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The Impact of Digitalization on the Formation of Human Capital at the Regional Level

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Abstract: Human capital becomes the most competitive and unique resource in the modern context of development of high-tech industries and formation of the digital economy. The ongoing digitalization processes have an impact on the formation and development of human capital. The aim of this work is to analyze the influence of digitalization factors on human capital in the regions of the Russian Federation. Based on statistical data from the State statistics service of the Russian Federation, the authors collected data for calculating the Index of conditions for the formation and development of human capital (CFDHC Index) for 82 regions and 34 factors that characterize the development of digitalization in Russia for the period from 2014 to 2018. The authors construct a multivariate regression using the ordinary least squares (OLS) estimation for describing the relationship between the Index and digitalization factors. With allowance for the individual effects of the regions of the Russian Federation, models with random and fixed effects were built. The results of the regression analysis confirmed the hypothesis that to form and develop human capital in the regions, measures should be taken aiming at developing digital infrastructure, reducing digital inequality, supporting higher education and research institutes, developing electronic services to provide public and municipal services.

Keywords: digital economy; human capital; human capital management; regional socio-economic policy

1. Introduction

The past few decades have been characterized by the rapid development of society. Transition to the fifth technological order in the early 60s of the 20th century, accompanied by the widespread dissemination of information technologies that allowed automating production and business processes may be considered the beginning of the economy and society transformation. These changes were the first prerequisite for the society transition to a new stage of development. The second prerequisite was the ubiquity of the Internet and mobile communications in the mid-90s, which naturally influenced further modernization of production and business processes [1]. Traditional economic processes are changing in the modern market environment. The fact that the current information, digital technologies, and innovations used in production, distribution, exchange, and consumption have become important in the process of increasing competitiveness was one of the prerequisites for these changes [2].

The diffusion of innovations and digital technologies is observed not only in the real sector of the economy, but also in the social sphere, that is, in education, health, and culture. Modern society perceive the world through the prism of "digits" because of the penetration of such phenomena of digital culture as personal computer, Internet, digital means of communication, computer games, technological art, etc., [3]. Changes in socio-economic spheres around the world, intensified by the increasing role of

information and communication technologies, as well as the development and implementation of innovations, have entailed structural changes in the economies of all developed and part of developing countries [4]. The product of these changes is a new type of economy—"digital economy."

In the period of post-industrial development and formation of the "digital economy" human capital becomes one of the most important factors in the socio-economic development of regions and the country as a whole [5]. As a combination of knowledge and skills, human capital is the most important and most competitive factor in production. It affects the productivity growth and, as a result, the economic growth [6]. The challenge of improving the quality of human capital is part of the long-term socio-economic development of many developed and developing countries, including the Russian Federation [7].

At the same time, the ongoing structural changes in the economy and society, caused by the impact of innovations which also include digital transformations justify the need to improve approaches to human capital management [8]. Given that the country's socio-economic development is largely determined by the effectiveness of regional management decisions, special attention should be paid to the development of human capital in the regions [9]. Under the current conditions, the existing mechanisms and tools for managing human capital should take into account the impact of digital transformations in all spheres of socio-economic activities.

The aim of this work is to analyze the impact of digitalization factors on human capital of the regions of the Russian Federation. Identifying positive relationships between digitalization and human capital will show directions of the regional socio-economic policies to improve the quality of human capital in the Russian Federation.

This paper considers theoretical aspects of human capital as an economic category. Then it addresses theoretical aspects of the formation of the digital economy in the world as a new medium for the formation of human capital. The current state of the digital economy in the Russian Federation is analyzed. The Index of conditions for the formation and development of human capital at the regional level is calculated on the example of the regions of the Russian Federation for the period from 2014 to 2018. The regression analysis is carried out to determine the relationship between the Index and the digitization factors. Based on the results of the regression analysis, the authors develop recommendations on further directions of human capital development in the digital economy at the regional level.

2. Theoretical Background

2.1. The Genesis of the Human Capital Theory

Although the 1960s are traditionally considered to be the beginning of the conceptualization of the Theory of Human Capital, the prerequisites for the development of this theory were formulated in the works of such founders of the classical economic theory as A. Smith, W. Petty, Jean-Baptiste Say, K. Marx, Irving Fisher, etc. W. Petty was the first to statistically measure the monetary value of a person for integrated assessment of national wealth [10]. A. Smith in "The Wealth of Nations" noted that "abilities acquired through training (education) are always worth real income" that "is real, fixed capital realized in a person" [11]. Jean-Baptiste Say also argued that since skills and abilities were acquired for a fee and tended to increase productivity, they should be seen as capital [12].

Over time, the idea of the impact of unique human abilities, skills, and knowledge gained during the education process on the production process, was formed into a separate theory, greatly influenced by such economists as T. Schultz [13], G.S. Becker [14,15], J. Mincer [16], C.R. McConnell, S.L. Brue [17], etc. In the neoclassical economic theory period, human capital was assessed in terms of human investments in education and professional training and retraining. Subsequently, such elements as the cost of information in the post-training labor market, health costs, professional and geographical mobility were added to the structure of human capital. Because of the research of Minser, Schultz, Becker, and other economists of the time, it becomes obvious that if the indicator of human capital is

added to traditional capital and amount of labor, the resulting model contributes to overall economic growth. Thus, a new academic field was formed. It was devoted to the assessment models of the human capital impact on economic growth, which was most often expressed through education. The empirically proven concept justified the economic sense of investing in a person, showing that difference in income might not depend on the workplace "quality," but on the effectiveness of an individual investment strategy in one's education and formation of specific competencies [18].

2.2. The Concept of the Digital Economy

According to the World Bank report, the digital economy refers to a "system of economic, social, and cultural relations based on the use of digital information and communication technologies" [19]. Generally, this definition of the "digital economy" is presented in a broad sense. The G20 The digital economy Development and Cooperation Initiative report states that the digital economy is a wide range of economic activities, including the use of digitized information and knowledge as a key factor in production, the use of modern information networks as an important area of activity, and the efficient use of information and communication technologies (ICT) as an important driver of productivity growth and structural optimization of the economy [20].

The English researcher Thomas L. Mezenburg [21] in early 2000s defined the digital economy as an economy of three main elements:

- E-business infrastructure (i.e., a share of the total economic infrastructure used to support e-business processes and e-commerce);
- E-business (any business process carried out over the Internet);
- E-commerce (e-trade) is the cost of goods and services sold over the Internet.

IT industry is the major driver of the digital economy. It is this industry that provides digital technologies supporting digitalization of other sectors of the economy.

The concept of "digitalization" does not have an exact definition. Some authors believe that digitalization is introduction of digital technologies to business processes [22]. The Gartner Glossary provides the following definition: "digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business."

Digitalization processes take place in all areas of society. Digitalization of production is associated with the adoption of Industrie 4.0 in Germany in 2011. This initiative combines a set of projects aimed at creating "smart production" in the manufacturing sector of the economy by integrating cyberphysical systems (CPS) into factory processes by connecting to the global industrial network, the Internet of Things (IoT) [23,24]. Extractive industry, including fuel and energy industry, uses Big Data, IoT, distributed registry systems, and artificial intelligence [25]. Service industry uses blockchain technology (distributed registry technology) to ensure payment security, NFC (near field communication) contactless technologies, 3D Touch, fingerprint scanners or voice authorization in mobile applications.

The trend toward introduction of digital technologies in higher education has led to the new forms of interaction between professors and students. Traditional forms of education are replaced by remote ones, such as online webinars. Educational platforms such as Open Edu, Coursera, Udacity, etc., are gaining particular popularity.

Considering the digital transformation of the healthcare sector, the use of medical information systems (MIS), e-health, online health, medical IT, telemedicine, introduction of medical Internet of things (IoMT–Internet of Medical Things), Big Data analytics (Big Data), and practical use of expert medical systems should be noted [26,27].

