, transport, retail, education, and medicine. [Brynjolfsson, McAfee, 2014; Schwab, 2017]. By changing the established economic structure, disruptive innovations create conditions for the “disappearance” of certain industries that employ a large number of workers, mostly poorly skilled ones. However, given the current rate of S&T development, it cannot be ruled out that in the near future automation will also affect more highly skilled labor. This implies a totally different scale of changes in the social sphere and economy.

The prospects for the robotization of various jobs are being actively explored in all countries. Experts at the University of Oxford suggested a methodology for identifying more vulnerable industries, taking into account the use of social and creative intelligence as well as specific aspects of perception [Frey, Osborne, 2017]. Having applied this methodology to the Russian context [Zemtsov, 2017], it was concluded that 26.5% of jobs were highly likely to be automated. Occupations employing the largest numbers of people in Russia are particularly susceptible to these threats, such as sales assistants, drivers, security guards, and movers (in total about 28 million) [Zemtsov, 2018]. The methodology suggested by McKinsey [Manyika et al., 2017] allows one to analyze the aggregated industries, identifying routine work operations in each of them. This makes it possible to estimate the automation potential for any economy based on the assumption that standard functions will be proliferating at the same rate in different countries. If new technologies are introduced simultaneously, at least half of able-bodied Russians (about 40 million people) can potentially be ousted by robots [Zemtsov, 2018]. However, the fact that such processes take time allows a country to prepare for them in advance.

Our study shows that less developed regions turn out to be more vulnerable. These include the Republics of Ingushetia, Chechnya, Dagestan, Karachai-Cherkessia, Kabardino-Balkaria, and Tyva. Their economies have high shares of “automatable” industries (retail, agriculture, and transport), and largely remain in the “shadow economy”.

Automation will also affect the raw material producing regions such as the Nenets, Yamal-Nenets, and

¹ The experience of the city of Tolyatti in the Samara Region, where 70,000 Avtovaz workers were laid off due to automation, shows that federal policy can be quite inefficient. Government support was mainly provided to pay one-off redundancy compensation, grant subsidies to start one's own businesses, put in place infrastructure for small technology companies (in particular engineering firms), but it did not solve the problems faced by the majority of the residents. So there are grounds to fear that when the rate of automation increases, the government will not be able to provide adequate adaptation tools in many cities and regions.

² The RF Presidential Decree No. 204 “On national goals and strategic development objectives for the Russian Federation for the period until 2024” of 7 May, 2018. Access mode: <http://www.kremlin.ru/events/president/news/57425>, last accessed on 15.04.2019.

Khanty-Mansi Autonomous Districts where mining technologies dominate production, along with oil and gas transportation. This trend will also affect developed regions with high shares of manufacturing in their economies, which already use automation technologies, in particular the regions of Leningrad, Chelyabinsk, Rostov, Sverdlovsk, and the Republic of Bashkortostan.

Compared with developed countries, the penetration of advanced technologies is currently happening in Russia at a slower rate. This is due to low population density, uneven distribution of economic activities, low income, insufficient availability of technologies, and weak links between the territories. The government policy to limit labor market freedom plays a particularly important role. In effect a ban on laying off large numbers of workers from major core enterprises is in place. However, the need to make the economy more competitive will eventually prevail over the social risks. When this happens the rate of digitalization would sharply increase, while opportunities for the people and the economy to adapt would shrink [Zemtsov, Baburin, 2014]. Increasingly more workers will have to find new occupations, master new technologies, and acquire new skills. There is a danger that the application of digital technologies will outpace retraining and new job creation. People who have lost their jobs and were unable to adapt to the new situation may create an “ignorance-based economy” [Zemtsov, 2018]. We use this term to describe an economic segment where people are engaged in “second-rate” activities such as the natural economy or shadow sector, with no advanced technologies and no need for continuous training. Technological exclusion³ from the modern economy may lead to sharply increased pressure on regional and municipal budgets, since it will require active social support. In more recent studies [Arntz et al., 2017] attempts were made to integrate workers’ ability to retrain into the model, along with other mechanisms for adapting the labor market to changing conditions. Under this approach, the estimates of potential technological exclusion only marginally exceed the current unemployment level. Still, with a high rate of digitalization, the latter figure may double. Companies’ innovative activity and retraining efforts usually have a positive effect on employment. Entrepreneurship and creative intelligence provide opportunities to deal with the labor market crisis [Sorgner, 2017]. Creating a new business as a way of self-realization contributes to new job creation.

Other mechanisms for adapting to robotization imply active training in STEAM disciplines: science, technology, engineering, arts, and mathematics. These are the spheres of activities where robots cannot yet replace humans [LaGrandeur, Hughes, 2017; Zemtsov, 2018].

Retraining may smooth over the social risks of digital transformation, so the latter are likely to be much lower in the regions with a high level of education [Chang, Huynh, 2016], where workers are better able to acquire new knowledge, master new technologies, and participate in continuous learning. To support conclusions by a number of international studies, [Zemtsov, 2018] demonstrates that in Russia, the social risks associated with automation are lower in technologically developed regions with a high share of urban residents, entrepreneurs, and workers with higher education.

New industries, activity areas, and professions are constantly emerging in the present-day context [Berger, Frey, 2016]. The ICT sector is the most rapidly growing industry with new jobs being created on a massive scale which are less susceptible to automation.

According to certain estimates, about twice as many jobs will be created by 2030 than cut due to digitalization [WEF, 2018]. Unfortunately, these processes will not be aligned territorially. Robotization is likely to affect developing countries first, with a high share of mining industries, such as Indonesia, Vietnam, India, and China. On the other hand, favorable conditions for new job creation in the ICT sector have largely emerged in developed nations such as the US, Japan, the UK, and Germany. This mismatch is also in place in Russia: the risks are highest in regions where manufacturing, agriculture, and mining have significant shares in the economy, while advanced high-tech companies are mainly being created in major urban agglomerations where the service sector dominates [Zemtsov, 2018].