In the field of culture, it is quite common practice to use modern technologies to interact with customers (using online services, ticket sales aggregators), change business models using virtual reality (VR) and augmented reality (AR) technologies (conducting online webinars, online broadcasting of

theater productions and music concerts, festivals), as well as for the purpose of changing functional processes (data digitizing, maintaining online catalogs of museums and nature reserves) [28].

The state, as one of the main actors in the development of the national economy in the digital age, is also actively involved in the field of stimulating the technological offer and commercialization of technologies [29]. Currently, most countries have programs to develop their digital economies (Table 1).

Table 1. National programs for the development of the digital economy [30–32].

Country	Program
USA	Department of Commerce's The digital economy Agenda (2016)
Germany	Industrie 4.0 (2011)
Italy	Industrie 4.0
France	Alliance pour l'Industrie du Futur/Alliance for the industry of the future
Spain	Industria Conectada 4.0/Connected Industry 4.0
Russian Federation	The National Program "Digital Economy"
China	Internet Plus
Republic of Korea	Manufacturing Innovation 3.0 Strategy
Japan	Super Smart Society 5.0

The main areas of government policies in the digital economy is elaboration of national and regional programs aimed at developing digital society, as well as measures to stimulate the use of digital technologies in all sectors of the economy: production, finance, and government.

Digitalization leads to a more efficient use of the existing resources, both capital and human resources. For example, the total economic effect of using open-data applications for 27 EU countries is between 140 and 160 billion euros per year [33]. Moreover, according to the McKinsley Global Institute, the transition to a new economy in Russia will become one of the main factors in GDP growth. For 2015, the economic effect of the digital economy was estimated at +4.1–8.9 trillion rubles to GDP by 2025 (in 2015 prices), which would amount from 19 to 34% of the total expected GDP growth [34].

2.3. Human Capital in the Digital Economy

In the framework of the digital economy, human capital takes on new forms, and its importance is confirmed by numerous studies and the very concept of the new knowledge-based economy.

The deepening processes of globalization, driven by the development of scientific and technological progress and revolutionary changes in digital technologies, are transforming human society in a natural way [35]. Advances in robotics, additive technologies, and expansion of end-to-end technologies contribute to the fact that traditional industrial processes become intellectually interconnected [35]. Human capital plays an important role in the framework of this transformation. People become the main factor in production, and their knowledge, skills, and competences in information technology become the driving force in the development of the digital economy [36]. Klaus Schwab, the President of the Davos Economic Forum, is convinced that "the main production factor in the digital economy will not be the capital, but human potential" [37], expressed primarily in the skills that will meet the new economy needs.

In accordance with these changes, a modern approach to the formation and development of human capital is formed in economic science. Thus, a number of researchers believe that human capital at its present stage of development is characterized by a high level of importance of digital skills and abilities, ICT literacy, electronic skills, ability to adapt to new environments, as well as "digital literacy," expressed in a special way of thinking that allows users to work intuitively in digital environment, as well as easily and effectively gain access to a wide range of knowledge [38–40]. Considering human capital in the overall concept of the digital economy formation, researchers often divide basic competencies into the so-called "hard skills," i.e., including technical skills, abstract thinking, ability to create and work with written texts, numeracy, and computer skills, as well as "softskills"

(flexible competencies), i.e., teamwork skills, decision-making, communication, and application of the situational approach in their activities [18].

In the digital economy context, highly qualified personnel possess technological knowledge that contribute to scientific and technical progress. The author of the study [5] notes that the development of telecommunications and information technologies requires that their creators and users have an appropriate level of qualification. For this reason, the ability to adapt to fast-changing environments, in which the propensity for continuous education (life-long education) will be the competitive advantage of the employee, becomes critical. In addition, the quality of human capital in the context of globalization include such characteristics as knowledge of foreign languages, mobility, high level of education, ability to use computer programs, independence, creativity, new competencies, knowledge and skills [5].

The importance of human capital in the transformation of the economy and society is undeniable, but the role of formal institutions in the observed changes in human capital management at the global, federal, regional and local levels is increasing.

In the digital economy format, not only training of highly qualified professionals with skills and competencies will be among the main tasks of these institutions, but also the task of forming and developing human capital in the framework of effective public administration of the national economy [36]. As it is noted in the study [41], effective management of human capital in the digital economy is impossible without transforming conditions and tools of its development.

In this regard, important aspects are the development of IT sector, creation of innovative technologies, organization of cooperation for their development at the international level, as well as institutional changes, namely, the formation of an appropriate legislative framework adapted to fast-changing conditions and associated with new technological solutions of business processes. However, in order to highlight the directions of the digital economy and to improve the quality of human capital, it is necessary to understand exactly what factors of digitalization affect human capital.

To date, the issue of the human capital role in shaping the digital economy is relevant. A wide range of research works on the theoretical aspects of management and assessment of human capital in the digital economy is presented in both Russian and foreign studies [8,18,35]. However, issues related to the analysis of the digital economy impact on the formation of human capital at the regional level, using mathematical and statistical research methods, are not sufficiently developed. For Russian realities, the influence of the "digital economy" phenomenon should be reflected in the government socio-economic policies aimed at the formation of human capital. Under the current conditions, the existing mechanisms and tools for managing human capital should take into account the impact of digital transformations. This premise forms the relevance of this work to the current situation.

3. Materials and Methods

The goal of this work is to analyze the impact of digitalization factors on human capital in the regions of the Russian Federation. The research algorithm is presented in Figure 1.

The regression analysis is the main research method. Regression is the dependence of one random variable on the values taken by another random variable (a physical variable). This relationship is represented as a regression equation that defines the functional relationship between the dependent variable (y) and the arguments (x). If the argument is greater than one, it is known as a multiple regression. The authors construct a multivariate regression using the method of least squares regression estimation (OLS). This method is based on minimizing the sum of squared deviations of some functions from the desired variables. The advantage of the chosen method is that based on real statistical data, the authors can build an econometric model and assess the impact of various factors on an economic object or process. An alternative to least squares regression modeling is correlation analysis. Correlation is considered as a sign indicating the relationship of numerical sequences. Correlation describes the strength of the relationship in the data and its direction. However, for the most complete analysis, regression analysis is traditionally used. This analysis will not only determine the

presence and direction of the relationship between variables, but also find coefficients that characterize this relationship.