The share of routine operations is diminishing, while that of creative work is growing [Autor et al., 2003]. The share of workers with “universal” skills such as programming, new technology development, and creative thinking on the US labor market is on the rise [Michaels et al., 2013]. If in the 1970s the correlation between the number of new jobs and the share of workers with universal competences was low, in recent years it has been growing [Berger, Frey, 2016]. Computers are increasingly used to deal with work-related tasks, which have become more complex. In Russia these processes are happening at a slower rate [Gimpelson, Kapeliushnikov, 2015; Zemtsov, 2018] due to the low competitiveness of most companies, working for which does not require the serious upgrading of skills. Obsolete production facilities with the wide application of manual and routine work do not have demand for new competences.

Digital transformation and the emergence of new industries largely depend on the quality of information and communication infrastructure. Russia has a high level of digital inequality between regions and locations. Closer to large urban agglomerations the situation is better, but in many Far Eastern, Arctic, and

³ Similar processes were observed in Russia at the time when computers started to proliferate: numerous members of older population groups in effect were excluded from modern economic activities. However, in the course of the natural alternation of generations, social risks were avoided. However, the rate of digitalization can be much higher, while changes are much more radical.

North Caucasus towns people still do not have broadband internet access. These disproportions have been smoothed over by wide mobile coverage⁴. Regions with developed ICT infrastructure tend to have larger ICT markets, offer better opportunities for online trade and other businesses, and for training (offline and online alike) [World Bank, 2016]. They have built a solid foundation for the growth of advanced sectors of the economy such as additive technologies, virtual reality, and telemedicine. Creating conditions for new activity types, primarily in the ICT sector, will help economies to better adapt to digitalization.

Thor Berger and Carl Frey identified factors contributing to changes in the sectoral structure of the US cities' economies, based on the sectors included in the new edition of the national job classification (mainly related to the ICT sphere) [Berger, Frey, 2016, 2017]. Diverse economic activities in megacities, the rate of ICT application, and the colossal flow of students and newly trained professionals turn out to be the key drivers of new job creation in cities. Let us take a closer look at each of these factors.

Diverse economic activities are a leading economic development factor [Jacobs, 1969]. A city offers opportunities to apply a wide range of competences and skills. This leads to the emergence of new, more advanced industries that can grow due to a large market.

Cities with a *high share of ICT professionals* among university graduates were able to create new jobs in new industries much more rapidly than others, primarily in the ICT sector [Lin, 2011; Beaudry et al., 2010]. A *large supply of well-trained students* provides a basis for the emergence of prospective industries, because many young professionals subsequently become new technology developers and establish their own companies. Regions that train just a few dozen ICT professionals a year are unlikely to achieve breakthrough solutions or encourage the creation of rapidly growing start-ups. In areas where routine activities dominate, digitalization leads to reduced employment, while in regions that already have a high share of creative workers, new industries tend to emerge [Moretti, 2012; Autor, Dorn, 2013]. Specializing in specific production activities may result in a lock-in, when the whole community, universities, and companies are focused on promoting the development of a single industry [Martin, 2010]. Therefore the predominance of manufacturing may negatively affect the emergence and growth of new industries [Berger, Frey, 2016].

In the US, employment in high-tech industries is linked to the increased concentration of highly educated people [Beaudry et al., 2010; Chen, 2012], while in China it largely depends on better standards of living [Chen, 2012].

Thus it is important not just to retain, but also attract highly skilled workers to promote the development of new industries. Various studies confirm that human capital properties in the region may accumulate with time, which means this factor deserves particular attention when regional policies are implemented.

Another important driver affecting the emergence and growth of new sectors of the economy is R&D potential, which can be measured by the number of R&D personnel, amount of relevant expenditures, or number of patents [Zemtsov et al., 2016; Berger, Frey, 2017]. The more knowledge and skills are accumulated in a regional community, the higher is the potential for technological progress, and the emergence of new activity areas. In the early stages, the application of new information technologies in Russia was largely determined by the availability of R&D centers, whose highly skilled personnel needed computers to process large volumes of data. A strong correlation was established between the number of regional R&D personnel in 1991 and the level of ICT in 2011 [Ivanov, 2016]. Employment in the US high-tech sector [Li, 2000] is also affected by the concentration of R&D institutes and students.

The following **hypotheses** are put forward on the basis of the literature review:

Hypothesis 1: Large cities with diverse economic activities and major markets have greater potential for the development of a new economy.

Hypothesis 2: The growth of prospective industries requires a high concentration of human capital: the higher the education level, the more opportunities are available for training, mastering new technologies and new activity types.

Hypothesis 3: Information and communication infrastructure is particularly important for the “young” sectors.

Hypothesis 4: High entrepreneurial activity and optimal conditions for doing business (establishing and running start-ups) create a firm foundation for the emergence of new industries.

Hypothesis 5: High levels of innovative activity in the region (as an indicator of the residents' accumulated innovative and creative potential) promotes the growth of emerging sectors.

Hypothesis 6: Employment in the information technology industry tends to be lower in regions where manual and routine work dominate (such as agriculture and manufacturing).

Data and Methodology

Reducing the risks and increasing regions' potential to adapt to digital transformation would require creating conditions for the development of new industries,

⁴ For this reason, in the North, for example, the number of active SIM cards per person is much higher than in Central Russia: mobile communications are used not just for making calls but also for accessing the internet.

primarily in the IT sector. Therefore we have used the share of workers employed in the information sector⁵ in the total workforce⁶ as the dependent variable. In other words, we measured the role of information technology and thus indirectly the level of digital economy development in Russian regions. According to 2017 data, the share of IT personnel in the total Russian workforce amounted to just 1.06% and in the high-tech sector about 3.1% [Zemtsov *et al.*, 2019]. In absolute terms, there are about 472,000 IT professionals out of 44.3 million workers. In a number of regions, their share remained persistently low throughout the period under consideration (2010-2017) (Figure 1), including the Kursk and Leningrad Regions, the Republics of Adygei, Dagestan, Kabardino-Balkaria, Karachai-Cherkessia, Chechnya, and the Chukotka Autonomous District (just 58 IT professionals). In 2017, capital urban agglomerations were far ahead of other areas: Moscow had 3.3% (about 160,000 IT workers), and St. Petersburg 3.4% (approximately 50,000); combined, they account for 44.5% of all IT personnel in the country. The regional averages were also higher in other major Russian urban agglomerations such as the Novosibirsk (1.6%), Yaroslavl, Tomsk, Ryazan, Samara, and Nizhniy Novgorod Regions, and the Republic of Tatarstan. Taken together, these regions employ 63,000 IT professionals (or about 13.3% of their total number).

In most leading regions the share of IT workers grew between 2010-2016. However, over the latest year the number of such professionals decreased in the Nizhniy Novgorod and Samara Regions, and in Tatarstan. This might be evidence of negative trends in these regions' economies but it may also be explained by the changes in the main Russian Classification of Economic Activities (OKVED).

In line with the suggested hypotheses, we propose the following empirical model to explain the factors affecting the development of the IT industry:

$$\ln IT_{i,t} = \alpha \ln Diversity + \beta \ln HumanCapital_{i,t} + \gamma \ln ICTinf_{i,t} + \delta \ln Entrepreneurship_{i,t} + \epsilon \ln Innov_{i,t} + \theta \ln EconomicSpecialization_{i,t} + \varepsilon_{i,t}$$

where:

IT is the share of IT workers in the total regional workforce, %

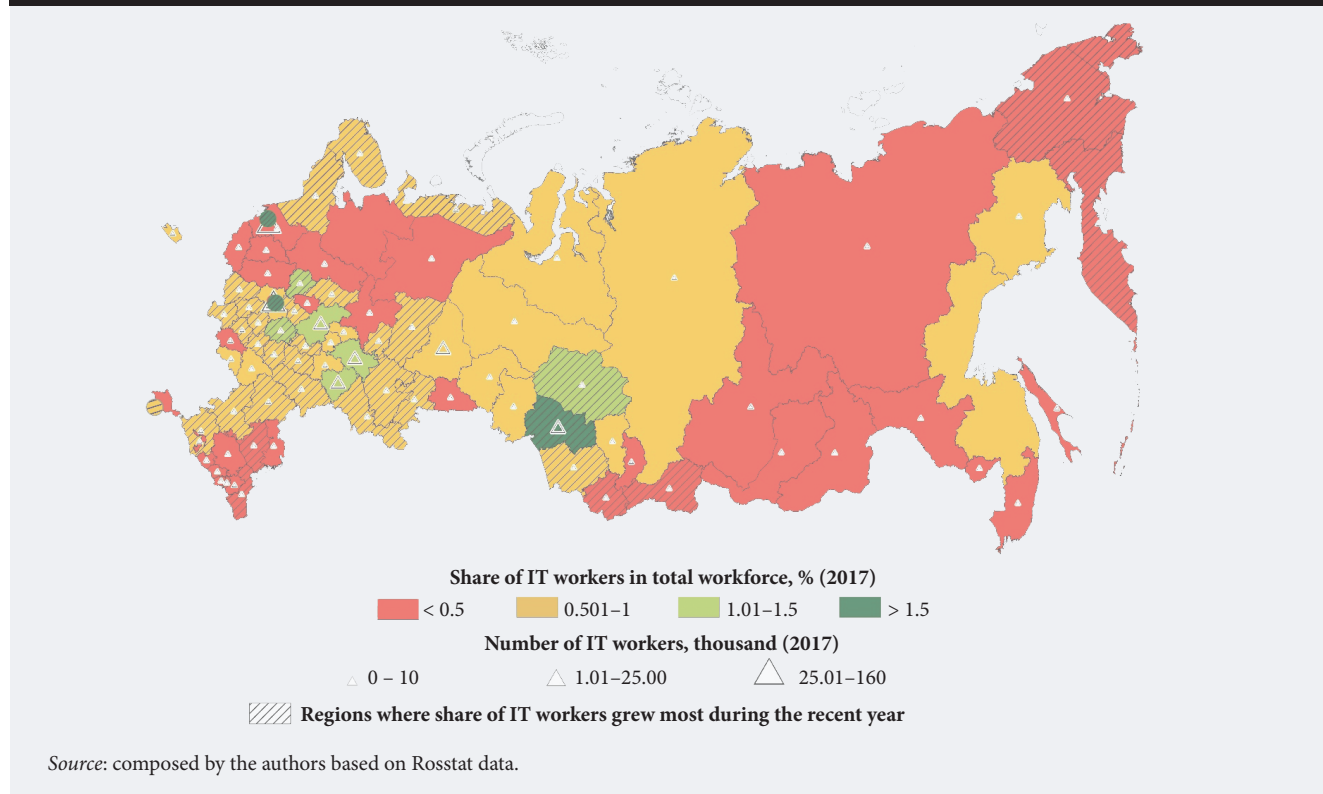
i is the Russian region;

t is the year;

Diversity are variables measuring the diversity of economic activities and agglomeration effects [Jacobs, 1969];

HumanCapital are variables measuring the concentration of human capital in the region, and residents' education level;

Figure 1. Development Level of the IT Sector in Russian Regions (2017)



⁵ Activity types: the development of hardware and software, relevant consulting, and other related services; IT-related activities.

⁶ Total number of workers on the payroll of all organizations. Access mode: <https://www.fedstat.ru/indicator/43007>, last accessed on 12.01.2019.