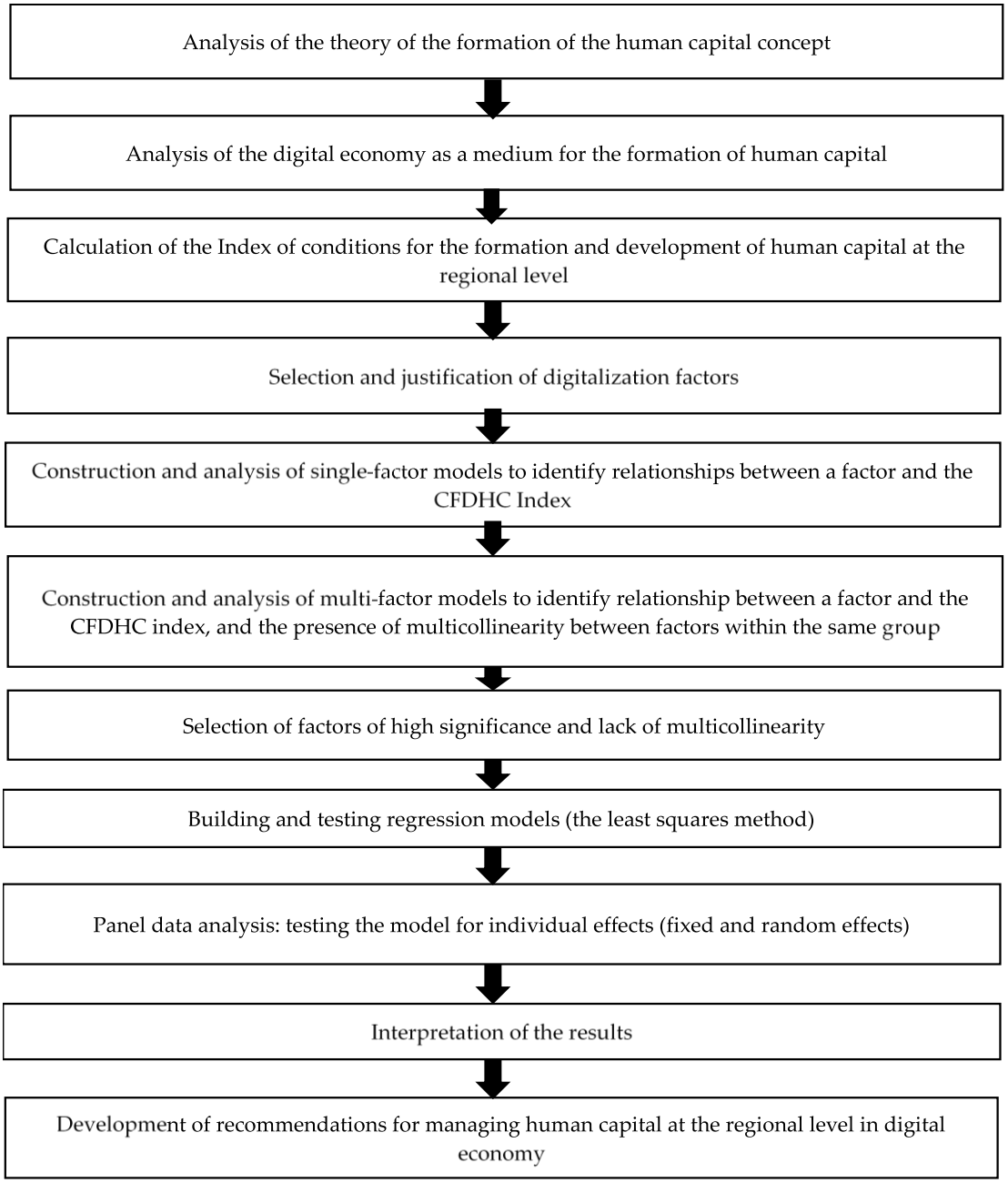

Figure 1. Research algorithm.

The regression model is based on a hypothesis. The null hypothesis of the study suggests that there is no link between dependent and independent variables, while the alternative hypothesis suggests this relationship:

Hypothesis 0 (H0): $p\ (X, Y) = 0$.

Hypothesis 1 (H1): $p\ (X, Y) \neq 0$.

Where H0 is the null hypothesis which claims the y and xn factors do not correspond to each other. HA is an alternative hypothesis that confirms the impact of variables xn on the variable y.

The Index of conditions for the formation and development of human capital, calculated for the constituent entities of the Russian Federation from 2014 to 2018, is the dependent variable according to the method of O.V. Zaborovskaia [9]. The main data sources are the annual collections of the Federal State Statistics Service of the Russian Federation "Regions of Russia. Socio-economic indicators" [42–44]. The calculation of the integral index was based on the data of indicators, combined into eight groups, characterizing conditions for the formation of human capital in the Russian Federation. The calculation is presented in Table 2.

Table 2. The structure of indicators for calculating the Index of conditions for the formation and development of human capital in a region [9].

Indicator Group	Name of Indicator
Indicators of economic development and growth	Gross regional product per capita GRP, mln. rub. Unemployment rate
Public health indicators	Total fertility rate Total mortality rate Morbidity per 1000 people
Environmental health indicators	Relative assessment of atmospheric pollution Emissions of pollutants into atmospheric air from stationary sources Capture of air pollutants from stationary sources
Indicators of physical reproduction conditions (nutrition value)—Nutrition rationality (by group):	Meat and meat products consumption per capita Milk and dairy products consumption per capita Potatoes consumption per capita Vegetables and food melons consumption per capita Eggs consumption per capita Sugar consumption per capita Vegetable oil consumption per capita Bread consumption per capita
Family sustainability as a core environment for the formation of human potential	Marriage-divorce ratio
Level of criminality	Number of registered crimes by type
Indicators of the intensity of use of the region's aesthetic habitat	Theater attendance, people Museum attendance, people
Structure of the educational space	Number of preschool education institutions, units
	Number of education institutions carrying out educational activities based on educational programs of primary, basic and secondary general education (private), units
	Number of education institutions carrying out educational activities based on educational programs of primary, basic and secondary general education (public), units
	Number of education institutions carrying out educational activities based on educational programs of secondary vocational education (private), units
	Number of education institutions carrying out educational activities based on educational programs of secondary vocational education (public), units
	Number of state higher education institutions and scientific organizations, units
	Number of private higher education institutions and scientific organizations, units
	Postgraduate training organizations, units
	Doctoral training organizations, units

The integral assessment is calculated on the basis of the average geometric according to Formula (1):

$$K_{ij} = \left(\prod_{l-1}^{20} k_{ij}^{l} \right)^{\frac{1}{20}} \quad (1)$$

where K_{ij} is assessment of the human capital formation and development conditions in j region within i time period; k_{ij}^{l} is a value of the l coefficient of unevenness (l = 1.20) in j region within i time period.

To select the factors of digitalization, the authors conducted a comparative analysis of research on the impact of digitalization on the development of the economy and society in the Russian Federation [45–47]. Based on the results of the study, the authors concluded that independent variables can be the factors that characterize digitalization in the following areas:

- Government digitization (indicators reflecting the level of accessibility of public and municipal services on the Internet);
- Information security (indicators reflecting the level of confidence in information technology, as well as the utilization rate of information security tools);
- Business sector (indicators reflecting the use of information technology in the business sector);
- Digital infrastructure (indicators of the development degree of information infrastructure);
- Digital skills (indicators characterizing the use of information technology by the population for the personal purposes, digital literacy);
- Digitalization of the social sphere (indicators characterizing the digitalization of culture, health care and education spheres);
- Costs of developing the digital economy (public costs or human costs).

The selected indicators characterize the development and level of use of digital technologies both at the state level, in the provision of public services to the population, and in the private sector.

The data sources for the selection of digitalization factors are:

- The methodology for assessing the development level of information society in the regions of the Russian Federation, establishing the procedure for carrying out the assessment of the development level for the information society in the regions of the Russian Federation for 2011–2020 in accordance with the provisions of the Concept of regional informatization, approved by the order of the Government of the Russian Federation of December 29, 2014, No. 2769-p (2769-r) [48];
- The results of the "Monitoring the development of the information society in the Russian Federation" [49];
- The "digital economy of the Russian Federation" national program [32].

The description of the selected variables is presented in Appendix A. The table in Appendix A includes:

- Designation of a variable in the x_n model (models), where x is a variable, and n is a serial number)
- A variable name;
- Unit of measurement (%, units, rubles, rubles per month);
- A name of the group of factors to which a variable is related according to the classification above;
- Rationale for using a variable in the model;
- Hypothesis.

Based on the data from the Index of conditions for the formation and development of human capital and the data on 34 variables, i.e., digitalization factors, a dataset was collected for the period from 2014 to 2018 for 82 regions of the Russian Federation.

The regression analysis was carried out according to the following algorithm:

First, single-factor and multi-factor models were built using the least-squares method, and tests were carried out to detect the presence of multicollinearity between digitization factors.

Next, panel data models were built to take into account individual fixed and random effects in the regions of the Russian Federation.

For some of the variables presented in absolute values, regression models were tested in two versions: the first option included the analysis of y and x_n dependency presented in absolute values, in the second option functional forms were changed for x_n (variable values were converted to log_x_n logarithms). The regression models were built and tested using the Stata 14 software product.