Table 1. Variables Applied in the Model

Variable	Designation	Indicator	Expected effect	Source
Diversity	ln_city	Number of regional capital residents, people	+	Rosstat
Human capital	ln_high_ed	Share of workers with higher education, %	+	Rosstat
	ln_high_urb_ed	Share of employed urban residents with higher education in the previous year, %	+	[Zemtsov et al., 2016]
	ln_stud(t-10)	Share of students in the population 10 years ago, %*	+	Rosstat
ICT infrastructure	ln_int	Share of people (households) with internet access, %	+	Rosstat
	ln_int2	Share of organizations with internet access speed of at least 2 Mbit/s in total number of organizations (% , annual value)	+	Rosstat, [Zemtsov et al., 2019]
Conditions for the development of entrepreneurship	ln_firm	Ratio of the number of small enterprises to workforce, <i>units per 10,000 people</i>	+	[Barinova et al., 2018]
Innovation potential	ln_patent	Ratio of the number of potentially commercialized patents to the number of employed urban residents with higher education, <i>units per 10,000 people</i> .	+	[Zemtsov et al., 2016]
Specific features of economic structure	ln_budg_emp	Share of workers employed by companies with public participation in total workforce, %	-	Rosstat, authors' calculations
	ln_manuf	Share of workers employed in agriculture and manufacturing, %	-	Rosstat, authors' calculations

* Number of students indicated with a 10-year temporal lag, since we assume students do not increase the region's human capital straight away.

Source: compiled by the authors.

ICT_inf are variables measuring the development level of ICT infrastructure in the region and the availability of internet access;

Entrepreneurship are variables describing the conditions for business development and the density of entrepreneurial activity;

Innov are variables measuring innovative potential, accumulated scientific knowledge, and researchers' creative potential;

EconomicSpecialization are control variables describing specific features of regional economic structures: the share of sectors where routine and manual work is common, i.e., those where opportunities for applying IT remain low. Shares of workers employed in agriculture and manufacturing and in the public sector were used for this purpose. The latter indicator describes the level of regional development, since in a number of Russian regions the public sector remains the only source of jobs.

Due to changes in the OKVED, the time series was limited to 2010 and 2016. Data for 2017 is not fully compatible with the statistics for the preceding years. All figures were taken from official Rosstat sources, unless indicated otherwise.

Table 1 presents the main factors and the indicators used to measure them. To test multicollinearity, Table 2

presents pair correlation coefficients for the variables. All indicators were logarithmized.

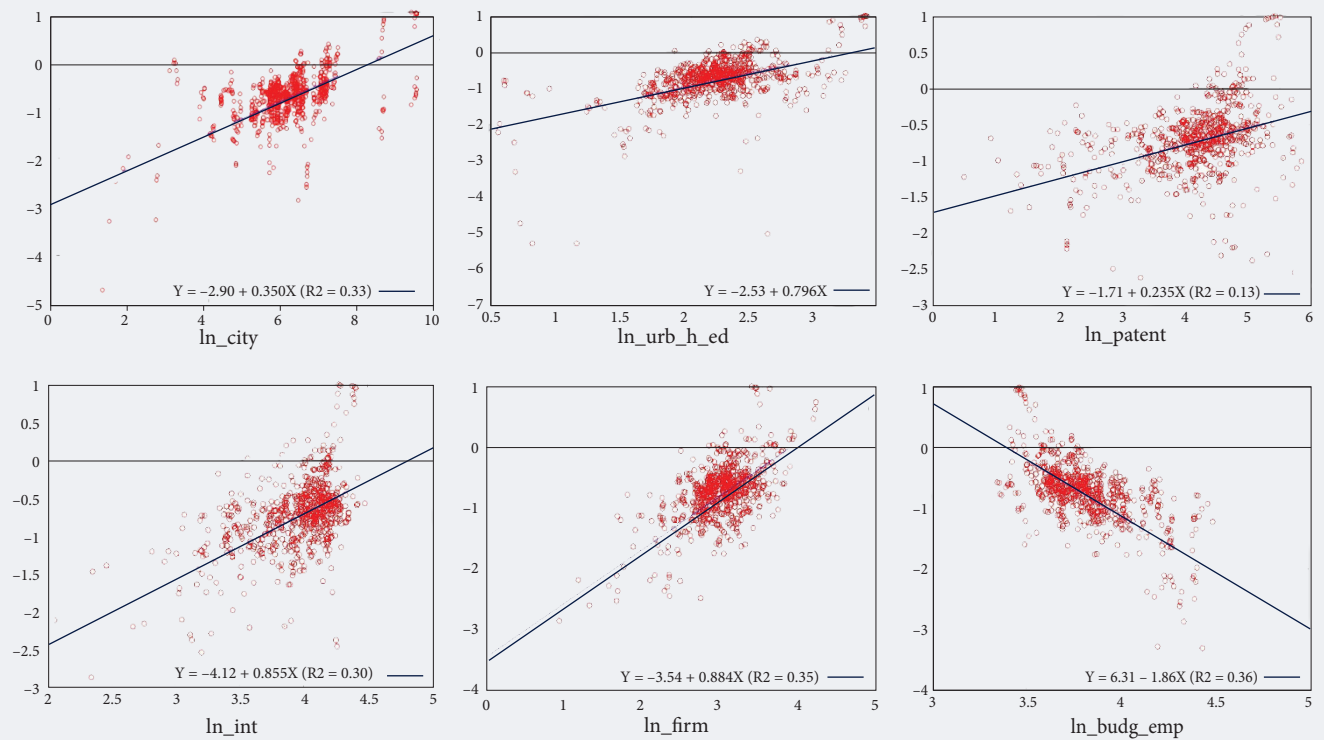
Figure 2 presents scatter plots to help better understand the directions and types of correlation between the dependent variables and the main factors.

A fixed effects model was applied to estimate multivariate regression coefficients as the most appropriate for a regional study. The set of identified factors is sufficient to describe the characteristics of regions that were more successful in creating new sectors of the economy. However, it is not enough to understand the relationship between the existing risks and the Russian regions' potential. Therefore additional research was conducted.

At the *first stage*, to obtain a better understanding, the number and share of graduates specializing in STEAM professions⁷ was estimated (Figure 3), which affects the possible future number of non-routine jobs. In total, about 332,000 such professionals were trained in Russia or less than 20% of the total number of graduates. Education systems in innovative regions such as the Tomsk, Samara, Voronezh Regions, the cities of Sevastopol and St. Petersburg, and the Republics of Mari El and Tatarstan turned out to be most STEAM-oriented ones (more than 25% of all graduates specialized in STEAM disciplines in these regions).

⁷ Data to calculate the admission and graduation of students specializing in STEAM disciplines was collected from reports published by the Russian Ministry of Education and Science based on federal statistical observation forms VPO-1 and SPO. The STEM Degree List approved by the US Department of Homeland Security in 2010 was used as a foundation. The current list (>400 training areas) is available on ICE.gov. The CIP codes (Classification of Instructional Programs) were converted into profession codes in line with the Russian Ministry of Education and Science's order No. 1061 of 12.09.2013. The following knowledge areas were taken into account: mathematics and engineering sciences, engineering, technology, arts, and culture. Researchers who have successfully defended their dissertations in all scientific domains (PhD and Doctor of Science) were added to the number of graduates.

Figure 2. Scatter Plots between Independent and Dependent Variables



Source: composed by the authors.

The 19 regions that train more than 5,000 professionals a year (Figure 3) account for about 63% of the total number of graduates. Mostly it is the largest urban agglomerations in the country.

At the *second* stage, the automation-related risks the regions faced were compared with their adaptation potential. As such, the measurements used for this purpose were only loosely related to future technology unemployment problems [Zemtsov, 2018]. They only allow one to assess the threats: the higher the share of the population whose jobs can potentially be automated, the higher the risk of technological exclusion. However, if at the same time factors affecting conditions for the

emergence of new industries are poorly developed in a region, it creates an additional risk of an “ignorance-based economy” emerging, along with “old industry” and “old service” areas with a high level of shadow employment and unemployment, low income, and other social issues.

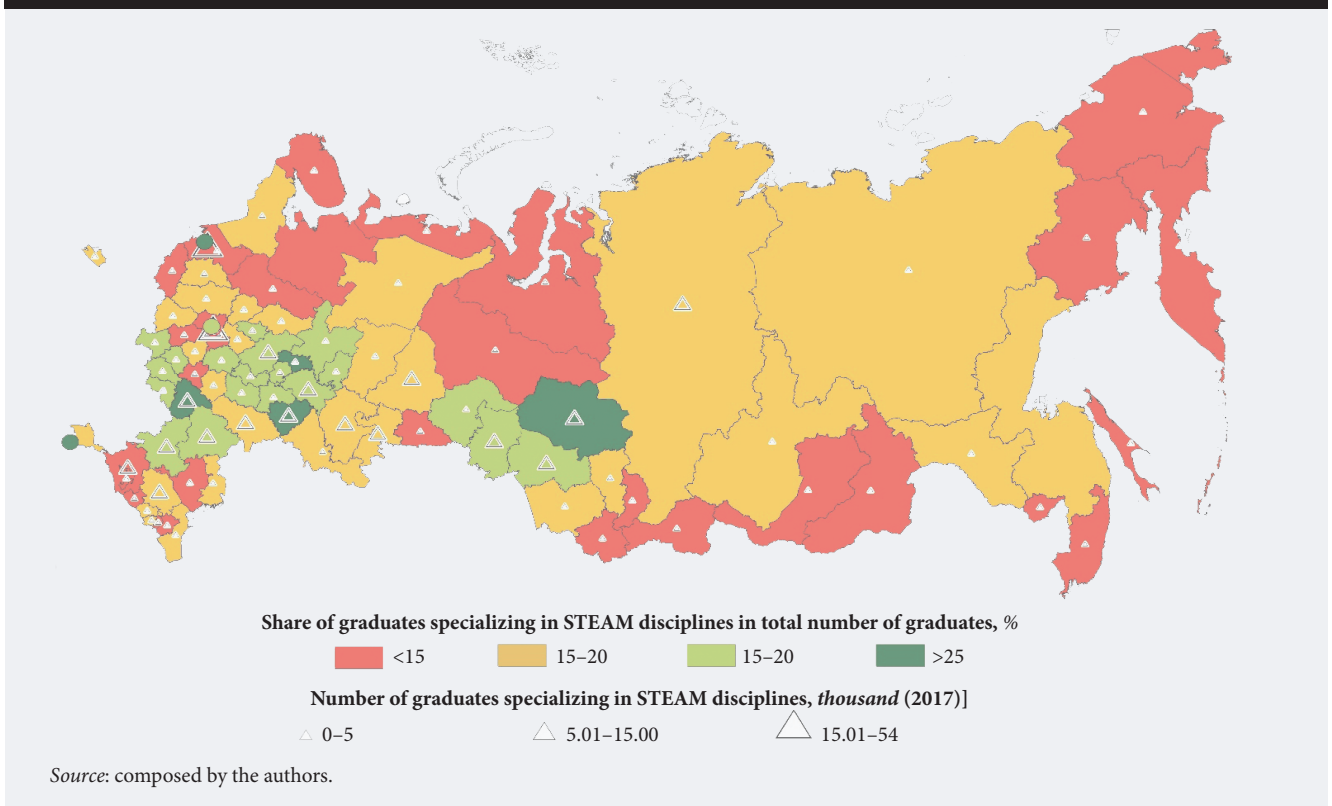
In Figure 4, the X axis represents automation-related risks (the share of regions’ residents whose jobs may be cut in the total workforce, as a percentage) (see [Zemtsov, 2018] for more). The Y axes shows regions’ potential to adapt. It was measured as the ratio of the number of IT workers (Figure 1) and graduates specializing in STEAM disciplines (Figure 3) to the