4. Results

4.1. The Digital Economy in the Russian Federation

According to a number of international experts, the Russian Federation is currently at the level of average developed countries in terms of digitalization [24]. One of the indicators by which the impact of digital technologies on the economies of different countries is assessed is the "Share of the digital economy in GDP" indicator. Figure 2 shows the ranking of the G20 countries by the share of the digital economy in GDP for 2010 and 2016.

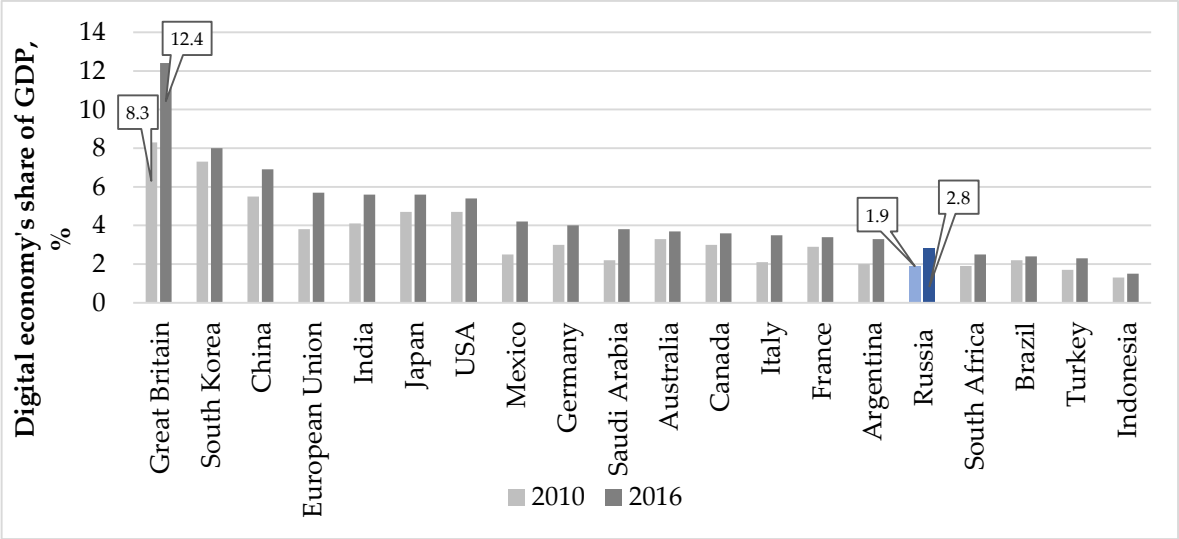

Figure 2. G20 countries ranking by the share of the digital economy in GDP for 2010 and 2016.

As it is seen in the figure, the United Kingdom leads the ranking with the digital economy share of 12.4% in GDP. Russia ranked 16th in 2016 with the result of 2.6% of GDP. The digital economy's share growth rate in the country's GDP was 47% compared to 2010 (49% in the UK). As of 2018, gross domestic expenditure on the development of the digital economy amounted to 3.795 billion rubles, which was equivalent to 3.7% of GDP [50]. The largest share of these costs at the end of 2018 accounted for a business sector (44.6% in 2018 and 45.1% in 2017) and households (36.8% in 2018 and 36.4% in 2017), for public administration (4.1%) and social sphere (2.8%) (4.6% and 2.6%, respectively in 2017). The costs of organizations and households on the consumption of content and media sectors production accounted for 11.7% (11.3% in 2017).

Russia is actively developing its IT industry, which is the main provider of digital technologies to the economy. Today, Russia has a number of its own IT companies, such as Yandex, whose market capitalization on the Moscow Exchange amounted to 1 trillion rubles as of January 2020 (for comparison, Gazprom, the leader in capitalization on the Moscow Exchange, has 5.551 trillion rubles, Sberbank has 5.544 trillion rubles), Mail.ru Group (capitalization is 3.54 billion rubles in 2020), Kaspersky Lab, Group-IB1 (one of the leading developers of solutions for detecting and preventing cyberattacks, detecting fraud and protection of intellectual property on the network), etc. [24]. The Internet of Things (IoT) market is one of the promising domestic markets. The IoT market grew by 8.3% compared to 2018, and amounted to 3.7 billion rubles by the end of 2019 [51]. The IoT market in Russia is represented by several segments: services (data collection and analysis, system integration, security, etc.,), hardware, software. For 2019, Russia has such major Internet of Things projects as online cash registers, transport, and logistics solutions, such as ERA-Glonass; telemedicine and smart cities solutions are gradually being developed, and introduction of digital tracking of goods is underway in industry and retail [52]. According to PwC, the Internet of Things will bring Russian economy a cumulative effect of 2.8 trillion rubles by 2025 [52].

The most dynamically developing is the mobile segment of the digital economy in Russia. Internet access in Russian households was estimated at 77% in 2018 (for example, in the Republic of Korea and Japan it is estimated at 99%, at 95% in the UK, and at 84% in the United States) [50]. In addition to a fairly high level of Internet penetration in Russia, there is a moderate increase in the share of the digitally skilled population (Table 3).

Table 3. Digital skills of the population, in % of the total population aged 15 and over [50].

Digital Skills	2015	2016	2017	2018
Working with a text editor	38.8	41.5	41.7	41.1
Transferring files between computer and peripherals	27.6	29	27.4	31.1
Using software for editing photos, videos, and audio files	21.3	21.4	20.6	21.2
Connecting and installing new devices	8.4	8.9	9.7	9.8
Installing a new operating system or reinstalling it	2.8	2.7	3	2.7

Despite the existing capacity for the development of domestic technologies, the study [24] notes that Russia is currently lagging behind the advanced countries in the IT industry, both in terms of equipment production and capitalization (the production of software and IT services is handled by several hundred companies, only about 20 of which have annual revenues above 6 billion rubles). As of 2018, the share of the ICT sector in the business sector gross value added in Russia was 3.2%, compared to 9.6% in the Republic of Korea [50]. According to the data for 2018, telecommunication services (59%) account for the largest share in the structure of goods and services of the ICT sector in Russia, while the production of computers and peripheral equipment accounts for 1%, communications equipment is 3%, data processing is 6%, and software development is 18% of all manufactured goods and services.

In terms of using digital technologies, Russian business is inactive in modernizing and introducing innovations: according to the 2017 Higher School of Economics (NRU HSE) estimates, Russia ranked 31st in the index of business digitization (index of 28 points) and was in line with such Central and Eastern European countries as Bulgaria, Hungary, Poland, and Romania; in 2018 the index value was 31 points, thereby Russia was ranked 29th. As of 2018, 27% of organizations in Russia use cloud-based business solutions, while in Finland and Sweden the figures are 65% and 57% respectively; the use of ERP and CRM systems in organizations is limited to 22% and 18%, respectively (39% in Finland, 28% and 47% in Germany, respectively).

In addition, currently there is a fairly high level of dependency on foreign ICT goods and services in Russia. As of 2018, imports of ICT goods and services in Russia amounted to USD 29.087 million, and USD 22.003 million in 2015, while exports for 2018 amounted to USD 7.366 million and USD 6.739 million in 2016 [50,53]. This aspect might be associated with a steady decline in the volume of domestic ICT industry between 2013 and 2017 (the decline in 2017 amounted to 8% of 2016 levels) [54].

Yet, as it is noted in the study [24], Russia is not far behind the leaders of the digital economy, the lag is about 5–8 years. However, the country has all the necessary prerequisites for further implementation of the digital potential and accelerating the pace of digitalization of the national economy [34]. Big business has the significant digital potential, especially in the energy, consumer, and public sectors [24].

The Government of the Russian Federation regulates development of the digital economy in accordance with the "The digital economy of the Russian Federation" National Program, which is valid for 2017–2030. The goal of this program is to ensure the accelerated introduction of digital technologies in the economy and social sphere. Following this program, six main areas of development of the digital economy in Russia were identified and supported by the eponymous federal projects:

1. Normative regulation of digital environment.
2. Personnel for digital economy.
3. Information infrastructure.
4. Information security.

5. Digital technologies.
6. Digital public administration.

The national program includes a fairly large set of measures aimed at developing human capital. The "Personnel for digital economy" federal project confirms the government's interest in developing tools for the effective formation and the use of human capital.

Among the challenges of the federal project aimed at the development of human capital in the digital economy, the following should be highlighted:

- Formation of the human potential;
- Formation of the information space, taking into account the needs of citizens and society in obtaining high-quality and reliable information;
- Use and development of various educational technologies, including distance learning and e-learning, in the implementation of educational programs;
- Development and implementation of partnership programs of higher education institutions and Russian high-tech companies, including the issue of improving educational programs;
- Encouraging Russian companies to provide employees with the remote employment opportunities [32].

In order to elaborate more specific measures aimed at the development of human capital in the regions of the Russian Federation, the analysis of the impact of digitalization factors on the Index of conditions for the formation and development of human capital is carried out.

4.2. Statistical Analysis of Relations

The regions of the Russian Federation differ significantly in their social and economic characteristics, rates of socio-economic development, and living standards. This differentiation suggests that the regions of the Russian Federation have different levels of the potential for the formation and development of human capital.

The analysis of the Index of conditions for the formation and development of human capital calculated for the regions of the Russian Federation for the period from 2014 to 2018 showed that there is a need to develop additional measures to improve the conditions for the formation and development of human capital for them.

Thus, the results of the analysis showed that in 2014, 38 out of 82 analyzed regions (46%) have unfavorable conditions for the formation and development of human capital; the intervention of regional authorities is required. The rest of the regions will require not only the resources of the regional authorities, but of the federal authorities as well, since the conditions for the formation and development of human capital are characterized as extremely unfavorable. As of 2018, it was enough to develop and implement regional strategies for 37 regions of the Russian Federation out of 82 analyzed (45%), while the rest required the resources of the federal authorities (see Figure 3).

The results show no positive dynamics of the calculated index. This means that currently the regions of the Russian Federation need to develop new approaches to improve conditions of human capital development within the framework of the regional socio-economic policy. However, an important feature of the regional policy on the formation and development of human capital in the region is that it should minimize imbalances and essential differences in the indicators that characterize the socio-economic situation in the region. At this stage we see that the differentiation of regions in socio-economic development is too high. New mechanisms should be used to achieve sustainable development and improve people's lives, including the achievement of the goals set out in national and regional digital economy programs, designed to ensure equal opportunities to use information technologies, improve information infrastructure, and reduce digital inequality.

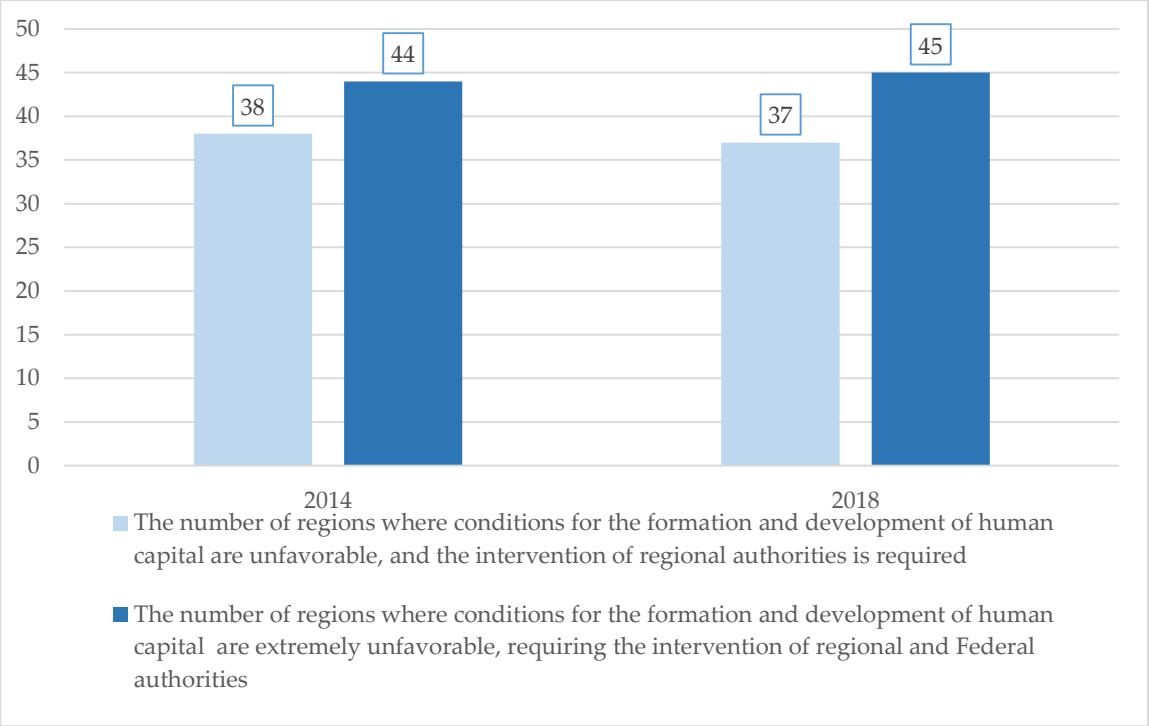

Figure 3. Distribution of the regions of the Russian Federation according to the conditions for the formation and development of human capital in 2018.

The regression analysis was carried out to confirm this statement and identify the relationship between the Index of the conditions for the formation and development of human capital.

The analysis of the obtained single-factor and multi-factor regression models revealed a number of low-value variables, as well as the presence of multicollinearity between a number of variables between factors within the same group. Six final models with a high degree of the variables significance were selected as the result of the multicollinearity model testing (see Table 4).

Having analyzed characteristics of the built models, we can suggest that the 3rd regression model is the most qualitative with the adjusted R2 values of 46.8%, which means that 46.8% of the explained y variance falls on the factors of digitization.

As it was previously stated, constructing this regression model was based on the method of estimating the least squares of linear regression (OLS). The panel data were tested in order to analyze and take into account the individual effects of the regions of the Russian Federation. The panel data models reflect the impact of all variables, both observable and unobservable, which take different values for the sample objects, but do not change over time (Table 5). Thus, there are two types of regression models: with fixed effects (FE) and with random effects (RE).

Table 4. Results of building regression models by the method of estimating the least squares (OLS).

Variables	Characteristic of Model	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
log_x_{10}	Coefficient B	0.0408035 ***		0.0222054 ***			
	SE	(0.0036645)		(0.0059296)			
	VIF	(1.229)		(3.262)			
log_x_{20}	Coefficient B	0.0326729 ***	0.0359172 ***	0.0301827 ***	0.0371104 ***	0.0263603 ***	0.0273211 ***
	SE	(0.0053759)	(0.0056188)	(0.0054483)	(0.0047426)	(0.0053971)	(0.0054868)
	VIF	(1.407)	(1.394)	(1.465)	(1.037)	(1.394)	(1.436)
x_{17}	Coefficient B	0.0180910 ***	0.0197163 ***				
	SE	(0.0049190)	(0.0051598)				
	VIF	(1.173)	(1.171)				
x_2	Coefficient B	−0.0006955 ***	−0.0008745 ***	−0.0007276 ***			−0.0006922 ***
	SE	(0.0001534)	(0.0001650)	(0.0001520)			(0.0001543)
	VIF	(1.332)	(1.398)	(1.326)			(1.321)
x_{23}	Coefficient B	−0.0006073 ***	−0.0006206 ***	−0.0005920 ***	−0.0006505 ***	−0.0005460 ***	−0.0006461 ***
	SE	(0.0001091)	(0.0001157)	(0.0001084)	(0.0001021)	(0.0001037)	(0.0001092)
	VIF	(1.219)	(1.243)	(1.220)	(1.012)	(1.083)	(1.198)
log_x_{12}	Coefficient B		0.0345732 ***				
	SE		(0.0039263)				
	VIF		(1.362)				
log_x_{15}	Coefficient B			0.0130659 ***		0.0112875 ***	0.0219927 ***
	SE			(0.0030012)		(0.0028691)	(0.0018547)
	VIF			(3.627)		(3.215)	(1.339)
log_x_{11}	Coefficient B				0.0353330 ***	0.0214244 ***	
	SE				(0.0030327)	(0.0046213)	
	VIF				(1.045)	(2.519)	
_const	Coefficient B	−0.2155594 ***	−0.1412216 ***	−0.0960728 *	−0.1410804 ***	−0.0798703 *	0.0667966 ***
	SE	(0.0366951)	(0.0374032)	(0.0466512)	(0.0292856)	(0.0326816)	(0.0171655)
Adj R-squared		0.461	0.406	0.468	0.431	0.452	0.450
Root MSE		0.052	0.055	0.052	0.054	0.053	0.053
P		0.000	0.000	0.000	0.000	0.000	0.000
F		66.138	53.007	68.107	97.117	79.496	78.902