Table 2. Cross-Correlation Matrix

	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]
[1] ln_IT	1	0.55	0.22	0.58	0.48	0.66	0.51	0.36	0.65	-0.62	0.26
[2] ln_city		1	0.2	0.38	0.35	0.36	0.31	0.61	0.38	-0.52	0.23
[3] ln_high_ed			1	0.49	0.49	0.19	0.32	0.01	0.21	-0.11	-0.28
[4] ln_urb_h_ed				1	0.4	0.55	0.35	0.08	0.58	-0.59	0.2
[5] ln_stud(t-10)					1	0.4	0.49	0.37	0.44	-0.19	-0.08
[6] ln_int						1	0.65	0.12	0.53	-0.48	0.21
[7] ln_int2							1	0.21	0.41	-0.45	0.15
[8] ln_patent								1	0.22	-0.34	0.3
[9] ln_firm									1	-0.57	0.23
[10] ln_budg_emp										1	-0.65
[11] ln_manuf											1

Source: composed by the authors.

Figure 3. Number of Graduates Specializing in STEAM Disciplines in Russian Regions (2017)



number of able-bodied residents whose jobs face the risk of automation⁸ [Zemtsov, 2018]. In other words, we assessed the balance between the existing risks and the IT sector's and educational system's potential to train STEAM professionals. The higher this indicator value is, the better the overall conditions for adaptation, since a strong IT sector is already in place and the educational system is training STEAM professionals. For example, in Moscow and St. Petersburg this ratio is close to 100% (Figure 4). Accordingly, at the last stage the resulting ratio was used to develop a typology of regions, identify problem territories, and prepare recommendations.

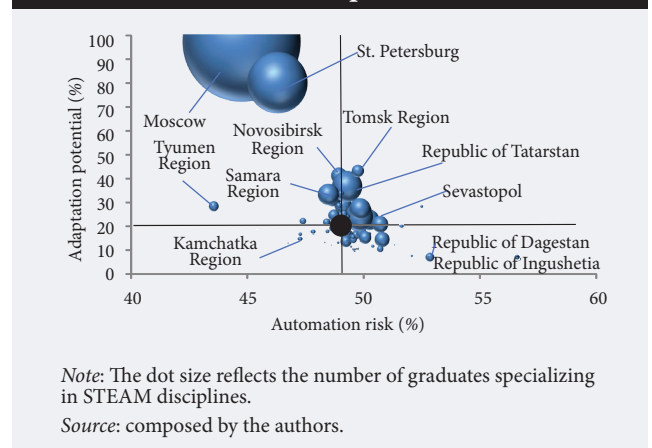
Results

Our calculations (Table 3) did not refute any of the suggested hypotheses. Generally, the important roles of the factors affecting the emergence of new industries (in our case information technology), and people's ability to adapt to automation described in the literature was confirmed. The high diversity of jobs and large labor markets in major cities determine self-realization opportunities for creative professionals and promote the emergence of new industries. Accordingly, in regions where the number of capital city residents was 1% larger, the share of workers employed in the IT sector was 0.85–0.9% higher.

In regions with a high concentration of human capital (a large number of employed urban residents with higher education) the IT sector develops at a higher rate.

The number of students also turned out to be a significant variable in a number of models, which suggests the need to accumulate human capital. The thesis that developed ICT infrastructure is a basic factor affecting the development of information technologies at the regional level was also confirmed.

Figure 4. Distribution of Regions by Robotization Risks, and their Adaptation Potential



⁸ The estimated number for 2015 [Zemtsov, 2018] is divided by 15, since we assume the most favorable scenario in the field of employment, when automation takes place at a steady rate over the next 15 years.

Table 3. Assessment of Regional Factors Affecting the Emergence of New Industries

Variable type and codes		1	3	4	5	6	7
Constant		-10.6 (1.17)***	-1.01 (1.99)	0.34 (1.93)	-3.15 (193)	-6.84 (0.75)***	-4.4 (1.84)**
Diversity	ln_city	1.25 (0.06)***	1.13 (0.04)***	1.12 (0.05)***	0.95 (0.05)***	0.98 (0.04)***	0.85 (0.06)***
Human capital	ln_high_ed	0.54 (0.3)*			0.4 (0.18)**		0.34 (0.16)**
	ln_high_urb_ed		0.35 (0.18)**	0.41 (0.21)**			
	Stud(t-10)	0.38 (0.12)***	0.17 (0.09)*	0.17 (0.1)*		0.17 (0.08)**	
ICT infrastructure	ln_internet					0.35 (0.04)***	0.28 (0.06)***
	ln_int2				0.14 (0.04)***		
Conditions for development of entrepreneurship	ln_firm				0.17 (0.05)***		0.18 (0.06)***
Specific features of economic structure	Ln_budg_emp		-1.91 (0.45)***	-1.84 (0.45)***	-1.15 (0.4)***		-1.18 (0.4)***
	ln_manuf		-0.76 (0.29)***	-0.72 (0.3)**	-0.47 (0.24)**	-0.47 (0.24)**	
Innovative potential	ln_patent			0.04 (0.02)**	0.04 (0.02)**		0.04 (0.02)**
LSDV R2		0.89	0.904	0.901	0.909	0.911	0.912
Within R2		0.457	0.522	0.520	0.557	0.559	0.574
Schwarz criterion		327.2	266.9	232.5	199.4	215.3	170.8

Note: a fixed effects model was applied. The number of observations was 561. Growth was measured for 83 regions in 2010-2016. Robust standard errors are indicated in the brackets. The share of ICT workers in the total workforce (%) was used as the dependent variable (%). All variables were logarithmized.