Note: Three stars *** indicates the highest degree of significance of factor x_n and influence on y at the 0.1% significance level. If there are * stars, it means that the significance of factor x_n and influence on y at the 5% significance level. If there are no stars, this indicates a practical lack of significance of the factor and influence on y.

Table 5. Evaluation of the regression models by the method of estimating the least squares (OLS), taking into account the fixed and random effects.

Variables	Characteristic of Model	OLS Model	Model with Fixed Effects	Model with Random Effects
log_x_{20}	Coefficient B	0.0301827 ***	0.0355808 ***	0.0279852 ***
	SE	(0.0054483)	(0.0066961)	(0.0054463)
log_x_{10}	Coefficient B	0.0222054 ***	−0.0060050	0.0267706 **
	SE	(0.0059296)	(0.0175779)	(0.0090947)
x_2	Coefficient B	−0.0007276 ***	−0.0003611 ***	−0.0004969 ***
	SE	(0.0001520)	(0.0000928)	(0.0000810)
x_{23}	Coefficient B	−0.0005920 ***	−0.0000353	−0.0000796
	SE	(0.0001084)	(0.0000634)	(0.0000628)
log_x_{15}	Coefficient B	0.0130659 ***	−0.0018768	0.0088433 *
	SE	(0.0030012)	(0.0063604)	(0.0041966)
_const	Coefficient B	−0.0960728 *	0.2361373	−0.1448873 *
	SE	(0.0466512)	(0.1670793)	(0.0712595)
	corr		−0.121	
	R2_adj	0.468	−0.135	
	R2_w		0.112	0.091
	R2_b		0.039	0.488
	R2_o		0.021	0.442
	N	382	382	382
	aic	−1167.154	−1946.110	
	bic	−1143.481	−1922.437	
	Root MSE	0.052	0.021	0.022
	P	0.000	0.000	0.000
	F	68.107	7.525	

Note: Three stars *** indicates the highest degree of significance of factor x_n and influence on y at the 0.1% significance level. If there are ** stars, it means that the significance of factor x_n and influence on y at the 1% significance level. If there are * stars, it means that the significance of factor x_n and influence on y at the 5% significance level. If there are no stars, this indicates a practical lack of significance of the factor and influence on y

The results of the regression model analysis confirm the presence of individual effects, however, their correlation with regressors is insignificant −0.121. Therefore, we reject the model with fixed effects, and accept the model with random effects.

Within the framework of the random effects model, R^2 within (0.09%), R^2 between (0.49%) and R^2 overall (0.44%) are estimated. Thus, in our opinion, this particular model may be considered as the final.

Unlike the model built by the least squares method, there is no x_{23} factor in the random effects model, which indicates that its impact is estimated to be negligible.

By interpreting regression coefficients in the random effects model, we can conclude that:

- An increase in expenditures of the consolidated budgets of the Russian Federation entities on social and cultural activities (education) by 1% leads to an increase in the Index by 0.000268 units;
- An increase in the number of fixed broadband Internet subscribers (per 100 people) by 1% leads to an increase in the Index by 0.0002799 units;
- An increase in the share of the population using the Internet to obtain public and municipal services in the total population that received state and municipal services by 1 unit, leads to a decrease in the Index by 0.0005 units;
- An increase in domestic research and development costs by 1% leads to an increase in the Index by 0.000088 units.

5. Discussion: Digitalization, Human Capital, and Open Innovation

Based on the results of the model interpretation, we may conclude that conditions for the formation and development of human capital in the regions of the Russian Federation are positively affected, first, by the infrastructure created within the framework of the digital economy, expressed in the accessibility of the Internet to the public. Latest information technologies, computers, and free access to the Internet

play an important role in human activities [55]. They allow people to receive new information faster, improve their skills through online training courses, etc. Moreover, as the international experience has shown, the Internet allows people to adapt quickly to the remote mode of work and study [39]. We assume that the positive relationship between the number of fixed broadband Internet subscribers and the Index of conditions for the formation and development of human capital is a consequence of the effectiveness of the federal project to reduce digital inequality in the Russian Federation, launched in 2014 by the Government in cooperation with PJSC Rostelecom, as well as implementation of tasks and goals within the Digital Infrastructure direction of the digital economy Program.

Second, the observed positive relationship between the Index and the indicator of internal expenditures on research and development may indicate that additional projects financing carried out by the Higher School of Economics and research institutes involved in the development of knowledge-intensive technologies will create favorable conditions for the development of local personnel in this area. We can assume that undertaking these measures may reduce the outflow of young scientists abroad. This hypothesis may also be confirmed by a positive relationship between the Index and the expenditures of the consolidated budgets of the regions of the Russian Federation for social and cultural events, i.e., education. The issue of intellectual migration in Russia has remained quite acute for more than 20 years. According to the monitoring of the economic situation in Russia [56], "the main channels of emigration of Russians with higher education are leaving for master's or postgraduate studies (about a third of respondents) and for work (about a quarter), and every second of those who moved to Europe received the Blue card for qualified professionals." Promotion of domestic higher education and science is one of the urgent tasks for the government of each region in the framework of socio-economic development, especially in the period of formation of the knowledge-based economy.

The regression model shows the inverse relationship between the Index and the proportion of the population that used the Internet to obtain public and municipal services in the total population that received public and municipal services. On the one hand, this relationship contradicts the original hypothesis. On the other hand, we can assume that this relationship is influenced by an unknown variable (i.e., not participating in the regression model), the influence of which is so significant that it shifted the estimates of the analyzed relationship. We can assume that the quality of the provided public and municipal online services, as well as their limited number, may be these unknown variables.

Digitalization of the public services sector is currently one of the most important priorities in the transition of the national economy to the digital format. As it is noted in the study [57], the transfer of public services into electronic form entails many positive social and economic effects. First of all, it is related to the increase in the speed of information processing and public services delivery. However, it is also accompanied by a number of problems:

- Security of the citizen's personal data and electronic signatures (e.g., there was a leak of personal data of 28,000 clients of the 'Public Services-UGRA internet portal' in December 2019 [58]);
- Feasibility of converting a number of services into an electronic form;
- Revision of administrative regulations, the possibility of public services to be provided electronically;
- Speed of updating departmental databases;
- Continuity and stability of the public services portal, as well as of departmental platforms [57].

Despite the systematic work of the Government and regional authorities aimed at creating a sustainable system of electronic public and municipal services, according to the Ministry of Economic Development rating of the regions of the Russian Federation, there was a strong differentiation between the regions in the quality of public and municipal electronic services in 2017 [59]. Thus, Moscow was the first in the ranking with the quality indicator of 89.92%, Moscow region was the second with 89.34%, and Tula region was the third with 86.73%. However, the Republic of Dagestan (7.30%), Pskov region (1.92%), and Tver region (1.65%) were among the regions of the Russian Federation lagging behind. Thus, the lag of the last rating region from the leader amounted to 88.27%.

Digital inequality also remains one of the deterrent mechanisms for the development of electronic public and municipal services in the Russian regions. As of 2018, the share of the population that used the Internet to obtain public and municipal services in the total population that received these services in the Yamal-Nenets Autonomous Area was 95.3%, while only 38.6% in the Chukotka Autonomous Area. Also, as it is noted in the study [60], some of the public and municipal services provided online are declarative, based on the necessity of the paper document, which does not cancel personal contact with representatives of government agencies. It should be stated that at the end of 2017, according to the Ministry of Economic Development of the Russian Federation, monitoring the quality of the services transfer to the electronic form, 80% (469, 5% more than in 2016) out of 585 services available on the Unified Public Services Portal had the "Get the service" button, but only in 45% (261, 1% more than in 2016) of the services it was possible to really make a request and only in 28% (165, 4% more than in 2016) a notification of the results of the request was received [61]. Low growth rates of these indicators point out the need for further work in this direction. Thus, the results show that electronic public and municipal services do not affect the formation of human capital; but the information infrastructure, which is currently at the stage of development and improvement, can reduce the Index.

Thus, the interrelationship identified by the regression analysis may determine the pressing directions for the formation of regional socio-economic policies aimed at the development of human capital in the regions of the Russian Federation, namely:

- Development of digital infrastructure, expressed in reducing digital inequality both within the region and between the regions of the Russian Federation;
- Development and implementation of activities to support higher education and research institutes focused on ICT research;
- Creating a favorable environment for maintaining human resources within the regions;
- Further modernization of the system of providing public and municipal services electronically, namely, the development of inter-agency information interaction in the provision of public and municipal services; reducing the share of paperwork; improving the efficiency of public administration.

Implementation of these measures will help create optimal conditions for the formation of human capital in the regions of the Russian Federation. Therefore, the concept of open innovation can become one of the mechanisms for accomplishing aims in the framework of regional socio-economic policy. The concept of closed innovations assumes that the processes of developing and commercializing innovations become the task of one company, while open innovations include collaboration (an example of this concept is clusters [62,63]). This approach is universal and can be used not only for the tasks of regional policy of the Russian Federation. Tasks of developing human capital by creating an innovative environment and increasing the availability of technologies can be delegated to the private sector or universities. For example, a number of foreign universities already have departments that implement orders from state authorities for the development of innovations in various sectors of the economy [64]. By delegating tasks for the development of innovations in the region to the private sector or universities, regional authorities solve problems to improve the innovation environment in the region, support private business and education, and create conditions for the development of human capital and its use for further economic and innovative development.

6. Conclusions

This study examined theoretical aspects of the formation of human capital with the emergence of the neoclassical economic theory. Theoretical aspects of the digital economy phenomenon were considered. It was determined that human capital is one of the most important factors of economic development in the framework of the digital economy. The analysis of the formation of the digital economy in the Russian Federation was carried out, the main directions of the formation of the digital

economy were considered. Objectives of the "Digital Economy of the Russian Federation" national program, focused on the development of human capital, were analyzed.

The Index of conditions for the formation and development of human capital at the regional level was assessed on the example of the regions of the Russian Federation for the period from 2014 to 2018. It was revealed that the regions of the Russian Federation have to develop new approaches to improve the conditions of human capital development within the framework of the regional socio-economic policy. The results of the regression analysis confirmed the hypothesis that these measures should include such areas as development of digital infrastructure, reducing digital divide, supporting higher education establishments and research institutes, and development of electronic public and municipal services.

It should be noted that the study is based on the open data, which are published biennially. In the course of the study, the open statistics data were marked 2018. Relying on the explosive growth of digitalization in the regions of the Russian Federation over the past 2 years, the urgency of this study is decreasing. In addition, given the large data set, which includes more than 300 observations, it is also impossible to specify the activities being developed to date.

Among the features of this study is the chosen methodology for assessing human capital at the regional level. The chosen methodology is characterized by a variety of selected indicators for assessing the conditions for the formation and development of human capital, which characterize not only the education or income level, but also the availability of medicine, living standards, through indicators such as food availability, environmental and ecology conditions, cultural component, etc. This approach contributes to a comprehensive assessment of the factors that contribute to the development of human capital in the region. On the other hand, this methodology was developed for the specifics of the Russian Federation, and the indicators used are available in Russian statistical collections. This feature is also a limitation since the approach described by the authors in this study cannot always be used to calculate the Index for another country. The authors are convinced that the methodology used for assessing human capital at the regional level can be improved and adapted to other countries, which can be implemented in future studies.

Today, the topic of human capital development is relevant because of the need to develop the regional economy, especially during the recovery period after the pandemic, which affected not only Russia, but the whole world. We believe that this study can be the first step in our further complex research devoted to analysis of the impact of developing technologies and innovations on the development of human capital as the main factor of economic development. Further research tasks will include: (1) Addition of statistical information on digitalization factors and updating the Index of conditions for the formation and development of human capital for 2019–2020; (2) analysis of the practices of implementing the socio-economic policies by the regions of the Russian Federation in the framework of the digital economy to specify the activities being developed; (3) formation of a new approach for the assessment of human capital at the regional level, taking into account the identified relationship. In other words, this study can become the basis for the development of a new method for evaluating human capital, taking into account the factors of digitalization.

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Appendix A

Table A1. Classification of variables-factors of digitalization.

Model Variable	Name	Unit of Measurement	Factor Group Name	Rationale for the Use of a Factor in the Model	Hypothesis
x_1	Share of the population using the Internet to obtain public and municipal services in the total surveyed population	%	Digitization of the government	These factors characterize the accessibility of public and municipal services to the population in the digital space, which indicates the development of e-government in Russia.	An increase in the share of the population using the Internet to obtain public and municipal services in the total population leads to an increase in the CFDHC Index
x_2	Share of the population that used the Internet to receive public and municipal services in the total population that received public and municipal services	%	Digitization of the government		An increase in the share of the population using the Internet to obtain public and municipal services in the total population receiving public and municipal services leads to an increase in the CFDHC Index.
x_3	Share of the population using the Internet to order goods and (or) services in the total population	%	Digital skills	This indicator characterizes the digital skills of the population, namely, in the context of the use of digital technologies for their own needs.	An increase in the share of the population using the Internet to order goods and (or) services in the total population leads to an increase in the CFDHC index
x_4	Share of households with broadband Internet access in the total number of households	%	Digital infrastructure	This indicator characterizes the level of development of the digital infrastructure of the Russian Federation	An increase in the share of households with broadband Internet access leads to an increase in the CFDHC Index
x_5	Share of organizations using means of protecting information transmitted over global networks in the total number of organizations surveyed (encryption tools)	%	Information security	This indicator characterizes the development of information security of the business sector in the Russian Federation, through the use of the encryption tools	An increase in the share of organizations using encryption tools leads to an increase in the CFDHC Index
x_6	Share of organizations using means of protecting information transmitted over global networks in the total number of organizations surveyed (electronic signature)	%	Information security	This indicator characterizes the development of information security of the business sector in the Russian Federation, through the use of an electronic signature	An increase in the share of organizations using electronic signature technologies leads to an increase in the CFDHC Index
x_7	Share of organizations that used means of protecting information transmitted over global networks in the total number of organizations surveyed	%	Information security	This indicator characterizes the development of information security of the business sector in the Russian Federation, through the use of information security tools	An increase in the share of organizations using information security tools leads to an increase in the CFDHC Index