Legend:

- ln_city — size of regional capital city’s population (*people*)
- ln_high_ed — share of workers with higher education (%)
- ln_high_urb_ed — share of employed urban residents with higher education in the previous year (%)
- Stud(t-10) — share of students in population 10 years ago (%)
- ln_internet — share of individuals (households) with internet access (%)
- ln_int2 — share of organizations with internet access speed of at least 2 Mbit/s in total number of organizations (% , annual values)
- ln_firm — ratio of number of small enterprises to number of workforce (*units per 10,000 people*)
- Ln_budg_emp — share of workers employed in public sector (organizations funded by the state budget and state-owned companies) (%)
- ln_manuf — share of workers employed in agriculture and manufacturing (%)
- ln_patent — ratio of the number of potentially commercialized patents to the number of employed urban residents with higher education, (*units per 10,000 people*)

Source: composed by the authors.

Another significant indicator is patenting activity, which reflects innovative potential, the new technology development rate, and accumulated knowledge base. High innovative activity implies broad opportunities for converting ideas into technologies and thus for the emergence of new industries.

A high share of sectors where manual and routine work operations dominate (such as agriculture and manufacturing) and of the public sector in the regional employment structure does not promote the emergence of new industries.

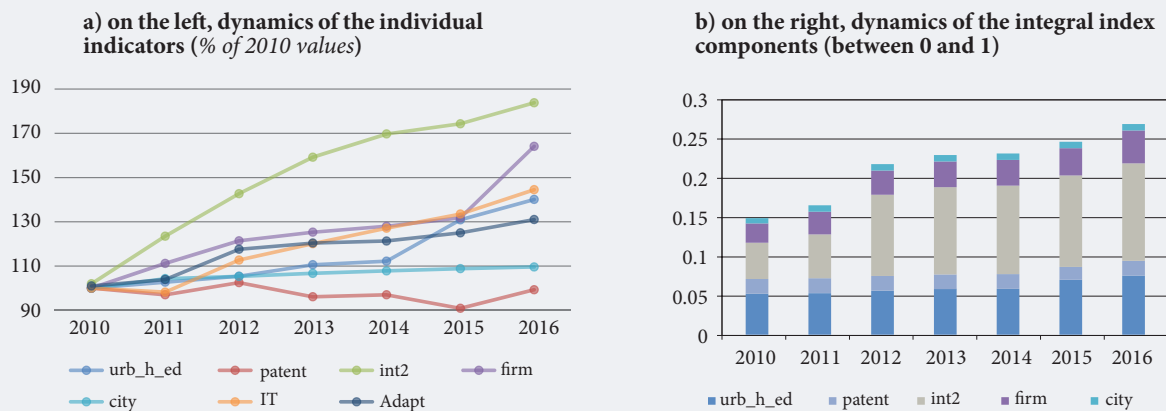
The identified factors are largely in line with previously described conditions for reducing automation-related risks [Zemtsov, 2018]. The obtained estimates help us to better understand the factors that reduce the risks associated with digitalization and those that help actors adapt to this process. Therefore the variables in Table 3 can be used to build a regional adaptation potential index. The ratio of the principle component’s

variables provided the basis for allocating weights in the integral index, which was calculated using a special toolset. Our experience shows that a small number of indicators not infrequently explains a phenomenon better than indices comprising ten or more components [Zemtsov et al., 2015]. An overabundance of indicators leads to distortion, particularly since many of the former may be unrelated to the phenomenon in question. Accordingly, we propose the following correlation to estimate the integral index:

$$adapt=0.23*high_urb_ed+0.16*patent+0.21*int2+0.15*firm+0.25*city.$$

This criterion can be applied to monitor regional development. Even if there are reservations about the quantitative estimates of digitalization-related risks and conditions for the emergence of new industries, knowing the mix of factors that increase the adaptability of the regional economy allows one to trace the dynam-

Figure 5. Dynamics of Main Indicators Describing Conditions for Regions' Adaptation to Digital Transformation, 2010–2016 (%)



Note: average values for Russia. See notes to Table 3 for explanation of the variables' designations.

Source: composed by the authors.

ics of adaptive potential and offer recommendations to the local authorities.

Figure 5 presents the dynamics of the main variables and the resulting index since 2010. Conditions for adaptation have improved in all regions, despite the recession during the economic crisis of 2014–2015. Negative trends noted in certain periods only apply to patenting activity. ICT infrastructure showed the highest rate of improvement, which largely determines the dynamics of the overall index (Figure 5 on the right).

The comparison between regional averages (the dark dot in Figure 4) allows one to identify four groups of regions based on the level of automation-related risks and adaptation potential (Figure 6). The territories more attractive to IT professionals are shaded – those where the rate of pay in the sector exceeds the averages for Russia and the relevant region. To successfully adapt to digitalization, regions should not simply retain but also attract human capital.

Group 1: Major urban agglomerations with a diversified tertiary sector: Moscow, St. Petersburg, the Nizhniy Novgorod, Novosibirsk, Samara, Tyumen, and Khabarovsk Regions. Automation-related risks here are lower since industrial production and the service sector that operate on highly competitive markets are already largely automated, while digital transformation is happening naturally. These regions have the most favorable conditions for the emergence of new industries: large and diversified markets (the largest agglomerations in the country), attractive compensation rates (the shaded areas on the map above), and good conditions for doing business [Barinova et al., 2018].

Group 2: Agglomerations where manufacturing industries dominate, but conditions for the emergence of new industries are in place. This group comprises the Rostov, Voronezh, and Omsk Regions, the Republics of Tatarstan and Bashkortostan. They will still have to

go through digital transformation, but they are better prepared for it.

Group 3: Far Eastern and Northern regions with limited conditions for automation, such as the Magadan, Murmansk, Archangel, and Amur Regions, Chukotka, Kamchatka, and the Republic of Sakha (Yakutia). Most of these areas have unfavorable conditions for the emergence of new industries due to factors such as the lack of large cities that would provide a dynamic and attractive environment for creative professionals [Zemtsov et al., 2019] and the lack of universities that would train STEAM professionals. This is combined with high business costs and poorly developed ICT infrastructure [Barinova et al., 2018].

Group 4: Regions facing high automation-related risks that have low adaptation potential. This group comprises most of the North Caucasus and Southern Russian regions, a number of areas where manufacturing industries dominate, and the Siberian oil-producing centers. In most such regions, institutional conditions limit the scope for new economic activities and the shadow sector plays a prominent role. In Southern regions the share of rural residents is high and their opportunities to adapt are more limited. New non-routine jobs are not related to STEAM disciplines exclusively: they can emerge in creative industries such as tourism, sports, and entertainment. Southern and Central Russia have rich recreational resources and cultural heritage. For example, the Krasnodar Region, despite the high risks and low adaptation capacity, is attractive to tourists and creative professionals and offers good compensation for IT professionals.

Conclusions and Recommendations

Opportunities for retraining and new job creation in Russia do not match the growing rate of digital transformation. Certain prospects to remain employed are associated with retraining for STEAM professions that

are less vulnerable to the risks of automation. However, not all Russians will be able to retrain, so regions facing high risks of automation should develop relevant adaptation mechanisms in advance. It would make sense to promote entrepreneurship as a good alternative to employment.

The Russian regions' example confirms the mainstream hypotheses about factors reducing digital transformation-related risks put forward by international researchers. Promising conditions for the emergence of new industries, first of all information technologies, exist in areas where a mix of factors are present: major agglomerations, diversified economy, high concentration of human capital, developed ICT infrastructure, attractive entrepreneurial environment, and high innovation potential. In territories with a favorable investment climate for business development (high density of companies, low investment risks, low corruption, etc.) [Barinova et al., 2018] digital transformation may turn out to be less painful.

At the same time there are quite a few locations in Russia where automation-related risks are high while opportunities for adaptation are insufficient. This applies to certain North Caucasus republics, southern areas of the Asian part of Russia, and old industrial centers in the northwestern part of the country.

Several global approaches to dealing with digital economy-related problems are suggested [Vermeulen, 2018; WEF, 2019]:

- Introducing a robot tax. The revenues could be used to provide social assistance and support to people made redundant by automation. The expected effect will be achieved if this measure is applied internationally.
- Protecting workers' rights. Includes introducing four-day working week or six-hour workday, in line with UN recommendations.
- Introducing universal basic income, which would partly level the uneven distribution of wealth. However, this would involve dealing with the resulting inflation and other issues.
- Encouraging the creation of new companies and involving laid off workers in retraining and obtaining new skills. This is the most suitable option for implementation at the regional and local levels.

Integrated regional digital development programs should be designed⁹, specifying adaptation steps to be taken in areas such as normative regulation, the development of information infrastructure, digital economy personnel, and the digitalization of public administration. Such initiatives should include mechanisms for

Figure 6. Grouping of Regions by Level of Automation-related Risks and Ability to Adapt to Digital Transformation



⁹ Industry-level digital technology development strategies are currently being implemented in the Republic of Tatarstan as well as the Ulyanovsk and Samara Regions.

training highly skilled professionals possessing relevant competences and providing support to high-tech businesses [Zemtsov *et al.*, 2019]. Regions in Group 4 need such adaptation strategies more than others (Figure 6), i.e., those with a high share of manufacturing industries and routine jobs.

The level of human capital in the region directly affects its adaptation potential in the digital age. Therefore R&D, entrepreneurship, creative industries, and STEAM professions should be supported. Acquiring new competences and providing retraining opportunities to the unemployed also contribute to the development of human capital [Zemtsov *et al.*, 2019]. Possible mechanisms include training programs in entrepreneurship, investments in R&D, and the establishment of relevant departments at universities. All such steps would promote cooperation between R&D, education, and the private sector. Setting up entrepreneurial universities favorably affects the emergence of new activities, first of all in the context of encouraging young people to create start-ups. For mature professionals it is recommended to arrange retraining and upgrading courses with the participation of successful companies and initiatives such as WorldSkills.

To extend the range of formats for cooperation between entrepreneurs and offer new self-realization opportunities for people who have been laid off, regional and local authorities may use tools such as coworking sessions, subsidized rents, online services for start-ups, and much more.

The following steps may help make regions look more appealing for skilled professionals and the creative class, they include the careful positioning of the region, the

creation of an attractive brand, and advanced city planning policies based on cooperation with recognized urban developers.

Large cities with innovation centers and strong universities can offer a favorable environment for the emergence and growth of high-tech companies. Keeping in mind the huge disparities in Russian regions' capacities [Zemtsov *et al.*, 2019], it would make sense to assume that only some of them would be able to specialize in digital technologies. This ability largely depends upon the level of ICT infrastructure and the rate of applying innovations. Advancing communication potential accelerates the emergence of new industries. Reliable mobile communications and free broadband internet access will help reduce transaction costs and create new markets for start-ups. Building regional entrepreneurial ecosystems would promote cooperation between the relevant players.

The creation of innovative companies in Russian regions was traditionally promoted on the basis of using infrastructure support facilities such as technology parks, special economic zones, and clusters. The development of high-tech sectors in regions requires not only, and not so much, relevant infrastructure (incubators, fab labs, accelerators) as access to markets created by large companies who are also potential customers.

A separate avenue for promoting entrepreneurship is venture capital support and the development of public-private partnerships. Special venture funding programs, technology brokerage, and export consulting are the most important areas for providing support to high-tech companies at the regional level.

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