Table A1. *Cont.*

Model Variable	Name	Unit of Measurement	Factor Group Name	Rationale for the Use of a Factor in the Model	Hypothesis
x_8	Share of the population not using the Internet for security reasons in the total population	%	Information security	This indicator characterizes the level of public confidence in information technologies.	A decrease in the proportion of the population not using the Internet for security reasons leads to an increase in the CFDHC Index
x_9	Share of the active Internet users in the total population	%	Digital skills	This indicator characterizes the digital skills of the population, namely, in the context of using digital technologies for their own needs.	An increase in the share of active Internet users in the total population leads to an increase in the CFDHC index
x_{10}	Consolidated budgets of the regions of the Russian Federation expenditures for social and cultural events (education)	Million rubles	Socio-economic indicators	The expenditures on social activities create favorable conditions for the formation of human capital in the region	An increase in the expenditures of the consolidated budgets for social and cultural events leads to an increase in the CFDHC index
x_{11}	Consolidated budgets of the regions of the Russian Federation expenditures for social and cultural events (public health)	Million rubles	Socio-economic indicators	The expenditures on social activities create favorable conditions for the formation of human capital in the region	An increase in the expenditures of the consolidated budgets for social and cultural events leads to an increase in the CFDHC index
x_{12}	Consolidated budgets of the regions of the Russian Federation expenditures for social and cultural events (social policy)	Million rubles	Socio-economic indicators	The expenditures on social activities create favorable conditions for the formation of human capital in the region	An increase in the expenditures of the consolidated budgets for social and cultural events leads to an increase in the CFDHC index
x_{13}	Advanced manufacturing technologies used	Units.	Business sector	This indicator characterizes the degree of dissemination and use of advanced production technologies, which are the basis of the digital economy concept.	An increased use of AMT leads to an increase in the CFDHC index
x_{14}	Costs of technological innovation	Million rubles	The digital economy development costs	This indicator characterizes the level of development of the digital economy in the Russian Federation through financing technological innovations, which are the basis of the concept of the Digital economy	An increase in the cost of technological innovation leads to an increase in the CFDHC Index
x_{15}	Internal research and development costs	Million rubles	The digital economy development costs	This indicator characterizes the level of development of the digital economy in the Russian Federation through funding research and development, which is the basis of the concept of the digital economy. It is one of the main indicators in the digital economy program	An increase in internal costs for research and development leads to an increase in the CFDHC Index
x_{16}	Average income per capita	Rubles per month	Socio-economic indicators	The indicator characterizes the level of the society well-being by region	An increase of the average per capita income leads to an increase in the CFDHC Index
x_{17}	Share of people employed in the ICT sector in total employment	%	Digital skills	This indicator characterizes the population's level of basic ICT knowledge and the development of the information technology sector	An increase in the share of employed in the ICT sector leads to an increase in the CFDHC Index

Table A1. *Cont.*

Model Variable	Name	Unit of Measurement	Factor Group Name	Rationale for the Use of a Factor in the Model	Hypothesis
x_{18}	Digitalization level of the local telephone network	%	Digital infrastructure	This indicator characterizes the development level of the digital infrastructure of the Russian Federation	An increase in the digitalization level of the local telephone network leads to an increase in the CFDHC Index
x_{19}	Internet access subscription fee	Rubles per month	The digital economy development costs	This indicator characterizes the level of development of the digital infrastructure of the Russian Federation and the availability of digital technologies for the population	A decrease in Internet access subscription fee leads to an increase in the CFDHC Index
x_{20}	Number of fixed broadband Internet subscribers per 100 people	Amount	Digital infrastructure	This indicator characterizes the level of development of the digital infrastructure of the Russian Federation	An increase in the number of fixed broadband Internet subscribers leads to an increase in the CFDHC Index
x_{21}	Number of mobile broadband Internet subscribers per 100 people	Amount	Digital infrastructure	This indicator characterizes the level of development of the digital infrastructure of the Russian Federation	An increase in the number of mobile broadband Internet subscribers leads to an increase in the CFDHC Index
x_{22}	Share of educational institutions implementing educational programs using distance educational technologies to carry out basic educational programs, in the total number of independent educational institutions: secondary vocational education	%	Digitalization in the social sphere	This indicator characterizes the level of information technologies use in education	An increase in the share of educational institutions that implement the educational process using DET in secondary vocational education leads to an increase in the CFDHC Index
x_{23}	Share of educational institutions implementing educational programs using distance educational technologies to carry out basic educational programs, in the total number of independent educational institutions: higher professional education	%	Digitalization in the social sphere	This indicator characterizes the level of information technologies use in education	An increase in the share of educational institutions that implement the educational process using DET in higher professional education leads to an increase in the CFDHC Index
x_{24}	Number of personal computers used for educational purposes per 100 students of public and municipal educational institutions	units	Digitalization in the social sphere	This indicator characterizes the level of information technologies use in education	An increase in the number of personal computers used for educational purposes leads to an increase in the CFDHC Index
x_{25}	Share of educational institutions with the Internet website in the total number of independent educational institutions: secondary vocational education	%	Digitalization in the social sphere	This indicator characterizes the level of information technologies use in education. The presence of a website ensures that information is more widely available.	An increase in the share of educational institutions of secondary vocational education with the Internet website leads to an increase in the CFDHC Index

Table A1. *Cont.*

Model Variable	Name	Unit of Measurement	Factor Group Name	Rationale for the Use of a Factor in the Model	Hypothesis
x_{26}	Share of educational institutions with the Internet website in the total number of independent educational institutions: higher professional education	%	Digitalization in the social sphere	This indicator characterizes the level of information technologies use in education. The presence of a website ensures that information is more widely available.	An increase in the share of educational institutions of higher professional education with the Internet website leads to an increase in the CFDHC Index
x_{27}	Number of personal computers with access to global information networks, per 100 workers in healthcare facilities	units	Digitalization of the social sphere	This indicator characterizes the level of information technologies use in the healthcare sector and is an indicator of the digital economy development	An increase in the number of personal computers with the Internet access leads to an increase in the CFDHC Index
x_{28}	Share of healthcare facilities with a website in the total number of surveyed healthcare facilities	%	Digitalization of the social sphere	This indicator characterizes the level of information technologies use in the healthcare sector. The website availability ensures that information is more widely available	An increase in the share of healthcare institutions with a website leads to an increase in the CFDHC Index
x_{29}	Share of cultural institutions using the Internet in the total number of cultural institutions surveyed	%	Digitalization of the social sphere	This indicator characterizes the level of information technologies use in the sphere of culture	An increase in the share of cultural institutions using the Internet leads to an increase in the CFDHC Index
x_{30}	Share of cultural institutions with a website in the total number of surveyed healthcare facilities	%	Digitalization of the social sphere	This indicator characterizes the level of information technologies use in the sphere of culture. The website availability ensures that information is more widely available	An increase in the share of cultural institutions with a website leads to an increase in the CFDHC Index
x_{31}	Share of organizations having special software tools for managing sales of goods (works, services) in the total number of surveyed organizations	%	Business sector	This indicator characterizes the level of digital technologies use by organizations to carry out their activities	An increase in the share of organizations having special software tools for their sales management leads to an increase in the CFDHC Index
x_{32}	Share of organizations using ERP systems in the total number of surveyed organizations	%	Business sector	This indicator characterizes the level of digital technologies use by organizations to carry out their activities. The organization's ERP system characterizes the digitization of its business processes.	An increase in the share of organizations using ERP systems leads to an increase in the CFDHC Index
x_{33}	Share of organizations with a website in the total number of organizations surveyed	%	Business sector	This indicator characterizes the level of digital technologies use by organizations to carry out their activities. The website availability ensures that information is more widely available	An increase in the share of organizations with a website leads to an increase in the CFDHC Index
x_{34}	Share of research and development costs aimed at economic development in the total volume of internal expenditures on research and development	%	The digital economy development costs	This indicator characterizes the level of the digital economy development in the Russian Federation through research and development funding aimed at developing the economy, which is the basis of the digital economy concept. The indicator is one of the main indicators in the digital economy program	An increase in the share of research and development costs aimed at developing the economy leads to an increase in the CFDHC Index

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